Optimal Energy management and Control of Micro-grids with Renewable energy sources

Thesis

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Kallol Roy

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JADAVPUR UNIVERSITY

KOLKATA – 700032, INDIA

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1. **Title of the Thesis**

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2. **Name, Designation & Institution of the Supervisor/s**:

   - **Dr. Kamal Krishna Mandal**, Professor, Dept. of Power Engineering, Jadavpur University, Salt Lake Campus, Kolkata-700098.
   - **Dr. Atis Chandra Mandal**, Professor, Dept. of Physics, Burdwan University, Burdwan-713104.

3. **List of Publications (Referred Journals):**

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[3] **Kallol Roy**, Kamal Krishna Mandal, Atis Chandra Mandal and S N Patra "Analysis of energy management in microgrid-A hybrid BFOA and ANN approach", **Renewable and Sustainable Energy Reviews, Elsevier,** Vol.82, No.3, pp.4296-4308, February 2018.

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[5] **Kallol Roy**, Kamal Krishna Mandal and Atis Chandra Mandal "Energy management of the energy storage based microgrid connected system: an SOGSNN strategy ", **Soft Computing, Springer**, pp.1-14, October 2019.

[6] **Kallol Roy**, Kamal Krishna Mandal and Atis Chandra Mandal "Application of ANFASO for optimal power flow management of MG-connected system with energy storage ", **International Journal of Energy Research, Wiley**, pp.5272-5286, March 2020.

[7] **Kallol Roy**, Kamal Krishna Mandal and Atis Chandra Mandal "A hybrid RFCRO approach for the energy management of the grid connected microgrid system" **International Transaction of Electrical Energy System, Wiley**, September 2020. DOI: 10.1002/2050-7038.12660

[8] **Kallol Roy**, Kamal Krishna Mandal and Atis Chandra Mandal "Smart Energy Management for Optimal Economic Operation in Grid connected Hybrid Power System" **Energy Sources Part A: Recovery, Utilization and Environmental Effects, Taylor & Francis**, July 2021. DOI: 10.1080/15567036.2021.1961945

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JADAVPUR UNIVERSITY
KOLKATA – 700032, INDIA

"Statement of Originality"

*I, **Kallol Roy**, registered on 3rd June, 2019 do hereby declare that this thesis entitled "**Optimal Energy management and Control of Micro-grids with renewable energy sources**" contains literature survey and original research work done by the undersigned candidate as part of Doctoral studies.*

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Kallol Roy

Signature of Candidate:

Date: 13.06.22.

Certified by Supervisor(s):

(Signature with date, seal)

1. 13/6/22

Professor
Dept. of Power Engineering
Jadavpur University
Salt Lake, 2nd Campus
Kolkata-700 098

2. 13.6.22

Dr. Atis Chandra Mandal
Professor
Department of Physics
The University of Burdwan
Burdwan

JADAVPUR UNIVERSITY

KOLKATA - 700032, INDIA

Certificate from the Supervisor/s

*This is to certify that the thesis entitled "**Optimal Energy management and Control of Micro-grids with renewable energy sources**" submitted by **Shri Kallol Roy** who got his name registered on 3rd June, 2019 for the award of Ph.D. (Engineering) degree of Jadavpur University, is absolutely based upon his own work under the supervision of **Prof. Kamal Krishna Mandal** and **Prof. Atis Chandra Mandal** and that neither his thesis nor any part of the thesis has been submitted for any degree/diploma or any other academic award anywhere before.*

1. 13/6/22

Signature of the Supervisor and
Date with Official Seal

Professor
Dept. of Power Engineering
Jadavpur University
Salt Lake, 2nd Campus
Kolkata-700 098

2. 13.6.22

Signature of the Supervisor and
Date with Official Seal

Dr. Atis Chandra Mandal
Professor
Department of Physics
The University of Burdwan
Burdwan-713104

Dedicated to

My Mother, Father and Wife

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Kallol Roy

KALLOL ROY

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LIST OF SYMBOLS AND NOMENCLATURE

P_D	Power Demand in kW
P_{Gen}	Total power generation in kW
$P_{Photovolaic}$	Output power of photovoltaic in kW
P_{Wind}	Output power of wind turbine in kW
$P_{Battery}$	Output power of battery in kW
t	Temperature
K	Boltzmann's constant
Q	Electron charge
M	Wind Mass
OM_i	The Operation with Maintenance Cost of Generating Unit
$EF_{i,j}$	Emission factor of generating unit
m	Emission types
n	Number of generating units
T	Simulating periods in time
C_{ϑ}^{NTr}	Energy generation cost through non-dispachable resources
C_{ϑ}^{Tr}	Energy generation cost through dispachable resource
C_{ϑ}^{ES+}	Energy generation cost by ES through charging mode

C_{ϑ}^{ES-}	Energy generation cost by ES through discharging mode
C_{ϑ}^{L}	Energy consume cost through responsive load
ψ_{ϑ}	Penalty cost of micro grid operator
ϑ	Interval period
ς	Random Number
σ^{i}	Control Variables
p_{stc}	Maximum Power Module at Standard Test Condition
G_{ira}	Incident Irradiation
C_{NG}	Fuel cost of Natural Gas of Fuel cell
SoC_{Max}	Maximum SoC
SoC_{Min}	Minimum SoC
D	Space Dimension
d_{R}	Desired Generated Requirement
g_{0}	Gravitational Constant
λ	Constant
P	Total Iteration Number
η_{e}	Efficiency of MT
$\rho_{h.l}$	Coefficient of Heat Loss

V_t	Thermal Voltage of The Solar PV Panel
N^l	Number of Responsive Load Requirement in MG-Linked System
S^d	Number of Dispatchable Resources in MG-Linked System
S^{nd}	Number of Non-Dispatchable Resources in MG-Linked System
$\Re_{\varphi}$	Penalty Cost
p_{Grid}	Grid generated power
$d_e(t)$	Deficit Energy
δ_{inv}	Inverter Efficiency
p_{netw}	MG Transmission Power with the Power Grid
Emi_{Max}	Maximum Available Emissions
$\psi_{mt}(t)$	Binary Variable
MG	Microgrid
RES	Renewable Energy Source
DER	Distributed Energy Resource
EMS	Energy Management System
PCC	Point of Common Coupling
PV	Photovoltaic
WT	Wind Turbine

DG	Diesel Generator
FC	Fuel Cell
MT	Micro Turbine
NO_x	Nitrogen Oxides
SO_2	Sulphur Oxides
CO_2	Carbon Oxides
SOC	State of Charge
ABC	Artificial bee colony
IABC	Improved artificial bee colony
GSA	Gravitational search algorithm
CAP	Cost Accuracy Percentage
P&V	Power And Voltage Controllers
CB	Circuit Breakers
SD	Static Switch
CS	Cuckoo Search
BAT	Bat Algorithm
ANN	Artificial Neural Network
BFOA	Bacterial Foraging Optimization Algorithm
DR	Demand Response
COE	Cost of Energy
ESS	Energy Storage System

RNN	Recurrent Neural Network
ALO	Ant Lion Optimizer
RLD	Responsive Load Demand
SSA	Squirrel Search Algorithm
STC	Standard Test Condition
MPPT	Maximum Power Point Tracking
ANFIS	Adaptive neuro fuzzy interference system
ASOA	Advanced salp swam optimization algorithm
MOPSO	modified particle swarm optimization
LPSP	Loss of Power Supply Probability
ALCC	Annual Life Cycle Cost
RF	Random Forest
CRO	Coral Reefs Optimization
OOB	Out-of-Bag
RBFNN-SSA	Radial Basis Function Neural Network- Squirrel Search Algorithm
GOAPSSN	Grasshopper Optimization Algorithm and partical swarm optimization with Artificial Neural Network
BFOANN	Bacterial Foraging Optimization Algorithm-Artificial Neural Network

Abstract

The energy demand is growing year on year, but the fossil fuel reserves are depleting at a faster rate. As a consequence, the sustainable energy sources like PV, WT along FC are gaining more attention and importance. Because of the intermittent nature of sustainable energy source, it is significant to have highly efficient energy management system in MG. A new hybrid energy management system and control techniques has been proposed in this thesis to achieve individual source level control to get desired power quality and reliability and the load level control to achieve economic operation at optimum cost and overall system control. Here, First chapter explains the introduction and literature review about the energy management of MG connected system for multi-objective function with various control approaches. Second chapter describes about the microgrid and its type, topologies of ac, dc & hybrid microgrid, basic components of microgrid and merits and demerits of microgrid. Next chapter, it formulates the mathematical problem on the above objective functions. Here, the illustration of MG architecture i.e micro grid architecture model utilizing proposed method, micro grid architecture utilizing proposed hybrid controller, construction of MG connected system with proposed controller, problem formulation, implementation of hybrid method for energy management system, overview of energy system and description of the proposed system are described. Fourth chapter portrays the soft-computing techniques that are used in energy management system. In this section the brief explanation of methodologies of soft computing techniques are elaborated. Fifth chapter presents the simulation result and discussion. Here, the research work has been carried out in different stages and presented in form of case-studies.

In case-study 1, a simple multi-objective function with reduction of fuel cost and emission has been formulated to minimize the fuel cost as well as operation and maintenance cost by the optimal energy management of MG sources. Here, a hybrid ABC strategy, the IABC and CS-BAT based modelling and management of Microgrid System (MG) has been presented. The ABC algorithm is designed in two phases based on objective functions. The initial phase of ABC demonstrates that MG's optimal configuration at low fuel costs. By least cost functionality, the second phase of ABC has been achieved with minimal O&M costs. At IABC, the scout bee phase has been relocated with GSA technology that promises for enhancing the search capability of scout bees. At hybrid CS-BAT here, the configuration of optimal MG is acquired by solving

the proposed multiobjective function along with load requirement. The performance of proposed system is examined with previous systems, viz online management, ABC, ABC-ABC, IABC and ABC-FA. The comparative outcomes portrays that proposed system to identify optimal parameters is the most effective technique when meeting the load requirement at the lowest fuel cost and it is more efficient than existing techniques.

In case-study 2, a novel SOGSNN algorithm has been proposed to solve the similar objective function as mentioned in the previous case-study but this time with different operating scenario of MG units with optimal load forecasting. The proposed SOGSNN method is the combined performance of GSA-ANN and SSA, hence it is named SOGSNN. The purpose of the SOGSNN method is to reduce the fuel costs, emissions and operation with maintenance costs with optimal use of RES. The optimization issue involves a kind of energy sources that can be performed in the MG like, photovoltaic, wind turbine, micro turbine, BESS. Control operations needs to the optimization issue to reflect few extra considerations with optimal load forecasting. The proposed hybrid technique is implemented in MATLAB/Simulink platform along its proficiency is assessed with various current approaches. The efficacy of the SOGSNN method is examined with other exiting techniques such as ABC, BFO and ANFASO technique. The comparative result provides the proposed method is more efficient than other previous approaches.

In case-study 3, the problem has been made more complex for better techno-economic analysis by considering multi objective problem formulation. The proposed hybrid technique is in terms of a combination of ANFIS and ASOA approach. The intention of the proposed technique is to reduce overall fuel cost and increase the use of RES with considering the generation cost of PV & wind power. The optimization issue involves maximum uses of energy sources that can be found in the MG like battery storage, photovoltaic, micro turbine and wind turbine sources. The control operations have been added to the optimization issue to reveal few another considerations that are mostly found in the smaller generation scheme. The proposed method is implemented in MATLAB/Simulink, also their effectiveness is analyzed with different existing methods. From the experimental outcomes, it clearly shows that the use of optimum power generating costs and energy sources for micro grid that the optimization works best and provides the optimum power scheme for the generators after carry out the objective functions. The proposed approach is compared with other previous methods like GA, ABC and BFA. Furthermore, the use of the proposed technique has led to a minimization of almost 25% in the entire cost of generating power.

In the fourth case-study of the work, a novel RBFNN-SSA method has been proposed for solving the multi objective problem in order to avoid premature convergence. For maximum techno-economic benefits, the multi objective problem has been formulated in such a way that it can minimizing various objectives including yearly economic loss which includes annual capital cost , annual replacement cost, annual fuel cost, annual operation and maintenance cost as well as optimal forecasting load demand. Here, maximizing usage of MG sources and minimizing the operational cost is performed by the RBFNN-SSA method. The proposed RBFNN-SSA is implemented in MATLAB/Simulink platform and then the proficiency is assessed and tested with the exiting techniques viz IABC, BFOANN, ALO, GOAPSNN methods.

Sixth chapter presents the conclusion and future scope of that proposed microgrid connected system.

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1 Introduction

1.1. GENERAL

In general, an extension of generation, transmission and proper distribution are required to achieve the increased demand of electricity power. The combination of renewable energy sources and sufficient energy storage elements are ecologically viable which gives heterogeneousness chances to support extra incomes for long distance places. To supply the electric power, the effectively developed micro grid system has some advantages such as protection of energy, minimum electricity rate, protection of devices, improvement of profit etc. An optimum energy management and control of a micro grid utilizing renewable energy sources is an energizing role for micro grid operators. In this role the contingency of load requirement as well as power generation of renewable energy sources should be considered. Now a day, the stability of electric power grid is managed via the adjustment of generation and transmission of grid. The micro grid energy storage system provides the stability to manage these adjustments. The improvement of energy storage systems are required to enhance the performance of micro grid and better pricing. Energy management systems and control techniques with energy storage system are required to manage multiple grid operations. The main role of EMS is to control of power supply and to reduce the cost of energy consumption as well as the operational and maintenance cost.

1.2. TYPES OF ENERGY

There are various types of energy like thermal, radiant, chemical, nuclear, electrical, motion, etc. [1]

- **Thermal Energy:**

  Thermal is also represented as heat energy. When a temperature is increased, the atoms and molecules run speedily and collide with each other which introduce the heat. This process provides an energy which called as thermal energy.

- **Radiant Energy:**

  This energy is generated from electromagnetic waves. Electromagnetic waves have an ability to travel from one place to another place via free space. The movement of group of

Photons are called as electromagnetic radiations. The light energy is generated from group of photons. Light is also called as radiant energy.

- **Chemical Energy:**

  Chemical is a type of energy which is generated from chemical particles. This energy is produced when a chemical reaction takes place. Generally, once chemical energy was introduced as a substance, that is moved into a newly substance.

- **Nuclear Energy:**

  Such type of energy is generated from nucleus or centre part of an atom. Atoms are small units that develop all things in the universe. There is a large number of energy in an atom's dense nucleus.

- **Electrical Energy:**

  Electrical is generated from a movement of electrons. Based on the speed of charge particles the electrical energy is produced. If the electrical charges move faster, more energy will be produced.

- **Motion Energy:**

  Motion energy is also called as mechanical energy. This energy is generated from movements of an object. The energy is depends on the speed of the movement of the object. When an object moves faster, more amount of energy will be produced. The integration of potential energy and kinetic energy is called as motion energy.

1.3. ENERGY MANAGEMENT

Energy management is the process of managing, monitoring, controlling and reducing energy usage for various applications [2]. The cycle diagram of energy management is displayed in Figure 1.1. The energy storage system plays two different operational phases of the MG, when the grid transitions from interconnected to island mode and while during continuous island operation. The effective transformation of the island's operation requires more coordinated and more rapid control action in milliseconds. At this time, the large power and rapid response capabilities of industrial proven battery systems (e.g. lithium-ion) can be used to effectively deliver instant power to MG for a limited period of time and to serve for most loads during the time of interruption. If there is no backup, The MG will only last until the storage system capacity is exhausted, i.e. actually between fifteen minutes to few hours. When switching from utility distribution to an independent island mode, some of the inverters are used to control voltage along frequency for maintaining the power quality of the islanded power system. This functionality is generally satisfied by the proper implementation of grid power generation as well as properly designed storage system.

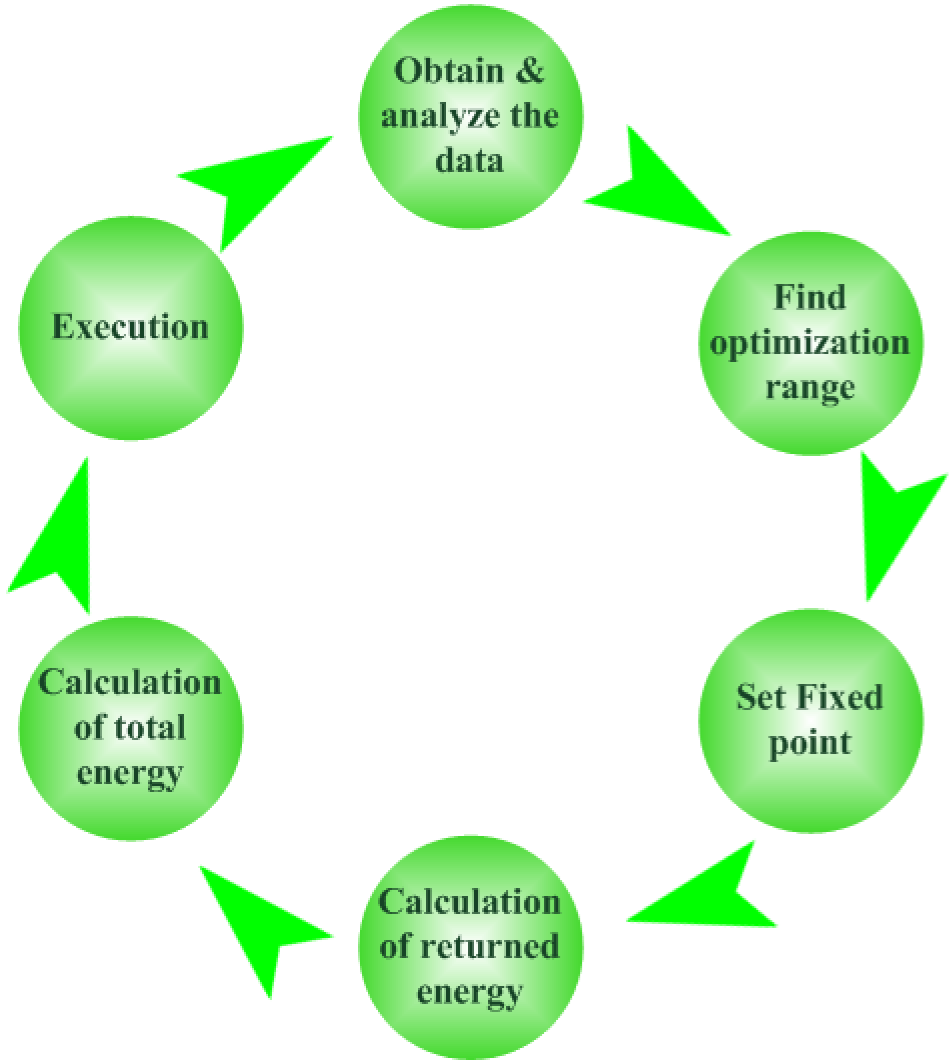


Figure 1.1: Cycle of energy management process

Processing steps of EMS is mentioned below:

Step 1: Gathering and analysing the continuous data.

Step 2: Finding optimization range for reducing consumption of energy.

Step 3: Set fixed value to increase the strength of energy.

Step 4: Evaluate the returned energy.

Step 5: Calculate the amount of energy stored and amount of energy transferred.

Step 6: Execute energy optimization values.

Step 7: Continue the process from step 2 until the energy becomes an efficient.

1.4. RENEWABLE ENERGY SOURCES

A renewable energy source is a static energy which cannot move and it has no end like sun. The sources of renewable energy are differing from non-static sources [3]. The various types of renewable energy sources are shown below:

- Solar energy.
- Wind energy.
- Hydro energy.
- Tidal energy.
- Geothermal energy.
- Biomass energy.

1.5. MG

MG is a self-sufficient energy system that provides energy in unique geographical footprints such as college campus and hospital campus. There are different kinds of energy sources in micro grid like solar energy, wind energy etc. Micro grid are decentralized power sources which connects to large synchronization grid as well as loads and may be disconnected in "island mode" to operate autonomously as dictated by physical or economic conditions. In this way, the micro grid based Distributed Generation (DG) can be effectively integrated with various renewable energy sources with RES and can provide alternative electricity in interconnected or islanded mode. MG connects the grid with point of the common connection, which maintains the current at similar level as the main grid and to disconnect the grid if any problem arises. The disconnection of Micro grid from the main grid by mechanically or physically through the switch is possible and then it is called as an island mode [4]. The protection and control of micro grid are the major challenges in the MG. It is also an important feature to provide the needs of multiple end useses like heat, cool, electricity simultaneously. MG's are the good platform as localized energy sources. Here, the generation and distribution of energy sources can defines MG as interconnected loads and DER (PV, WT, MT, and FC) within clearly defined power limits, performing as a single controllable entity depends on grid. It can be connected to the grid as well as disconnected or islanded mode. If the function of the MG in the network is managed and integrated efficiently, it can provide benefits for the entire system performance.

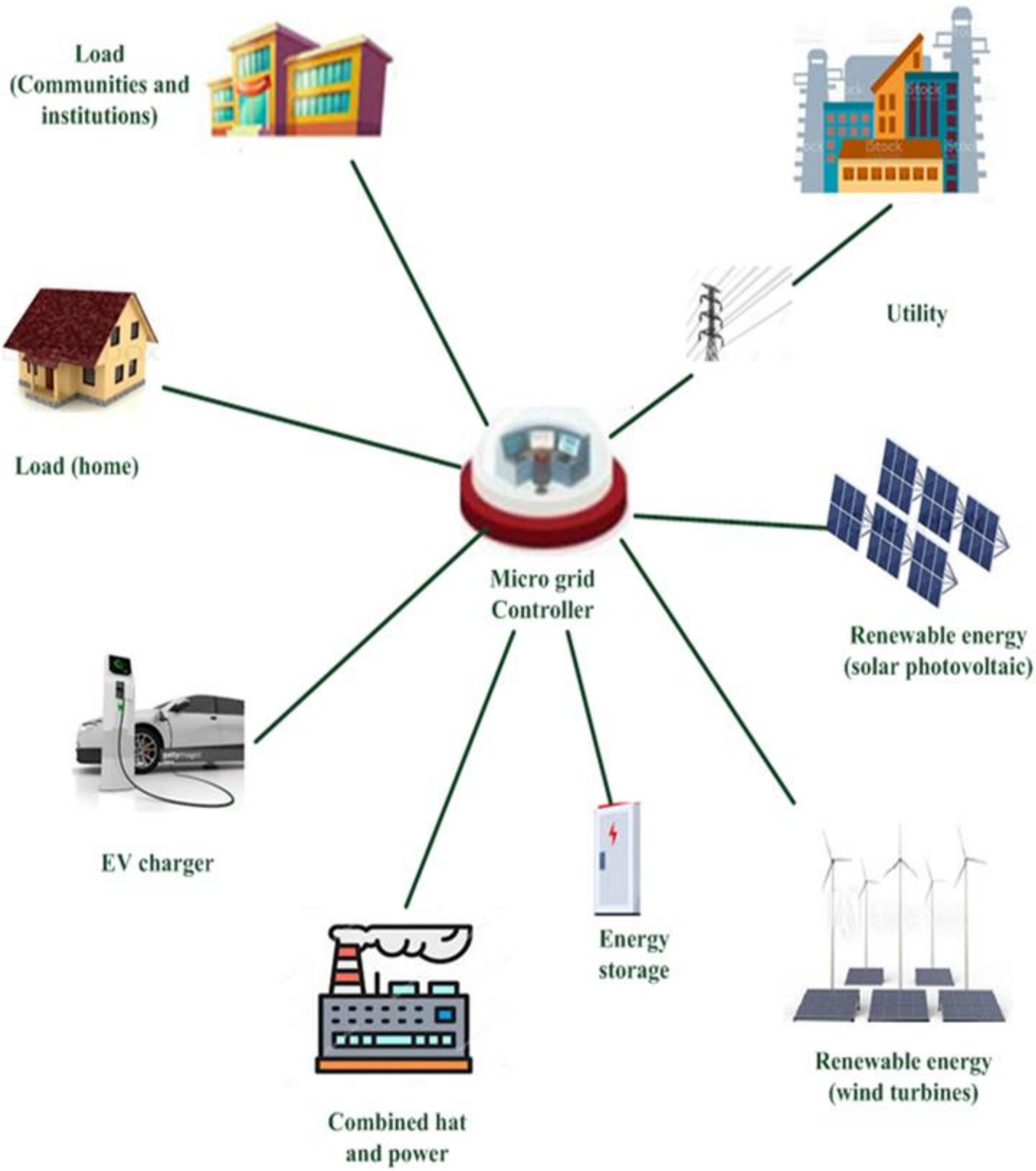


Figure 1.2: Working process of micro grid controller with various organizations

The modern Micro grids have the facility to store energy through the battery. A Micro grid has control strategies such that which has an ability to isolate from the basic grid as well as which can operate as individually. The working process of micro grid controller is shown in Figure 1.2.

1.6. CHARACTERISTICS OF MICRO GRID

A Micro grid has three basic characteristics which are shown below:

- **A micro grid is local.**

Micro grid is a type of local energy which means it generates energy for neighbouring systems. This property differentiates the micro grid from various types of grids. A micro grid gives large amount of electric power for previous hundred years [5]. The central grids trigger the electric power from main centre to rural areas through transmission lines. The received power is not accurate due to long distance. Because there are large amount of energy will be loss during the transmission. A Micro grid has an ability to overcome these problems which produce the power to nearest building or systems.

- **A micro grid is independent.**

A Micro grid has an ability to isolate from the central grid as well as working at individually. This ability permits the micro grids to give power to the receivers when natural disorders affect power grid. Micro grids do not depend on any other systems. In rural and remote areas, micro grids are used instead of central grids.

- **A micro grid is intelligent.**

A micro grid is an intelligent based advanced system. A micro grid controller is represented as brain of the system which controls the inverters, storage devices etc. For the implementation process a micro grid needs controller which provides pure and efficient energy, high reliability with minimum cost. The above mentioned objectives with micro grid resources can be achieved by Micro grid controller.

1.7. WORKING OF MICRO GRID

The micro grid can be installed in houses, hospitals and buildings with central power sources to utilize electronics devices, temperature systems. Due to this interconnection, if one section is failed, all section becomes faulty. When micro gird connected with grid it becomes to a working condition. Also, it may be stopped and working on separately in islanded mode when a natural disorders and other outages cause in the micro grid operations [6]. The energy is provided to the micro grid through generator, battery, wind energy, solar panels etc. The working of micro grid is done based on fuel requirements and control of micro sources. The connection of micro grid with grid is done through point of common coupling which balances the voltages to both sides.

But if problems arise in this micro grid then the connection can be separated from main grid to micro grid with the help of static switch.

1.8. CONTROL METHODS OF MICRO GRID

- **Primary Control:**

  The primary control layer is developed with droop control technique. The primary control method is used for controlling power supply. Depending on the adjustment of voltage, frequency and amplitude, the power supply is controlled. The power supply is controlled by droop control technique which allow more synchronous generators to work in parallel distribution based on load to minimize the frequency at a time of maximized active power on the grid [7]

- **Secondary Control:**

  It is utilized to reduce losses in frequency and voltage amplitude. The losses may be generated due to droop control in steady state. The secondary layer reinstates the output power for particular testimonial and also controls the power sharing on primary layer. In the secondary control layer, the reinstating of frequency and voltage to fixed values is done with the help of sum of faulting term and movement of droop function to starting characteristics of all section.

- **Tertiary Control:**

  It is utilized to control the flow of current amid micro grid and main grid. This process is done with the help of automatic changes in energy supply. Sometimes an energy supply may be connected and disconnected from the main grid due to some problems like damage of grid, disturbances, cost of energy system etc. [8].

1.9. ENERGY MANAGEMENT FOR RENEWABLE ENERGY SYSTEM

Due to minimum number of energy resources, cost of system as well as an increasing the requirements of energy, the management of energy is all most important [9]. So the optimal management of the renewable energy sources is required to optimal power flow. The block diagram of energy management system is displayed in Figure 1.3.

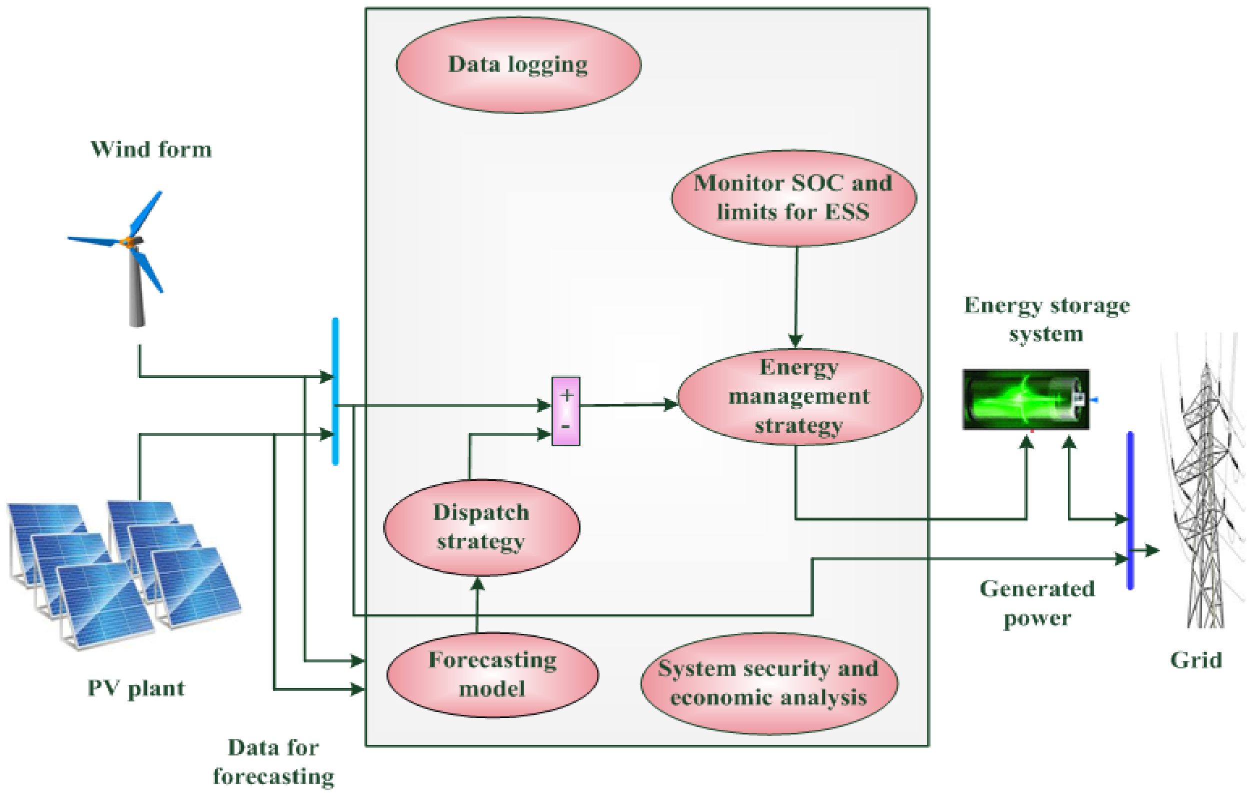


Figure 1.3: Block diagram of EMS

It is used to provide power to the places where not joined with public grid [10]. The energy management system has some drawbacks such as which require effective load, more number of renewable resources and high cost. This drawback can be overcome by regulating the use of the system using various techniques.

1.10. ADVANTAGES OF ENERGY MANAGEMENT SYSTEM

- Managing and reducing energy consumption.
- Control power supply.
- Making informed decisions.
- Finding the power quality issues.
- Remote access.
- An automatic solution.
- Good Performance.
- Saving of energy.
- Saving of cost.
- High reliability.

1.11. DISADVANTAGES OF ENERGY MANAGEMENT SYSTEM

- Higher storage capabilities.
- Intermittency.
- Higher upfront cost.
- Problems generated due to natural disorders.

1.12. APPLICATIONS OF ENERGY MANAGEMENT SYSTEM

- Hospitals.
- House.
- Generators.
- Electronic vehicles.
- Commercial and industrial applications.

1.13. LITERATURE SURVEY

In General, the variety of methods have been utilized for EMS and control of MG with renewable energy sources. For the most distributed systems, sources like PV, WT, MT, fuel cells are usually connected through power electronic components to form an MG system. The MG with RES and their adaptable control characteristics has improved through power electronics. Due to this, it has quick controllable dynamics that can be established with solutions for both power benefits and frequency response consequences. MG can work as grid connected with island mode of operation. The voltage/ frequency and the demand of power supply of MG are balanced and strictly operated by the grid. In island mode, inverter based distributed generation are reliable for the voltage/frequency stability and balance the correct power distribution due to their corresponding estimates.

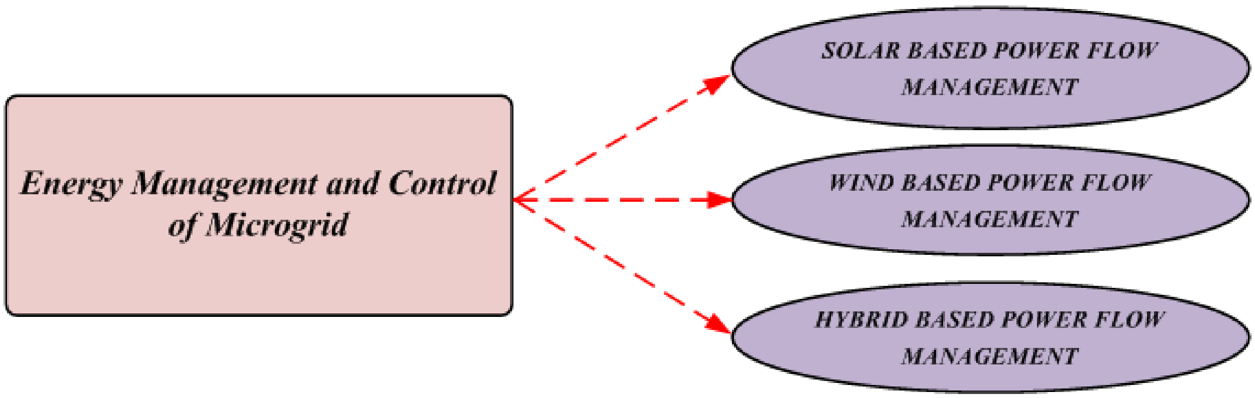


Figure 1.4: Literature survey of EMS and control of Micro Grid

The literature survey of EMS and control of micro grid is displayed in Figure 1.4. The processing methods of the various techniques and drawbacks of the research work as well as the correction methods are explained in this literature survey. There are various studies in the literature for energy management of MG. Each research work have a common objective i.e. to calculate the maximum usage of the distributed renewable energy sources, reducing the price of the energy delivered by sources and reduce extra usage of charging and discharging of battery etc.

(A) SOLAR BASED POWER FLOW MANAGEMENT

A.A.Jaina et al [1] have illustrated hybrid method of solar PV array (SPV) generating system to maximize power to load demand. The proposed hybrid method was combined execution of Quasi Oppositional Chaotic Grey Wolf Optimizer (QOCGWO) with Random Forest Algorithm (RFA) and therefore, it was called as QOCGWO-RFA. RFA calculates controlling signals of Voltage Source Inverter (VSI) and it depends on reactive power and active power variations under different load demand.

Y.Riffonneau et al [2] have presented an optimal power management mechanism of grid connected PV systems utilize storage. Its purpose was to support exhaustive penetration of PV production into the phase by offering a lesser cost in peak time. The structure of power supervisor was proposed depend on optimal forecasted power scheduling algorithm. Optimization was achieved with Dynamic Programming and likened to modest ruled-based management.

A.Varghese et al [3] have illustrated the lesser voltage DC micro grids, an encouraging idea that creates enhancements on power quality as well as consistency to end users over dissimilar control methods among sources and loads and regulate the DC bus voltage. This dissimilar operating mode was made based on the charge level of the battery and the DC bus voltage. Droop control was an actual solution for power sharing among PV, battery and loads. A separate control strategy has been established for battery charging and discharging.

M.O.Badawy and Y. Sozer [4] have presented an optimal power flow system of PV-battery. The continuously fast EV charging station was obtainable with lesser the operational cost. The impartial was to support the penetration of PV-battery systems into the grid and support the rising need of fast EV charging. An optimization problem was articulated and the required constraints and the operating cost function were selected with consideration of the electricity grid prices and battery degradation cost. In the principal stage of the proposed optimization procedure, the Particle Swarm Optimization (PSO) was implemented in prediction layer.

V. Sheeja and R Kalpana [5] have presented a power flow management algorithm with newly four port converter for grid integration of PV and battery power with load in low voltage. The efficiency of the system was high that reduced the number of power conversion levels in the four port converter. When lower grid power was obtainable the battery energy storage system used as back up to support the load.

S.Sheng et al [6] has approached an optimal power management method to lessen operating cost through managing power flows on PV-diesel generator based hybrid Nano grid with batteries. The proposed algorithm utilizes Dynamic Programming (DP) method to optimize the power flows in the system to meet the load demand. It also attains maximum utilization of renewable energy sources, lesser fuel consumption and improvement of life cycle of battery.

B.I.Rani et al [7] has introduced a rising concern for energy storage that has increased the usage of LED-based street lights, electronic chokes, compact fluorescent lamps and inverter-fed drives. The load profile through the electrical grid was undergoing a prominent change as these devices have to work as dc source. Here, PV represents the main energy source and the above-mentioned loads may be linked directly to the dc bus. A grid-connected PV includes a power source (PV array), a power sink (load), and two power sources/sink (utility and battery) and therefore the power flow management system was essential for balancing power flow amongst such sources.

K.M.S.Y.Konara et al [8] have presented a hybrid energy management system with energy storage containing PV array, battery and super capacitor bank. It was going to work as an active generator with innovative load management and power flow control strategies to manage the active power demand along with the grid constraints. The configuration for the PV-based active generator is such that it can deliver the active energy in a controlled manner while maintaining frequency stability in the power grid.

Sakshi Mishra and Praveen Palanisamy [9] have illustrated a methodology for efficiently managing the power flow and that provide huge saving of energy with micro grid based renewable energy sources. Here, it presents the simulation result and the design of PV source through MG that attained peak saving and efficient power flow management utilizing advanced metering and a smart control unit.

Y.Guo et al [10] has presented an optimal EMS for grid-connected micro grid system with PV array. The method was derived based on the dynamic programming algorithm and grid Input/output (grid I/O) strategy. The method utilizes the solar power to meet demand loads, minimize battery life cycle losses, and maximize the economic benefits to end users.

(B) WIND BASED POWER FLOW MANAGEMENT

N. Mendis et al [11] has illustrated a hybrid EMS with energy storage in a wind dominated remote area. This system consists of doubly-fed induction generator (DFIG), a battery storage system, a super-capacitor, a dump load and main loads. Here, the life of the battery has improved by using super capacitor bank. In this regard, the battery storage system was linked to the load side of the system while the super capacitor was linked to DC bus.

M.J.V.Pakdel and B.M.ivatloo [12] have demonstrated the probabilistic methods utilizing set of perfect linear power flow equations.The linear power flow equations have been proposed for modeling the distribution network instead of typical Newton-Raphson approach that decreases the computing time per every simulation. The well-known approaches of two points estimate and Latin hypercube sample methods are implemented in this methodology.

L.Wang and Q.S.Vo [13] have presented the power-flow control and stability improvement of a DFIG-based offshore wind farm (OWF) and linked to a one-machine infinite-bus (OMIB) system by utilizing a static synchronous series compensator (SSSC). An oscillation damping controller (ODC) of the proposed SSSC is calculated through utilizing model control theory to render proper damping to the dominant mode of the studied Synchronous Generator (SG).

J. Luo et al [14] has presented the solution methodology of optimal power flow through consideration of uncertainties caused in wind generation and several factors in the power grid. In case of uncertainties studied, multiple types of uncertainty modeling methods were applied in this research. The evidence theory and extended affine arithmetic were applied and mixed with the framework of uncertainty propagation to probability distributions. The probability distributions and the necessary among variables ware handled through copula theory and affine arithmetic.

C.Lin et al [15] has presented a Density Distribution Fitting Method (DDFM) relating with the Copula function to establish a joint probability model for wind power generation. A special Impulse- Mixed Probability Density (IMPD) integration method is also introduced. Lastly, a Fast Cumulant Method (FCM) was proposed and to reduce the computational burden of output cumulant calculation in a nonlinear context.

S.K. Jadhav [16] has illustrated a control strategy of micro grid energy management with energy storage system. Energy from the renewable sources is stored for additional usage and by optimizing this storage energy to optimize the entire power source in MG. This work proposes the use of an optimal power flow solution in the systemize. storage device, voltages and currents with power limits.

D.Kotur and P.S.fanov [17] have introduced the optimal control of power converters to minimize the power losses in the system. The main task of proposed method was to meet up the load, depending on the forecasted production of WP plants of the power converters that would enable its optimal decentralized work in the presence of intermittent production from wind power plants.

X.Fang et al [18] has illustrated a hybrid Distributionally-Robust Chance-Constrained and Interval Optimization (DRCC-IO) based model to consider the influence of WP uncertainty and its spatial-temporal correlation on IEGSs operation. Mainly, the DRCC-OPF model was proposed to attain reliable economic dispatch solutions for the electricity network considering WP forecast errors.

M.J.Carrizosa et al [19] has illustrated a power flow strategy for multi-terminal HVDC grids. The energy was mostly generated through renewable energy sources and the grid in the network utilizes the probability for storing energy. This energy was generated taking into account the actual weather conditions to create the optimal scheduling of the system in a realistic algorithm.

S.Rahmani and N.Amjady [20] have presented a new generation method that is to model WP improbability. The proposed generation approach contains the construction of Probability Density Function (PDF) that affecting the WP forecasting error and segmentation of PDF by efficient clustering method to attain two optimum number of WP scenarios utilizing the optimized clusters via roulette wheel mechanism.

(C) HYBRID BASED POWER FLOW MANAGEMENT

V. N. Murty and A. Kumar [21] have presented a techno-economic analysis for optimal EMS in renewable energy sources based micro grid system. The supply of electric power was a difficult one for long distance places which can be overcome by using this approach. This approach was very expensive but this provides good performance as well as high reliability. The protection of grid from various natural disorders has been done by the help of this technique. The different types of techniques were explained for analyzing process. The optimization strategies were implemented with the help of hybrid optimization method for electric power system. The requirement analysis has been done for the accurate output achievements. The capability of photo voltaic system, renewable resources, generators as well as the price of the overall operations has been calculated.

E. J. Aknoletto *et al.* [22] have worked on an optimal EMS stand alone battery based micro grids using the concept of constraint method for grid tied. The sporadic features of micro grids were trigger the implementation of energy control process which has been utilized to reduce power consumption. The development of EMS has been done by the help of various analysing technique that has the ability to protect the life of batteries and generators. The energy transmission problem for long distance areas has been overcome by using energy management system with various strategies. In this technique, the extract values have been calculated for energy management systems to manage the micro grid renewable sources. In these techniques, the operational cost as well as the energy leakage of the system has been reduced. The performance analysis has been done by using two strategies such as the examination of distributed and non-dispatch able sources as well as dispatch able sources and batteries.

P. Zhuang *et al.* [23] have illustrated a stochastic multiple timescale energy of greenhouses through renewable energy sources. In this technique energy management was done using particle swarm optimization algorithm. The coupling of super capacitor with battery has been used for many applications. This coupling mechanism provides good performance, better effectiveness, high reliability, less weight and low price. The modern energy control techniques have been utilized for managing energy storage devices. The energy has been controlled by utilizing PSO algorithm. The main objective of particle swarm optimization algorithm is to lessen the energy usage and increase the reliability. After the optimization process was finished, the managing process starts to produce good performance result, which is analyzed using proper simulation techniques.

R. H. Byrne *et al.* [24] have developed an EMS and optimization methods for grid energy storage systems. The steadiness of micro grid is based on the basis of production and requirements. To achieve this complementary function, grid scale energy storage systems were used which provides higher reliability and good performance. The energy management system has been used to sponsor many grid operations which give the solution for usage of energy with protective manner.

J. Choi *et al.* [25] has suggested a robust control of a micro grid energy storage system utilizing several methods. This method provides the management of energy at very difficult situations, which has been used to reduce the abnormalities developed during generation in energy management process. The fault or abnormalities has been calculated using combined integer linear operation with small calculation period. The managing steps have been modernized to rectify the fault management. The charging condition of batteries has been evaluated by using linearization methods. An amplitude control reaction technique has been implemented at a time of optimization which provides good performance, high reliability and low cost.

F. Delfino*et al.* [26] has worked on EMS for the optimum control of active as well as reactive power in micro grids. During the transmission of energy between the grids, there was a decrease in the price of transmission as well as release of carbon dioxide. In EMS for the optimum control of active as well as reactive power in micro grids, the various types of analyzing methods and optimization strategies have been used for achieving the system goal. The output has been obtained using simulation process and compared with extract values. If in the returning path the amount of energy is decreased from source energy, then the system identifies that some energy lost has been occurred.

Y. Xu and X. Shen [27] have demonstrated an optimum control based EMS of multiple energy storage systems in MG. The MG with renewable energy sources was used to provide energy to various organizations like hospital, industries, home, institutions, etc. but latter it was affected by some natural calamities. So the MG incorporated with renewable energy sources are used to control a micro grid was a difficult role in natural environment. So this problem has been overcome by using optimum control based EMS of multiple energy storage systems in MG. By using this technique, the operational price was reduced and energy storage devices which are used as a backup device, provides good performance. An energy loss was overcome with the help of this technique.

A. M. A. Haidar *et al.* [28] have developed an optimum EMS and power sharing control utilizing power line communication. An efficient energy distribution method for clustered micro grid has been implemented in this approach. The energy has been controlled and the power has been accurately delivered to various organizations with the help of optimization techniques as frequency shift keying used in this approach. The energy was transmitted through the power line communication by the help of frequency shift keying. An optimization strategy has been analyzed for the use of energy distribution. This technique provides good performance, high reliability and low cost facilities. By using frequency shift keying technique the transmission of energy without loss has been found which provides good solution in solving the deviation problem when compared with other techniques.

Y. Liu *et al.* [29] have demonstrated a distributing robust EMS of multiple MG system to reduce the cost of power of micro grids. By using the optimization techniques as frequency shift keying the amount of energy generated from renewable sources, power usage and the cost of micro grid has been calculated. During transmission of current between the grids, the goal process was to decrease high price of the system and also the release of carbon dioxide. In this technique, the various types of analyzing methods and optimization strategies have been used for achieving the system goal. The data obtained from the output uses simulation process and compared with reference values. Now if the energy level which was returning from the grid was to some extent less, compared to that from source energy level, the system was then identified as loss of energy system.

Y. Liu*et al.* [30] has implemented multiple objective optimization of EMS approach in hybrid energy storage system. This approach was used to reduce the cost of energy management for unknown dynamics. Here, two stage optimization methods were implemented with the benefits of the grid as well as the receiving end user. By using the multiple objective optimization technique, the utility grid achieves good result with the help of reduction of cost as well as also satisfies the user with proper utilization of energy sources to reduce price. This operation was completed in many steps. The user reaction was used to overcome the optimization problem at every step by reducing unidentified problem with the help of penalty process. The energy usage of the consumer has been calculated by the help of various control techniques. An extreme seeking control algorithm contains non-sequential expression based on variables. When the user reaction becomes equal, a utility organization enhances the price of power using PSO algorithm. The coupling of extreme seeking algorithm and PSO algorithm was known as electromagnetic algorithm. This algorithm has been implemented in this technique.

S. Sahoo *et al.* [31] have demonstrated a cooperative adaptive droop based EMS with optimum voltage regulatory system for direct current micro grids. This approach mainly deals with Photo Voltaic based automatic direct current system. The control of many number of energy storage devices creates some problem in direct current network. This drawback can be overcome by using cooperative cyber network. The energy management system delivers the supply of energy to various applications. Multiple optimization techniques have been implemented to manage the energy supply and provide good performance as well as high reliability. The electricity load moves from higher amplitude to lower amplitude systems with the help of optimization techniques with some arrangement in the processes, that has been implemented in this approach which schedule the on and off conditions for decreasing the delay period.

H. Zhang*et al.* [32] has explained distributed optimal energy management for internet of energy. A new energy control mechanism for internet of energy has been implemented in this approach. In this technique, a combination of energy groups were performed which serves many functions at parallel. The mechanism for using the renewable sources with unlimited power usage was a difficult task in environmental appliances. This problem can overcome by using IoTs based energy management system which provides an ability to use renewable sources with unlimited manner. Also, this approach provides good performance. IoTs based energy management system have been introduced to delivering the energy for long distance areas without any deviations. The IoTs based energy management system give a chance to the system for providing excellent accuracy rate at output. Particle swarm optimization algorithm have implemented on this approach for providing perfect delivering of energy to various organizations.

M. Collota *et al.* [33] have implemented a fuzzy logic approach by utilizing PSO for effective energy management. An industrial wireless sensor network permits to utilize energy storage devices for easy implementations of power transmission without loss and achieve better performance. The implementation of network elements was difficult work. The energy usage of industrial wireless sensor networks has been reduced by using optimization method. The fuzzy logic techniques have been applied in this energy management based on condition of storage device and its ratio between maximum processing time and work load. This approach has been used to find the activation period of sensors. The required output and parameters have been obtained by using particle swarm optimization process.

H. A. Gabbar *et al.* [34] have explained an optimal development of hybrid nuclear based renewable micro energy system through PSO method. The nuclear based renewable system is an effective system which has been used to transfer the power for various organizations. By using this system the power loss has been reduced and the performance of the system has been improved. The energy system combination of nuclear reactors, WT and PV provides low priced energy to the consumer. These combinational methods have been utilized to analyze and finding significance of energy management system. The operational parameters were analyzed based on system reliability. The output of the system has been analyzed by using MATLAB/ simulation platform. The net cost for the consumption of current has been reduced with the help of AI based optimization algorithm.

K. Ma *et al.* [35] have demonstrated an energy management system considering unknown dynamics depending on extreme seeking control and PSO method. The approach was used to reduce the production cost in energy management for un-identified dynamics. The two stages optimization methods were implemented upon user and its utility. By using this technique, a utility organization achieves good result with the help of consumer feedback by adjusting utilization of energy to reduce price. This operation was done in many steps. The user reaction was used to overcome the optimization problem at every step. Also it was moved into unidentified problem with the help of penalty process. The energy usage of the user has been calculated by the help of various control techniques. An extreme seeking control algorithm contains non-sequential expression based on variables. When the user reaction becomes equal to the variables, a utility organization enhances the price of power by using an algorithm known as PSO algorithm. The coupling of extreme seeking algorithm and PSO algorithm is known as Electromagnetic Algorithm. This algorithm has been implemented in this methodology.

T. Mesbahi *et al.* [36] have implemented optimal energy management system for lithium ion battery. In this technique, energy management was done using particle swarm optimization algorithm. The coupling of maximum energy storage devices with battery has been utilized for many applications. This coupling mechanism provides good performance, better effectiveness, high reliability, less weight and low price. The modern energy control techniques have been utilized for managing energy storage devices. The energy has been controlled by utilizing particle swarm optimization algorithm. The main objective of this method is to reduce energy usage and increase the reliability. This can be done by utilizing particle swarm optimization algorithm. When the optimization process was finished, then the management process starts to produce good performance. The output was analyzed using proper simulation process.

Z. A. Khan *et al.* [37] has developed a nature inspired based artificial intelligence methods to coordinate load development in a day by effectively managing energy in smart grid. The energy management system issued in accordance to the load required in rural areas as well as improper power delivering conditions. The energy management system delivers the supply of energy to various applications. Multiple optimization techniques have been implemented to manage the energy supply and provide good performance as well as high reliability. The electricity load moves from higher amplitude to lower amplitude systems with the help of optimization techniques. Also, some processes has been arranged which has implemented in this approach for scheduled on and off conditions for decreasing the delay period.

M. Manbachi and M. Ordonez [38] have suggested an intelligent agent based energy management system of islanded alternative current to direct current or direct current to alternative current micro grid. In this system, the better solution has been obtained for the problems. In this technique, there are three agents such as alternating current micro rid, direct current micro grid and device manager agents that implemented in alternating current or direct current micro grid. These three agents have been interacted with all for providing good performance, more effectiveness and long life time. The energy flow from alternating micro grid bus system to direct micro grid bus system is done through AC/DC converter. By using this approach, the device price can be reduced and the performance of the system can be improved. Particle swarm optimization algorithm have been implemented in this approach to overcome the above arise problem in energy controlling process.

D. Phan *et al.* [39] have implemented an intelligent energy management system of conventional autonomous vehicles. The protection of vehicle from accident has improved by the help of automation. The implementation of automatic vehicles reduces energy usage. But the usage of energy storage automatic vehicle is much more compared to other normal vehicles. The control of energy was difficult but it's essential one for normal vehicles. Fuzzy controller technique was implemented to control the energy flow also proportional integral derivative controller was implemented to manage fuel ratio.

P. Pawar *et al.* [40] have developed an internet of things depending on intelligent smart energy management system. The mechanism for using the renewable sources with unlimited power usage was a difficult task in environmental appliances. This problem is overcome by utilizing IoTs based energy management system which provides an ability to use renewable sources with unlimited manner. Also, this approach provides good performance. Some predictive techniques have been introduced to delivering the energy for long distance areas without any deviations. The predictive techniques give a chance to the system for providing excellent and accuracy output. Particle Swarm Optimization algorithm is implemented on this approach for providing perfect delivering of energy to various organizations.

B. Rajasekhar *et al.* [41] have demonstrated a review of smart computing methods for air conditioners energy management. The strong implementations applied on air conditioner management systems have ability to decrease the price of system and energy usage. The optimization process of AC was very difficult. The difficulties have been overcome by using this approach of smart computing methods for air conditioners energy management. In this approach some predictive strategies and optimization techniques have been implemented to lessen the energy usage and controlling the power flow. The result has been tested using computation process, which provides good performance, high reliability and low cost facilities.

1.14. GAP IN STUDY

Here, the optimum energy management and control of MG utilizing renewable source has been briefly studied. Lot of scopes is available in this area. From the literature survey it is concluded that the energy management system is important factor to achieve the effective power delivery and minimization of operational cost [42-45]. The micro grid is an energy network which manages the power flow. MG obtains or delivers the power with the help of main grid to various organizations. In an existing method, various control techniques have been implemented but some problems arise during the transmission or reception of power so that the effective usages of energy were reduced and there can be a chance to the disconnection of micro grid from main grid [46, 47]. The disconnection of micro grid from the main grid problem can be overcome by using this approach. In this approach the interconnection of micro grid and main grid was done with the help of network connection which gives high reliability, better performance, and effective power delivery without any loss [48-50]. By using this technique the price of energy can be minimized. Proper control processes and optimization techniques are used to deal with these issues. In the related works, some control techniques are shown to improve the optimal energy management in the MG. But this research work is motivated by the previously stated limitations [51, 52].

1.15. OBJECTIVE OF THE PRESENT WORK

- To reduce energy cost.
- To achieve good performance.
- To achieve high quality of output.
- To reduce the power loss.
- To reduce the transmission loss.
- To minimize environmental pollution.
- To increase the efficiency.
- To reduce carbon emission.
- To achieve protection from climate change.
- To find superior energy alternatives.
- To achieve and maintain optimum energy procurement and utilization throughout the organization.
- To reduce import dependency.

- To enhance energy security.
- To increase economic competitiveness.

1.16. ORGANIZATION OF THE THESIS

The research works carried out in this thesis are organized in chapters. This chapter gives the deep introduction about optimum energy management and control of MG utilizing renewable energy sources. The working process of EMS with micro grid controller by different optimization techniques as well as various control methods is also described. The purpose of energy management system and the techniques used for control of micro grid was studied.

CHAPTER 1 analyzes the literature survey of optimal energy management system and control of MG utilizing renewable energy source. From the literature review, the motivation and objective of thesis is also outlined. The organization of thesis and chapter wise summary is also outlined.

CHAPTER 2 explains micro grid connected system with PV, WT, MT, fuel cell and battery.

CHAPTER 3 describes mathematical modeling of Micro grid connected system.

CHAPTER 4 describes implementation of proposed hybrid method utilizing different optimization techniques.

CHAPTER 5 determines the simulating outcomes and discussion with proposed and existing techniques.

CHAPTER 6 concludes main objective of the thesis and suggests future scope of research in this research area.

1.17. SUMMARY

From the above literature survey, it can be concluded that the micro grid system is one of the important and needful strategies to expand the existing power system. It shows both positive and negative impacts on the system depending on the planning strategies. The optimal energy management of MG units in the existing system with proper planning strategies may lead to several technical, economical, operational and environmental benefits. Since, the optimal management of MG units in the existing system is an important task, so, it attracts several researchers to work in this area and proposed different optimization techniques to solve the above mentioned complex multi-objective optimization problem considering different objective functions. From the literature survey, it can also be noticed that most of the authors had considered either technical aspect or economical aspect only and considered the problem as either single objective scenario or multi-objective scenario. So in this work, both aspects can be considered as the objective function to maintain the proper balance between technical as well as economic benefits by considering meta- heuristic based multi-objective scenario. For this type of multi-objective scenario, a very few number of works have been analyzed by state-of-the-art Meta -heuristic optimal methods. So, there is some scope to implement the well-known multi-objective algorithms or to propose some novel state-of-the art meta-heuristic based multi-objective algorithms. The formulation of the proposed objective functions have been discussed in the subsequent chapter.

2 Microgrid

2.1. GENERAL

The Micro Grid (MG) is a relatively small scale localized energy energy network which includes loads, network control system and a set of distributed energy resources such as generators and energy storage devices. There is also micro grid utility connection to buy electricity when there is not enough electricity generated from local generators or to sell electricity back when there is excess electricity generated. When there is an emergency, the micro grid can be disconnected and micro grid can work independently which provide electricity in the islanded mode. The micro grid is an independent energy framework that provides energy in local area likes school grounds, clinic complex, business complex, etc.

2.2. OVERVIEW OF MICRO GRID

Micro grid is a group of DERs that includes the interlinked loads. There is single controllable switch which can attach with main grid called grid connected mode or remove from main grid called islanded mode. In EU micro grid definition, the MG involves low-voltage (LV) in distribution systems among DERs and flexible loads along energy storage system [52]. The MG can be connected or disconnected from main grid. The architecture of MG is displayed in Figure 2.1.

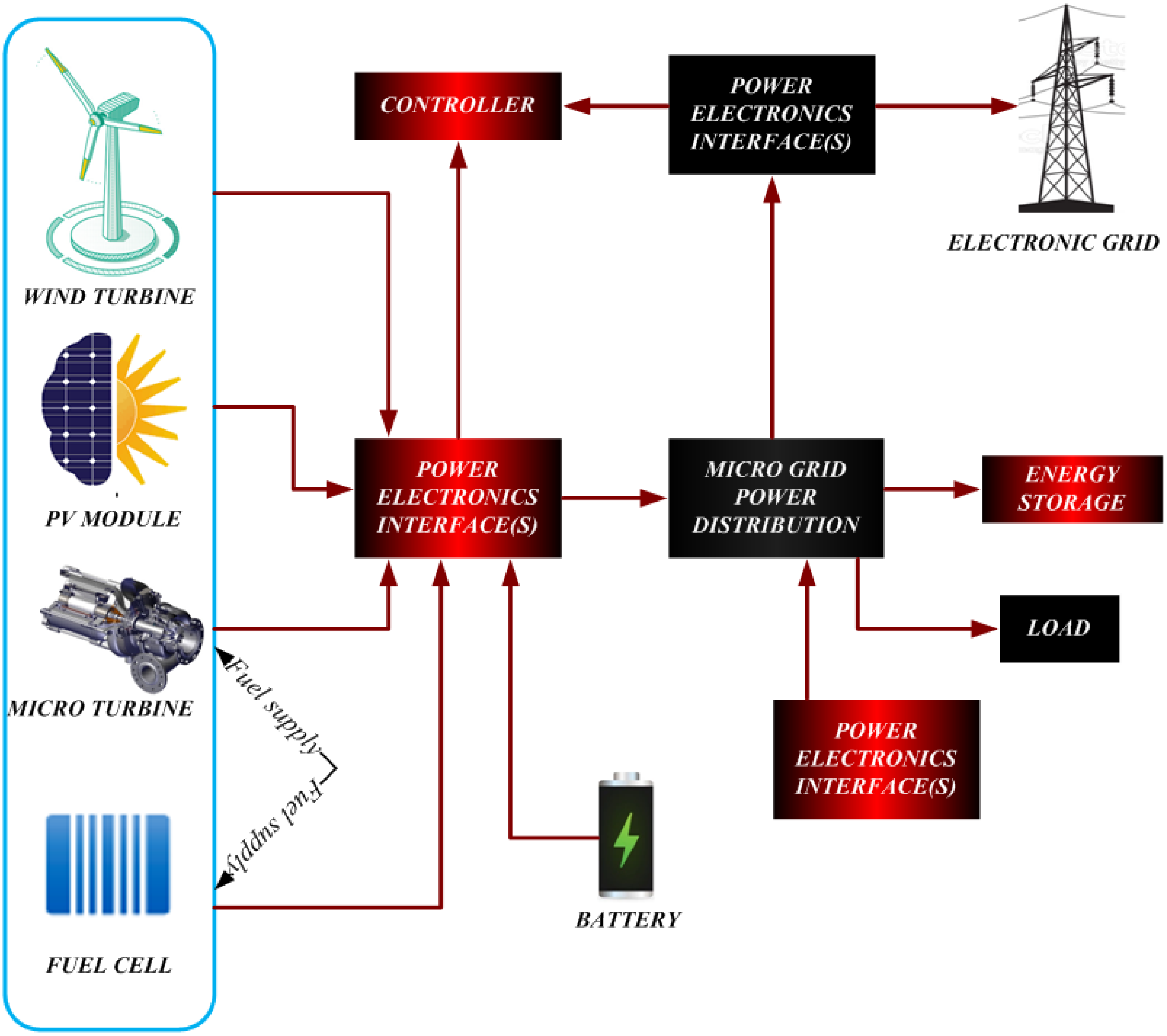


Figure 2.1: Architecture of Micro Grid

The micro grid operation gives the network to improve the efficiency as well as overall performance of the system. The MG also describes a group of DERs in the range of medium voltage or low voltage which can distribute the electric power according to the load demands. The generated power from the micro grid can be delivered to the associated group of consumers in grid connected mode or islanded mode [53-56].

2.3. TYPES OF MICRO GRID

In Figure 2.2, it displays the types of Micro grid. Here, the two types of micro grid are deemed which is explained below.

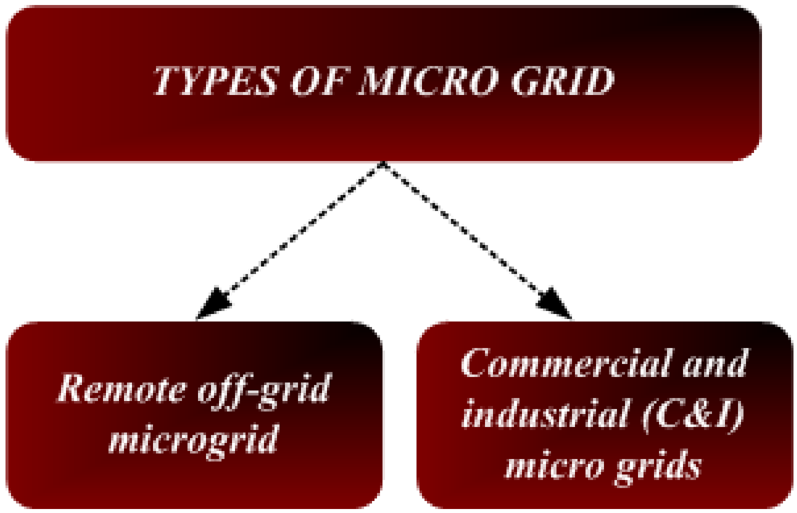


Figure 2.2: Types of Micro grid

2.3.1. REMOTE OFF-GRID MICRO GRID

It never connects to the grid due to economic problems and geographical location and operates in islanded mode. The “off-grid” MG is structured in remote location that is far-away from any distribution infrastructure and transmission and not connected to the utility grid. The islands “off-grid" micro grid is acumstances with renewable sources and lessen the production cost of electricity generation compare to the grid connected MGs. The load demands of the remote area are meet up through certain independent micro grid with various renewable energy sources. The MGs are typically structured with energy self-sufficient and intermittent renewable sources. If any unanticipated events are happened then it can overcome the situation and also ability to store the excess power in micro grid. If any unacceptable voltage deviation and frequency deviation occurred in the micro grid, then its nearest micro grid can have the ability to improve the frequency deviation as well as voltage deviation by using the power electronics converters and also provide system stability [57]. By using optimization or decision making approached the micro grid can determine the optimal load demand and accordingly it can interlink the adjacent micro grid as required.

2.3.2. COMMERCIAL AND INDUSTRIAL (C&I) MICRO GRID

The purpose of installation an industrial MG is secure power distribution with its reliability. Several manufacturing process are hampered in distribution of power and causes maximal revenue losses along longer start-up time. The industrial micro grid is structured in a way to provide energy in industrial modes, the zero economy and zero-emission. It also incorporates the combined heat and power production. The renewable energy sources and energy storages are employed to enhance the process of these sub systems [58-60].

2.4. TOPOLOGIES OF MICRO GRID

The structures have needs to uphold the power movement from various kinds of sources in the electric grid. The MG is categorized as three topologies.

2.4.1. AC MICRO GRID

The main components of AC micro grid such as harmonics, reactive power, active power and unbalanced component these are required to synchronize. The DC-AC inverter utilized to converter DC power to AC power. In PV system, DC is generated then the DC is converted into AC during the process of AC micro grid. In Figure 2.3, it portrays the AC micro grid structure.

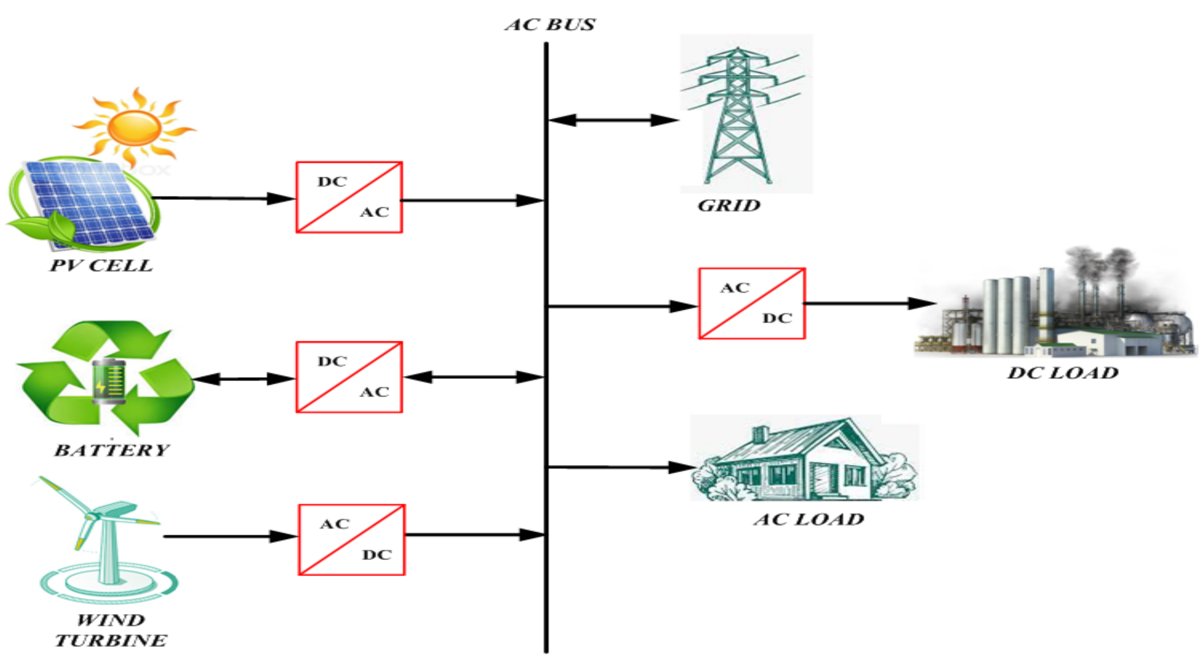


Figure 2.3: AC Micro Grid Architecture

To feed the DC loads the rectifier is used to convert the AC to DC power. Without any alteration the AC load derives the DC supply via AC bus. The interconnection is occurred among the AC bus and the power generation system in wind as well as AC bus used to deal active with reactive power. For main grid and AC micro grid, the interconnection to the main grid needs only phase matching [61].

2.4.1.1. ADVANTAGES OF AC MG

(i) AC MG is the application of a higher capacity transformer.

(ii) Increase and decrease the voltage of AC micro grids for the purpose of distribution.

(iii) By regulating the reactive power the independently steady voltage is derived.

(iv) AC load derives directly from the distribution of the AC micro grid and also it cannot affect by disturbances in the main grid.

(v) A constant voltage is acquired independently by controlling the reactive power.

2.4.1.2. DISADVANTAGES OF AC MICRO GRID

(i) Owing to these conversions, the effectiveness is decreased.

(ii) The control of electronic converters suggests harmonics in core grid.

(iii) The interlink of DC PV sources are complicated.

2.4.2. DC MICRO GRID

The main component in DC micro grid is DC power that is used to control. The DC micro grid is simple when likened with AC micro grid scheme. By increasing the efficiency of converter the DC bus may incorporate the DC loads without any changes. The DC to AC converter is mandatory in case of interconnection in AC loads [62]. The study of DC micro grid field is rapidly developed owing to the development of DC renewable energy sources. In Figure 2.4, it portrays the structure of DC micro grid.

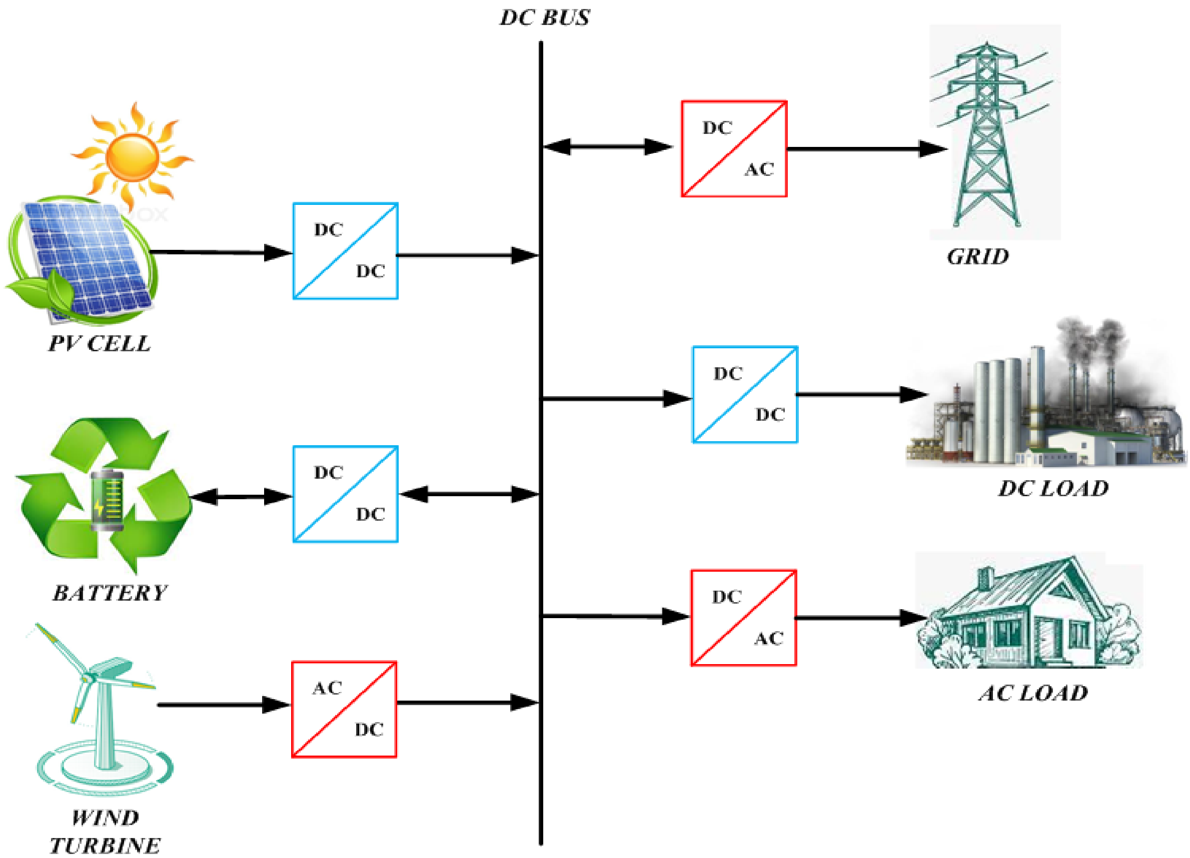


Figure 2.4: Architecture of DC Micro Grid

At the topology of DC micro grid, DC output along power sources straightly coupled with DC bus via DC/DC converter. Likewise, AC output with power sources straightly coupled with DC bus via AC/DC converter.

2.4.2.1. ADVANTAGES OF DC MG

(i) Battery storage system is linked straight forwardly for supplying holdup power. Back up storage scheme try to maintain the control when the period of peak load or lack of any distributed generator.

(ii) The straight inter-link lessens the multi-power conversions but enhances the system performance.

(iii) Simply RESs interconnection.

(iv) Storage of battery of DC micro grid generally gives power towards load if there is some energy interruption occurred at AC core grid.

(v) Owing to one inverter unit linked to AC core grid is needed, the loss of power converter including operating cost of DC system could lessen.

2.4.2.2. DISADVANTAGES OF DC MICRO GRID

(i) The load units require AC power in DC power system. So the distribution of DC network is not possible.

(ii) The voltage transfer in dc mode is less classified than that of AC system.

(iii) In AC to DC, an inverter is used with AC generators.

2.4.3. HYBRID MICRO GRID

Hybrid AC-DC MG has advantages of AC with DC MG [63]. The bidirectional-DC converter is utilized to linking AC and DC micro grid. The DC-DC boost converters have been employed to regulate the output power of Fuel Cell (FC). The Bidirectional AC-DC converters have been employed to connect both AC, DC micro grids. The DC-DC boost converters have been employed to connect DC power generators like FC, PV to DC micro grid. The DC-DC buck converters are employed to connect the DC loads viz fluorescent, EVs to DC micro grid. Bi-directional DC to DC converters have been employed to connect the energy storage devices to DC micro grid. Figure 2.5, depicts the construction of Hybrid AC-DC MG.

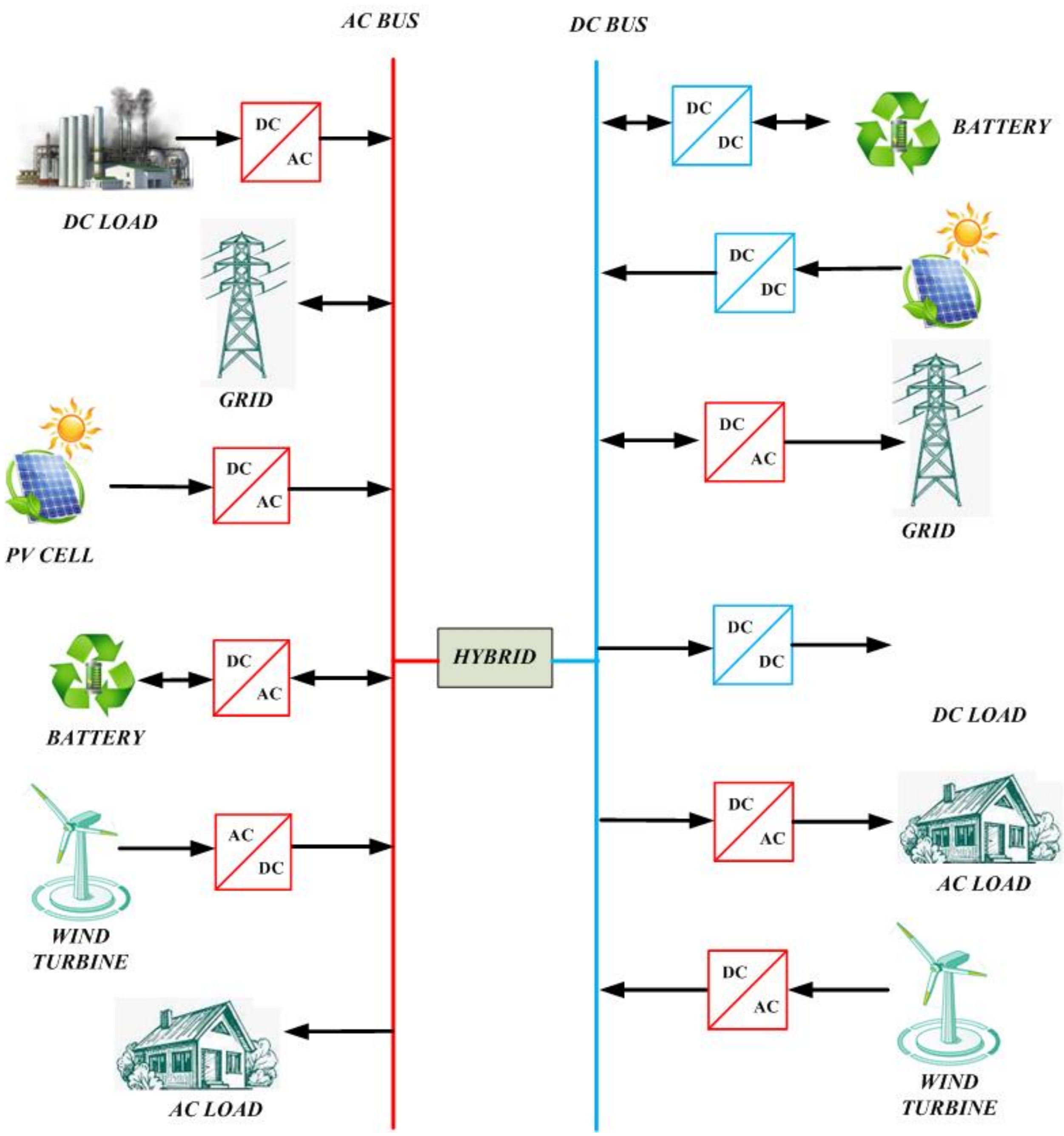


Figure 2.5: Structure of Hybrid AC-DC MG

The AC loads are straight forwardly linked with AC micro grid and the power transmitted from AC to DC micro grid. It occurs at condition of overloaded in AC micro grid. AC-DC converter is activated as inverter. DC micro grid analyzes the power flows from AC to DC micro grid for overloaded condition, then the interconnection of the converter activates as rectifier [64]. The aim of the bidirectional AC/DC MG is to manage power flow along DC as well as AC by stabilizing the DC bus power, AC bus frequency and AC MG power.

2.4.3.1. ADVANTAGES OF HYBRID AC-DC MG

(i) Hybrid MG decreases the multi-conversions.

(ii) The higher power grade system for various loads.

(iii) It decreases the loss of generation during multi-conversions.

(iv) It lessens the loss, also improves the dependency and economy of the overall system.

(v) Hybrid MG has two different grids linked with various loads and generators with different units.

(vi) It reduces the overall cost.

(vii) It helps lessening the greenhouse effect.

2.4.3.2. DISADVANTAGES OF HYBRID AC-DC MG

(i) Several properties of AC with DC MG generate structural complexity.

(ii) The control of cost minimization is the major problem as it acquires less power transmission in AC and DC micro grid uses the course of power conversion.

(iii) It is difficult to integrate a distributed generation with two sub grids with different characteristics.

(iv) The AC with DC buses is linked with via bidirectional converter and permits to power flow in both directions among two buses.

2.5. BASIC COMPONENT OF MG

2.5.1. LOCAL GENERATION

Numerous kinds of generation sources deliver electricity, heat, cool to the user present in micro grid. The sources are divided into two groups i.e. renewable generation sources and thermal energy sources [65].

2.5.2. CONSUMPTION

The consumption implies the components that deals with electricity, warmth, cool and the range can be for single device for illumination as well as warming process of commercial centers, buildings etc. The electrical consumption is changed according to the load demand.

2.5.3. ENERGY STORAGE

The storage of energy enables the multi-operations in the micro grid such as control of frequency, voltage by proper coordination of storage system and DGs. For optimizing the cost of power of the system the backup power plays a significant role. It includes all storage technologies such as electrical, gravitational pressure, chemical heat storage and flywheel. When certain energy sources containing various capacities are accessible in the MG, it is liked to facilitate to charge the storage element and also does not discharge to lower than its minimum capacity. This is very common and will not be overcharging the storage element. It is accomplished under an organized charge controller that always checks the condition of charge of storage. This framework is better useful in islanded mode of micro grid operation.

2.5.4. POINT OF COMMON COUPLING (PCC)

Micro grids are linked to main grid in electrical circuit. Non-PCC micro grids are known as confined micro grids, which are generally located in remote locales and cannot be linked to one another due to other special or economic constraint.

2.6. MICRO GRID CONTROL

In micro grid control, the two different methodologies are utilized: (i) decentralized (ii) centralized. Before the decision is made in the single point the huge amount of information is transmitted during the involvement of fully centralized units. The implementation is very difficult and the interconnection of the power system involves huge number of units [66]. Figure 2.6 represents the Micro Grid Control.

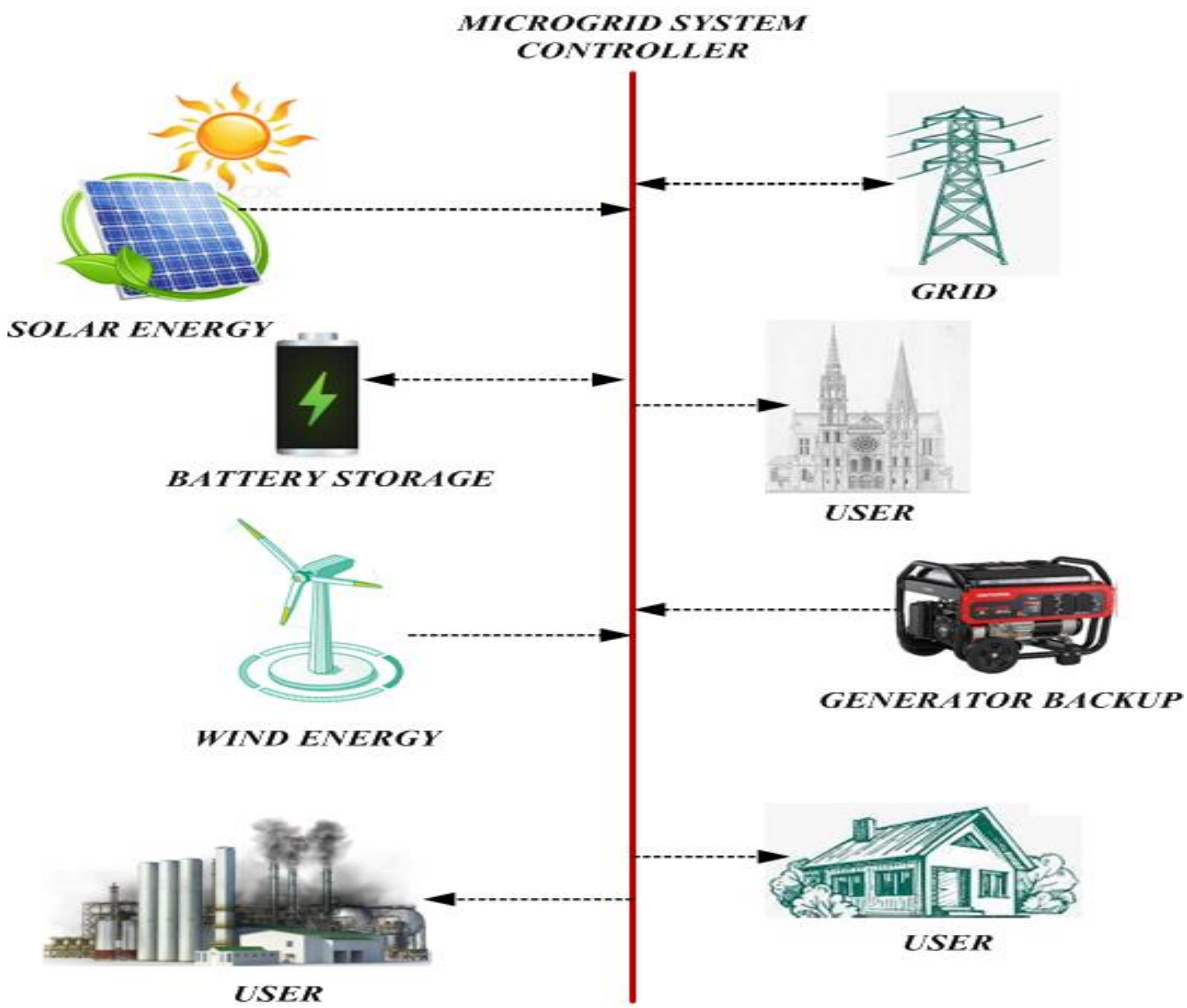


Figure 2.6: Micro Grid Control

Whereas, every unit is regulated through its local controller without specifying the state of others in fully decentralized control methods. Both of these control models are contained three control levels such as primary, secondary and tertiary. Types of Micro Grid Control are demonstrated in Figure 2.7.

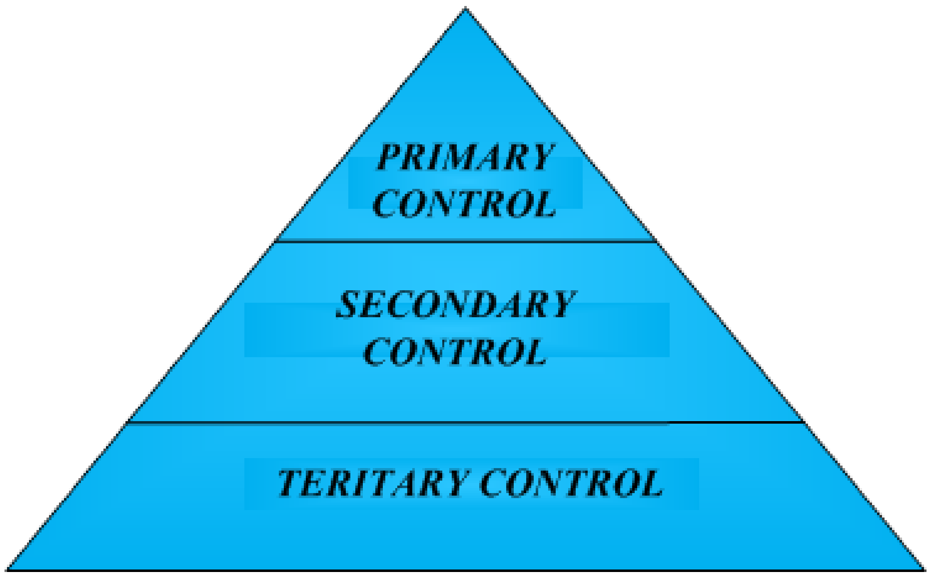


Figure 2.7: Types of MG Control

2.6.1. PRIMARY CONTROL

This is structured to meet the given anticipations:

- For stabilizing the power and frequency.
- To provide DER plug and play capacities, correctly sharing the active with reactive power without some connection of interaction.
- To lessen the circulating currents causing high current occurrence in electronic devices.

The primary control gives their set points for lesser controllers that are voltage including current control loop of distributed energy resources. Such inner control loops signified as zero-level control.

2.6.2. SECONDARY CONTROL

This is the second step of control level in micro grid system after primary level. The set mark of the primary control is provided by the auxiliary control. Here like the central controller, the micro grid capture the voltage, current and compensates to the distortions occurred by the various loads or renewable sources. To satisfy the requirement of the power quality the secondary control can be design accordingly.

2.6.3. TERTIARY CONTROL

This is the final control level that deems economic concerns at optimum MG operation which also maintains the power flow amid micro grid along main grid. It includes weather forecasting, grid tariff and loads at subsequent hours or day for designing the generator dispatching schedule which attains the financial savings. Several methods present in micro grid for end to end control utilizing machine learning approaches like deep reinforcement learning. In the occurrence of an emergency or power outage, the tertiary control acts as a simulated power plant for managing the interlinked MGs and meet the load demands known as "micro grid clustering". Under these circumstances, the center controller must choose one of the micro grids as slack and the remaining MG as PV including load buses as per the pre-defined approach with previous conditions. Here, the control of MG is at real time or higher sample rate [67].

2.7. ADVANTAGE AND DISADVANTAGE OF MICRO GRID

2.7.1. ADVANTAGES

- The micro grid is used for improving the efficiency of energy.
- The micro grids have much lower financial commitments.
- It needs less technical skills to operate and depends more on automation.
- It minimizes the overall energy consumption at peak hours.
- It reduces the peak demand, cost of energy and energy losses.
- It improves the power quality and also increases the grid reliability.
- It generates the power locally and to lessen the reliance on longer distance of the transmission lines and also isolates the loss of transmission.
- It makes possible for the environmental benefits by the use of the aero or low emission generators.

2.7.2. CHALLENGES IN MICRO GRID

- MG security is a vital challenge during the micro grid implementation.
- Re synchronization of MG, keeping its utility intact is also an important role.
- Voltage regulation and frequency regulation is another challenge.
- Capital cost is high.
- It damages the equipment.
- The maintenance and operation cost is high.

2.8. SUMMARY

From the above discussion, it can be concluded that the micro grid system is one of the important and needful strategies to expand the existing power system. The micro grid system is a system which enable to utilization of pollution-free energy in remote area. It provides energy to energy storage system for stabilize the micro grid connected system. During the failure of power grid, a micro grid is a great alternative. Here the detailed explanation for alternative current and direct current micro grid, hybrid micro grid, micro grid controller and the components of the micro grid are also explained in this chapter.

3 Mathematical Problem Formulation

3.1. GENERAL

MG is part of a power system with loads, network control system and set of distributed energy resources such as generators & energy storage device which can be used in parallel that from a large transmission grid or operate separately in islanded mode and provides uninterrupted power to multiple loads and end users. With regard to decentralised power delivery, the micro grid is one of the alternatives to deliver the power in remote area. The MGs can have various parameters and sizes. The optimal management of micro grid requires a correct economical procedure to establish the actual production cost. The advantages of renewable energy based micro grid system are control of production cost, reducing the external energy dependency, reducing transmission and distribution loss and improve the system reliability [68-70]. The wind turbine and photo voltaic array are two main sources of renewable energy in micogrid. The MG operator minimized the operating costs and environmental efficiency of system when increasing its dependability on micro grid based system. Several researches have been published so far to solve the micro grid energy management with planning [71].

3.2. PROPOSED METHODOLOGY

3.2.1. ILLUSTRATION OF MICRO GRID ARCHITECTURE

The micro grid energy management is a mechanism to transmit power to the end users through distributed energy resources. To fix the exact optimization method in accordance with the operational cost of distributed resources in micro gid energy management for generating power is one of the main issues in EMS. Here, the proposed method is utilized for optimal energy management in the MGs at least fuel cost [72]. Here, the objective functions are used to reduce the cost of fuel and to reduce the operational & maintenance cost and safety of the distribution system. The implemented approach for micro grid configuration is presented in the Figure 3.1.

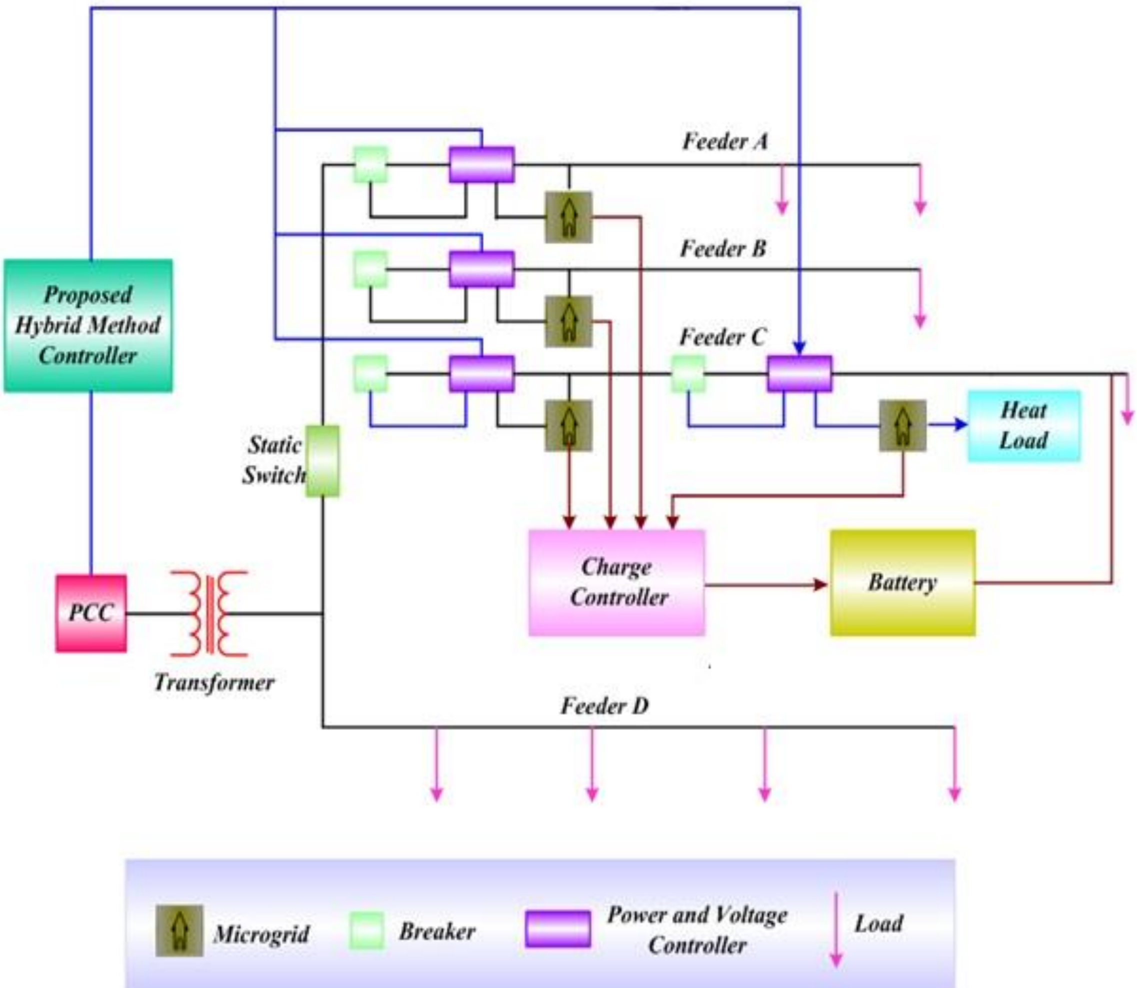


Figure 3.1: MG Architecture

The MG construction consists a group of radial feeders along point of common coupling, i.e., PCC. The feeders are connected to sensitive and non-sensitive loads. Furthermore, the feeder has micro sources like WT, PV, DG, FC and MT. For DG, FC & MT, the fuels were needed for generating power but for WT and PV, the fuel comes from environment with no cost. When any unwanted event occurs, a static switch is applied to island feeder from utility. Breakers are utilized to avoid system reoperation when an unanticipated occurrence. While usage of MGs as well as the battery storage device the whole construction is utilized for solving the power demand problem. The battery needs a separate charging controller for limiting the depth of discharge as well as charge current supplying to the battery as well as prevents the overcharge of the battery. Each of the components used in Figure3.1 is designed based on the configuration provided in Ref [73].

3.2.2. MICRO GRID ARCHITECTURE MODEL WITH PROPOSED METHOD

The construction of micro grid in Figure 3.2 consists of radial feeders, along point of common coupling, i.e., PCC. The feeders are connected to sensitive and non-sensitive loads. Here, the feeders contain several kinds of power sources like PV, WT, micro turbine, fuel cell and diesel generator. When any unwanted event happens the static switch used to island the feeder from utility. If the unforeseen events occur, breakers are used to avoid system reoperation. The entire construction has been built to meet the demands on the power issue related to the MGs with storage of battery. The battery needs a separate charging controller for limiting the depth of discharge as well as charge current supplying to the battery as well as prevents the overcharge of the battery. Therefore the entire MG power output is built to support load and battery [74, 75].

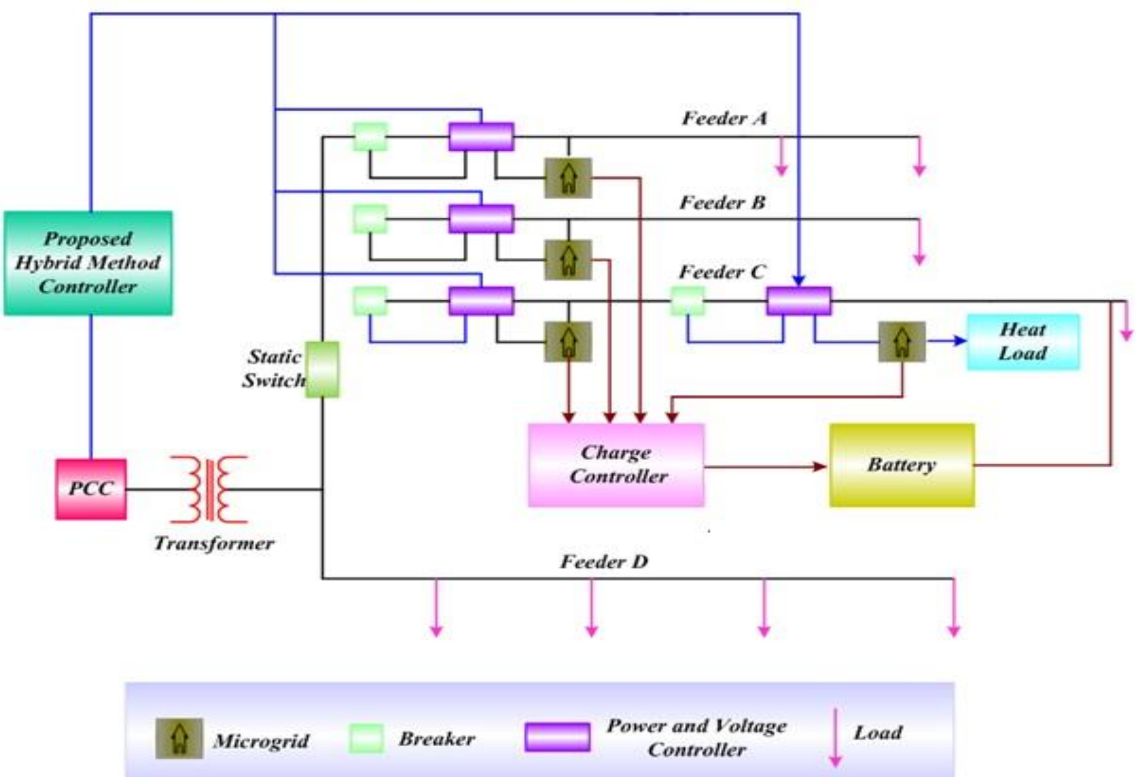


Figure 3.2: Structure of the MG architecture

The proposed MG configuration and the established model are mentioned in the research [76]. Since the energy sources such as PV, WT mechanisms are natural and zero operating cost because its fuel for generation comes from nature. Then the generation of power of other micro grid sources i.e. MT, FC and DG are required fuel with cost. Generally, in most of situations the load demands are meet up by using the two micro sources i.e. PV, WT. If it is not possible to fulfil the total demands of the load then the MT, FC as well as the DG is used. With the proper selection of MG combinations it must fulfil the demand of loads with less cost of fuel, less of emission of NO_X,SO_2, CO_2 and less operational and maintenance cost. Statistically, it can be found that the output power generation of MG is directly contributed to the load requirement, which is mathematically defined as follows:

$$\sum_{i=1}^{n} P_{Gi} = P_L - P_{PV} - P_{WT} - P_{Bat} \tag{3.1}$$

Where P_{Gi} specifies the sum of control generation in kW; P_L specifies demand power in kW; Ppv implies output power of the PV in kW; P_{WT} specifies output power in the WT in kW and P_{Bat} specifies output battery power in kW. Restriction in control of generation is given in the following relation.

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \tag{3.2}$$

Where $P_{Gi}^{\min}$ specifies minimum power generation in the unit kW, $P_{Gi}^{\max}$ specifies the maximum power generation unit kW.

The output power generated by the wind turbine generator is given as:

$$\begin{aligned} &P_{WT} = 0, && V < V_{ci} \\ &P_{WT} = a^* V^2 + b^* V + c, && V_{ci} < V < V_r \\ &P_{WT} = P_{WT,r} && V > V_{co} \end{aligned} \tag{3.3}$$

Where, $P_{WT,r}$, V_{ci}, V_{co} are the rated power, cut-in and cut-out wind speed respectively. Also, V_r and V are the rated, actual wind speed.

The output power of photovoltaic is given as:

$$P_{PV} = P_{STC} \frac{G_{ING}}{G_{STC}} \ (1 + k(T_c - T_r)) \qquad (3.4)$$

Where, P_{PV} is the output power at irradiance (G_{ING}), P_{STC} is the maximum power at Standard Test Condition (STC), G_{ING} & G_{STC} are the incident irradiance and irradiance at STC 1000 (W/m^2), k is the temperature coefficient of power, T_c & T_r are the cell temperature and reference temperature.

The objective function for attaining minimal cost factor is illuminated in the following Segment such as in 'Proposed Objective Function'.

PROPOSED OBJECTIVE FUNCTION

It depicts the objective function of the proposed approach. The optimum formations of MGs are related to load demand and several objective functions such as minimum fuel cost, maximum reduction of emission factors and minimum operational and maintenance cost. The necessary multi-objective functions are shown in below [77].

$$F(C) = Min \sum_{i=1}^{4} \{ fi(C) \} \qquad (3.5)$$

Where

$$f_1(C) = \sum_{i=1}^{N} (d_i + \mathrm{e_i P_{DG},_i} + fi\mathrm{P^2}_{\mathrm{DG,i}}) \quad \text{(Fuel cost of the DG)} \qquad (3.6)$$

$$f_2(C) = \sum_{L} \frac{\mathrm{F_{NG}} P_L}{\eta_L} \text{(Fuel charge of MT)}, \qquad (3.7)$$

$$f_3(C) = \sum_{J} \frac{\mathrm{C_{NG} P_J}}{\eta_\mathrm{J}} \text{(Fuel charge of FC)}, \qquad (3.8)$$

$$f_4(C) = (\sum_{i=1}^{N} (\mathrm{C_i F_i} + \mathrm{OM_i}) + \sum_{i=1}^{N} \sum_{j=1}^{M} \alpha_j (EF_{ij} P_i)), \text{(Emission, operation and maintenance cost)}$$

$$(3.9)$$

$$OM_i = K_{OM} \sum_{i=1}^{N} P_i \,, \tag{3.10}$$

Where, the proportional constant is K_{OMi} for each generation unit. The values of K_{OM} for different generation units are as follows: $K_{OM1} = K_{OM}(DG) = 0.01258$ \$/kWh, $K_{OM2} = K_{OM}(FC) = 0.00419$ \$/kWh and $K_{OM3} = K_{OM}(MT) = 0.00587$ \$/kWh. With, P_{DGi} specifies the generator output power ; N specifies the number of generators; d_i, e_i, f_i specifies coefficients of fuel cost utilize $i = 1, 2, 3 \ldots n$; F_{NG}, C_{NG} specifies natural gas value (\$/kW h) of the MT, fuel cell; $F_{NG} = C_{NG} = 2.3$ \$/kWh; P_L, P_J specifies the MT,FC output power; η_L, η_j specifies MT ,FC efficiency; $\eta_L = \eta_j = 0.47$; C_i specifies cost of fuel generated unit as \$/L for the diesel , \$/kW specifies for natural gas; F_i specifies fuel consume rate of generating unit i; OM_i specifies operational and maintenance cost of a generated unit i; α_j specifies the externality cost for emission type j; EF_{ij} specifies the emission factor of the generating unit of emission type j; M specifies the types of emission as well as N specifies the number of generating units [78].

3.2.3. MICRO GRID ARCHITECTURE WITH HYBRID PROPOSED CONTROLLER

The proposed hybrid controller of micro grid construction is demonstrated in Figure 3.3. This construction contains different types of MG sources. The choice of radial feeders is related to the distribution system, the position is only the connection to use the specific electrical power referred to as PCC. Feeders such as A and B are integrated, utilizing sensitive and non-sensitive loads [79-82].

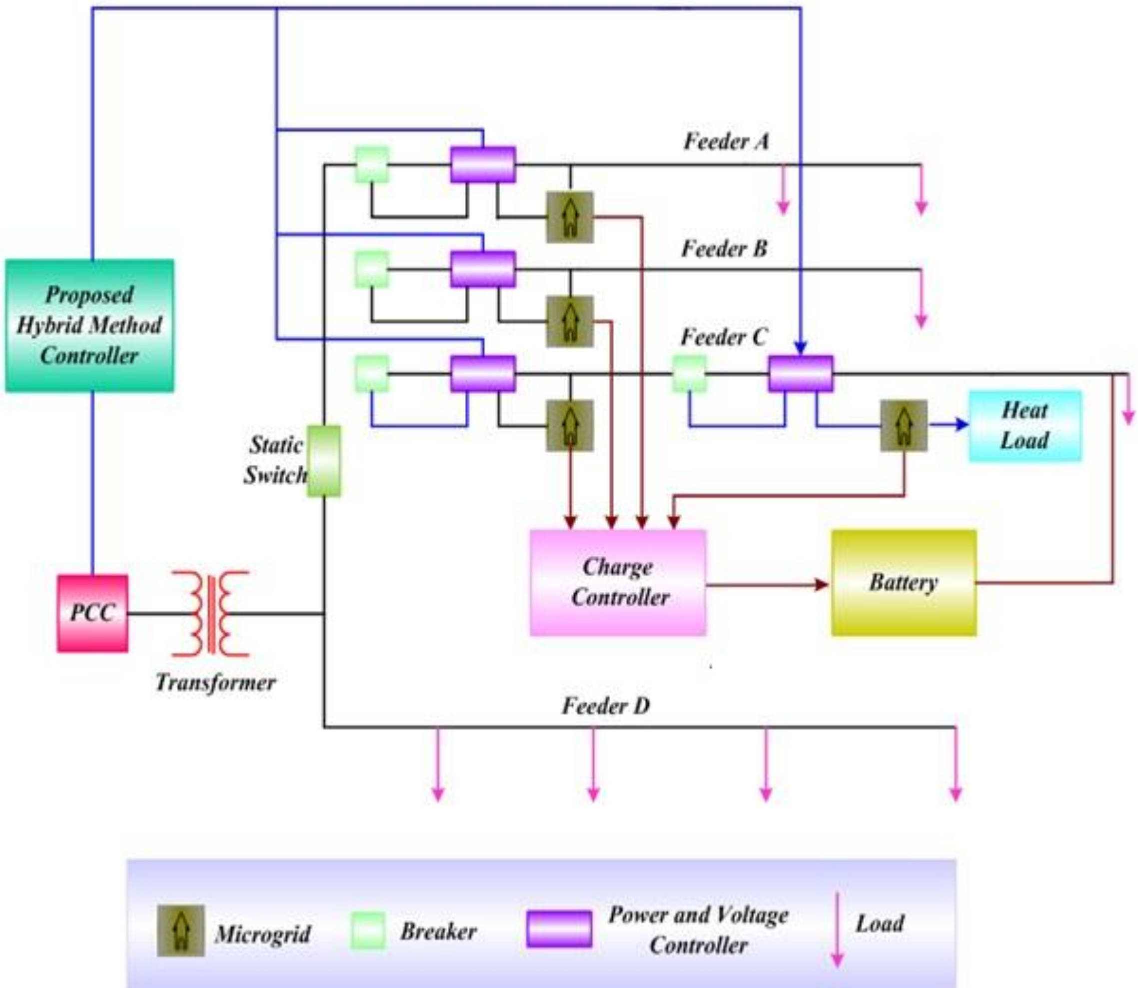


Figure 3.3: Structure of the proposed method

Energy resource input is applicable only for allocating diesel generator, fuel cell, MT and energy resources of WT and PV is derived from environment. SD is used to activate the specific feeders A, B when required. Breakers are commonly used for system protection as additional damage in the event of an emergency [83-87]. The MG source power is used for charging the battery and also the battery power is used to serve the additional load. The micro grid can be determined based on the visible features as well as limitations [88, 89]. The charging controller is needed for limiting real level of discharging battery power and also used for restricting the overcharging.

A. MULTIPLE-OBJECTIVE FUNCTION FORMULATION

Multiple objective function of MG modelling consist of fuel cost function for MG sources such as MT, FC, DG, based combination of structure modelling utilize min fuel cost and the cost of operational and maintenance. Here, there will be cost factors depending upon the externality cost in the research paper [90].

The output power generated by the wind turbine generator is given as:

$$P_{WT} = 0, \qquad V< V_{ci}$$

$$P_{WT} = a^* V^2 + b^* V + c, \qquad V_{ci} < V < V_r \tag{3.11}$$

$$P_{WT} = P_{WT,r} \qquad V > V_{co}$$

Where, $P_{WT,r}$, $V_{ci,}$ V_{co} are the rated power, cut-in and cut-out wind speed respectively. Also, V_r and V are the rated, actual wind speed.

The output power of photovoltaic is given as:

$$P_{PV} = P_{STC} \frac{G_{ING}}{G_{STC}} (1 + k (T_c - T_r)) \tag{3.12}$$

Where, P_{PV} is the output power at irradiance (G_{ING}), P_{STC} is the maximum power at Standard Test Condition (STC), G_{ING} & G_{STC} are the incident irradiance and irradiance at STC 1000 (W/m^2), k is the temperature coefficient of power, T_c & T_r are the cell temperature and reference temperature.

Multiple objective functions are given below:

$$X = Min \sum_{i=1}^{4} fi(C) \tag{3.13}$$

Where, f_i *(C)* refers to the cost function of MG like as MT, FC and DG.

(i). Power balance constraints [91]

$$\sum_{i=1}^{n} P(G_i) = P_L - (P_{PV} + P_{WT} + P_{Batt}) \tag{3.14}$$

(ii). Generating capacity constraints [91]

$$P_{\min}(G_i) \le P(G_i) \le P_{\max}(G_i) \tag{3.15}$$

MGS COST FUNCTION

(a). Fuel cost for MT [91]

$$f_1(C) = \sum_L \frac{\mathrm{F_{NG}} \mathrm{P}_L}{\eta_L} \tag{3.16}$$

(b). Fuel cost for FC [91]

$$f_2(C) = \sum_J \frac{\mathrm{C_{NG}} \mathrm{P_J}}{\eta_\mathrm{J}} \tag{3.17}$$

(c). Fuel cost for DG [91]

$$f_3(C) = \sum_{i=1}^{N} (d_i + \mathrm{e_i} \mathrm{P_{DG\,i}} + f_i \mathrm{P}^2{}_{\mathrm{DG\,i}}) \tag{3.18}$$

(d). Operational and maintenance cost function of micro grid [91]

$$f_4(C) = (\sum_{i=1}^{N} (\mathrm{C_i F_i} + \mathrm{OM_i}) + \sum_{i=1}^{N} \sum_{j=1}^{M} \alpha_j (EF_{ij} P_i)), \tag{3.19}$$

$$OM_i = K_{OM} \sum_{\mathrm{i=1}}^{\mathrm{N}} \mathrm{P_i}\ , \tag{3.20}$$

Where, the values of proportional constant i.e. K_{OMi} for each generation unit are given in section 3.2.2. Here, P (G_i) specifies overall generation of power in kW; P_L specifies the demands of power in kW; P_{PV} denotes the PV generated power in kw; P_{WT} specifies the power that is generated as of the WT in kW; P_{Batt} specifies output battery power in kW; P_{min} (G_i) specifies the minimum output power from the unit i , P_{max} (G_i) specifies the maximal output power from the unit *i ; N* specifies the total number of generators; Pdgi specifies the power generated as of diesel generator; d_i, e_i, f_i specifies the fuel cost coefficients utilize $i = 1,2,3....n$; F_{NG}, C_{NG} specifies the value for natural gas ($/kWh) for MT, fuel cell; F_{NG} = C_{NG} = 2.3$/ kWh ; P_L, P_J specifies MT , FC power correspondingly; η_L , η_J specifies the efficiency of MT, FC,; $\eta_L = \eta_J = 0.47$; C_i specifies cost of fuel generated unit as $/L for the diesel , $/kW specifies for natural gas; F_i

specifies fuel consume rate of generating unit i; OM_i specifies operational and maintenance cost of a generated unit i; α_j specifies the externality cost for emission type j; EF_{ij} specifies the emission factor of the gecreating unit, emission type j; M specifies the types of emission as well as N specifies the number of generating units.

3.2.4. STRUCTURE OF MG CONNECTED SYSTEM WITH PROPOSED CONTROLLER

In Figure 3.4, the proposed method is ascertained and explained the construction of the micro grid linked system. The MG associated system contains group of radial feeders, the feeders is connected utilize sensitive along non-sensitive loads along PCC as point of common coupling. Additionally, feeders have micro sources, e.g., WT, PV, DG, FC and MT. Also, the micro sources of the feeders i.e diesel generator, MT, fuel cell are needed fuel to generating power. But the WT as well as PV works depend on nature i.e free generation cost. When the unexpected things happen to island feeder, static switch is used. When an unexpected event occurs the breaker is utilized for avoiding the system reoperations. While utilizing the MGs as well as the battery storage, the whole construction is utilized for solving issues of power demand [92]. To limits penetration of discharge, the battery needs a charge controller. It also limits the charging current supply to the battery and prevents the overcharging of the battery. The generating power from every MG is utilize for serving load and battery charge. Initially the two micro sources i.e WT as well as PV is used to meet up the load demand due to zero operating cost. Whenever, it does not satisfy the condition, the diesel generator, fuel cells along MT are used to solve this issue. Figure 3.3 shows generating power as of each micro source can direct to assist the load and the battery charging [93]. The overall method is articulated below as:

$$p_i = p_{i,load} + p_{i,battery}, \quad \forall\, i = 1,2,\cdots,N \tag{3.21}$$

Here, p_i implies output power of unit i, $p_{i,load}$ implies load demand of unit i, ($p_{i,battery}$) implies the power of unit i for charging the battery. (N) implies the number of generators.

3.2.4.1. MULTIPLE-OBJECTIVE FUNCTION OF PROPOSED METHODOLOGY

MG fulfills load demand which utilize minimum fuel cost and cost of operational and maintenance cost. So, the diesel generator, fuel cell and MT fuel cost functions are consider as multiple-objective function.

The output power generated by the wind turbine generator is given as:

$$P_{WT} = 0, \qquad V < V_{ci}$$

$$P_{WT} = a^* V^2 + b^* V + c, \qquad V_{ci} < V < V_r \qquad (3.22)$$

$$P_{WT} = P_{WT,r} \qquad V > V_{co}$$

Where, $P_{WT,r}$, $V_{ci,}$ V_{co} are the rated power, cut-in and cut-out wind speed respectively. Also, V_r and V are the rated, actual wind speed.

The output power of photo voltaic is given as:

$$P_{PV} = P_{STC} \frac{G_{ING}}{G_{STC}} \left(1 + k(T_c - T_r)\right) \qquad (3.23)$$

Where, P_{PV} is the output power at irradiance (G_{ING}), P_{STC} is the maximum power at Standard Test Condition (STC), G_{ING} & G_{STC} are the incident irradiance and irradiance at STC 1000 (W/m^2), k is the temperature coefficient of power, T_c & T_r are the cell temperature and reference temperature.

The multi-objective function shown in equation (3.24)

$$F_{obj} = \min_{i=1}^{4} \{F_i(c)\} \qquad (3.24)$$

Where, F_{obj} indicates the multiple-objective function to minimum the cost of fuel, operational and maintenance cost of the MG connected system, $F_i(c)$ implies the sum of fuel cost for MG models [94].

$$F_1(c) = \sum_{i=1}^{N} a_i + b_i\, P_{DG,i} + c_i\, P_{DG,i}^2 \qquad (3.25)$$

Here, $F_1(c)$ indicates fuel cost of the diesel generator. Here (a_i b_i c_i) indicates coefficient of fuel cost utilize *i*=1, 2… n, N implies number of generators. P_{DGi} Indicates generated output power.

$$F_2(c) = c_{NG} \sum_{FC} \frac{P_{FC}}{\eta_{FC}} \qquad (3.26)$$

Here, $F_2(c)$ implies fuel cost for Fuel cell, P_{FC} implies output power of the FC. η_{FC} Implies efficiency for Fuel Cell, c_{NG} implies cost of natural gas for FC. The efficiency of Fuel Cell is

$\eta_{FC} = 0.47.$

$$F_3(c) = \sum_{MT} \frac{f_{NG} P_{MT}}{\eta_{MT}} \tag{3.27}$$

Here, $F_3(c)$ indicates fuel cost of MT, P_{MT} implies MT output power. η_{MT}, implies efficiency of the MT, f_{NG} implies cost of natural gas for MT. Efficiency of MT is $\eta_{MT} = 0.47.$

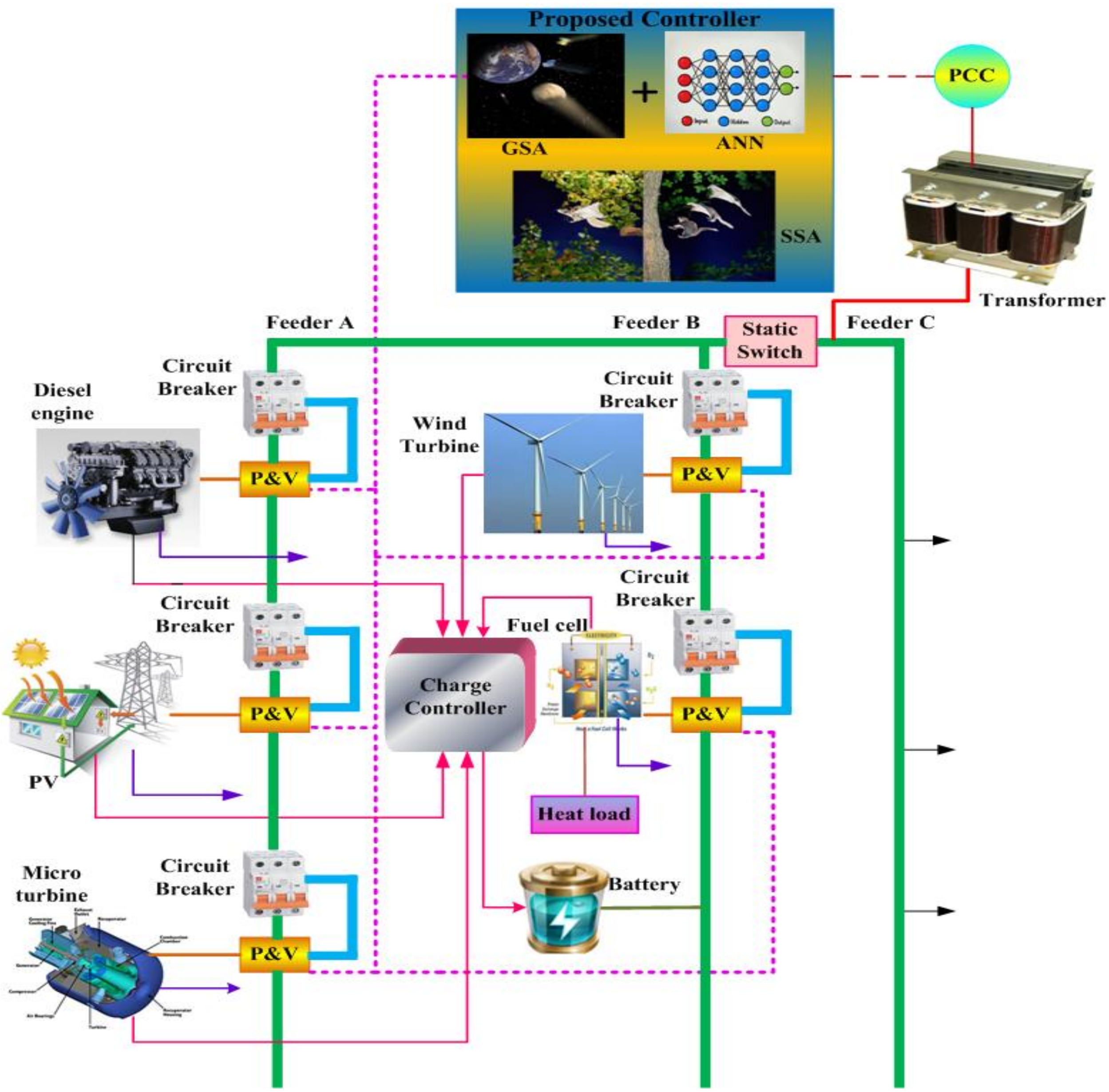


Figure 3.4: Architecture of Micro Grid connected systems with proposed controller

$$F_4(C) = (\sum_{i=1}^{N}(\mathrm{C_i F_i} + \mathrm{OM_i}) + \sum_{i=1}^{N}\sum_{j=1}^{M}\alpha_j(EF_{ij}P_i)), \tag{3.28}$$

$$OM_i = K_{OM}\sum_{\mathrm{i=1}}^{\mathrm{N}}\mathrm{P_i}\ , \tag{3.29}$$

Where, the values of proportional constant i.e. K_{OMi} for each generation unit are given in section 3.2.2. Here, c_i indicates fuel cost of generating unit i in $/L for the Diesel and $/kW specifies for the natural gas, f_i specifies ratio of fuel consumption of generating unit i in L/h, OM_i specifies operational and maintenance cost of a generated unit i in $/h, α_j specifies external cost for emission type j . N Implies the number of generating units, M indicates number of emission types, ef_{ij} specifies emission factor of the generating unit [95].

3.2.5. PROBLEM FORMULATION

Micro grid consists as the non-dispatch able as well as the dispatching resource and ES. The non-dispatch able resources in MGs are WT, PV and the dispatch able resource is MT. The ES sources are known as EWH, DR/loads. The objective function is defined as follows:

$$O_f = \min\sum_{\delta}^{N}\Delta_\delta\left(C_\delta^{ND} + C_\delta^{D} + C_\delta^{ES-} - C_\delta^{L} - C_\delta^{ES+} + \psi_\delta\right) \tag{3.30}$$

Where,

N $\longrightarrow$ number of simulating periods

C_δ^{ND} $\longrightarrow$ Cost of energy produced through non- dispatch able resources

C_δ^{D} $\longrightarrow$ Cost of energy produced through dispatch able resources

C_δ^{ES-} $\longrightarrow$ Energy generating cost by ES during discharging mode

$C_{\delta}^{ES+} \longrightarrow$ Energy generating cost by ES during charging mode

$C_{\delta}^{L} \longrightarrow$ Cost of energy used by responsive load

$\psi_{\delta} \longrightarrow$ Penalty cost for the MG operator during δ time interval

The equations mentioned above reduce the total production costs and satisfy the resources of generating constraints. The cost of the penalty is added to the objective function and is considered by the micro grid provider to avoid power not provided in the NRL. Every cost can plan in advance as follows given below:

Cost of the energy generated by non-dispatch able resource is examined using the following equation:

$$C_{\delta}^{ND} = \sum_{i=1}^{N_{nd}} P_{\delta}^{i,ND}\left(\pi_{\delta}^{i,ND}\right) \tag{3.31}$$

Cost of the energy generated by dispatch able resource is examined using the following equation as given below:

$$C_{\delta}^{D} = \sum_{i=1}^{N_{d}} P_{\delta}^{i,D}\left(\pi_{\delta}^{i,D}\right) \tag{3.32}$$

Then, the generation cost of load and ES is determined. The below mentioned equations specifies the cost of energy consumed by the responsive load

$$C_{\delta}^{L} = \sum_{i=1}^{N_{L}} P_{\delta}^{i,L}\left(\pi_{\delta}^{ik,L}\right) \tag{3.33}$$

Where, the above equations such as, $\pi_{\delta}^{i,ND}$ and $\pi_{\delta}^{i,ND}$ are the cost of the ith non-dispatch able as well as the dispatch able resource $P_{\delta}^{i,ND}$, $P_{\delta}^{i,D}$ implies output power generated via ith non-dispatch able and dispatch able resources. When, N_{ND} and N_{D} are the number of non-dispatch able as well as dispatch able resources in the micro grid. Furthermore the costs of energy gained by the ES are examined by using the below mentioned equation [96]:

$$C_{\delta}^{ES+} = \sum_{i=1}^{N_{ES}} P_{\delta}^{i,ES+} \left(\pi_{\delta}^{i,ES+} X_{\delta}^{ES} \right) \tag{3.34}$$

$$C_{\delta}^{ES-} = \sum_{i=1}^{N_{ES}} P_{\delta}^{i,ES-} . \pi_{\delta}^{i,ES-} \left(1 - X_{\delta}^{ES} \right) \tag{3.35}$$

$$\psi_{\delta} = \pi_{\delta}^{UP} . P_{\delta}^{UP} \tag{3.36}$$

Where, in the above equations, π_{δ}^{UP} specifies the offering price when the system is not met the UP.P_{δ}^{UP} specifies the sum of power not delivered in the micro grid. In this, X_{δ}^{ES} specifies the status of energy source of operating type. $X_{\delta}^{ES} = 0$, specifies energy source in discharging mode and $X_{\delta}^{ES} = 1$ specifies charging mode. $\pi_{\delta}^{i,ND}$ $\pi_{\delta}^{i,D}$ $\pi_{\delta}^{i,L}$ $\pi_{\delta}^{i,ES}$, specifies as different cost that evaluates the objective function [97]. To achieve objective function successfully, the following process is examined and determined.

3.2.5.1. CONSTRAINTS

Here, the equality as well as the in-equality constraints are determined.

Equality constraints

The power balance equation is shown below:

$$\sum_{i=1}^{N_{ND}} P_{\delta}^{i,ND} + \sum_{i=1}^{N_{N}} P_{\delta}^{i,D} + \sum_{i=1}^{N_{ES}} P_{\delta}^{i,ES-} \left(1 - X_{\delta}^{i,ES} \right) + P_{\delta}^{UP} = \sum_{i=1}^{N_{L}} P_{\delta}^{i,L} + \sum_{i=1}^{N_{ES}} P_{\delta}^{i,ES+} \left(X_{\delta}^{i,ES} \right) + P_{\delta}^{NRL} \tag{3.37}$$

Inequality Constraints

The inequality constraint of non-dispatch able resource is shown in below equation:

$$0 \leq \sum_{i=1}^{N_{ND}} P_{\delta}^{i,ND} \leq P_{\delta}^{m,ND} \tag{3.38}$$

Here, $P_{\delta}^{m,ND}$ specifies maximal power produces in the non-dispatch able generating unit's through δ interval time.

So the above process were analyzed and found that [98] during the daily OS, the sum of consume power can be equal to the sum of EGP [99].

3.2.6. PROBLEM FORMULATION

In this segment, according to objective function, the accurate implementation for EMS optimizing problem is defined as below:

$$B(Y): \min F(X) \tag{3.39}$$

$$F(X) = \sum_{\kappa}^{N} \Phi_{\kappa}\left(\Psi_1(K) + \Psi_2(K) + \Psi_3(K) + \rho_{\kappa}\right) \tag{3.40}$$

Where, $\Psi_1(K), \Psi_2(K), \Psi_3(K), \rho_{\kappa}\ and\ \Phi_{\kappa}$ are described as cost function for non-dispatch able along dispatch able resources and cost function for energy storage system in charging as well as discharging mode. Later, the values are calculated as the cost of energy consumed through responsive load demand (RLD) and the penalty cost resulting from Undelivered Power (UP) through the time period t. Here, the total generation cost is minimized by satisfy the generating resource constraints. The penalty cost is included in the objective function as well as it is considered as the micro grid operator, which avoids power supply to the NRL. Every cost is designed as follows [100]:

$$\Psi_{\kappa}^{\alpha} = \sum_{i=1}^{N_{\alpha}} \mathrm{H}_{\kappa}^{i,\alpha}\left(\sigma_{\kappa}^{i,\alpha}\right) \tag{3.41}$$

$$\Psi_{\kappa}^{\beta} = \sum_{i=1}^{N_{\beta}} \mathrm{H}_{\kappa}^{i,\beta}\left(\sigma_{\kappa}^{i,\beta}\right) \tag{3.42}$$

$$\Psi_{\kappa}^{\lambda} = \sum_{i=1}^{N_{\lambda}} \mathrm{H}_{\kappa}^{i,\lambda}\left(\sigma_{\kappa}^{i,\lambda}\right) \tag{3.43}$$

By utilizing the above equation, the loads are determined by the energy cost which are generated from non-dispatch able as well as dispatch able resource. The above equations, $\sigma_{\kappa}^{i,\alpha}, \sigma_{\kappa}^{i,\beta}$ are denoted as the cost of i[th] non-dispatch able as well as the dispatch able resources, $\mathrm{H}_{\kappa}^{i,\alpha}$ and $\mathrm{H}_{\kappa}^{i,\beta}$ are the output power generated from i^{th} non-dispatch able as well as dispatch able resources. Then, the N_{α}, N_{β} are the number of non-dispatch able as well as dispatch able resource in the micro grid system.

Furthermore, the energy consumption cost and the consumption of ES system is evaluated by the following equation:

$$\Psi_{\kappa}^{\mu+} = \sum_{i=1}^{N_{\mu}} \mathrm{H}_{\kappa}^{i,\mu+}\left(\sigma_{\kappa}^{i,\mu+}, \gamma_{\kappa}^{\mu}\right) \tag{3.44}$$

$$\Psi_{\kappa}^{\mu-} = \sum_{i=1}^{N} \mathrm{H}_{\kappa}^{i,\mu-}\sigma_{\kappa}^{i,\mu-}\left(1-\gamma_{\kappa}^{\mu}\right) \tag{3.45}$$

$$\psi_{\kappa} = \mathrm{H}_{\kappa}^{\Gamma}.\sigma_{\kappa}^{\Gamma} \tag{3.46}$$

In equation (3.35), (3.36) and (3.37), the σ_{κ}^{Γ} Specifies the offer price while the system is encountered with the UP, $\mathrm{H}_{\kappa}^{\Gamma}$ specifies sum of power which is not supplied via micro grid. Here, γ_{κ}^{μ} denotes ES operation mode position. $\gamma_{\kappa}^{\mu} = 0$, when the ES implies discharging mode, $\gamma_{\kappa}^{\mu} = 1$ specifies the mode of charging [101]. To achieve objective function, the constraints are examined along planned. Power balance equations are referenced in the following:

$$\mathrm{A} : \left(\aleph + \Re^{-} + \mathrm{T}\right) = B : \left(\mathrm{E} + T + \Re^{+}\right) \tag{3.47}$$

Above equation is presented as the energy generated through non-dispatch able and dispatch able resources and loads individually [102]. Later, the following equations are regarded to evaluate the objective functions.

$$0 \le \sum_{i=1}^{N_\alpha} \mathrm{H}_\kappa^{i,\alpha} \le \mathrm{H}_\kappa^{m,\alpha} \tag{3.48}$$

Here, $\mathrm{H}_\kappa^{m,\alpha}$ specifies maximum power produced by non-dispatch able generating units at time period κ . The equality and in equality constraints are considered and determined [103]. Therefore, the summation of the consuming power is equivalent to sum of EGP during the customer's day-to-day operating system. [104]. Here, a hybrid technique is recommended to solve optimizing problem mentioned overhead. Here, RNN, ALO is used to obtain optimal output.

3.2.7. IMPLEMENTATION OF HYBRID METHOD OF EMS

Here, for energy management of MG connected system in a distributed system, a hybrid control method is presented. The micro grid connected system includes PV, WT as well as BS. For proposed method, the power flow management between the sources of energy as well as the grids is implemented. Similarly, to precede the grid power requirement from the grid operator and meet up with accessible RES is the proposed technique. A reference to input of MG is provided as the required electric power by using the grid operator. The objective function of the proposed approach is to reduce fuel cost on micro grid within the limits of equality and inequality. In Figure 3.5, layout on energy management system (EMS) is depicted. Two different algorithms are presented for executing EMS by utilizing optimizing method, as shown in Figure 3.5. The proposed method includes with two types of phases. These are primary phase and secondary phase. In first phase, the load demand is predicted in 24 hour and in the Second phase predicting outcomes is upgraded [105].

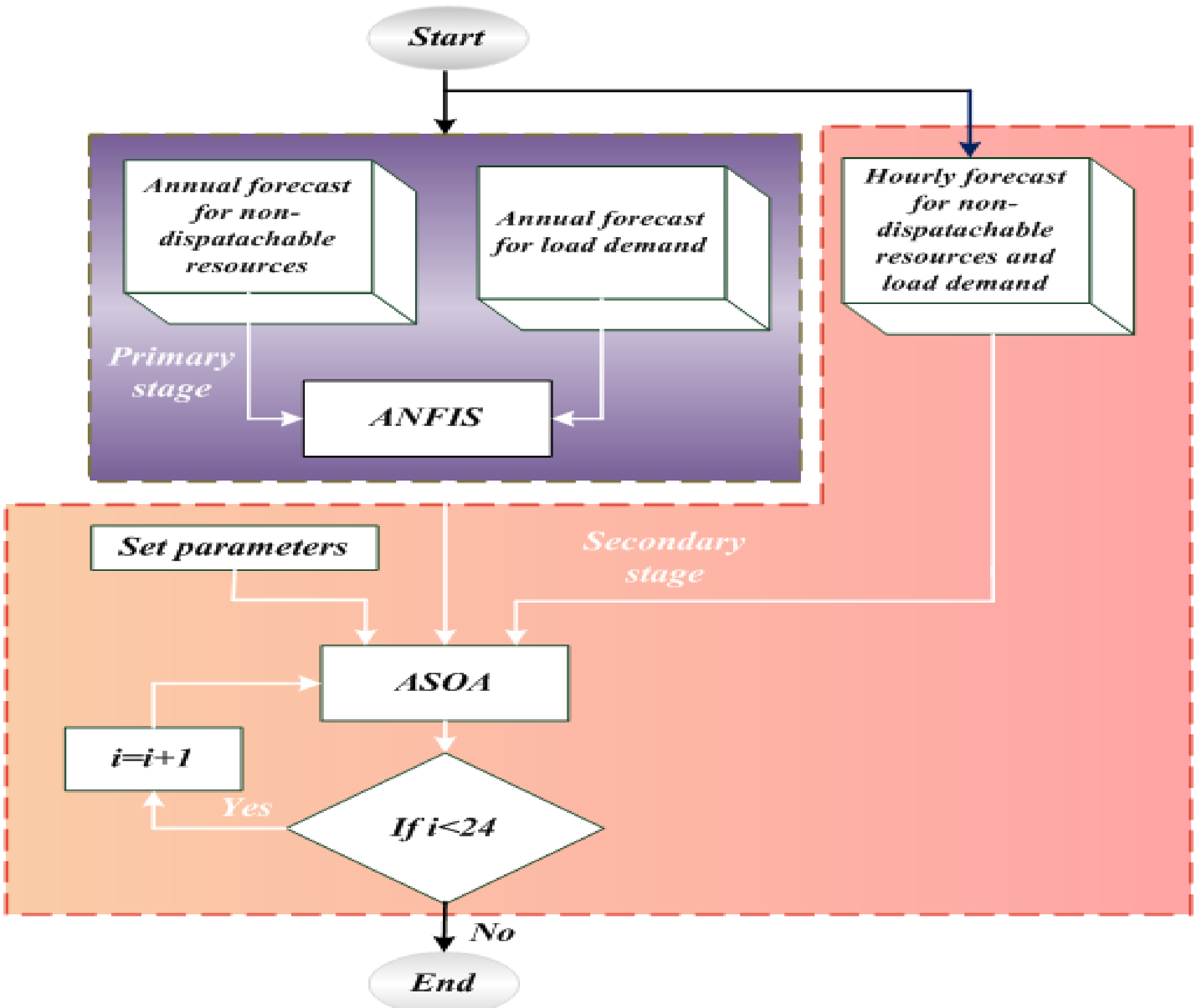


Figure 3.5: Proposed ANFASO Algorithm: Block Diagram

In Figure 3.5, the initial tracking level, PV, WT and battery sources of the existing 24 hour loads are used as inputs of ANFIS [106]. The component of low frequency on a comparable day and output of the primary tracking are separated in complete tracking level. The value of load of i^{th} hour of the component of small frequency is utilized as the input of ASOA. This procedure is performed to finish the estimation of next day at every 24 hour of a daytime. The analysis of the proposed procedure are illuminated in the below segment.

3.2.7.1. THE MATHEMATICAL MODELLING OF DGS

A) THE MATHEMATICAL MODEL OF THEMICRO TURBINE

It can be calculated as:

$$Q_{mt} = P_{gt}(1 - \mu_e - \mu_l) / \mu_e \tag{3.49}$$

$$Q_{ht} = Q_{mt} \cdot K_{ht} \tag{3.50}$$

$$C_{mt} = C_{nl} \times (\sum P_{gt} \Delta t / \mu_e L) \tag{3.51}$$

Where, the exhaust residual heat indicates Q_{mt} , μ_e indicates MT generating efficiency, the heat loss coefficient is signified as μ_l and through the period Δt in kW the MT output power indicates P_{gt} . MT heat provided by Q_{ht} , K_{ht} indicates the cooler heat coefficient, C_{mt} implies the MT gas consume cost, the gas remaining thermal value implies L and gas price indicated by C_{nl} .

B) THE MATHEMATICAL MODEL OF THE PV

The renewable energy is available on fewer volumes the PV array is sloping at 60^o and the generation of solar radiation is amplified in the winter period. MPPT is utilizing to create as performance of PV. The mathematical mode of PV can be calculated in the following equation [107]:

$$I = I_{pv} - I_o[\exp\left(\frac{V + R_s \times I}{V_t \times a}\right) - 1] - \frac{V + R_s \times I}{R_p} \tag{3.52}$$

Here output current, PV and saturation current are indicated as I , I_{pv} , I_o individually. Thermal Voltage of PV panel is V_t , the equivalent series and parallel resistance of the PV panel are indicated as R_s , R_p

C) MODEL OF THE WT

The mechanical power of WT depends upon the power coefficient of a wind rate and it is signified as:

$$P_m = \frac{1}{2}(C_p \rho \pi R^2 v^3) \tag{3.53}$$

Where P_m indicates the mechanical power, v indicates the wind rate, ρ indicates air density , R indicates the radius of turbine propeller range respectively.

D) MATHEMATICAL MODEL OF BS

Battery state of charge is denoted to the ratio of residual energy and the rated energy. This is required to charge of control as well as discharge process while accurately anticipating the SOC of battery. The SOC of the battery is provided during the process of charging by the relation [108],

$$SOC_t = SOC_{(t-1)}(1-\delta) + (P_c \Delta t \mu_c / E_c) \tag{3.54}$$

Where P_c indicates charging power, the charge efficiency implies μ_c , E_C implies the whole volume of BS during the time period Δt in kW. SOC_t implies SOC for BS in time t and SOC_{t-1} denotes the SOC of BS in time period t-1. The SOC of battery during discharging process is given by the equation [109],

$$SOC_t = SOC_{(t-1)}(1-\delta) - (P_d \Delta t / E_c \mu_d) \tag{3.55}$$

Where, the discharging power is represented as P_d , the discharging efficiency implies as μ_d and δ indicates the self-discharge storage ratio in percentage per hour.

3.2.7.2. MATHEMATICAL MODELING OF MG

Here, the micro grid contained non-dispatch able along dispatch able generating resources. WT and PV represent Non-dispatch able resource, MT represent dispatch able resource. Here, multiple-objective optimization regarding cost function is given below [110]:

$$F(X) = \min\sum_{\theta=1}^{N}(c_\theta^{nd} + c_\theta^{d} - c_\theta^{ec} + c_\theta^{ed} - c_\theta^{l} + \Omega_\theta)\times\Delta_\theta \tag{3.56}$$

Here, N implies number of simulation periods in time θ, c_θ^{nd}, c_θ^{d} represents energy generating cost from non-dispatch able as well as dispatch able resources. c_θ^{ec}, c_θ^{ed} represents the charging and discharging mode generation cost of ESS , c_θ^{l} specifies the energy consume cost of responsive load demand, Ω_θ specifies penalty cost for undelivered power in θ time interval. The objective of entire cost of generation can minimize while meeting the limitation of resource generation. Based upon following equation, the cost for each one can be calculated,

$$C_\theta^{nd} = \sum_{i=1}^{N^{nd}}\left(\lambda_\theta^{i,nd}\cdot\eta_\theta^{i,nd}\right) \tag{3.57}$$

Where $\lambda_\theta^{i,nd}$ and $\eta_\theta^{i,nd}$ represent ith non-dispatch able resources cost and output power produced. The number of non-dispatch able MG source system is denoted by N^{nd} .

$$C_\theta^{d} = \sum_{i=1}^{N^{d}}\left(\lambda_\theta^{i,d}\cdot\eta_\theta^{i,d}\right) \tag{3.58}$$

Where, $\lambda_\theta^{i,d}$ and $\eta_\theta^{i,d}$ represents the i^{th} dispatch able resources cost as well as the output power generated. The number of dispatch able micro grid system resources is denoted as N^{d} .

$$C_\theta^{l} = \sum_{i=1}^{N^{l}}\left(\lambda_\theta^{i,l}\cdot\eta_\theta^{i,l}\right) \tag{3.59}$$

Where, $\lambda_\theta^{i,l}$, $\eta_\theta^{i,l}$ specifies the i^{th} cost of responsive load demand and the output power consumed during θ time interval, in the micro grid N^{l} denotes the number of responsive load demand. Also, by ESS, the cost of energy storage system can be calculated by:

$$C_\theta^{ec} = \sum_{i=1}^{N^{es}}\left(\rho_\theta^{i,ec}\cdot\chi_\theta^{es}\cdot\eta_\theta^{i,ec}\right) \tag{3.60}$$

$$C_{\theta}^{ed} = \sum_{i=1}^{N^{es}} \left(\rho_{\theta}^{i,ed} \cdot (1 - \chi_{\theta}^{es}) \cdot \eta_{\theta}^{i,ed} \right) \tag{3.61}$$

Where, $\chi_{\theta}^{i,es}$ specifies operation mode status of ESS.

$$\Omega_{\theta} = \rho_{\theta}^{UP} \cdot \eta_{\theta}^{UP} \tag{3.62}$$

Where, ρ_{θ}^{UP} and η_{θ}^{UP} represent the offer price.

3.2.7.3. CONSTRAINTS OF THE SYSTEM

A) POWER BALANCE OF MICRO GRID SYSTEM

$$\sum_{i=1}^{N} P_i + P_{grid} + P_b - P_{load} = 0 \tag{3.63}$$

Here, P_i specifies output power of i^{th} generating unit as well as P_{grid} specifies the output power of grid and P_b denotes output power of battery.

B) POWER LIMITS OF DGS

$$P_i^{\min} \le P_i \le P_i^{\max} \tag{3.64}$$

Where, $P_i^{\min}$ implies the i^{th} generating unit lower limit and $P_i^{\max}$ implies the i^{th} generating unit upper limit.

C) OPERATION CONSTRAINTS OF BATTERY

$$SOC^{\min} \le SOC_t \le SOC^{\max} \tag{3.65}$$

$$P_{bc}^{\max} \le P_b \le P_{bd}^{\max} \tag{3.66}$$

Where, $SOC^{\min}$ represents the SOC of lower limit and $SOC^{\max}$ represents the SOC upper limit, $P_{bc}^{\max}$ and $P_{bd}^{\max}$ represent the charging as well as the discharging the max power of battery [111].

D) CAPACITY OF LINE TRANSMISSION BETWEEN MG AND GRID SYSTEM

$$-P_l^{\max} \le P_g \le P_l^{\max} \tag{3.67}$$

Where P_g indicates transmitting power amid micro grid and grid and $P_l^{\max}$ indicates the transmission power higher limit. If the grid transmits power to the micro grid, P_{grid} is positive and if the grid absorbs power from the micro grid, P_{grid} is negative.

E) INEQUALITY CONSTRAINTS

$$0 \le \sum_{i=1}^{N^{nd}} P_\theta^{i,nd} \le P_\theta^{m,nd} \tag{3.68}$$

Here $P_\theta^{m,nd}$ implies the maximum power generated by non-dispatch able generation units during time θ.

3.2.8. OVERVIEW OF ENERGY SYSTEM

The overview of hybrid management system for WT, PV, FC and battery with smart grid is shown in Figure 3.6. The system consists of WT, PV, FC as well as battery. The hybrid energy system relies on solar and wind energy as the primary power resources and it is backed up by batteries as storage. MOPSO-based EMS is intended to provide the reference energy to each controller converter, taking into account SG limitations, various numbers of parameters, and objective functions. All PV, fuel cell, WT and battery controllers are intended to operate the present mode of control. The current-controlled 3-stage hysteresis inverter is utilized to transmit the power from DC bus to AC bus through the MG with the voltage rate of 440 V via a 230/440 V, three phase transformer [112].

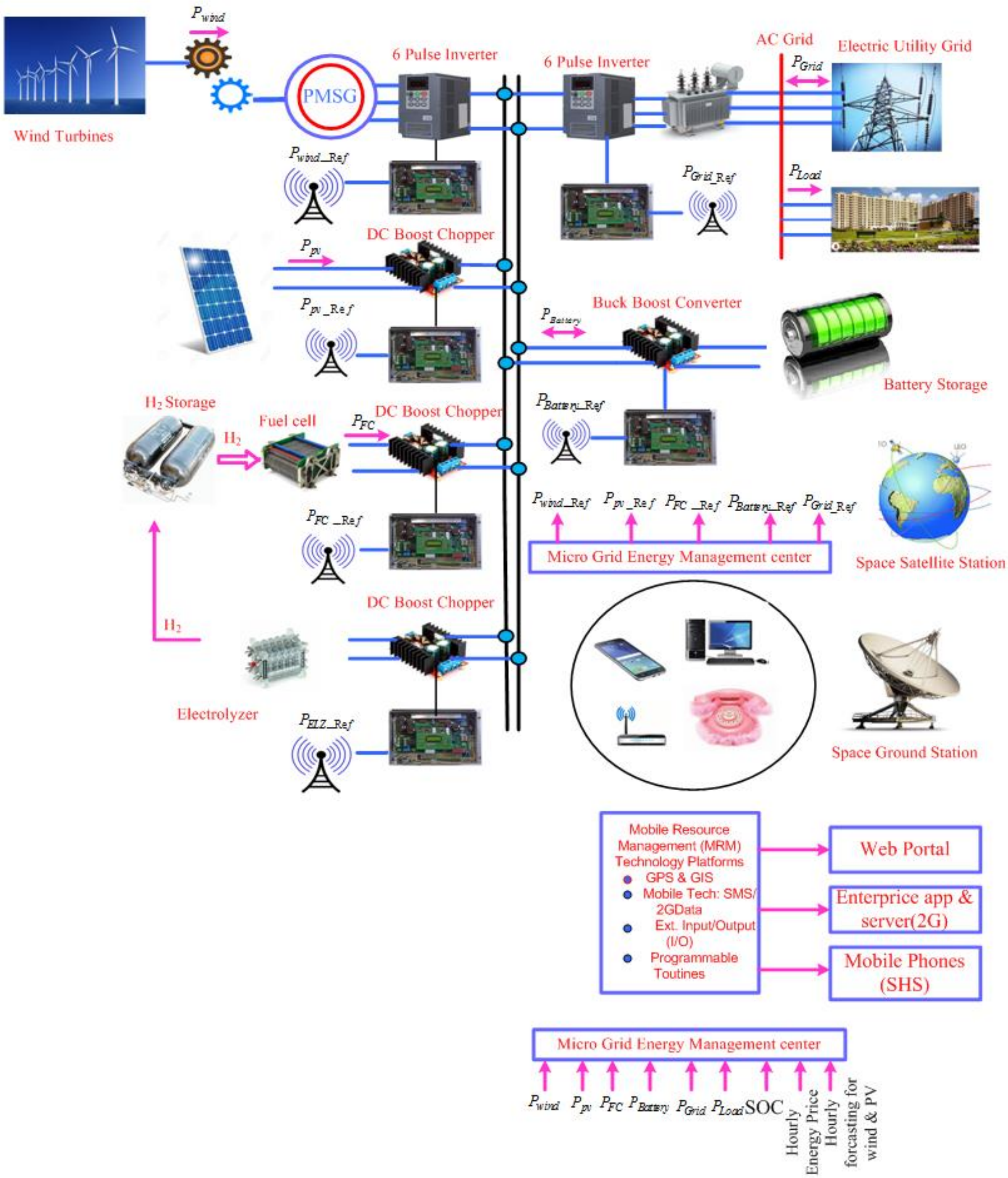


Figure 3.6: Simplified architecture of the Micro Grid-based distributed Renewable Energy-Grid Connectivity

The selective WT can deliver 150 kW power and the PV is capable of delivering 200 kW power in optimal meteorological conditions, although FC can deliver up to 100 kW. For manufacturing of hydrogen, a pressurized 20 kW alkaline electrolyzer is used. For later use, the fuel cell of hydrogen is stored in a boiler. A 50 Ah capacity battery bank is used in accordance with SOFC. The fuel cell unit is to store the plenty of DC energy and then return it when that power is needed. The purpose of control method is to satisfy the request of load by using WT/ PV / FC / ELZ / battery in the period of the day. Through the suggested energy efficient management strategy, power conversion and transfer happens between these parts. Exchanging information, power conversion and transfer happens between the generating unit as well as ESS through the suggested energy management system, the GPS communication scheme is installed. The grid-side inverter controller designed to regulate with enhanced the power injected into the grid using the frame called dq reference. Dc-link power controller is utilized to generate present orientations in calculating the energy of the active as well as the reactive energy references. Its purpose is to provide load, constant energy, which can be controlled at any level.

3.2.8.1. CONFIGURATION OF ENERGY SYSTEM

EMS generates reference power values of power converter for managing rated power amid PV, fuel cell, WT and ESS according to weather conditions, corresponding to information available in quantities, SOC contains as a description of every objective aspect to meet the variables and unpredictable needs for load. EMS maintains the state of charge to a certain extent (20-90 percent). Functional principle of EMS [113] is the energy produced through the PVand WT has given the first priority if it meets the load demands. Generated power by the PV as well as the WT goes beyond the requirements of load, i.e. $P_{PV+}P_{wind} > P_{Load}$, the excess power is utilized to charging battery along reference value

$$P_{B-\mathrm{Re}f} = -P_{Load} + (P_{pv} + P_{wind}) \tag{3.69}$$

Where $P_{B-\mathrm{Re}f}$ implies the battery power reference which is utilized to charge the battery, P_{pv} *and* P_{wind} implies the PV power generation as well as the WT power respectively, P_{Load} specifies the power demand. Continuous charging of battery takes place pending SOC of battery reaches at maximal, i.e. $SOC_{Max} = 90\%$. ELZ may use the remaining energy to produce the SOFC hydrogen until load reaches its maximum stage. Next, the produced extra energy is transferred to the grid .If the load requirement is higher than the power produced in PV, WT, i.e., the battery can reach an acceptable charge depending on the SOC, differential power is supplied the load through the battery using battery power reference.

$$P_{B-\mathrm{Re}f} = -P_{Load} - (P_{pv} + P_{wind}) \quad (3.70)$$

The energy produced in the fuel cell is utilized, while battery is not meet up the load requirements. In this segment, the reference power of fuel cell is:

$$P_{FC-\mathrm{Re}f} = -P_{Load} - (P_{pv} + P_{wind}) - P_{Battery} \quad (3.71)$$

Where, $P_{FC} - _{\mathrm{Re}f}$ specifies reference power of the fuel cell and $P_{Battery}$ specifies battery power distribution. EMS controls the SOC while continuing to load the battery until the state of charge reaches its minimal (SOCminimal = 20%). After, battery is turned off along utility grid the load power is imported. EMS as well as the MOPSO together used for addressing the following tasks of objective and the limitations taking into account distinct uncertainties in the prediction.

3.2.8.1.1. MINIMIZE THE SYSTEM COST

EMS-MOPSO-based control scheme minimizes system operating costs via managing flow of energy between each power source, grid and battery as energy storage with the right low-cost transmission, taking into account that the nature of fluctuation of requirement of continuous its variations in the price of electricity. Operational cost is shown as given below:

$$Min\ J_1 = \sum_{K=1}^{T} \mathrm{Pr}ice(k) \begin{pmatrix} P_{Load(k)} - P_{wind(k)} - P_{pv(k)} \\ P_{FC(k)} \pm P_{B(K)} \pm P_{Grid(K)} \end{pmatrix} \quad (3.72)$$

Hence, T implies the simulating horizon. This study considers 24 hour simulation horizon, $\mathrm{Pr}ice(k)$ specifies the functional time with the electricity price, P_{Wind} specifies the utility power generated by WT, P_{pv} specifies the utility power produced by the PV, P_{FC} implies utility power produces by the fuel cell, P_B specifies the battery power utilized to load and the grid utility, and P_{Grid} implies the utility grid power with the smart grid that is replaced with the other components. Since, the movement of power to storage battery and grid is bidirectional, the term polarity is associated with the battery as well as the grid in the equation is negative when power is distributed as well as positive when the power is obtained. (P_{Load}) implies the required load power. While reducing the operating costs of the system, the following limitations should meet [114] the energy of micro grid which is equal to micro grid load requirement plus the loss of transmission energy:

$$\left(P_{W2L(K)} + P_{PV2L(K)} + P_{PC2L(K)} + P_{B2L(K)} + P_{Grid2L(K)}\right) = P_{Load(K)} + P_{Loss(K)} \tag{3.73}$$

Hence, P_{W2L} implies the supply power by the WT to the load, P_{PV2L} implies the supply power of PV power to load, (P_{PC2L}) specifies the fuel cell power supplied to the load, P_{B2L} specifies the supply of power in the battery for load, P_{Grid2L} implies the supply of grid power to the load, and $P_{Loss(K)}$ implies the loss of transmission power. The limitation of power load is preserved.

$$0 \le P_{Load}(K) \le P_{Load-\max} \tag{3.74}$$

Where, P_{Load_max} specifies max demand load and the *SOC* of the battery is preserved a specific value

$$SOC_{Min} \le SOC(K) \le SOC_{Max} \tag{3.75}$$

Where, SOC_{min} and SOC_{max} specify the minimum and maximum SOC of the battery, correspondingly.

Balancing power through interval time for discharging battery is preserved

$$P_{W2B}(K) + P_{PV2B}(K) + P_{FC2B}(K) - P_{B2G}(K) = P_{charge}(K) \tag{3.76}$$

Where, P_{W2B} specifies the transfer of power from the WT to the battery, P_{PV2B} specifies the transfer of power from PV to the battery, P_{FC2B} specifies the transfer of power from the fuel cell to the battery, P_{B2G} implies the transmitting of power from the battery to the grid and P_{charge} implies the charging power needs in battery. Balancing power through the era of discharging battery is preserved [115, 116].

$$P_{B2L}(K) + P_{B2G}(K) = P_{Discharge}(K) \tag{3.77}$$

Where, $P_{Discharge}(K)$ implies the discharge battery power. The upper and lower limits of power for every RES can be preserved.

$$0 \le P_{Wind}(K) \le P_{Wind-Max} \tag{3.78}$$

$$0 \le P_{PPV}(K) \le P_{PPV-Max} \tag{3.79}$$

$$0 \le P_{FC}(K) \le P_{FC-Max} \tag{3.80}$$

Here, $P_{Wind-Max}$, $P_{PPV-Max}$ and P_{FC-Max} indicate upper limits of power of the WT, PVand fuel cell generating units correspondingly. The power balancing to every RES is preserved [117].

$$P_{W2G}(K) + P_{W2L}(K) + P_{W2L}(K) = P_{Wind}(K) \tag{3.81}$$

$$P_{PV2G}(K) + P_{PV2L}(K) + P_{PV2B}(K) = P_{PV}(K) \tag{3.82}$$

$$P_{FC2G}(K) + P_{FC2L}(K) + P_{FC2B}(K) = P_{FC}(K) \tag{3.83}$$

Where, P_{W2G} specifies transmit of power from the WT to the utility grid, P_{PV2G} specifies transmit of power as of PV to grid, P_{FC2G} specifies transmit of power as of the fuel cell to grid.

3.2.9. PROPOSED SYSTEM DESCRIPTION

Figure 3.7 shows the proposed HRES topography. Figure 3.8 depicts the micro grid system connected to the grid with output. MG system consists of PV, WT, MT, BESS. The hybrid system in PV as well as wind power is the main source of power, which is supported by batteries. Batteries are used because of the physical properties on system input, solar radiation, wind speed, and power consumption. The use of MT in the hybrid method is more reliable, with low power fluctuations, low environmental pollution and low noise production [118].

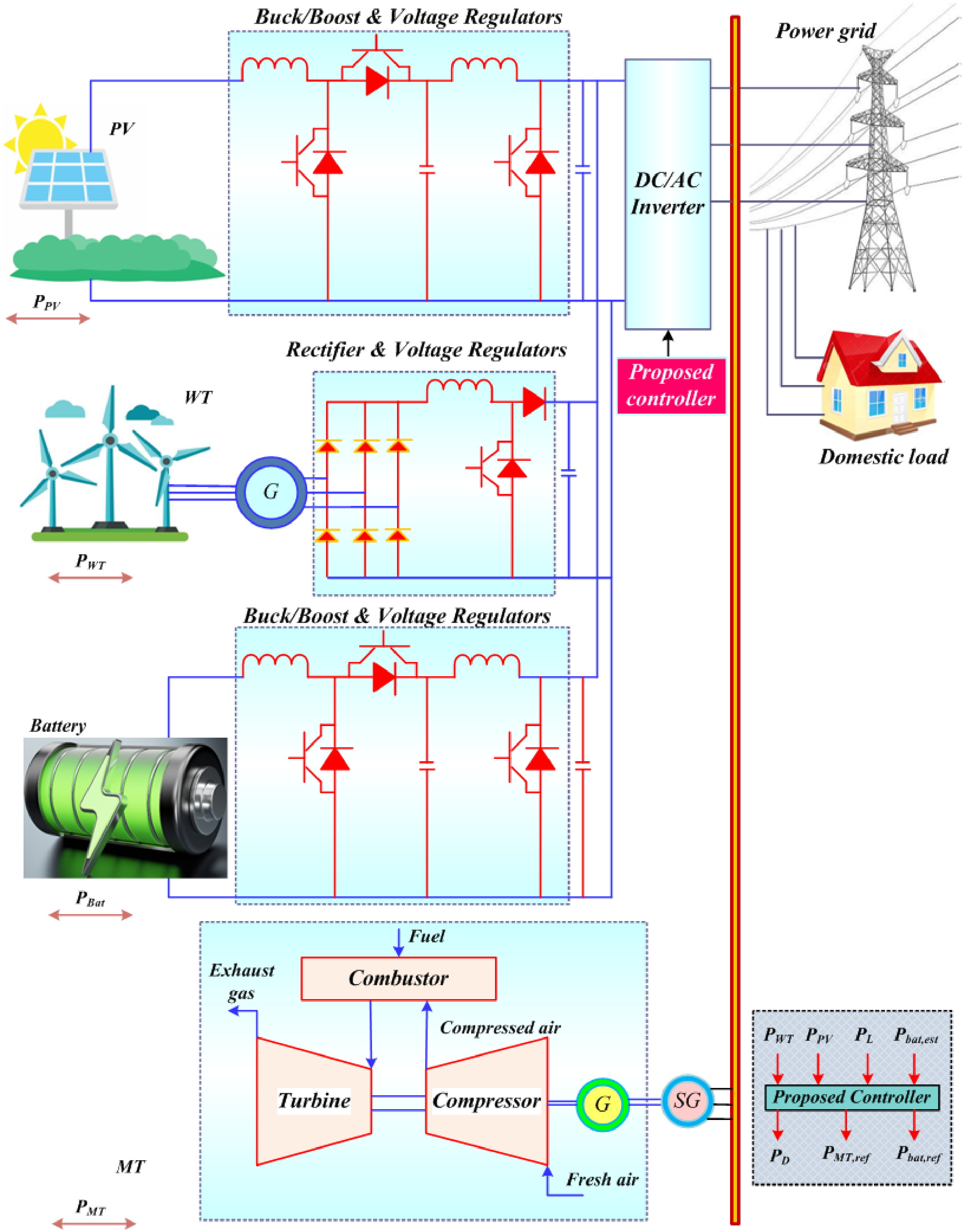


Figure 3.7: Topology of proposed Grid-Connected Micro Grid

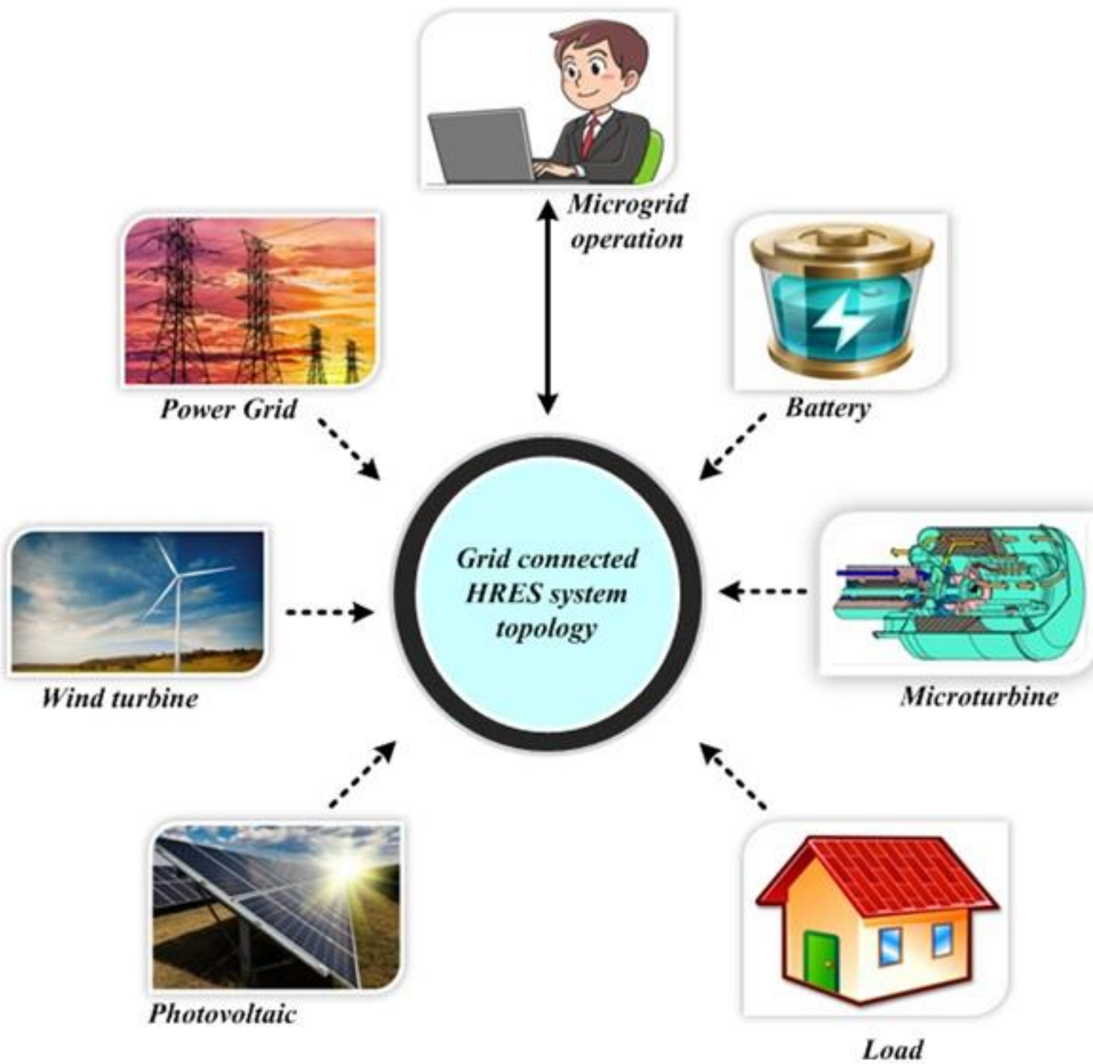


Figure 3.8: Grid connected MG system utilize output

3.2.9.1. OPTIMAL DESIGN AND ECONOMIC ANALYSIS FOR MG WITH GRID CONNECTED

Figure 3.7 depicts procedure of the proposed method. To find optimal EM in the grid connected PV / WT / MT / battery utilized to meet the load demands along with the economic analysis. To achieve the optimal framework of the hybrid approach, a hybrid technique is implemented in finding optimum solutions globally and especially for multimodal optimization problems. ACS includes annual fuel cost, capital, replacement, operational and maintenance cost, PV, WT, MT and batteries, addition certain devices of the controller, inverter, rectifier, chopper, which is considered to be the optimal design for economic analysis through hybrid method. The equation for ACS is given as follows [119]:

$$ACS = C_{acap}(PV + WT + MT + Battery) + C_{arep}(Battery) + C_{aOM}(PV + WT + MT + Battery) + C_{afuel}(MT) \tag{3.84}$$

Here C_{ACC} indicates annual capital cost, C_{ARC} indicates annual replacement cost, C_{AOM} indicates annual operation with maintenance cost, C_{AFC} and implies annual fuel cost. Furthermore, these methods are used to reduce renewable energy, to predict frequent errors, and to manage energy in MG.

3.2.9.1.1. ANNUALIZED CAPITAL COST (ACC)

The annual cost for every component is defined in terms of its equation (3.75)

$$C_{ACC} = C_c \times CRF(i, y_{proj}) \tag{3.85}$$

Where, the initial capital cost of every component implies C_c, component's life span as y_{proj}, CRF implies capital recovery factor.

$$CRF(i, y_{proj}) = \frac{i \times (1+i)^{y_{proj}}}{(1+i)^{y_{proj}} - 1} \tag{3.86}$$

Where, annual real interest ratio corresponds to nominal interest ratio indicates *i*. Actual interest rate is:

$$i = i' - f \tag{3.87}$$

Here f as annual inflation rate.

3.2.9.1.2. ANNUALIZED REPLACEMENT COST (ARC)

ARC illustrates to BESS and equation when lifetime of project is as follows:

$$C_{ARC} = C_{rep} \times SFF(i, y_{proj}) \tag{3.88}$$

Here, the full form of SFF is sinking fund factor, which is expressed in the following equation (3.83)

$$SFF\left(i, y_{proj}\right) = \frac{i}{(1+i)^{y_{proj}} - 1} \quad (3.89)$$

3.2.9.1.3. ANNUALIZED FUEL COST (AFC)

For MT, the annual fuel cost is derived in the following equation (3.84). It is modeled for obtaining the cost function of MT from the fuel cost curve and output power.

$$C_{AFC} = \alpha + \beta \times P_m + \gamma \times P_m^2 \quad (3.90)$$

3.2.9.1.4. ANNUALIZED OPERATION WITH MAINTENANCE COST (AOM)

Depending on maintenance cost in initial year C_{AOM} and maintenance cost on nth year C_{AOM} are computed by following equation (3.85)

$$C_{AOM}(n) = C_{AOM}(1) \times (1+f)^n \quad (3.91)$$

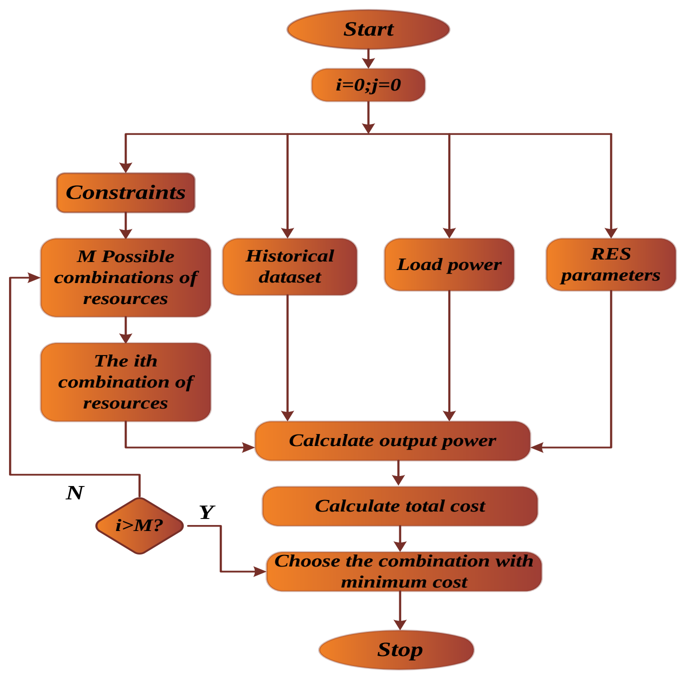


Figure 3.9: Procedure of the proposed method

3.2.9.2. CONSTRAINTS

An effect of micro grid is served directly for the load necessity, which is calculated mathematically utilizing the following equation [120]:

$$\sum_{i=1}^{n} P_{Gi} = P_L - P_{PV} - P_{WT} - P_{bat} \tag{3.92}$$

Here P_{Gi} implies overall generating power, P_L indicates load demand. The electric power generated may constrain within limits.

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \tag{3.93}$$

Here $P_{Gi}^{\min}$ implies minimum generated power in the unit *i*, $P_{Gi}^{\max}$ implies maximum generated power in the unit i.

3.3. SUMMARY

The MG linked system depends on the solar PV, WT, MT, DG and battery. The micro grid consists of non-dispatch able resources, dispatch able resources and energy storage (ES). The non-dispatch able resources are solar PV, WT and dispatch able source is MT. ES sources are deemed electric water heater (EWH) and demand response (DR) / loads. The specific management of micro grid products involved an appropriate financial method to explain the actual fuel cost. The advantages of renewable energy infiltration contain reducing external energy dependency, reducing transmission and transformation loss improving system reliability. Here the mathematical derivations of various components are explained.

4 Soft-Computing Techniques

4.1. GENERAL

In this chapter the detailed explanation of Artificial Bee Colony (ABC), Gravity Search Algorithm (GSA), Cuckoo Search Algorithm, BAT algorithm, Ant Lion Optimization (ALO), Recurrent Neural Network (RNN), Artificial Neural Network (ANN), Squirrel Search Algorithm (SSA), Adaptive Neuro fuzzy inference system (ANFIS), Salp Swam Optimization (SOA), Radial Basis Function Neural Network (RBFNN), Randomly Forest algorithm as well as Coral Reefs Optimizing Algorithm are presented. Here, optimizing methods are utilized to minimize the actual operating costs. RNN, ANN, ANFIS as well as RBFNN are operating on the basis of machine learning technique. Each algorithm is used to obtain the optimal outcomes [121-122].

4.2. A BRIEF EXPLANATION OF METHODOLOGIES

4.2.1. OVERVIEW OF THE HYBRID METHOD

The recommended approach is interaction for artificial bee colony (ABC) in 2 phases, namely ABC_Phase I, ABC_Phase II. Optimum formation for micro grid is determine in initial phase ABC; It takings cost functions of DG, FC, MT as WT, PV produce powers as zero working cost. The load demand, approval in minimum cost functions is utilized to develops the optimum formation of MG. Since with minimum fuel cost of MG’s, the operation and maintenance costs are reduced using ABC's secondary phase [123-126].

4.2.1 1. ABC PHASE I

Essential load demand is often used utilizing WT and PV because of the no cost of fuel for generating the power. When that is not satisfying the situation, DG, FC and MT takes the explanation to solve the issue. The designated formulation of MG must meet load demand utilize a least fuel cost. Consequently, the diesel generator, fuel cell, micro turbine fuel cost functions consider to the first multiple-function utility of ABC. The multiple-objective purpose is referred to given as follows:

$$\phi = \min_{C \in F} \{ f_1(C), f_2(C), f_3(C) \}, \tag{4.1}$$

Here,

$$f_1(C) = \sum_{i=1}^{M} (d_i + \mathrm{e_i P_{DG\,i}} + f_1 \mathrm{P^2}_{\mathrm{DG\,i}})(\text{Fuel cost of the DG}) \tag{4.2}$$

$$f_2(C) = \sum_{L} \frac{\mathrm{F_{NG} P}_L}{\eta_L} (\text{Fuel charge of MT}), \tag{4.3}$$

$$f_3(C) = \sum_{J} \frac{\mathrm{C_{NG} P_J}}{\eta_\mathrm{J}} (\text{Fuel charge of FC}), \tag{4.4}$$

Where, $\mathrm{P_{DG\,i}}$ implies output power for generator; N implies number of generators; d_i , e_i , f_i implies the fuel cost coefficients utilize $i = 1,2..,n;F_{NG},C_{NG}$ indicates natural gas value ($/kWh) for MT, FC, $F_{NG} = C_{NG}$ = 2:3$/kWh; P_L, P_J indicates output power of MT, fuel cell; η_L, η_J implies efficiency of MT, FC correspondingly, $\eta_L = \eta_J = 0.47$. The steps to optimize for the configuration of micro grid can be described as follows [127-130]:

Step 1: Initializing population of the micro grid models (X_i) likes WT, PV, DG, FC, MT, cost function as well as corresponding ratings.

Step 2: Create a random number of population cost based on load demand.

Step 3: Calculate the fitness function according to equation 4.5

$$\phi = \min_{C \in F} \{ f_1(C), f_2(C), f_3(C) \}, \tag{4.5}$$

Step 4: The employee bee phase that can assess the fitness of the population given the many purpose required

$$\phi = \min_{C \in F} \{ f_1(C), f_2(C), f_3(C) \}, \tag{4.6}$$

Step 5: Establish iterative count as 1, that is, iterative K = 1.

Step 6: Recurrence.

Step 7: Onlooker bee attain best formation of micro grid combination and improves velocity of population utilizing

$$V_{i,j} = x_{i,j} + \phi_{i,j}(x_{i,j} - x_{k,j}), \tag{4.7}$$

Here,*k = 1,2,…,n*,*j = 1,2,…,n* indicates arbitrarily select index.

Step 8: Apply the selection procedure to determine the optimum fitness of new solution and determine the probability

$$\text{Probability} = \frac{\phi}{\sum_{i=1}^{n}\phi} \tag{4.8}$$

Step 9: If optimum solution is not available, discard solution and use a random number of scout bee solution

$$x_i^j - x_{\min}^j + rand\,[0,1]\ (x_{\max}^j - x_{\min}^j) \tag{4.9}$$

Step 10: Remember the optimum solution attained until now.

Step 11: Check the limit again and if iteration not reaching the maximal value increases the count of iterations to K = K + 1, while the iteration reaching maximal value, the procedure is complete [131]. The secondary ABC operating development is utilized to reducing operational as well as cost maintenance of the micro grid.

4.2.1.2. ABC PHASE II

Optimum growth of diesel generator, fuel cell, MT by the minimal fuel cost reaches the first phase of ABC output. Since improving micro grid cost, the second phase of ABC lessens operational along maintenance cost. It calculates the external charges of the environment by reducing the radiations of NOx, SO_2 and CO_2. Objective functions are develop to reduce operational and maintenance charge of MG, that is defined as given below [132]

$$\psi = \min_{C \in F} \{ f_i (C) \} \tag{4.10}$$

$$F(C) = \sum_{T=1}^{T} \left(\sum_{i=1}^{N} (\mathrm{C_i F_i} + \mathrm{OM_i}) + \sum_{i=1}^{N} \sum_{j=1}^{M} \alpha_j (EF_{ij} P_j) \right), \tag{4.11}$$

Here, C_i implies fuel cost for producing unit at $/L in diesel along $/kW of natural gas; F_i implies fuel consumption ratio to generating unit; OM_i implies operational and maintenance cost at generating unit, α_j is externality cost of emission type *j*; EF_{ij} implies emission factor of the generating unit, emission type j; *M* indicates emission type; *N* indicates number of generating unit. The step to improve operational as well as cost of maintenance of micro grid is specified as below [133]

Step 1: Initializing population output (Y_i) of the initial phase in ABC, i.e., optimal formation of micro grid as a minimal fuel charges as well as emission cost and external factors.

Step 2: Produces random number for operational along maintenance cost depending upon load demand and cost function.

Step 3: Employee bee for computing the fitness of

$$\psi = \min_{C \in F} \{ f_i (C) \} \tag{4.12}$$

Step 4: Establish the iterative count to 1, that is, iterative K = 1.

Step 5: Recurrence.

Step 6: Optimal operation with maintenance cost of the appropriate load dead is determine utilizing the onlooker bee and cost is improved using

$$V_{i,j} = y_{i,j} + \psi_{i,j} (y_{i,j} - y_{k,j}), \tag{4.13}$$

Here, k = 1, 2, n, j =1, 2, n are the randomly select index

Step 7: Use selective procedure for discovering optimum fitness of newly solution and determine the probability

$$\text{Probability} = \frac{\psi}{\sum_{i=1}^{n} \psi} \tag{4.14}$$

Step 8: Optimum solutions have yet to be found and the scout bee for a newly one will create using the solution

$$y_i^j = y_{\min}^j + rand[0,1](y_{\max}^j - y_{\max}^j), \tag{4.15}$$

Step 9: Storing the optimum solution found up to now.

Step 10: Rise iterative count K = K + 1, till it reaches maximum value as of [134-136].

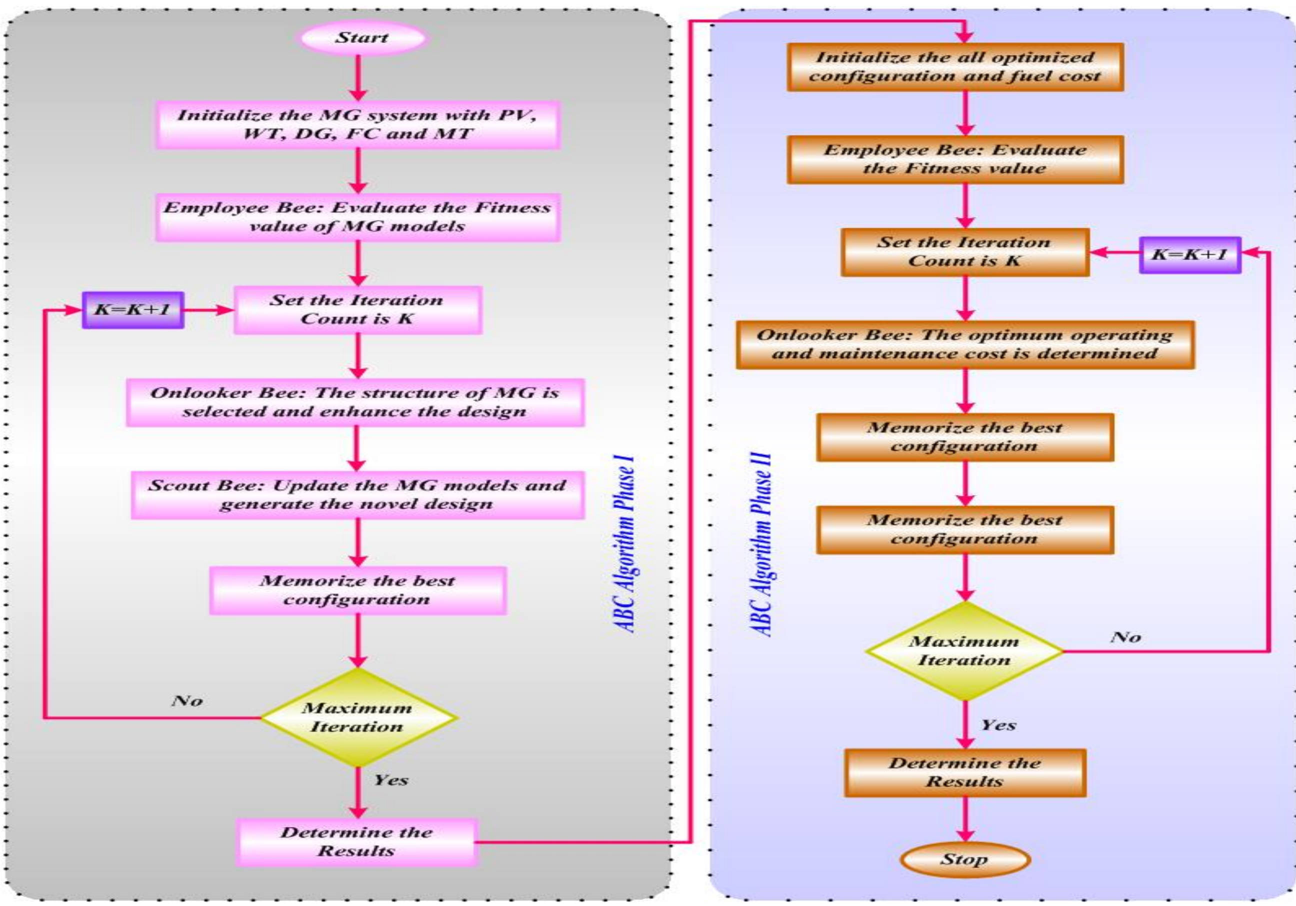


Figure 4.1: Structure of proposed method

When the process is complete, the proposed hybrid system is complete to deliver the optimum configuration of MG at the lowest fuel cost. The procedure of the proposed hybrid approach is demonstrated in Figure 4.1. The proposed method is validated using MATLAB platform and the performance is examined through the comparison.

4.2.2. IABC BASED MG COMBINATION OPTIMIZATION

Mathematical optimizing problems are used based on the foraging activity of bees [137]. ABC process is one of the swarm intelligence optimizing algorithms [138]. Normally ABC has three stages like employee bee, onlooker bee and scout bee. Despite many variants have been described in the works [139], here improved the scout bee enhancement functionality by using GSA agent updating process. GSA is a population based law of gravity as well as mass interaction creates an efficient scout bee phase, it is known as IABC [140–142]. The proposed IABC is calculated to improve the optimizing ability of the algorithm over on extended set of problems. The hybrid searching mechanism uses load selection strategy and proximity based trigger aids to achieve arrangement of exploration as well as exploitation performance by enhancing the algorithm's local and global search capability. It enhances the efficiency of Swarm agents, optimizing areas for newly fitness sinks and energy close to global convergence rate [143 and 144]. The proposed IABC is used to select the optimum configuration of MG according to load demand through decreasing fuel cost, emission factors, operation and maintenance cost. The inputs such as WT, PV, DG, FC, MT achieve proposed IABC purpose by utilizing MG generation and corresponding cost functions. First, the actual power group of MG is selected as the input, based on power demand, randomly creates MG’s applicant solution, i.e. the employee bee. Input of (IABC) is defined as given below:

$$X_i = X_i^{min} \leq X_i \leq X_i^{max}, \forall i = 1,2,...,n \tag{4.16}$$

Here, X_i implies produced power employed bee to attain optimum fitness along onlooker bee improves input speed population utilizing the following Equation. (4.16)

$$V_{i,j} = X_{i,j} + F(C)_{i,j}(X_{i,j} - X_{k,j}) \tag{4.17}$$

Here, k = (1; 2; 3 ... n), j = (1; 2; 3 ... n) indicates arbitrarily selecting index. After the onlooker bee the possibility formulation to select nectar source are articulated as given below:

$$\text{Probability} = \frac{F(C)}{\sum_{i=1}^{n} F(C)} \quad (4.18)$$

Then, the formulation of upgrading the combination in the GSA method is calculated as following [145] then:

$$X_i^d(t+1) = X_i^d(t) + V_i^d(t+1) \quad (4.19)$$

Here, $V_i^d(t+1) = rand[V_i^d(t) + a_i^d(t)]$ (4.20)

Where, $X_i^d(t)$, $X_i^d(t+1)$ indicates location of the bees at time t , *t+1* with d dimension , $V_i^d(t)$, $V_i^d(t+1)$ indicates velocity vectors for the bees at time t, *t+ 1* with dimension d, rand indicates random number in the interval [0,1], $a_i^d(t)$ indicates acceleration at time t with d dimension. Before, the optimum fitness for newly food source is created utilizing Eq. (4.19) and the optimum solution is selected in optimum formation of micro grid with minimum cost factors. To discover the optimum formation of micro grid utilizing IABC is described as following [146].

STEPS OF IABC TECHNIQUE

Step 1: Firstly, initiation of whole parameters of algorithms like input parameter limits and random population N limits. Here, MG methods are used as input as the generation limits.

Step 2: MG's combination creates the applicant solution arbitrarily according to the power demand achieved during the employed bee phase.

Step 3: Calculate the fitness function.

Step 4: A random solution is realistic in fitnessE_q. and find the best solutions.

Step 5: An onlooker bee, the neighborhood search differs in speed of the input population utilizing the Eq. (4.16) and discover optimum solution utilizing Equation.

Step 6: Optimum solution is categorized into two groups, the initial group is minimum optimum solution and additional group is maximum optimum solutions.

Step 7: For every optimum solution group, the size of the neighborhood search is determined. Creates a solution of selected internal solutions of neighborhood size.

Step 8: If the onlooker bee search does not reach optimal solutions, abandon the solution and produce the random number of scout bee solutions using GSA updating technique (4.19)

Step 9: Select the optimum solution for every connection as well as create related fuel cost for the load demand.

Step 10: To check the ending principle. If it is fulfilled, terminates the search, otherwise move to step 11.

Step11: Assigned newly population to generate new solutions. Go to step 2.

When the procedure is completed the IABC can provides optimum formation of MG's with least charge factors. Here, the hourly varying load demand is arbitrarily attained from the user's knowledge base. The whole process of achieving the optimum development of MG with the lowest payment factor is demonstrated in the following [147]. Construction of the proposed approach is presented in Figure 4.2.

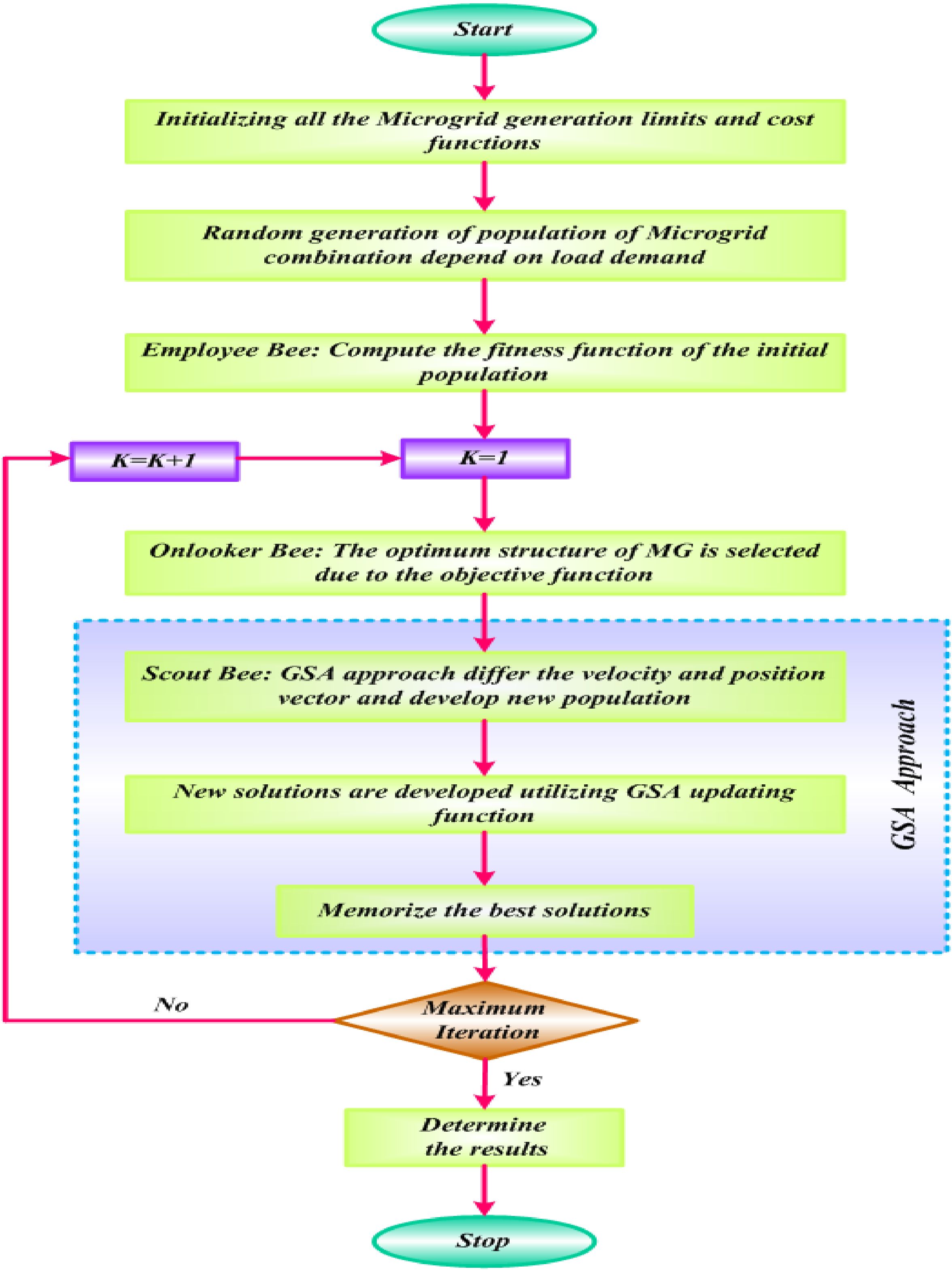


Figure 4.2: Structure of the proposed method

Next, the proposed IABC is used on the MATLAB / Simulink platform and the properties are established by comparison using the effects of various techniques.

4.2.3. MICRO GRID SOURCES MANAGEMENT USING HYBRID OPTIMIZATION TECHNIQUE

The CS is the metaheuristic optimizing method that is inspired through activity of cuckoo species that use the levy flight search at certain birds [148]. Levy Flight's practice demonstrates the method of searching strategy with optimum local and global solution. The Bat Algorithm is a bio-inspired algorithm [149]. Where, the hybrid CS and BA are utilized for comparing upgraded fitness function and select the optimum result that is the optimum MGs combination by minimum fuel cost, operation and maintenance cost. Design the MGs combination of optimization method stages are defined as given below:

ALGORITHM

Step1: Initialize MG models X_i such as load demands, cost functions and corresponding generation limits.

Step 2: Improves combination of micro grid sources based on load demand at *n* host nest

$$X_i = [X_1, X_2, X_n] \tag{4.21}$$

Step 3: Establish iterative count at k=1.

Step 4: Finding the fitness of nest utilizing fitness equation

$$X = Min \sum_{i=1}^{4} f_1(C) \tag{4.22}$$

Step 5: Upgrade the solution

$$X_i = (t+1) = X_i(t) + \alpha \oplus Levy(\lambda) \tag{4.23}$$

Here, $\alpha > 0$ indicates step size which should be related to the scales of the problem of interests along product $\oplus$ means entry-wise multiplications. Levy flight performance is step lengths that have a tendency with allocate utilizing the next probability distribution.

$$Levy(\lambda) = t^{-\lambda}, 1 < \lambda \leq 3 \tag{4.24}$$

Step 6: Searching worst nest based on probability Pa ∈ [0, 1] along replace the worst nest by newly group of solutions.

Step 7: Bat-inspired method utilize to search fitness function updation as given below:

$$x_i^t = x_i^{t-1} + \varepsilon A_i^t \tag{4.25}$$

Where, ε implies a random number among [-1, 1], A_i^t implies the average loudness of whole bats a present generator on time t. An average loudness constraints limits implies $A_{min} \leq A_i \leq A_{max}$ .Generate the new solution utilizing the upgrading fitness equation (4.22) and determine the optimum echolocation performance solution.

Step 8: Comparing the fitness function, a proficient fitness are the optimum solution.

Step 9: Examines termination principles. If it is fulfilled, then terminates the search, otherwise move step 10.

Step 10: Allocate the new population to create newly solutions or move step 3.

When the procedure is done, the controller preserved to determine the optimum combination of the micro grid depending upon multi-objective function. The proposed approach is carried out in MATLAB/Simulink platform.

4.2.4. ENERGY MANAGEMENT USING SOGSNN TECHNIQUE

4.2.4.1. LOAD DEMAND PREDICTION UTILIZING GSA BASED ANN

The hybrid method is the combination of GSA as well as ANN. The proposed ANN is utilized to fulfill renewable energy power, also to retain the grid demand power as grid operator. ANN is a universal approach to depict the procedures in logical format. The motivation beyond the approach is basic elements called "neurons". Using standard input time intervals, which are trained for ANN utilizing target power demand. GSA is utilized for training the ANN [150]. GSA is newly and a meta-heuristic optimizing approach generated by Rashedi et al [151]. This approach is motivating in law of Newton's gravity as well as law of motion; it is optimum possible to a break-through optimizing approach. All these objects are attracted to each other by the force of gravity and apply mass to the objects, which causes the universal motion of the whole object. To predict load demand, ANN based GSA is used here. It then relates local optimum and global optimum results. ANN is the input layer, hidden layer as well as the output layer. Every layer provides a feed forward connection. Network is trained to utilize historical databases as previous year's demand database. The variance load for every hour is referred to as the training input dataset for ANN. As a result, it created the optimum demand output according to load. The load for every hour is varied. GSA was adopted to train the neural network, which can be taken later.

4.2.4.1.1. STEPS OF GSA

GSA, like the meta-heuristic algorithm, was created in sense of gravity. Where, beginning of the random generation of position of agents during a given search interval. For solving the problem, GSA is used. Optimal found result is adjusted by the local search method i.e., pattern search. GSA operator is implied, as well as agents going to the search space in beginning of every iteration. For more iteration, the serial combination is repeated.

Step 1: Initialization

Initializing population array of particles utilize input indicates time interval and the output as power demand.

Step 2: Random Generation

Then the initial method creates system initial input parameters randomly.

$$random^{i} = \begin{bmatrix} p_d^{11} & p_d^{12} & \cdots & p_d^{1n} \\ p_d^{21} & p_d^{22} & \cdots & p_d^{2n} \\ \vdots & \vdots & \vdots & \vdots \\ p_d^{m1} & p_d^{m2} & \cdots & p_d^{mn} \end{bmatrix} \tag{4.26}$$

Where, p_d indicates power demand.

Step 3: Fitness

It predicts optimum load demand, fitness completion for all agents. Fitness are calculated and defined as below:

$$Error, e = \frac{1}{2}\sum\left(t_D - d_D\right) \quad (4.27)$$

Where, d_D implies the desired output demand, t_D implies the target output demand.

Step 4: Gravitational Constant Computation

Utilizing the t iteration in the succeeding equation (4.28), the gravitational constant $g(t)$ is computed.

$$g(t) = g_0 \exp\left[-\alpha \frac{t}{I}\right] \quad (4.28)$$

Where, g_0 indicates the gravitational constant selected randomly, α , between 0.9 to 0.98 indicates constant, t indicates current period, I implies maximum iteration number.

Step 5: Inertial Mass Upgrading

The inertial mass with the gravitational constant is enhanced via succeeding iteration as shown in below:

$$Mg_j(t) = \frac{Fit_j(t) - W(t)}{B(t) - W(t)} \quad (4.29)$$

Where, $Fit_j(t)$ indicates the fitness value of the agent j at time t, W (t) and B (t) are the worst & best fitness value in time t.

It depicts quantity of the j^{th} agent and is given as below:

$$mg_j(t) = \frac{mg_j(t)}{\sum_{i=1}^{n} mg_j(t)} \quad (4.30)$$

Step 6: Total Mass Calculation

The following is given to evaluate the full force acting on the j^{th} agent:

$$F_j^d(t) = \sum_{i \in k\mathbf{B} i \neq j} rand_i \, F_{ji}^d(t) \quad (4.31)$$

Where, $rand_i$ indicates random number amid interval as of [0, 1] and kB indicates the set of 1st k agents with the best fitness falue and biggest mass $F_{ji}^d(t)$ implies the asset substitute in j^{th} mass from the i^{th} mass.

Step 7: Acceleration and Velocity

Through the law of gravity and law of motion, the acceleration $A_j^d(t)$ at iteration t as well as speed $V_j^d(t+1)$ of j^{th} agents at iteration $t+1$ in d^{th} dimension is upgraded.

$$A_j^d(t) = \frac{F_j^d(t)}{mg_j^d(t)} \tag{4.32}$$

$$V_j^d(t+1) = rand_j \times V_j^d(t) + A_j^d(t) \tag{4.33}$$

Step 8: Agent's Position Updation

The succeeding locations of j^{th} agents in d^{th} dimension of agents are upgraded utilizing the associated equation given as:

$$X_j^d(t+1) = X_j^d(t) + V_j^d(t+1) \tag{4.34}$$

Step 9: Termination

Steps 3 through 9 will be repeated until the iteration reaches that maximum limit. In the last iteration, the optimum solution of the algorithms is calculated as global fitness function of the problem and at specified dimension the position of the corresponding agents as the global solution. The optimum solution is selecting at the end point based upon fitness objective. Optimum value for optimization process is represented as e^{best} and p_d^{best}. The optimal datasets of the optimal parameter are defined as:

$$\begin{bmatrix} e^{11} & e^{12} & \cdots & e^{1n} \\ e^{21} & e^{22} & \cdots & e^{2n} \\ \vdots & \vdots & \vdots & \vdots \\ e^{m1} & e^{m2} & \cdots & e^{mn} \end{bmatrix} = \begin{bmatrix} p_d^{11} & p_d^{12} & \cdots & p_d^{1n} \\ p_d^{21} & p_d^{22} & \cdots & p_d^{2n} \\ \vdots & \vdots & \vdots & \vdots \\ p_d^{m1} & p_d^{m2} & \cdots & p_d^{mn} \end{bmatrix} \tag{4.35}$$

Therefore, the optimum combinations of error signal as well as demand power can be established.

4.2.4.1.2. STEPS OF ANN

Step 1: Input vector b refers to the use of the network input layer. The input vector b may be calculated as given follows:

$$b = \{b_1, b_2, b_3 \cdots b_n\}^t \tag{4.36}$$

The net input for the j^{th} hidden unit is given by:

$$N_j^h = \sum_{i=1}^{n} w_{ji} b_i + \beta_j^h \tag{4.37}$$

Here, w_{ji} indicates weight on the connection from the i^{th} input unit, β_j^h indicates bias for hidden layer as $j = 1,2 \cdots h$.

Step 2: Output of neurons in hidden layer is calculated as follows:

$$H_j^h = f\left(\sum_{i=1}^{n} w_{ji} b_i + \beta_j^h \right) \tag{4.38}$$

The net input of the neurons in output layer translates

$$O_k^o = \sum_{j=1}^{m_h} w_{ji} b_i + \beta_j^o \tag{4.39}$$

Step 3: Lastly, the neurons output, i.e. actual output of feed forward loop implies- χ_a at the output layer is calculated as given below:

$$H_k^o = f\left(\sum_{j=1}^{n_h} w_{ji} b_i + \beta_j^o \right) \tag{4.40}$$

Step 4: ANN are done thru optimizing weights with biases using a back-propagation algorithm to reduce the mean-square-error performance index (MSE)

$e = \min\left\{ \frac{1}{2} \left(\chi_o - \chi_t \right)^2 \right\}$ (4.39)Where, χ_t implies the target output, χ_o implies the actual output of ANN.

Step 5: The expression for enhancing synaptic weights is given below:

$$w_{ji}(n+1) = w_{ji}(n) - \varsigma \left(\frac{\partial e}{\partial w_{ji}(n)} \right) + \xi \Delta w_{ji}(n) \tag{4.41}$$

$$\Delta w_{ji}(n) = w_{ji}(n) - w_{ji}(n-1) \tag{4.42}$$

Here, ς indicates learning factor and ξ indicates momentum factor. The controller can use for determining the optimum formation of micro grid compounds based on load demand upon completion of overhead declared process. The Gravitational Search Algorithm (GSA) based Artificial Neural Network (ANN) is utilized for predicting demand load in the micro grid linked system.

4.2.4.2. OPTIMUM CONFIGURATION OF MICRO GRID (MG) CONNECTED SYSTEM UTILIZING SSA

Here, the optimal configuration of MG in light of load demand by Squirrel Search Algorithm (SSA) is presented. The multiple-objective function is essential for minimization of fuel cost functions of MT, FC and DG to improve the design of the MG connecting system. Here, load demand is taken as input and output as the optimal configuration of micro grid connected system. The SSA is newly, simple along powerful nature inspiring searching algorithm for numerical optimizing problems [141]. The dynamic foraging performances of southern flying squirrels are simulated. An effective way of locomotion of this algorithm is called as gliding. This approach is totally clarified the every aspect of its food search. Optimizing the formation of the micro grid connecting systems is rapidly explained as follows given below:

4.2.4.2.1. LAYERS OF SSA ALGORITHM

Layer 1: Initialization

Initializing load demand refers to input and micro grid connecting systems such as WT, PV, DG, FC, MT, cost functions and output as generation limits.

Layer 2: Random Generation

This layer randomly indicates the number of flying squirrels with a forest and the position for flying squirrel in a vector. The total number of flying squirrels is as given below:

$$fs = \begin{bmatrix} fs_{1,1} & fs_{1,2} \cdots\cdots & fs_{1,j} \\ fs_{2,1} & fs_{2,2} \cdots\cdots & fs_{2,j} \\ \vdots & \vdots \quad \vdots \quad \vdots & \vdots \\ \vdots & \vdots \quad \vdots \quad \vdots & \vdots \\ fs_{i,1} & fs_{i,2} \cdots\cdots & fs_{i,j} \end{bmatrix} \tag{4.43}$$

Here, $fs_{i,j}$ implies of i^{th} flying squirrel in j^{th} dimension. For allocating first position of every flying squirrel with forest as well as uniform distribution are utilized.

$$fs_i = fs_l + U(0,1) \times (fs_u - fs_l) \tag{4.44}$$

Here, fs_l and fs_u indicates lower as well as upper bounds correspondingly in i^{th} flying squirrel at j^{th} dimension, $U(0,1)$ implies uniformly distributed random number in the ranges of [0, 1].

Layer 3: Fitness Function

The location of each flying squirrel is figured, the fitness level of every flying squirrel are inferred. Multiple-objective function is implicitly as given below:

$$Fitness\,Function = Min\{cf_1, cf_2, cf_3, cf_4\} \tag{4.45}$$

Here, cf_1 implies cost function of DG, cf_2 implies fuel cell cost, cf_3 implies MT fuel cost, cf_4 implies the operation and maintenance cost.

Layer 4: Sorting Declaration along Random selection

The array is arranged in ascending order and stores the fitness values in every flying squirrel's position. The flying squirrel with least fitness value is guaranteed in the hickory nut tree. Subsequent optimum flying squirrels will cross the Hickory nut tree in anticipation of the acorn nut trees. The remaining flying squirrels head towards a normal tree. Some squirrels are tested near hickory nut tree and to fulfil day-to-day food needs. The remaining squirrels look at the acorn nut trees for day-to-day energy needs. By the presence of predators the foraging behaviour of flying squirrels is constantly affected. Utilize the location updating mechanism with predator presence probability (Pdp) the normal behaviour is modelled.

Layer 5: Newly Location Generation

Three situations can occur due to the dynamic foraging of flying squirrels previously discussed. It is assumed that the flying squirrel in every situation effectively glides and explores the entire forest for its preferred food in the absence of predator. If the predator is existed in the forest then the flying squirrels utilize lesser random work to search a close hiding location. The numerical method of the dynamic foraging performance is calculated as follows: It contains of three cases:

Case 1: The flying squirrel in acorn nut trees (fs_{at}) can move to the hickory nut tree. The new positions of squirrels may be calculated as follows the equation:

$$fs_{at}^{t+1} = \begin{cases} fs_{at}^{t} + d_G \times g_c \times \left(fs_{ht}^{t} - fs_{at}^{t}\right) & r_1 \geq P_{DP} \\ Random\ Location & Otherwise \end{cases} \tag{4.46}$$

Here, d_G indicates random gliding distance. Using gliding constant g_c implies the mathematical model, the equilibrium among exploration as well as exploitation are attained, fs_{ht}^{t} indicates position of squirrel flying that reached the hickory nut tree, t signifies present iteration, r_1 implies random number in the range of $[0,1]$.

Case 2: Flying squirrel in acorn nut trees (fs_{at}) can moves to natural nut trees to fulfil for day-to-day energy needs. The new positions of squirrel may be calculated as given below:

$$fs_{nt}^{t+1} = \begin{cases} fs_{nt}^{t} + d_G \times g_c \times \left(fs_{at}^{t} - fs_{nt}^{t}\right) & r_2 \geq P_{DP} \\ Random\ Location & Otherwise \end{cases} \tag{4.47}$$

Here, r_2 implies random number in the range of values $[0,1]$.

Case 3: Some squirrel in the natural tree, as well as previously used acorn nuts may move on the hickory nut tree, saving hickory nut at the time of scarcity. The location of new squirrels can be determined as follows given below:

$$fs_{nt}^{t+1} = \begin{cases} fs_{nt}^{t} + d_G \times g_c \times \left(fs_{ht}^{t} - fs_{nt}^{t}\right) & r_3 \geq P_{DP} \\ Random\ Location & Otherwise \end{cases} \tag{4.48}$$

Where, r_3 implies random number of the value of $[0,1]$ P_{DP} implies the predator presence possibility. The value of P_{DP} for all circumstance is 0.01.

Layer 6: Aerodynamics of Gliding

The combination of lift (L) and traction (D) force describes the sliding mechanism of the flying squirrel, with the stability sliding forming an adjacent force (R) equal to the direction of the weight of the flying squirrel. The estimated sliding distance is obtained as follows:

$$d_G = \left(\frac{h_G}{\tan\varphi}\right) \tag{4.49}$$

Here, h_G indicates loss of height transpired when gliding.

Layer 6: Seasonal Monitoring Condition

Seasonal monitoring condition avoids local optimization. It can depict the seasonal monitoring status along similarly for checking the seasonal monitoring condition i.e. $s_c < s_{\min}$.

$$s_{\min} = \frac{10E^{-6}}{(365)^{\frac{t}{t_m/2.5}}} \tag{4.50}$$

Where, s_c implies the seasonal constant, $s_{\min}$ indicates the least value of seasonal constant, t and t_m implies the current as well as maximum iterations respectively. Value of $s_{\min}$ affect the exploration and exploitation capabilities. Greater value of $s_{\min}$ promotes the exploration and lesser value of $s_{\min}$ enhances the exploitation capability. Because of these activities, the gliding constant is utilized. If seasonal monitoring condition is found true, then the relocation of flying squirrels may be upgraded [142].

The Flowchart of GSA-ANN and SSA are given below:

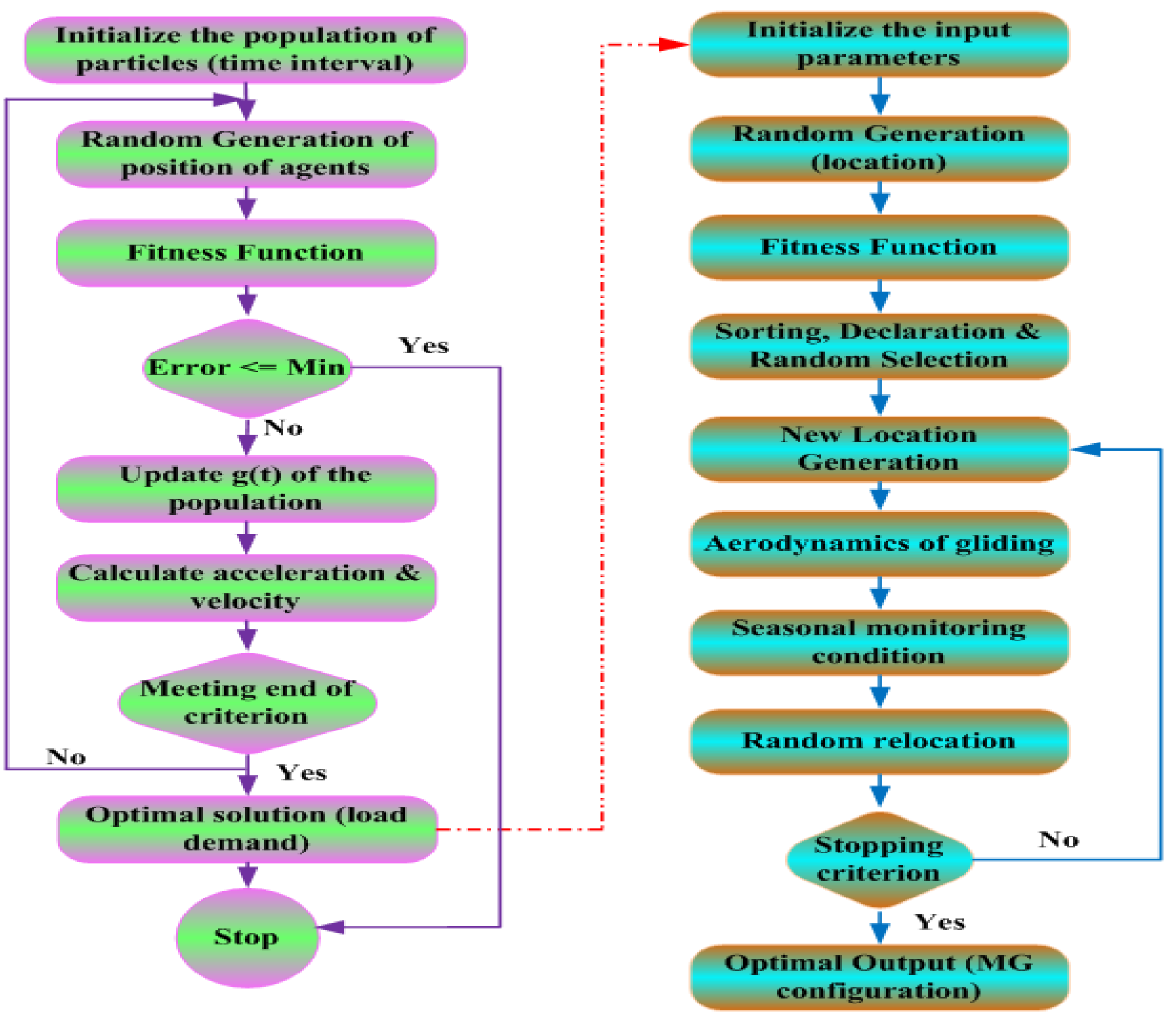


Figure 4.3: Flowchart of GSA-ANN and SSA

Layer 7: Random Relocation

The relocation of those flying squirrels are modelled by the following equation as:

$$fs_{nt}^{new} = fs_L + Le'vy(n) \times \left(fs_u - fs_l \right) \tag{4.51}$$

Here, $Le'vy$ distribution encourages the optimum and efficient search space exploration.

Layer 8: Stopping Criterion

Check whether the stopping criterion is satisfied. Move step 5 if this is not satisfactory, otherwise stop the search.

As a result, the system delivers the optimum MG output using the lowest fuel cost, operation and maintenance cost upon completion of the mentioned process. The recommended hybrid system structure is illustrated in Figure 4.3 below [143].

4.2.5. ANN AND BFOA TECHNIQUES

Here, a hybrid control system is expected on micro-grid energy management, which utilizes distributed system resources that utilize MG. The hybrid approach is a group of Bacterial Foraging Optimization Algorithm (BFOA) and Artificial Neural Network (ANN). Here, the PV, WT as well as storage system is considered as MG. The proposed control strategy is to manage the power flows between the energy sources and grid. The proposed method is to meet the available renewable energy power along maintain the grid power demand from the grid operator. The power required via grid operator is supplied as a reference to the input of the micro grid. The proposed strategy should be distributed the entire power reference between the system parts properly. In the proposed method, the objective function is to reduce the output cost of the micro grid, which is defined by the system data subject to the equality and inequality constraints. The constraints are the availability of PV power, wind power, power demand and state of charge for storage components. The battery is used as a source of energy, which allows the renewable power system to maintain units operating at safe and constant output power. First, PV, WT, MT, battery demands are predicted for 24 hour using the ANN technique. Then, the forecast values are given to the input in BFOA and capture optimum micro grid output [144].

4.2.5.1. PREDICTION OF LOAD DEMAND USING ANN

Here, discussed load demand estimation utilizing ANN, which is based on a machine learning method utilize multiple artificial neurons modeled on the human brain. Distributed neurons have internal networks and every neuron of ANN obtains multiple inputs depending upon active ANN effects on the output neuron. The learning task is the practice of instances called training examples [145]. Usually ANN contains three layers, namely the input layer, hidden and the output layer, which are described in Figure 4.4 below. Here, we are training the ANN using the target power demand with the corresponding input time intervals of a day, i.e., daily demand dataset based on the available WT and PV energy. The back propagation algorithm is used for training process. The training process is described below:

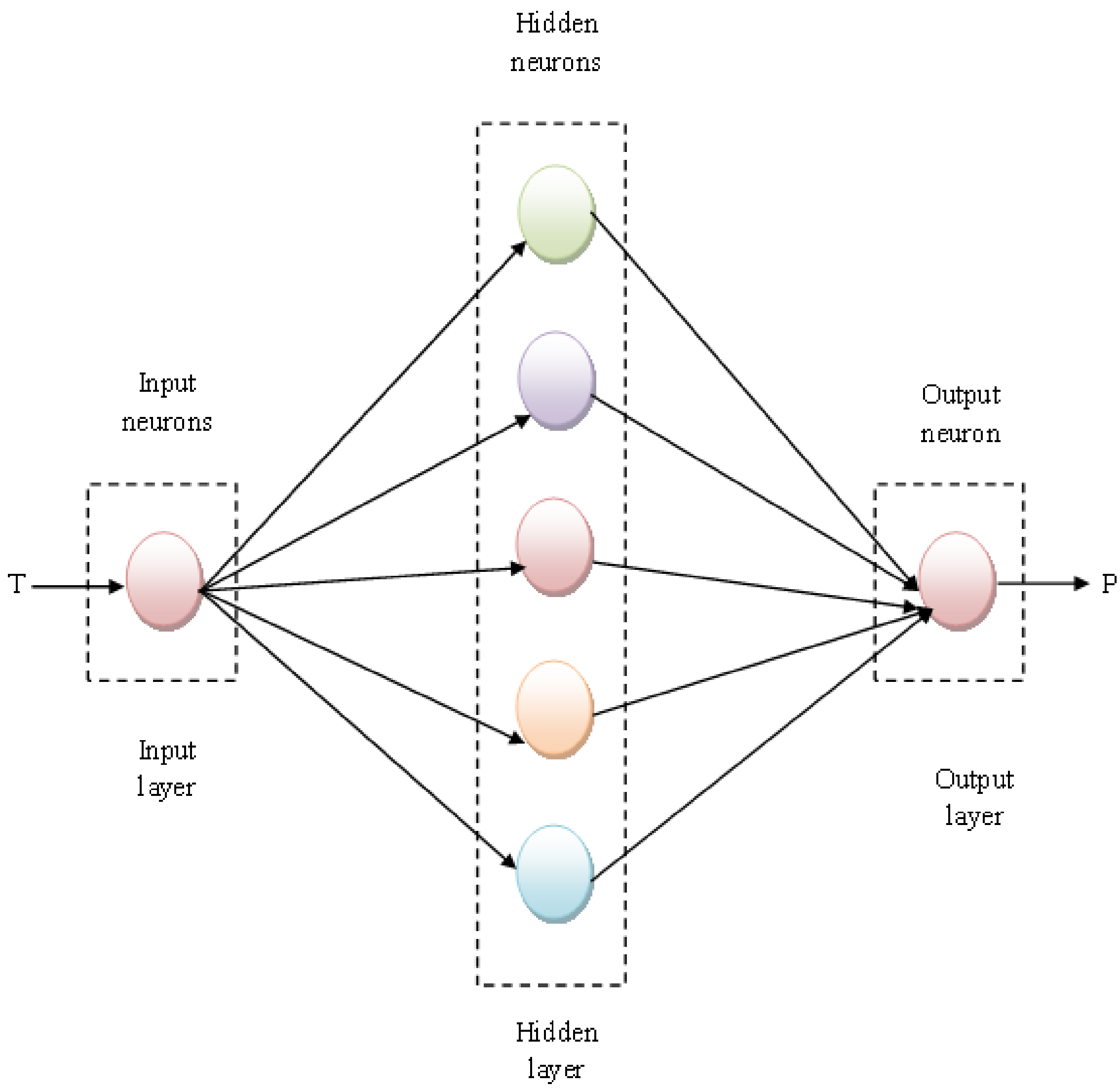


Figure 4.4: Structure of ANN

BACK PROPAGATION LEARNING ALGORITHM STEPS:

Step 1: Initialization of input layer, hidden and output layer weight of the neural networks. Here, interval time t implies input of the network; power demand $P_{WT}(t)$ implies output of the network

Step 2: Learn the network according to input with a corresponding target

Step 3: Calculating back propagation error of the target $P_{WT}(1), P_{WT}(2)$ $P_{WT}(n)$.

$$\left.\begin{aligned} BP_{error}^{1} &= P_{WT}(1)^{NN(tar)} - P_{WT}(1)^{NN(out)} \\ BP_{error}^{2} &= P_{WT}(2)^{NN(tar)} - P_{WT}(2)^{NN(out)} \\ BP_{error}^{n} &= P_{WT}(n)^{NN(tar)} - P_{WT}(n)^{NN(out)} \end{aligned}\right\} \quad (4.52)$$

Here, $P_{WT}(n)^{NN(tar)}$ indicates the networks target for n^{th} node, $P_{WT}(n)^{NN(out)}$ indicates current network output.

Step 4: Output of the network is expressed as follows:

$$\left.\begin{aligned} P_{WT}(1)^{NN(out)} &= \alpha_1 + \sum_{n=1}^{N} w_{1n}\, P_{WT}(1)^{NN(k)} \\ P_{WT}(2)^{NN(out)} &= \alpha_2 + \sum_{n=1}^{N} w_{1n}\, P_{WT}(2)^{NN(k)} \\ P_{WT}(n)^{NN(out)} &= \alpha_n + \sum_{n=1}^{N} w_{1n}\, P_{WT}(n)^{NN(k)} \end{aligned}\right\} \quad (4.53)$$

Here, $\alpha_1\ \alpha_2\ \alpha_n$ indicates the bias in node $1, 2\, and\, n$ correspondingly.

$$\left.\begin{aligned} P_{WT}(1)^{NN(k)} &= \frac{1}{1+\exp(-w_{1n}P_{WT}(1) - w_{2n}P_{WT}(2))} \\ P_{WT}(2)^{NN(k)} &= \frac{1}{1+\exp(-w_{1n}P_{WT}(2) - w_{2n}P_{WT}(n))} \\ P_{WT}(n)^{NN(k)} &= \frac{1}{1+\exp(-w_{1n}P_{WT}(n) - w_{2n}P_{WT}(1))} \end{aligned}\right\} \quad (4.54)$$

Step 5: The newly weight for every neuron in the networks is upgraded with $w_{new} = w_{old} + \Delta w$

Where, w_{new} indicates new weight, w_{old} indicates the previous weight and Δw indicates change of weight in every output.

The change of weight is calculated as given below:

$$\left.\begin{aligned} \Delta w_1 &= \delta . P_{WT}(1).BP^{1}_{error} \\ \Delta w_2 &= \delta . P_{WT}(2).BP^{2}_{error} \\ \Delta w_k &= \delta . P_{WT}(n).BP^{n}_{error} \end{aligned}\right\} \quad (4.55)$$

Here, δ indicates learning rate (0.2 to 0.5).

Step 6: Repeat the above steps until BP_{error} acquires minimized $BP_{error} < 0.1$.

It is trained to identify and improve the power demand according to the input interval time. [147]. The BFOA algorithm optimizes the management of MG based on the network's output. Furthermore, PV power demands are evaluated within 24 hours. BFOA is explained in the following section.

4.2.5.2. BFOA FOR OPTIMUM MANAGEMENT OF MG

BFOA was proposed by Kevin Passino, a new comer to the family of nature inspired algorithm. The main idea of this new algorithm is to provide a group foraging technique for E. coli bacteria in enhancing multiple-optimal function. Bacteriological study of nutrients is a method of maximizing the energy received per unit time. Individual bacteria communicate by sending signals to others. A bacterium makes foraging decisions when considering the two previous factors. The process, through which bacterium spread by taking small steps, even when searching for nutrients, is called chemo taxis. [148]. The main idea of the BFOA is to mimic the chemo tactic movement of virtual bacteria at the problem search space.

P: Dimension of search space,

S: Total number of bacteria in the population,

No: Number of chemo tactic stages,

Ns: Swimming length.

Nerd: Number of reproduction steps,

Ned: Number of elimination-dispersal events,

Pad: Elimination-dispersal probability,

C(I): The size of stage takes place in the random direction specified by the tumble.

In the foraging model, the study of animals receives nutrients that increase their energy consumption E per unit time spent foraging. Therefore, they tend to increase E / T-like activity (or they increase the long-term average energy intake rate). Improving such functionality provides additional sources of nutrition and the duration of another significant function (e.g., struggling, escaping, breeding, replicating, asleep, or shelter construction). Shelter construction and activities to find friends can sometimes be similar to foraging. Clearly, food search is actual different to different species. Plants usually look for food and then eat a lot of requirements. Carnivores usually have trouble finding food and then not having to eat it because food is high energy. The "environment" establishes the pattern in obtainable nutrients (e.g., nutrients which can be obtained by other organisms, such as geological constraints such as rivers and mountains and weather patterns) and it places constraints on access to food (e.g., small position of food may be separated by large distance). During foraging there can be risks because of predators prey on the movable, consequently it necessity running and the physical features of the foraging constrains that ability along ultimate success. Bacterial Foraging Optimizing is described by following stages:

- Chemotaxis
- Swarming
- Reproduction and
- Elimination-Dispersal

- **CHEMOTAXIS**

This process is simulating the movements in E.coli cell via swamming, tumbling through flagella. Physically an E. coli bacterium moves at two various methods. It can swim in the similar direction of a certain time of period or it can tumble that can be switched amid these two operating modes of the whole life span. Supposing $\theta^i(j+1,k,l)$ implies i^{th} bacterium in jet chemo tactic, ki^{th} reproducing with lath elimination-dispersal step. $C(i)$ Indicates the size of stage takes place in random direction specified by the tumble (run length unit). Then, computing chemo taxis movements in bacterial can characterized as:

$$\theta^i(j+1,k,l)=\theta^i(j,k,l)+C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}} \tag{4.56}$$

Here, Δ implies a vector for arbitrary path that components lie in [-1, 1].

- **SWARMING**

An interesting group behavior is experienced of a variety of movable bacterial, includes E.coli and S. typhimurium. Here, complex, steady spatial-temporal structures (swarms) develop in semisolid nutrient quality. The set of E.coli cells, located in the middle of the semisolite matrix, then connects to it travel ring by transmitting nutrient gradient upwards. The cells are stimulating by a large amount of succinate, and an attraction is released into the sperm, which is used to group the clusters, so that the focal forms of the clusters use a higher bacterial density.

- **REPRODUCTION**

When each healthy bacterium (which gives a low value of objective function) splits into two bacteria and placed in the same place, the minimally healthy bacteria eventually die. This retains the swarm size constant.

- **ELIMINATION AND DISPERSION**

Regular or rapid variations of the local environments wherever a bacterial population exists can occur for a number of reasons. Events such as the killing of entire bacteria in a region or the isolation of a group can occur. The significant local rise of temperature destroys bacterial group that currently exists in an area and focuses more on nutrient degradation. Actions can take place in such a way that the entire bacteria in an area is destroyed or a group is discrete to a newly location. Eventually, those events spread many types of bacterial from each part of the environmental to hot springs along secret environments. Various bacteria are spontaneously excreted with very little possibility to simulate this sensation in BFOA, although new alternatives are spontaneously launched at the study site. Removal and disintegration events have the effect of destroying the chemical progression, and then there are side effects in the chemical development, which can then make the dispersal bacteria almost optimal food sources. From a broader perception, deletion with diffusion is the dimensions of long-distance movement at the population level. [149]. Here, BFOA is used to provide optimum management of the micro grid and to obtain the least generational payment of the micro grid. Inputs are considered in WT Power, PV, MT and Battery. The purpose of the proposed method is to reduce cost function. Based on the objective the optimum management procedure is determined. Overall BFOA are defined as given below:

STEP BY STEP PROCES OF BFOA

Step 1: Initialization

First, initializing parameters such as S, No, Ns, Nerd, Ned, Pad, C (i), (i = 1, 2, S). First parameters are selected. These requirements are met in areas where there may be optimal value. The control variables (θ^i) indicates WT, PV, MT along battery power and their constraints are initialized. Control variables are arbitrarily generated depending on demand values; also it is measured through area of optimum location. After computation of θ^i completed, the value of P (level of every participant in the population of S bacteria) is updated automatically as well as the termination test is done for maximum number of specified iterations.

Step 2: Eliminating Loop

Eliminating dispersal loop is encountered into i.e. $l = l + 1$

Step 3: Reproducing Loop

Reproduction loop is considered to have been improved thru following equation as:

$k = k + 1$

Step 4: Chemo taxis loop

The subsequent equation signifies Chemo taxis upgrading. $j = j + 1$

(i) For i= 1, 2,….,S take chemo tactic steps for bacterial 'i' as given:

(ii) Computing cost from equation 3.21.

(iii) Search the optimum cost value.

(iv) Tumbling: Produce an arbitrary vector $\Delta(i) \in R^p$ with every component $\Delta_m(i), m = 1,2......p$ an arbitrary count of (-1, 1). Here, R implies real number.

(v) Move let

$$\theta^i(j+1,k,l) = \theta^i(j,k,l) + C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}} \tag{4.57}$$

The outcomes is stape of size C (i) in a direction of the tumble for bacterium i.

Computing cost

The value of micro grid, PV, WT, MT and battery power are calculated. If the cost function is low, the next step can be accepted, otherwise move step 3.

Step 5: Swim

(i) Let m=0 (counter for swimming distance)

While m<Ns

(ii) Let m=m+1

Search optimum least cost and computing the function again

$$\theta^i(j+1,k,l)=\theta^i(j,k,l)+C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}} \quad (4.58)$$

(iii) Calculate the new fitness of the new result

Move to bacterium (i+1) if i < S

Step 6: Here, the situation is verified, if j< Nc, go to Step 3. In this step, continue chemo taxis, since the life of the bacteria is not over.

Step 7: Reproduction

For the given k, l, and every i = 1, 2... S, healthy bacteria can be articulated as follows:

$$j^i_{health}=\sum_{j=1}^{N_{c+1}} J(i,j,k,l) \quad (4.59)$$

It is the health of bacterium i. Sort Bacteria along Chemo tratic parameter as C (i) in order of ascending cost j^i_{health} .

Where, S_r indicates bacterium with the maximum j^i_{health} values die and another S_r indicates bacteria utilize the optimum values splitting.

Step 8:

If ($k < N_{re}$), then move step 2. In this case, the number does not extend the number of reproduction steps.

Step 9: Eliminating Dispersion

For i = 1,2, ..., S with probability Ped, it eliminates and disperses each bacterium to a random location on the optimization domain. If $l < N_d$, then go to step 1, else move end. The PV, WT, MT, battery power and cost are obtained distinctly. The flow chart of the proposed method is presented in Figure 4.5.

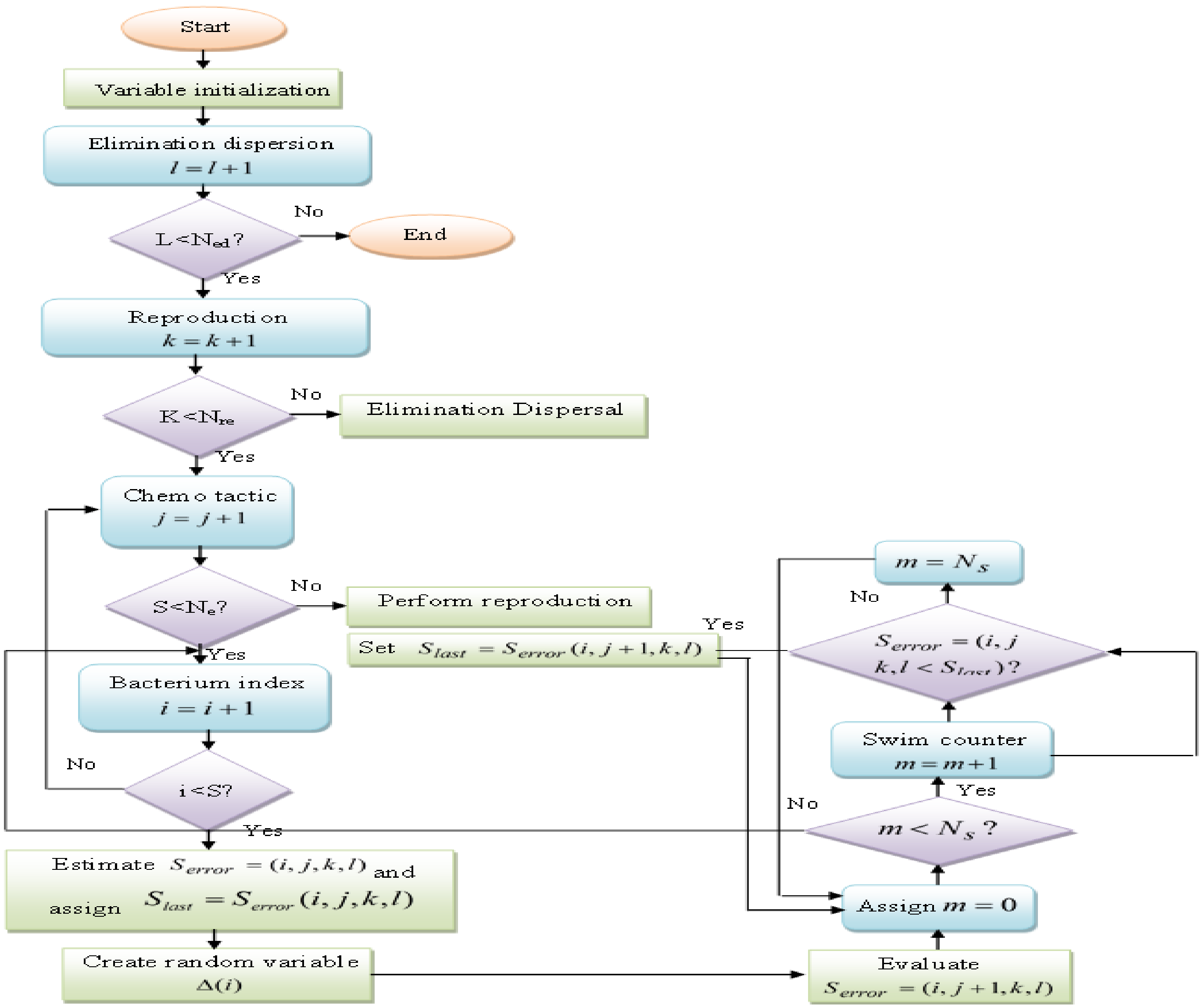


Figure 4.5: Flowchart of proposed BFO algorithm

4.2.6. RNN AND ALO WITH MICRO GRID FOR OPTIMUM ENERGY MANAGEMENT

Here, the intelligent controlling method for the use of distribution system resources with energy management micro-grid is recommended. This method is a combination of Recurrent Neural Network (RNN) and Ant Lion Optimizer (ALO). The micro grid connecting system is based on PV, WT as well as associated storage system. The recommended method is utilized for managing power flows among power sources and grid. It maintains the available renewable energy and grid power demand as a grid operator. The power required in the grid operator is provided from the constant input of the micro grid. The proposed method is to distribute the entire power orientation correctly amid system components. Here, batteries are utilized as an energy source, to stabilize and allow the renewable power system units for operating in steady and constant output power. A complete analysis of the proposed approach is described in the section below.

4.2.6.1. RNN FOR LOAD DEMAND

RNNs differ from fundamental feed forward neural networks in hidden layers. Every RNN hidden layer attains inputs not only from its preceding layer but also from initiations of itself for preceding inputs. An approximate form of a completely recurrent neural network is a Multi-Layer Perceptron (MLP), the previous group of hidden unit function that was feeding back as a network system using inputs. Every time set indicates the need to discretize time with upgrades for beginners [150]. Time measurement can be utilized as a multi-step scale that looks like the function of real neurons or to match a given problem for reproduction schemes. A delay unit wants to be familiarized with activation in hold till that can administer in next interval time. An abbreviated form is displayed in Figure.4.6. The actual RNN utilized for every node in hidden layer is related, utilized with the previous activation of each node in hidden layer. Nevertheless, for clarity, maximum links are missing from the image [151]. Here, RNN is used to estimate load demand. The RNN contains a number of inputs depending on the applications of activation function of RNN effects on the neuron output. Here, RNN training using target demand power uses standard input interval time of a day, that is, day-to-day demand data depending on available WT along PV energy. Trained process is described below:

TRAINING STRUCTURE OF RNN

The training and testing are two phases while the input layer, hidden layer, the context layer and output layer are the four layers which cover the RNN, where the 'n' neurons are activated in hidden and context layer. [152]. The feedback path has a one-step time delay in that preceding output of the hidden layer, is called as the states of the network, are involved in calculating the new output values. Topography is similar to the feed forward network; Outputs of individually hidden layers are activated as the feedback signals. The formulating graph for an RNN uses the voltage as input and the current as output in Figure.4.6.

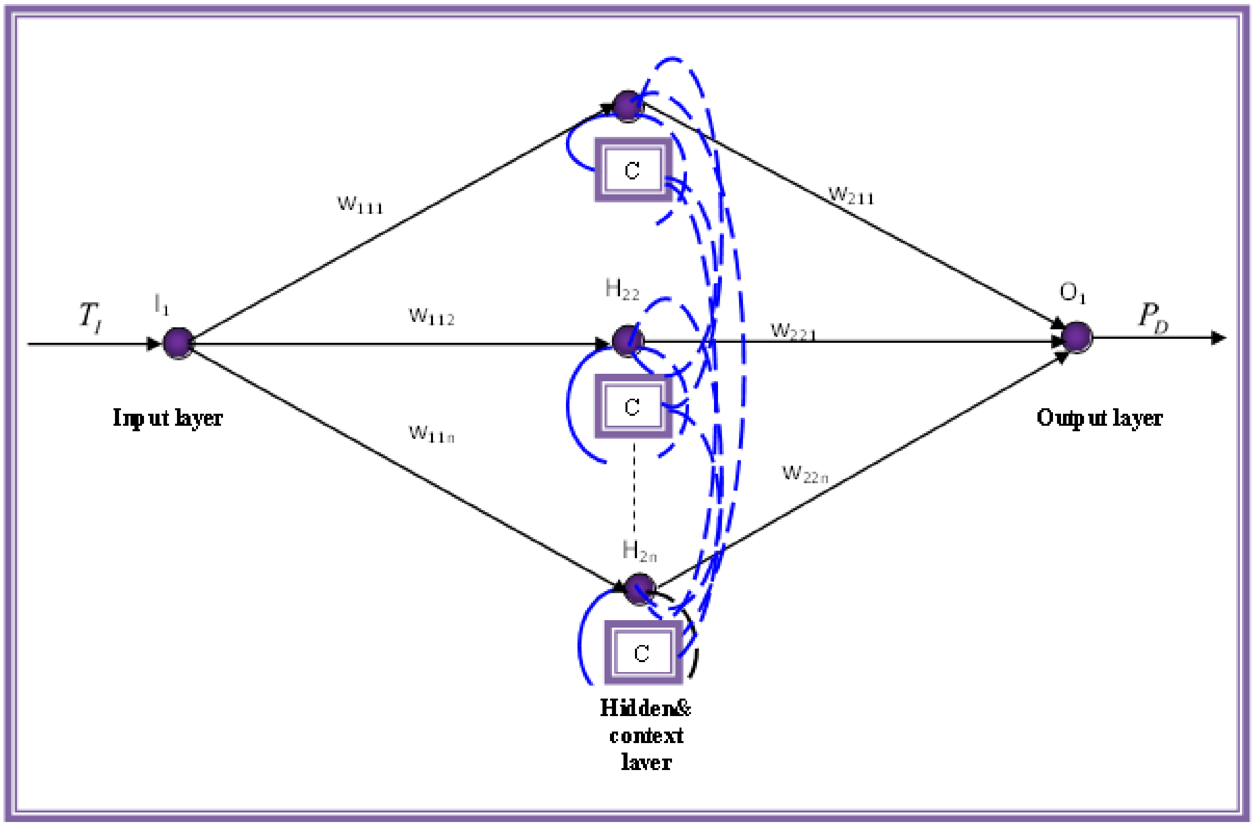


Figure 4.6: Training structure of proposed recurrent neural network

Where, the interval time t indicates input of the network, power demand $P_{WT}(t)$ indicates the output of the network. RNN output is supplied to the inverter current controller. Presently, input layer to hidden layer weights are calculated as ($w_{11}, w_{12},........, w_{1n}, \text{ and } w_{21}, w_{22},.....w_{2n}$). The random weight of recurrent layer and output layer of the neuron are generated as quantified intervals

$[w_{\min}, w_{\max}]$. The each neuron of the input layer weight is used as unit value. The RNN is trained with the help of Back Propagation through Time Delay Algorithm (BPTT) along with Bayesian regulation. In this training process, inputs and output are quantified as $\gamma_i(n) = \sum_j \delta_j(n) w_{ij}(n)$. RNN is based on forward as well as backward pass. The Bayesian Instruction BPTT algorithm is maintained as given below:

TRAINING PROCEDURE

1) Initialize all the inputs to the input layer along assign its weights.
2) The forward pass of RNN is designated as given below:

$$\gamma_i(n) = \sum_j \delta_j(n) w_{ij}(n) \quad , \; \delta_i(n) = f_i(\gamma_i(n)) \tag{4.60}$$

Where, δ_i and w_{ij} indicates the activation state of neuron i at time n, optimizing weight value. The activation function f_i depends upon the basis of network input and the context layer inputs.

3) Now, hidden node function is calculated based on activation functions. A unseen node activation function determines decision vector through the sigmoid function.

Here, $i = 1,2$ and the RNN output indicates $\hat{y} = W_{2i} f_i$ for single output system output weight matrix.

4) The forward process of back propagation, the output of every neuron is calculated in the backward pass using the following equation

$$\delta_i(n) = f_i(\gamma_i(n), C_i(n)) \tag{4.61}$$

$$\gamma_i(n) = \sum_{j \in H} \delta_j(n) w_{ij} + \sum_{j \in I} \gamma_j(n) w_{ij} + \sum_{j \in C} \delta_j(n - \tau_{ij}) wij \tag{4.62}$$

Here, f, H, I, C are indicated activation function of neuron, hidden layer values, input neuron values, the values of the neuron that stored in data in the previous network level. Then γ_j indicates a j^{th} neuron input, τ_{ij} indicates an integer value representing the displacement in recurrent linking done over the periods.

5) The back propagation error is decisive as below:

$$\mu_m = \delta^t - \hat{\delta} \tag{4.63}$$

The error can be reduced using Bayesian Regularization method.

6) Currently, the neural network is trained using the Bayesian regularization method. The objective performance is modified by the mean sum of square network errors and weights and builds an optimal work network with preferably precise integration. These processes involve the Bayesian regularization system, which is based on functionality utilized network training as well as the Levenberg-Marquardt Optimization, which improves weight and bias values in this process.

$$\mu_d = \frac{1}{N}\sum_{i=1}^{N}\left((\mu_m)^2\right) \tag{4.64}$$

7) Finally, the network weights have been improved. To improve the weights, this equation is expanded to the following:

$$B_r = \kappa\mu_d + \eta\mu_w \tag{4.65}$$

Where, μ_w indicates the summation of squares of the network weights. Then η , κ are the parameters to be optimized in Bayesian structure [153, 154]. The process is repeated until the back propagation (BP) error is reduced to minimum value. Optimal networks are efficient at the output of the neural network system. The study of the proposed method is defined in the next segment.

4.2.6.2. ALO APPROACH FOR MICRO GRID

Recently, in 2015 Mirzalili presented a nature inspired algorithm called Ant Lion Optimizer (ALO) that can reflect the performance of an ant lion's hunting behavior in the nature [155]. The ALO has found the best optimum designs for popular classical engineering problems; showing that this algorithm has qualified in solving constrained problems with separate search spaces. The main inspiration of the ALO derives as the foraging performance of ant lion's larvae. Larvae phase as well as adult phases contains two important phases in lifespan of ALO. The larval level provides inspiration of ALO. Ant lions dig a cone shaped pit in the sand and energy in a round pathway, pitching sand out with jaws. Then the trap larvae dig up and wait for the prayer (ants). The trap depends upon starvation level of ant-lion with size of the moon [156]. If the amount of hunger or the size of the moon is high, then trap size is more and vice versa. If the pray come into cone surface it will simply fall down into it. If the ant lion finds request on the web, it catches the request. The ALO has five main functions, namely spontaneous ants, movement trap creation, trapping of ants in traps, catching prey and reconstruction of traps.

OPERATORS OF ALO APPROACH

The ALO algorithm reflects interactions amid the ant lions along the ants in the trap. To model such interactions, ants must moves in the search space and ant lions are allowed to hunt and become fitters utilizing traps. Subsequently ant transmits stochastically in nature for searching of food; an arbitrary walk is selected for modeling ants' movement as follows:

In the ALO algorithm, an ant lion with the ant matrices are arbitrarily initialized utilizing the function A. For each iteration the function B is upgraded the location of every ant on the selected antlion.The range of position of updates is defined in proportion to the current number of iteration. Two random walks reach the upgrade selecting ant lion as well as elite. When all ants are arbitrarily walks, they are assessed by the fitness function. If any one of the ants is fitter than the other ant lions, their positions will be considered a new post for ant lions in the next iteration. Optimum Ant Lion are likened with Optimal Ant Lion (Elite) can be replaced if required. These phases are recurring until the function C becomes invalid. Here, the proposed ALO can assess the global optimizing for improving issues for the following reasons:

- Exploration of the search space is accessed by the random selection of ant lions and random movements of ants around them.
- Adaptive shrinking boundaries of ant lion traps ensure the exploitation of search space.
- It is more likely to resolve local optimum stagnation with the use of random walks and the roulette wheel.
- ALO is a population-based algorithm, consequently local optimum avoidance are essentially high.
- The strength of movement of the ants decreases adaptively during course of iterations, which is guaranteed convergence in ALO.

- Calculates random walks in each ant, each dimension inspires diversity in the populations.
- An ant lions relocating of optimum ants through optimizing, thus the promising search spaces are stored.
- Ant lions guide ants to promising regions of search space. The optimum ant lion in every iteration is stored and compared to the best ant lion obtained up to now (elite).
- The ALO algorithm has very few parameters to adjust.
- ALO is a gradient-free algorithm and considers problem as a black box [157].

Here, ALO algorithm is utilized to provide the optimum management of micro grid as well as receiving the minimal generating cost of micro grid. The inputs are considered as the WT, PV, MT as well as battery power. The proposed method is for minimizing cost according to the objective function. Depending on the objective, the optimum management process is determined. The important steps in ALO are to evaluate TCSC volume. Firstly, WT, PV, MT and battery power are utilized to initialize in the ALO. The random position of ants stored in matrix M_{ant}.

$$M_{ant} = \begin{pmatrix} A_{1,1} & A_{1,2} & \cdots & A_{1,n} \\ A_{2,1} & A_{2,2} & \cdots & A_{2,d} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ A_{n,1} & A_{n,2} & \cdots & A_{n,d} \end{pmatrix} \tag{4.66}$$

$A_{m,n}$ implies the value of m^{th} variable (dimension) of the n^{th} ant, n= number of ants (population size).

Then, calculate the fitness function of the ants, by utilizing the following equation as below:

$$F_i = \min(F(X)) \tag{4.67}$$

Fitness of all the ants is stored in the matrix M_{OA} in terms of objective function f.

$$M_{OA} = \begin{pmatrix} f(|A_{1,1}, A_{1,2}, \ldots\ldots, A_{1,d}|) \\ f(|A_{2,1}, A_{2,2}, \ldots\ldots, A_{21,d}|) \\ . \\ . \\ . \\ f(|A_{n,1}, A_{n,2}, \ldots\ldots, A_{n,d}|) \end{pmatrix} \tag{4.68}$$

Then, the location as well as fitness of ant lion are represented as matrices $M_{Antlion}$, M_{OAL} respectively.

$$M_{antlion} = \begin{pmatrix} AL_{1,1} & AL_{1,2} & ... & AL_{1,n} \\ AL_{2,1} & AL_{2,2} & .... & AL_{2,d} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ AL_{n,1} & AL_{n,2} & ... & AL_{n,d} \end{pmatrix} \tag{4.69}$$

$$M_{OAL} = \begin{pmatrix} f\left(\left|AL_{1,1}, AL_{1,2}, ..., AL_{1,d}\right|\right) \\ f\left(\left|AL_{2,1}, AL_{2,2}, ..., AL_{2,d}\right|\right) \\ . \\ . \\ f\left(\left|AL_{n,1}, AL_{n,2}, ..., AL_{n1,d}\right|\right) \end{pmatrix} \tag{4.70}$$

Utilizing the fitness function, the ant lions fitness is assessed. Then the arbitrary movements of ants are arbitrarily moves to search the food. A random movement of ant is specified by:

$$X(t) = \left[0, cumsum(2r(t_1)-1), cumsum(2r(t_2)-1), ..., cumsum(2r(t_n)-1)\right] \tag{4.71}$$

Here, cumsum indicates cumulative sum, n=maximal number of ants, t= step of random walk (iteration):

$$r(t) = \begin{cases} 1 & if\ rand > 0.5 \\ 0 & if\ rand \leq 0.5 \end{cases} \tag{4.72}$$

The rand implies a random number created to utilize uniformly distribution as [0, 1]. For restricting random movement in the search space, normalizing form is utilized, that is based upon minimum–maximum normalization. Location of ant is upgraded with equation as below:

$$X_m^t = \frac{(X_m^t - a_m)(d_m - c_m^t)}{(d_m^t - a_m)} + c_t \tag{4.73}$$

Here a_m and b_m are minimum and maximum of random walk of ants and c_m^t , d_m^t indicates minimum and maximum m^{th} variable at t^{th} iteration.

Trapping of ants

Mathematic expression of the trapping of ants to the ant lion's pits are expressed as below:

$$c_m^t = Ant - lion_n^t + c^t \tag{4.74}$$

$$d_m^t = Ant - lion_n^t + d^t \tag{4.75}$$

Construction of trap

Here, the fittest ant lion is chosen by roulette wheel model. Ant sliding towards ant lion, sliding of ants into pits is given as

$$c^t = \frac{c^t}{I} \tag{4.76}$$

$$d^t = \frac{d^t}{I} \tag{4.77}$$

Let $I = 10^{w\left(\frac{t}{s}\right)}$, t implies the current iteration and S implies maximal count of iteration, w implies constant whose values are:

$$w = \begin{cases} 2 & if\ t > 0.1S \\ 3 & if\ t > 0.5S \\ 4 & if\ t > 0.75S \\ 5 & if\ t > 0.9S \\ 6 & if\ t > 0.95S \end{cases} \tag{4.78}$$

Catching the pray and reconstructing procedure of pit

While, the ant reaches the bottom of the pit, the ant lion catches the ant. After that, ant has to update the position to catch new prey.

$$Antlion_n^t = Ant_m^t \qquad\qquad if\ \ f\left(Ant_m^t\right) > f\left(Antlion_j^t\right)$$

Elitism

This is employed to hold the optimum solutions of every stage. Optimum ant lion preserved as elite that is the fittest ant lion. Elite affects the ant lion at all levels (random movement). Every ant is assumed to associate with an ant lion by Roulette wheel and elite which is given by equation.

$$Ant^t = \frac{R_A^t + R_B^t}{2} \tag{4.79}$$

Where, R_A and R_B indicates the random walk around the selected ant lion by roulette wheel and random walk around elite int^{th} iteration respectively. After completion of the above procedure, the optimum outcomes is acquired through the objective function. The procedure is repeated until reaches the maximal iteration. Figure 4.7 depicts the flowchart of the anticipated method. The pseudo code for ALO delineated as below.

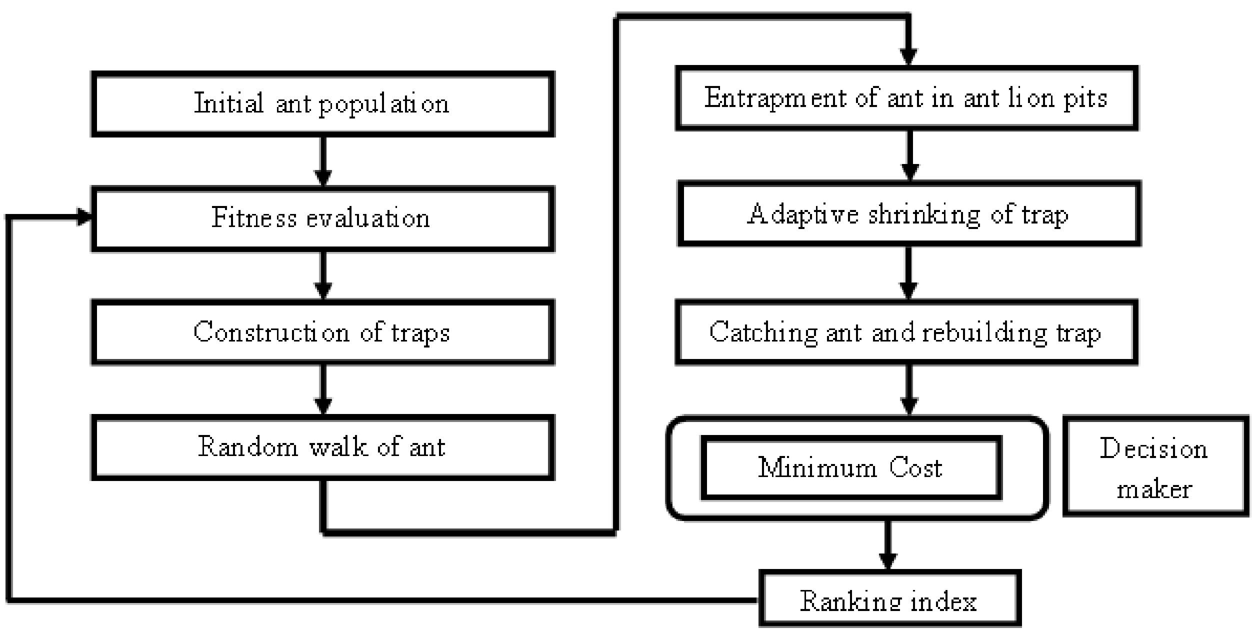


Figure 4.7: Flowchart of ALO algorithm

Pseudo code of ALO method

Initialize first populance of ants, ant lions randomly

Compute fitness of ants, ant lions

Choose optimum ant lions and consider as the elite (determined optimum)

While not fulfilled the end criterion

For each ant

Choose ant lion utilizing Roulette wheel

Upgrading c, d utilizing equations

Generate a random walk as well as normalize it utilizing equations

Upgrading the ants position utilizing equations

End for

Compute fitness of all ants

Exchange an ant lion utilize its corresponding if it becomes fitter

Upgrading elite if ant lion develops fitter than elite

Finish while

Return elite

4.2.7. PROPOSED METHODS OF ANFIS AND SSO

4.2.7.1. TRACKING OF LOAD DEMAND USING ANFIS

Here, it presents the Adaptive Neuro-Fuzzy Inference System (ANFIS) technique. ANFIS is an artificial intelligence strategy combination of artificial neural network as well as fuzzy system [158]. ANFIS has the five layers. Every layer comprises various nodes in the function of node; (1) Fuzzy process (2) Fuzzy of the previous part of fuzzy rules; (3) Normalization of membership functions; (4) Consequent part of the fuzzy rules; (5) network output. For deciding fuzzy inference system parameters on ANFIS construction of hybrid Sugeno training algorithm is used. This training algorithm combines the least squares technique and back propagation gradient descent algorithm to generate and train a set of parameters of membership function of the fuzzy inference system.

a) Fuzzification layer

First stage is utilizing the fuzzy rule, determination of input variables as well as fuzzification. Every node of *i* indicates node at adaptive and the functions of the nodes are described in this layer:

$$O_i^1 = \mu^{A_i}(X), \quad i = 1, 2 \qquad (4.80)$$

Here, X implies input to the ith node as well as A_i implies a fuzzy set associated with this node. Therefore, membership grade of fuzzy sets (A_1, A_2) indicates O_i^1 and it specifies the degree to which the given input X satisfies the quantifier A.

b) Rule layer

It determines thru "*M*" indicates circle node. The output of this layer is represented by this equation:

$$O_i^2 = W_i = \mu^{A_i}(X) \cdot \mu^{B_i}(Y) \quad for\ i = 1, 2 \qquad (4.81)$$

Every *T*-norm operator can perform the fuzzy AND operation in this layer.

c) Normalization layer

Here, every node implies "N". The output of the node in this layer implies $O_i^3\ or\ \overline{W_i}$, also, it is calculated as below:

$$O_i^3 = \overline{W_i} = \frac{W_i}{W_1 + W_2}, \quad i = 1, 2 \qquad (4.82)$$

d) De-fuzzification layer

In this layer, each node 'i' is adapted to the node function.

$$O_i^4 = \overline{W_i} \cdot f_i = \overline{W_i} \cdot (p_i x + q_i y + r_i) \quad i = 1,\ 2 \qquad (4.83)$$

Here, $f_i = p_i x + q_i y + r_i$ as well as (p_i, q_i, r_i) is the parameter set of the i^{th} node.

(e) Output layer

It is declared in ‘‘S’’. Here, ANFIS output is equal to the output of the single node in this layer.

$$O_i^5 = f = \sum_i \overline{W_i} \cdot f_i = \frac{\sum_i W_i \cdot f_i}{\sum_i W_i} \tag{4.84}$$

Here, an adaptive network is functionally equivalent to a Sugeno-type fuzzy inference system. The membership functions and the fuzzy rules of ANFIS are acquired from a large lot of exciting data instead of experience. This network consists of triangular shape membership function for every input variable. Once the network training process is completed, the network is trained well for identifying the load demand depending upon the input time interval. The advanced Salp Swam Optimization (ASOA) method optimizes the management of micro grid based on the output network of ANFIS.

4.2.7.2. OPTIMUM MANAGEMENT OF MG BY SSO

The SSO approach is employed in the second level of the load prediction in Figure.4.9 as according to the proposed algorithm. The swarming behavior of salp (SSO) is proposed by Mirjalili [159]. In the proposed algorithm, the main objective function is the minimization of the cost function. The optimal management of MG is determined based on the objective function. The procedure of SSO algorithm is depicted as the following:

Step 1: Initialization

Initializing the constraints and the control variables are WT, PV, MT and battery power. Control variables are randomly generated depending upon the demand. The population X_i is initialized as follows:

$$X_i = \begin{bmatrix} X_1^1 & X_2^1 & \dots & X_d^1 \\ X_1^2 & X_2^2 & \dots & X_d^2 \\ \vdots & \vdots & \vdots & \vdots \\ X_1^n & X_2^n & \dots & X_d^n \end{bmatrix} \tag{4.85}$$

Step 2: Fitness Evaluation

The salp fitness is evaluated depending on objective values. The evaluation of F_i is determined by:

$$F_i = \min[F(X)] \tag{4.86}$$

Here, $F(X)$ indicates cost function.

Step 3: Updation

In ASOA, the vital parameter coefficient implies C_1. The C_1 coefficient is upgraded utilizing the below expression

$$C_1 = 2e^{-\left(\frac{4l}{L}\right)^2} \tag{4.87}$$

Here, the current iteration is l and maximum number of iteration is L.

Step 4: Position of leading salp

Each dimension and the position of the leader is being updated, thereby utilizing the source of food

$$X_j^1 = \begin{cases} f_j + c_1[(ub_j - lb_j)c_2 + lb_j] & c_3 \geq 0.5 \\ f_j - c_1[(ub_j - lb_j)c_2 + lb_j] & c_3 < 0.5 \end{cases} \tag{4.88}$$

Here, X_j^1 represents the position of the first salp in j^{th} dimension, F_j is the position of the food source in the j^{th} dimension, ub_j indicates the upper bound of j^{th} dimension, lb_j indicates lower bound of j^{th} dimension. c_1, c_2, c_3 are the random numbers in uniformly generated in the interval of [0, 1].

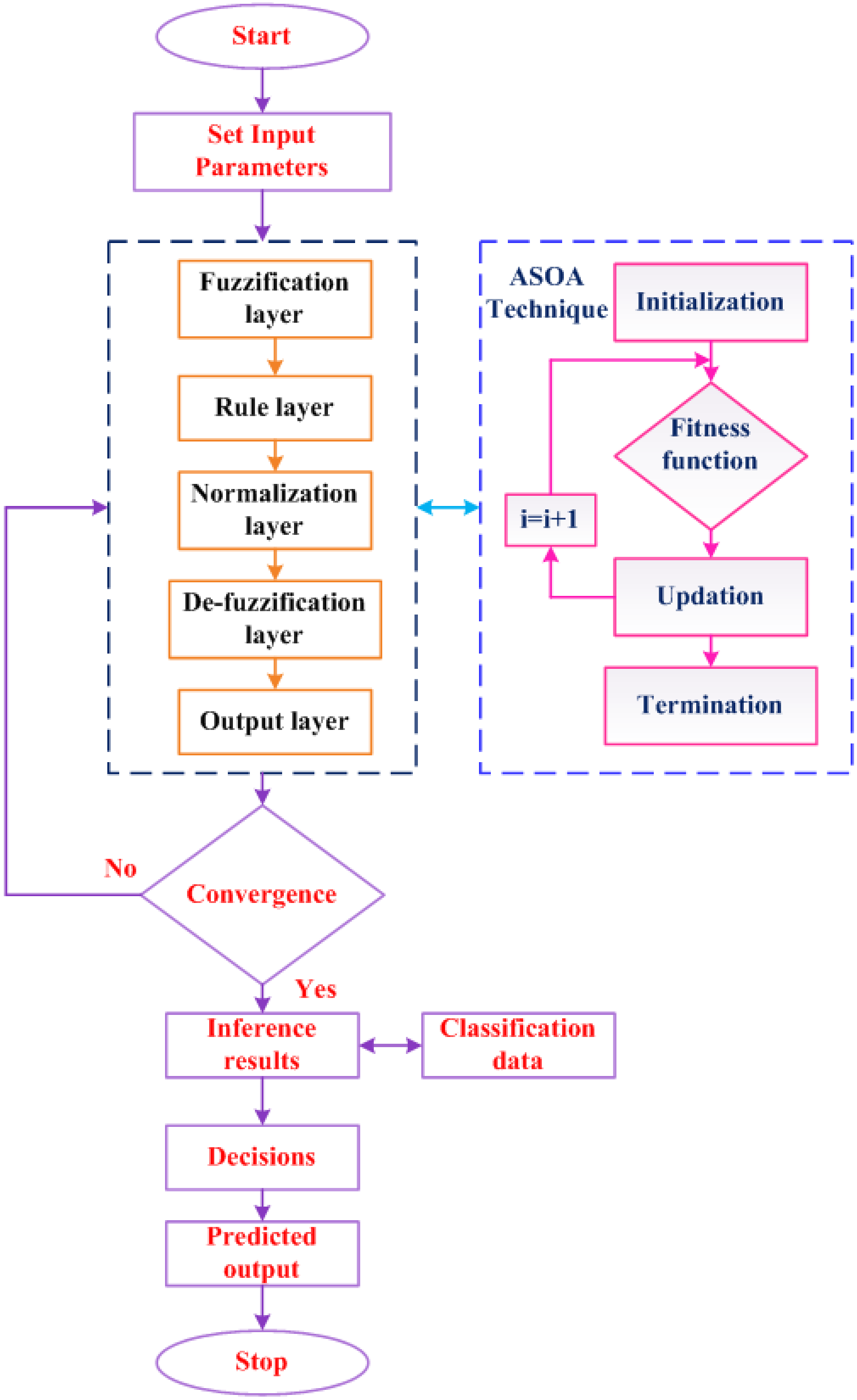


Figure 4.8: Flowchart of the proposed ANFASO approach

Step 5: Salp follower Position

Here, the position of the salp followers is updated in the following expression,

$$X_j^i = \frac{1}{2}(X_j^i + X_j^{i-1}) \qquad i \geq 2 \tag{4.89}$$

Here, the position of i^{th} follower salp in dimension of j^{th} indicates x_j^i . The chain of salp may be simulated with the equations 4.88 and 4.89.

Step 6: Termination

Utilizing the objective function the optimum outcomes is obtained when the above process is completed. Until the satisfaction of an end criterion, all the above steps are iteratively executed except the initialization process.

4.2.8. OPTIMAL ENERGY MANAGEMENT USING RFCRO

Here, it describes an energy management strategy (EMS) based on an effective hybrid method for grid connected micro grid. The main objective of RFCRO is to reduce operating electricity cost and increasing the power flow amid source and load subject to power constraints. The RFCRO consolidated Random Forest (RF) and Coral Reefs Optimization (CRO) i.e. RFCRO. RF is a process of learning a newly with group machine [160,161]. CRO is optimization algorithm depend on the performance of true coral reef. Here, the CRO is used to improve the fundamental arrangements as well as connect the pursuit room to a greater level. CRO is pervasiveness in non-linear structures that require high accuracy for inserting and expanding arbitrary data. The RF is continuously tracking necessary demand load of the grid connected micro grid. CRO is optimizing the micro grid with perfect combination of MG along with the expected requirement of load demand. The goal of the proposed method is described by the grid connected MG system involve fuel cost, hourly grid power and operation along with maintenance cost. The limitations are RESs energy sources accessibility, power request along with storage element. Batteries are utilized as an energy source to stabilize as well as the renewable power system continues to operate in stable and provide stable output [162-164].

4.2.8.1. LOAD DEMAND PREDICTION USING RFA

The random forest algorithm (RFA) is a learning process for machine novels and ensembles. RFA constantly monitors the essential load requirement of the MG connected to the grid. Using this control system system parameter changes and internal conflicts are minimized and load requirements are optimized. RFA uses the same function of active and reactive power variation to define input signals. Every tree in the forest is the highest tree, and the custom of cutting down by extra dimension is not used. The RFA optimum predicted the demand load based on the historic data sets in the proposed method. The following step by step RFA process is given below:

Step 1: At RFA assume input (training set) is $x(t)$ and Z_{output} implies training group (that is.

$$Z\,(P_l\,, P_{PV}\,, P_{WT}\,)). \tag{4.90}$$

Here, P_l implies the power demand, P_{PV} implies the generated PV power and P_{WT} implies the generated WT power.

Step 2: RFA generates integrated decision trees of classification system. Firstly, Y count of trees in forest is considered as decision tree, it creates $Y = \{x_1(t), x_2(t), \cdots x_n(t)\}$ a combnation is called bootstrap samples.

Step 3: RFA trains depending on input with output target. Several input variables are accepted when creating output through each tree. Depending on the maximal vote, the last optimum outcomes are attained.

Step 4: Assessing input variables is characterized by predicting the importance of random decision forest (RDFs). The variance is realized when connecting an error prediction using the data term out-of-stock. The out of bag (OOB) target error are pre-planned as given below:

$$OOB_{error} = Z^{RDF(tar)} - Z^{RDF(out)} \tag{4.91}$$

Various data sets are managed through every illustration to enhance RDF. The count of differences is randomly chosen in entire node for generating binary rules. RMSE is generated in the tree for predicting optimal split, RMSE errors is compared with OOB data.

Step 5: The value is dignified to reduce the correctness of estimate. These errors are close to the forest by the time they are fitted and every data error is calculated in the bag. Then, every data is calculated after the variation of the error that was not previously in the bag and after the combination of all the trees. The significance of variable is expressed in the following equation as below:

$$V_I^{(tr)} = \frac{1}{T}\left(\frac{\sum_{xa \in \phi^{c(tr)}} I\,(l_b = C_a^{tr}) - \sum_{xa \in \phi^{c(tr)}} I\ (l_b = C_{a,nz}^{tr})}{\phi^{c(tr)}} \right) \tag{4.92}$$

Where, $\phi^{c(tr)}$ indicates out of bag trail specimen to particular tree, tr indicates number of tree, T presents total amount of tree, $C_a^{(tr)}, C_{a\ ,\ nz}^{(tr)}$ presents the forecasted class for every specimen of trail X_a, a , b indicates sample value represent the amount of trail specimens per tree exit as well as amount of trail specimens per tree at forest. The outcomes of unsatisfied demand loads are predicted as training data set, the detecting requirement of unsatisfied load eliminated as well as restored. RFA is the optimal training for forecasting load demand and generated power of PV, WT are depends on the input interval duration.

4.2.8.2. CRO FOR ENERGY MANAGEMENT

The coral reefs optimization (CRO) is an evolutionary type search and optimization algorithm in terms of the process behavior, which occurs in coral reef. R is R1 reef depicted via R2 grid, where each R position (ij) may assign a coral or a coral colony (C_{ij}). i.e. temptative solutions for the current problem of optimization. The base CRO uses some arbitrary R positions first arbitrary corals, separating some other spaces ("with holes"). These reef holes are accessible to host fresh corals, which can settle and grow freely in subsequent algorithm stages. At the beginning of the procedure between the free / employed positions in R indicates the parameter of the CRO. Figure 4.10 portrays the flow chart of the CRO. The following step by step CRO method displayed below:

Step 1: Initialization

The coral reefs optimization (CRO) is the complete of P coral in reef, each of which is a tempting response to the issue. The number of free locations at initializing coral reef is noted through user at original version of CRO. The initialization in CRO comprises of generating N random time series segmentations ((m − 1) 1s is randomly selected and remainder is 0 second.

Then, the corals that verify their fitness is given below:

$$f_{i1} \notin (f_1 - S_{f1}, 1) \tag{4.93}$$

Step 2: Random Generation

Randomly generate the PI controller gain parameters such as:

$$K_P, K_I\ r^i = \begin{bmatrix} (K_p K_i)_{11} & (K_p K_i)_{12} & \dots & (K_p K_i)_{1b} \\ (K_p K_i)_{21} & (K_p K_i)_{22} & \dots & (K_p K_i)_{2b} \\ \vdots & \vdots & \vdots & \vdots \\ (K_p K_i)_{a1} & (K_p K_i)_{a2} & \dots & (K_p K_i)_{ab} \end{bmatrix} \tag{4.94}$$

Step 3: Fitness Function

Here, the perception of the current and energy parameter difference, the fitness function is well defined for restricting the error. The fitness function is shown in the equation below:

$$FF_i = Min\ (\xi) \tag{4.95}$$

Step 4: Asexual Reproduction

Asexual reproduction is an actual helpful coral reef mechanism. There are two kinds of procedures of asexual reproduction. The first is called fragmentation, and external agents are accountable for it. Another one is budding, which is precise valuable to produce newly reefs on extra parts. To fragment, collection of selected corals created through those whose satisfies the value of fitness.

$$f_{ij} \in (f_{j+} S_{fj,1}) \tag{4.96}$$

Step 5: Larvae Settlement

The newly people (larvae) attempt to settle down and develop in the reef once the asexual along sexual reproductions are executed. An arbitrary reef position is selected in every larva. The larvae are employed on straight of coral reef and the position is empty. But, if another coral occupies the place, the larva will only be resolved if its situation. The process is repeated until two attempts if the individual is not recognized in the coral.

Step 6: Depredation

The approach eliminates the number of individuals whose fitness function verified once the settlement is created:

$$f_{ij} \in [f2S_{fj}] \tag{4.97}$$

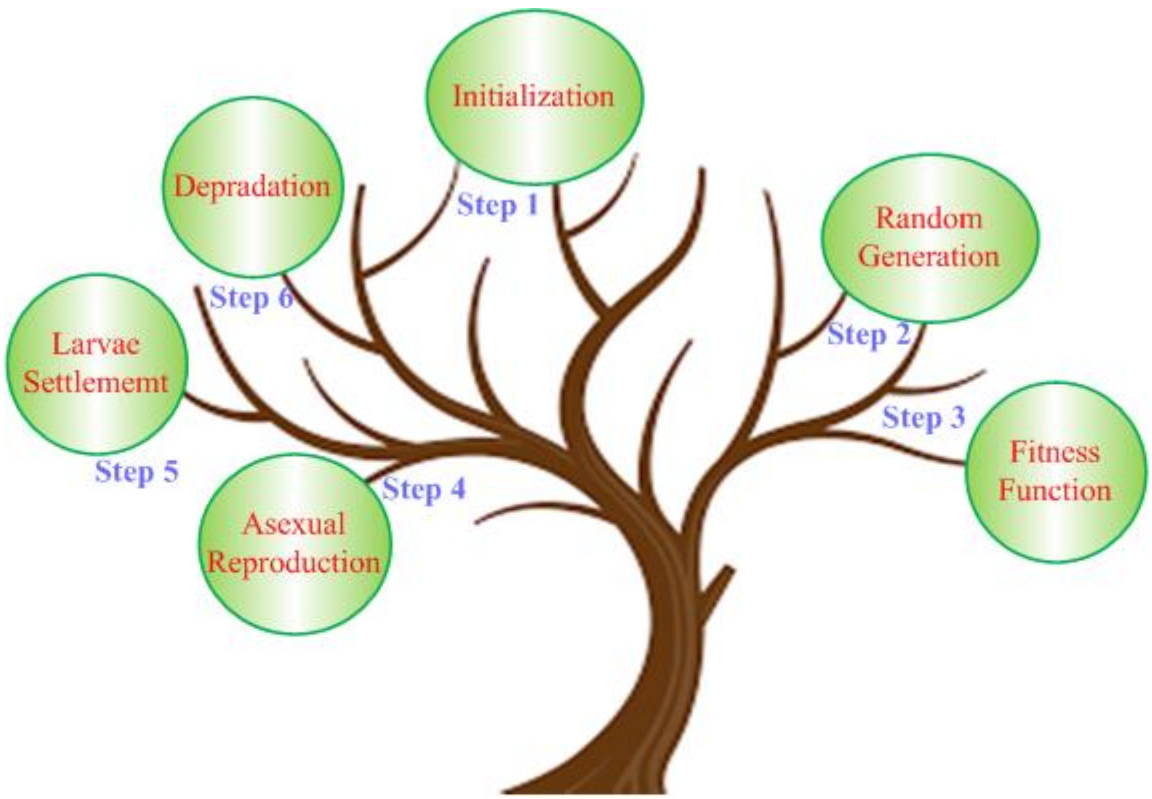


Figure 4.9: Flow chart of proposed technique

4.2.9. RBFNN AND SSA TECHNIQUES

4.2.9.1. AI BASED LOAD DEMAND PREDICTION

Artificial intelligence method is Radial Basis Function Neural Network (RBFNN). It is used to generate multiple and nonlinear maps [165]. The learning algorithm for RBFNN is associated for linear problem solution, unlike error back propagation. The fastest process is defined as network training. The learning algorithm incorporates linear issue solution is one of the optimal advantages of the RBF network. However, since basic functions are not linear, complex nonlinear maps can be created by the network. The historic data sets are trained by the network that already needs the annual database. The variation of the requirement to every hour specifies the input dataset that RBFNN network has been trained on. That why it generates the optimal demand load output per hour. The stages of RBFNN are given as follows:

(A) THE STEPS OF RBFNN

Step 1: Firstly, input vector indicates time interval and output indicates power demand.

Step 2: When, the initialization process are complete, randomly initialize the parameters of system's input.

$$random^{i} = \begin{bmatrix} P_d^{11} & P_d^{12} & \cdots & P_d^{1n} \\ P_d^{21} & P_d^{22} & \cdots & P_d^{2n} \\ \vdots & \vdots & \vdots & \vdots \\ P_d^{m1} & P_d^{m2} & \cdots & P_d^{mn} \end{bmatrix} \tag{4.98}$$

Where p_d implies power demand.

Step 3: Calculate fitness by minimizing error function.

$$Error, e = \frac{1}{2}\sum(t_D - d_D) \tag{4.99}$$

Here, d_D represents requirement of desired output, t_D indicates the need for target output.

Step 4: Gaussian activation function (GAF) for RBFNN specified with RBFNN output is obtained.

$$r(z_p - c_i) = \exp\left(-\frac{1}{2\varsigma^2}\left\|z_p - c_i\right\|^2\right) \tag{4.100}$$

Where z_p indicates p^{th} input sample, ς signifies GAF.

$$u_j = \sum_{i=1}^{h} w_{ij} \exp\left(-\frac{1}{2\varsigma^2}\left\|z_p - c_i\right\|^2\right) \; j = 1,2,..., n \tag{4.101}$$

Here,*h* implies number of nodes in hidden layer. Figure 4.10 portrays RBFNN process.

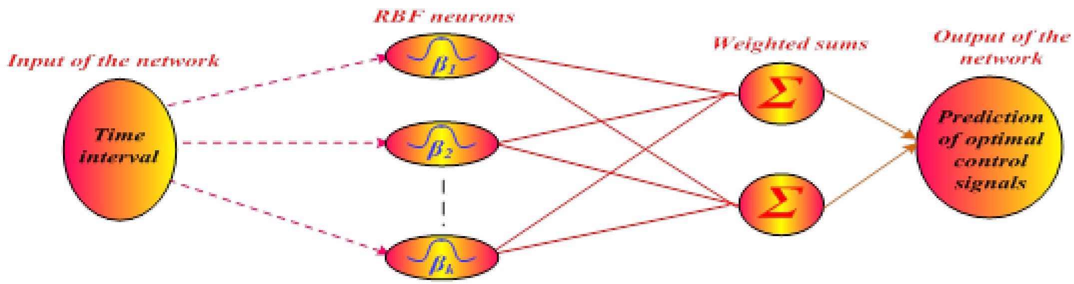


Figure 4.10: Procedure of RBFNN

4.2.9.2. SQUIRREL SEARCH ALGORITHM (SSA) BASED MG COMBINATION OPTIMIZATION

In light of the load requirement, the MG system is optimized in this section using SSA [166]. Multiple objective functions are required to enhance the system structure of MG, which is linked to the fuel at low cost. In SSA, the combination of micro grid connected systems is considered as the output and the load requirement as input. The SSA is a very simple as well as powerful nature-inspired searching algorithm developed in the issues of non-restricted numerical optimization. Using this dynamic foraging behavior simulates southern flying squirrels. This approach indicates gliding is an efficient path for locomotion. All features of food search is totally illuminated in this approach. MG-linked system structure upgrading stages are rapidly and clearly understood.

4.2.9.2.1. LAYERS OF SSA ALGORITHM

Layer 1: Initialization

Firstly, load demand and micro grid related systems like PV, WT, MT, cost functions with their generation limit as input.

Layer 2: Random Generation

It produces approximately n number of Flying Squirrels (FSs) in the forest along with vector i^{th} represents location of the flying squirrel. All flying squirrel locations can be articulated as,

$$fly = \begin{bmatrix} fly_{1,1} & fly_{1,2} & \dots & fly_{1,j} \\ fly_{2,1} & fly_{2,2} & \dots & fly_{2,j} \\ \vdots & \vdots & \vdots & \vdots \\ fly_{i,1} & fly_{i.2} & \dots & fly_{i,j} \end{bmatrix} \tag{4.102}$$

Where, $fly_{i,j}$ specifies j^{th} dimension of i^{th} flying squirrel. At the forest, to assign every flying squirrel initial location is utilized by uniform distribution.

$$fly_i = fly_l + U(0,1) \times (fly_u - fly_l) \tag{4.103}$$

Here, fly_l and fly_u implies the lower and upper bounds on j^{th} imension of i^{th} FSs, $U(0,1)$ stands for uniformly distributed [0, 1] random number.

Layer 3: Fitness Function

The multi-objective fitness function is given below to find the fitness in every flying squirrel

$$F = Min[ACS] \tag{4.104}$$

Here, ACS represents the annual cost of micro grid connected system.

Layer 4: Declaration of Sorting and Random selection

The arrays are stored in ascending order and the fitness values of every flying squirrel are stored. Flying squirrels are reported in lesser fitness values on hickory nut tree. Consider the optimal flying squirrel of the acorn nut trees can move near hickory nut tree. The rest of the FSs are predicted to in the normal tree. Some squirrels move forward with the hickory nut tree, which is predictable to see day-to-day food needs. The remaining squirrels can see the day-to-day energy needs of the acorn nut trees. The behavior of flying squirrel is modeled through utilizing a location-updating mechanism with predator presence probability (p_{dp}).

Layer 5: Generation of New Location

Three scenarios may occur when a flying squirrels is looking for dynamic foraging. It was considered a lack of predator in all situations; flying squirrels glides proficiently and search the whole forest of their favorite food. Otherwise, if it has predator, the flying squirrel will searching the neighborhood with a small random walk. The behavior of the dynamic forging method is consists of three types of cases, that are mentioned from the reference (Jain et al., 2018) [166].

Layer 6: Gliding Aerodynamics

By gliding the stability on every lift sum (L), using the drag sum (D), the resulting (R) force generated so that the sum and the directional weight of the FSs are equal and opposite, then the gliding mechanism of flying squirrel has been illustrated. The estimated gliding distance d_G is obtained as:

$$d_G = \left(\frac{h_G}{\tan \varphi} \right) \tag{4.105}$$

Here $h_G = 8m$ that is in height loss happened then gliding.

Layer 7: Condition of Seasonal Monitoring

This is defined as to ensure that there are locally optimized solutions in the SSA.To check condition of seasonal monitoring which is $s_c < s_{\min}$. And the equation is:

$$s_{\min} = \frac{10\text{E}^{-6}}{(365)^{\frac{t}{t_m/2.5}}} \tag{4.106}$$

Here s_c indicates seasonal constant, $s_{\min}$ indicates low seasonal constant value t , t_m and represents present and high iterative values. $s_{\min}$ Value affects the ability of exploration as well as exploitation. Big value on $s_{\min}$ support exploration and small value on $s_{\min}$ enhance exploitation ability. The gliding constant is utilized due to certain functions. If the seasonal monitoring condition is found to be true, the flight squirrel migration can transformed.

4.3. SUMMARY

This chapter suggested a hybrid ABC strategy and the IABC based modeling and management of Micro grid System (MG). The ABC algorithm is designed in two phases based on objective functions. The initial phase of ABC demonstrates that MG's optimal configuration at low fuel costs. The hybrid approaches are CS-BAT algorithm and ANN-BFOA technique. The purpose of SOGSNN is to reduce the production cost and make better use of RES. The micro grid associated system depends on the PV, WT, MT, DG, battery power. The specific proposed process with the BAT algorithm present the advantage of CS facility and there is certain simplicity in making a quick trip to a location immediately where the offer price already have been identified. The purpose of proposed system is to reduce the charge of production along make better use of renewable energy resources. To achieve the intention function, the DR is assessed using RNN that provides information about the client's reply and period. The DR controls are disclosed in conjunction with other consumer information, and excess electricity generated is designed to yield the lowest entire cost of production as well as lowest market settlement price. The purpose of the SOGSNN method is to reduce fuel costs, reduce emissions and operating with maintenance costs, also makes optimal use of RES. The control operations have been added to the optimization issue to reveal few another considerations that are mostly found in the smaller generation scheme. The RFCRO method is used to improve productivity, accuracy and uncertainty quality in search likened to existing methods.

5 Results and Discussion

5.1. GENERAL

The simulation result and discussion with renewable energy sources with proposed and existing method is presented. Here the results are tested in MATLAB / Simulink platform which gives better outcome compared to existing method. Also several test cases were considered. The comparative output demonstrates that proposed system is used to identify optimal bidding parameters, which is the most effective technique while meeting the load requirement at the lowest energy sources, and it is more efficient than existing techniques.

5.2. CONSIDERED CASES

Here, the optimal results obtained by the corresponding optimization algorithms for every case study have been presented in details. The presented results have also been compared with other state-of-the-art meta-heuristic algorithms to check the effectiveness and superiority of the proposed algorithm. Along with this comparative study, the results have also been statistically tested to prove their robustness.

5.2.1. CASE STUDY-1

(A) HYBRID OPTIMIZING ALGORITHM FOR MODELING AND MANAGEMENT OF MIRO GRID CONNECTED SYSTEM

The MG construction consists a group of radial feeders along point of common coupling, i.e., PCC. The feeders are connected to sensitive and non-sensitive loads. Furthermore, the feeder has micro sources like WT, PV, DG, FC and MT. For DG, FC & MT, the fuels were needed for generating power but for WT and PV, the fuel comes from environment with no cost. The proposed method is executed on MATLAB/ Simulink platforms shown in Fig 5.1(a) and the data of PV and WT power are extracted from Fig 5.1(b) [96]. The numerical outcomes of the proposed method are compared to existing methods, that is, online micro grid management, ABC that is useful to recognize the proficiency of the proposed method. Overall operational with maintenance cost is examined to certain demand load, viz 4 kW up to 14 kW. Table 5.1 tabulates the MG ratings and emission factors. The ABC approach with proposed method is allowed as of 100 numbers of iterations and 20 numbers of bees. It takes7.89 sec for the ABC for completing maximal iteration, and then it takes 6.94 sec only for the proposed method. The acquired outcomes are mentioned in the range of power generation including entire cost of the micro grid sources in several power requirements. Table 5.2(a) represents 24 hour wind and solar data and Table 5.2(b) represents the full load demand along with PV & WT power in 24 hour. Table 5.3 displays overall cost of power generation for micro grid under online optimum management (OM) of micro grid, ABC and proposed method. Here, the online management of micro grid and ABC attains huge amount of the total cost of the full range of load demand variations that is comparable high with respect to the proposed approach. The optimum formation of micro grid with a minimal cost is chosen as demand load basis for an hour, since the system load requirement varied in all situations. The micro grid sources allocation are depending on demand load, cost and emission. Figure 5.2 displays the load demand for every single hour per time, and then the related power demand remains as PV, WT which is plotted against time. The demand load is fulfilled utilizing accurate formation of micro grid sources. All the parameter's data of PV, WT, FC and DG given in Table 5.7.

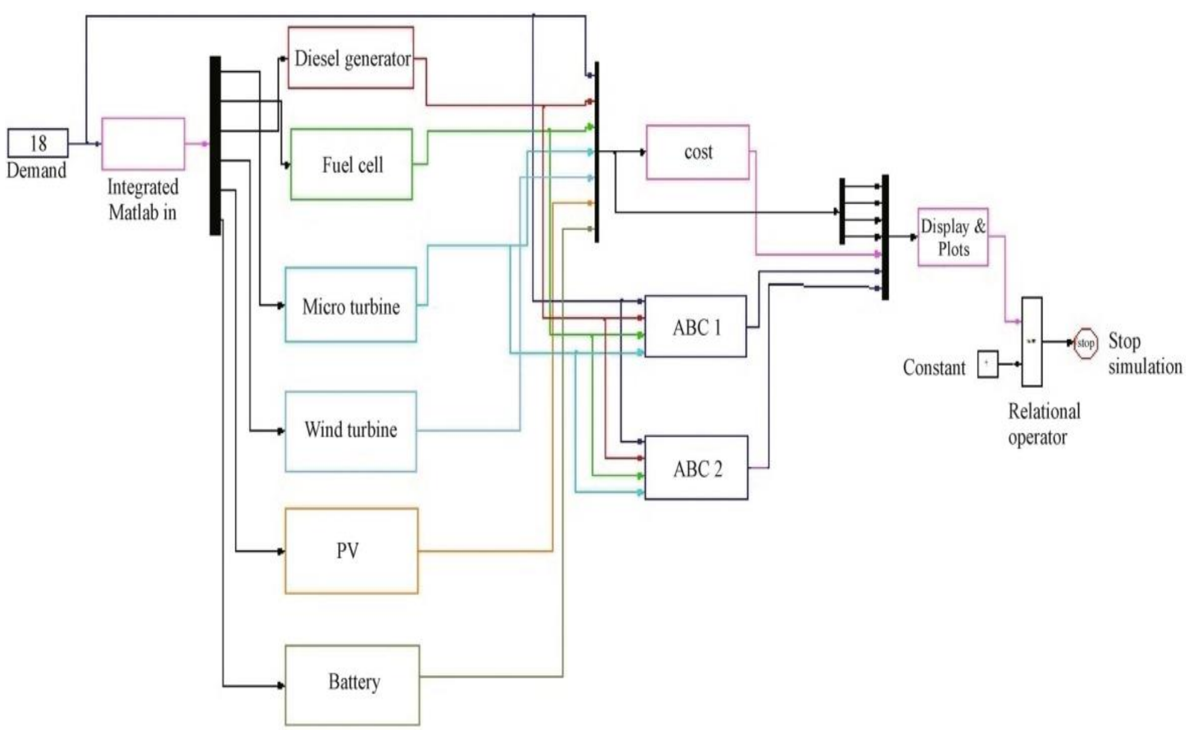


Figure 5.1(a): MATLAB/Simulink diagram of proposed system

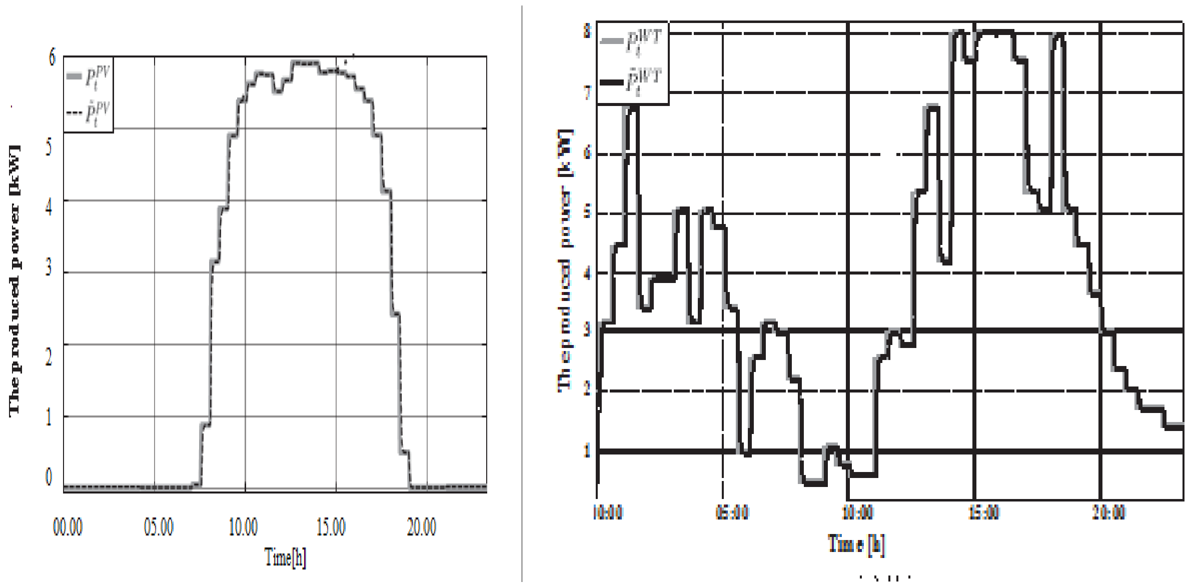


Figure 5.1(b): PV and WT power [96]

Table 5.1: Micro grid Sources Ratings and Emission Factors [73]

MG sources	Emission factors/(kg/MWh)			Externality costs ($/kg)			Ratings/kW	
	NOx	SO2	CO2	NOx	SO2	CO2	Min	Max
FC	0.04	0.007	1.079	For FC, MT & DG			1	4
MT	0.04	0.009	1.597	4.2	0.99	0.014	1	4
DG	21.9	0.455	1.433				1	5.7

d_1	e_1	f_1
0.4333	0.2333	0.0074

Table 5.2: Micro grid load demand with PV & WT power

Time (hr.)	Load demand (kW)	PV Power (kW)	WT Power (kW)
1	3.9072	0.0631	2.8923
2	3.9072	0.0355	4.2461
3	3.9072	0.0510	3.2615
4	5.0810	0.0241	3.8461
5	5.5938	0.0420	3.0769
6	9.3762	0.0687	4.5538
7	9.3762	0.9130	0.8000
8	11.1521	3.8801	2.9538
9	11.1521	3.9534	2.0615
10	11.1521	5.3813	0.2461
11	11.1521	5.4774	0.6153
12	12.0415	5.6435	2.4000
13	12.0415	5.8129	2.6153
14	12.0415	5.6770	6.5538
15	12.0415	6.0144	7.7538
16	5.1947	5.8163	7.7846
17	11.1521	5.6104	5.2615
18	9.3762	5.0086	7.7846
19	11.1521	4.2409	4.3076
20	10.0593	2.5171	2.8307
21	13.0139	0.0923	1.7230
22	13.0139	0.0726	1.1692
23	10.0593	0.0783	3.4461
24	12.3504	0.0924	2.1539

Table 5.3: Selection of power generators of Micro grid for various methods

Demand Load /kW	FC/kW	MT/kW	DG/kW	Total cost/($\$h^{-1}$)		
				OM	ABC	Hybrid Method
3.9	0.00	3.90	0.00	0.8382	0.8260	0.7935
4.5	0.50	4.00	0.00	1.0043	1.0004	0.8905
5.5	1.50	4.00	0.00	1.2268	1.2021	1.1106
6.7	2.70	4.00	0.00	1.4941	1.3540	1.3323
8.3	4.00	4.00	0.30	2.5116	2.1024	2.1024
9.6	4.00	4.00	1.60	2.9082	2.8171	2.7135
10.8	4.00	4.00	2.80	3.2747	3.1142	3.0175
12.3	4.00	4.00	4.30	3.7334	3.6260	3.3221
13.5	4.00	4.00	5.50	4.1007	4.2354	3.9308

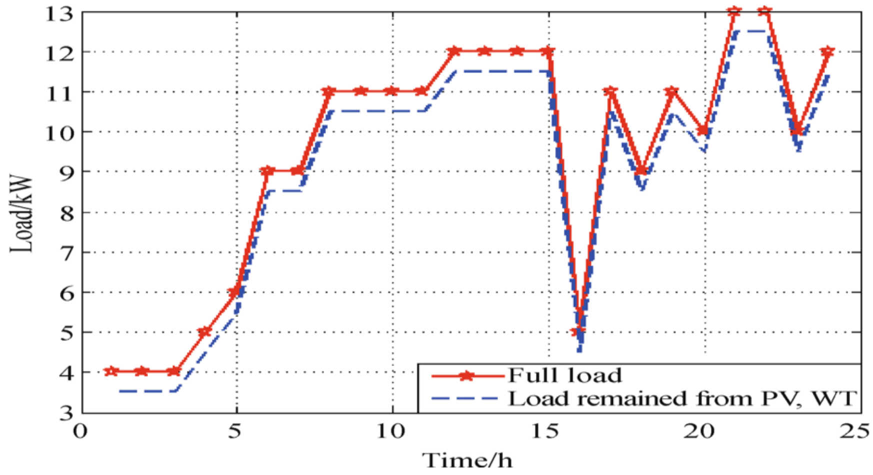


Figure. 5.2: Load of hours

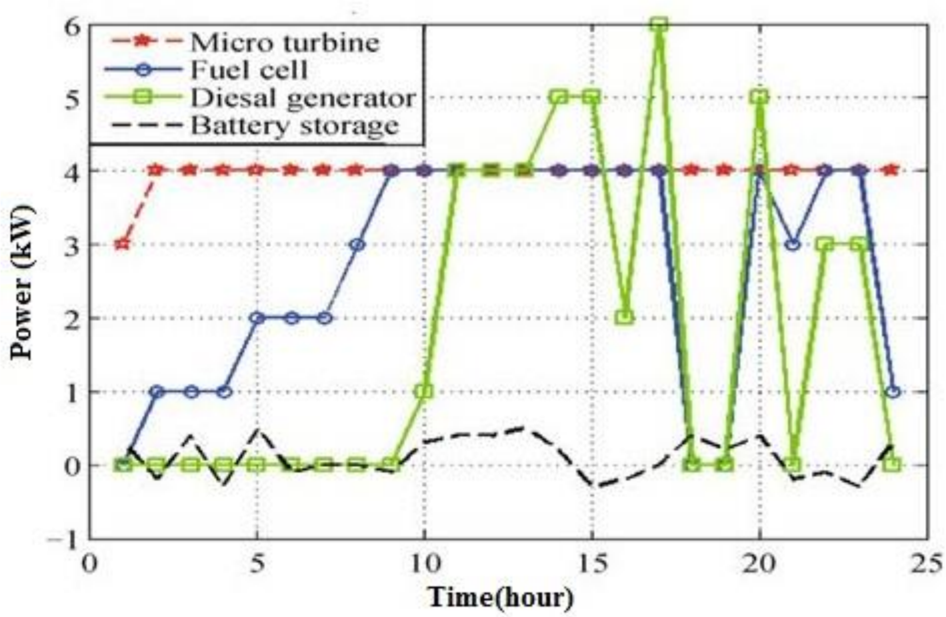


Figure. 5.3: Curves of MG power for hours

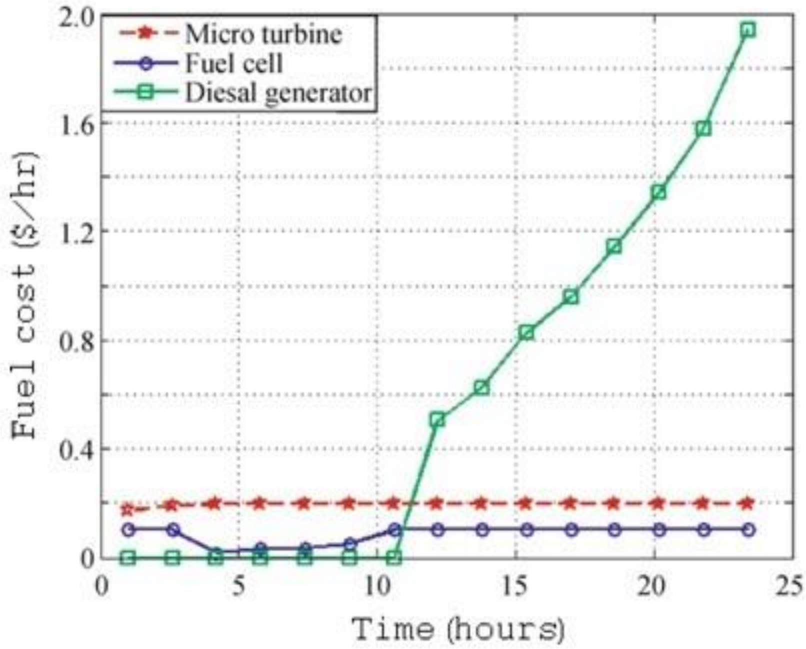


Figure. 5.4: Hourly fuel cost for OM technique

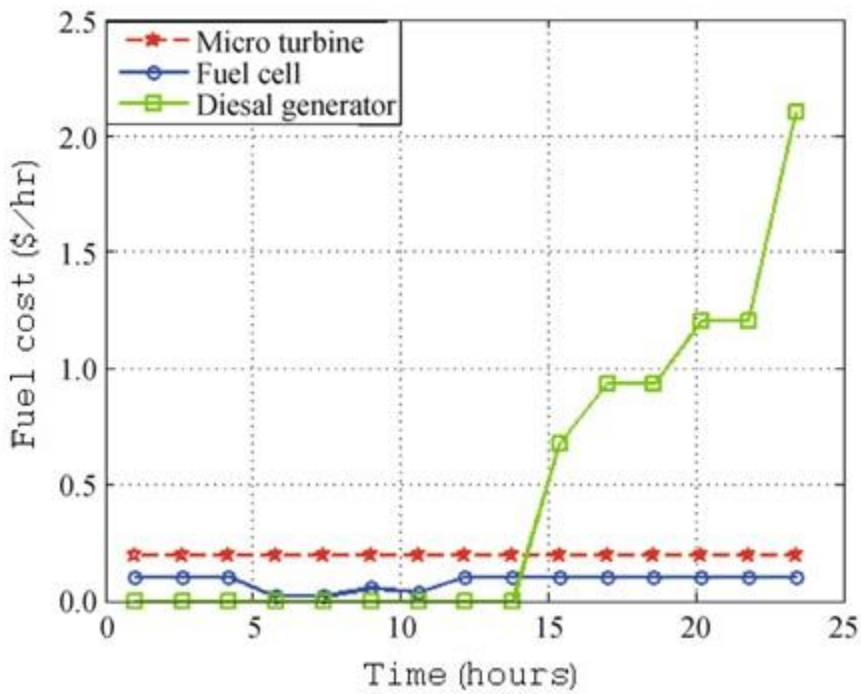


Figure. 5.5: Hourly fuel cost for ABC technique

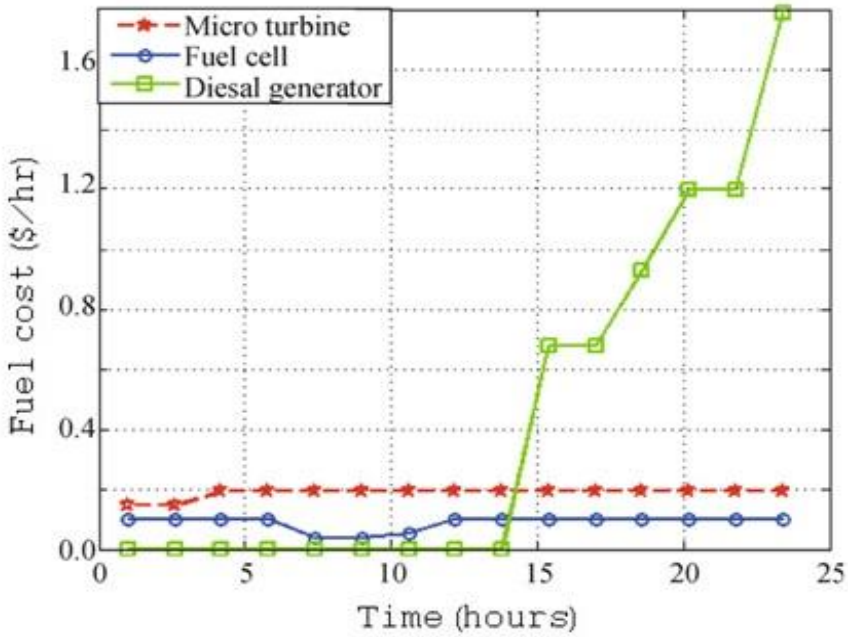


Figure 5.6: Hourly fuel cost for proposed technique

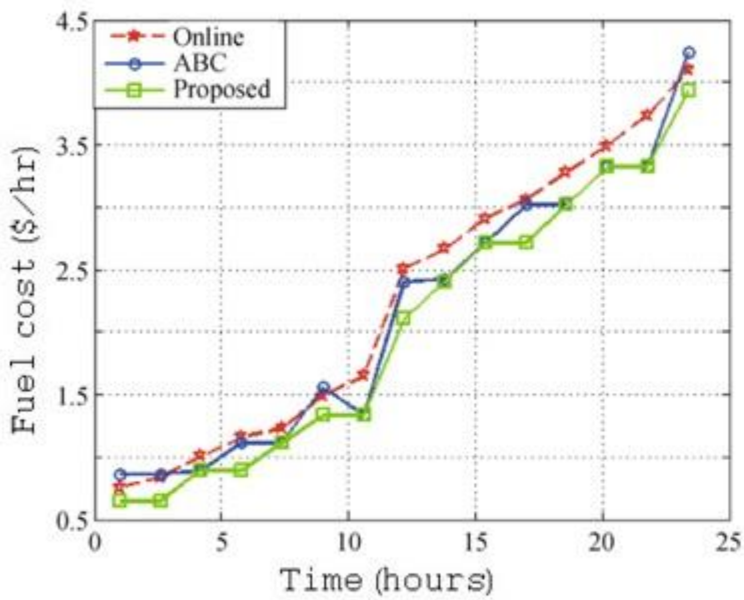


Figure 5.7: Overall cost for various methods

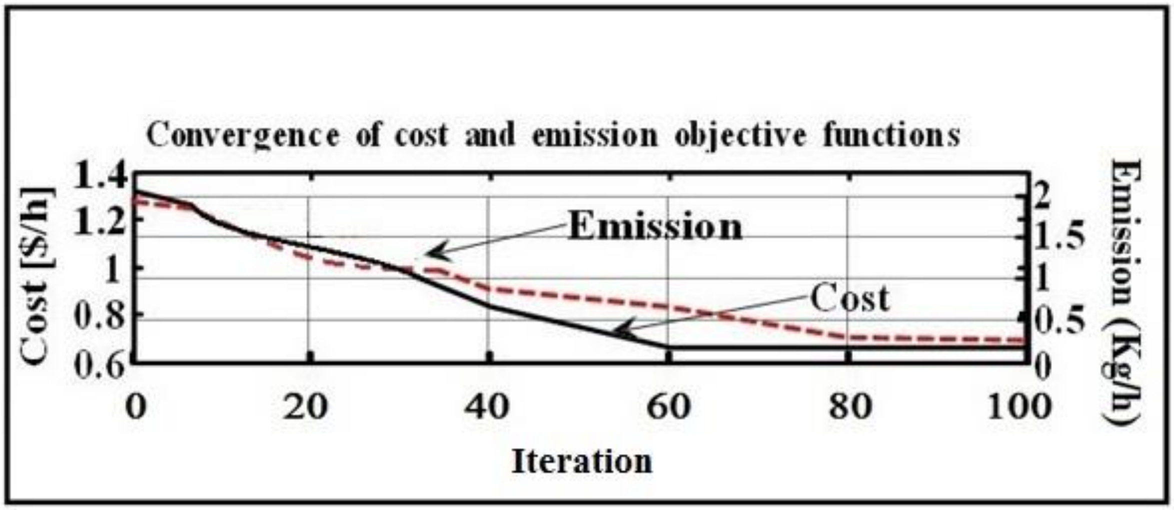
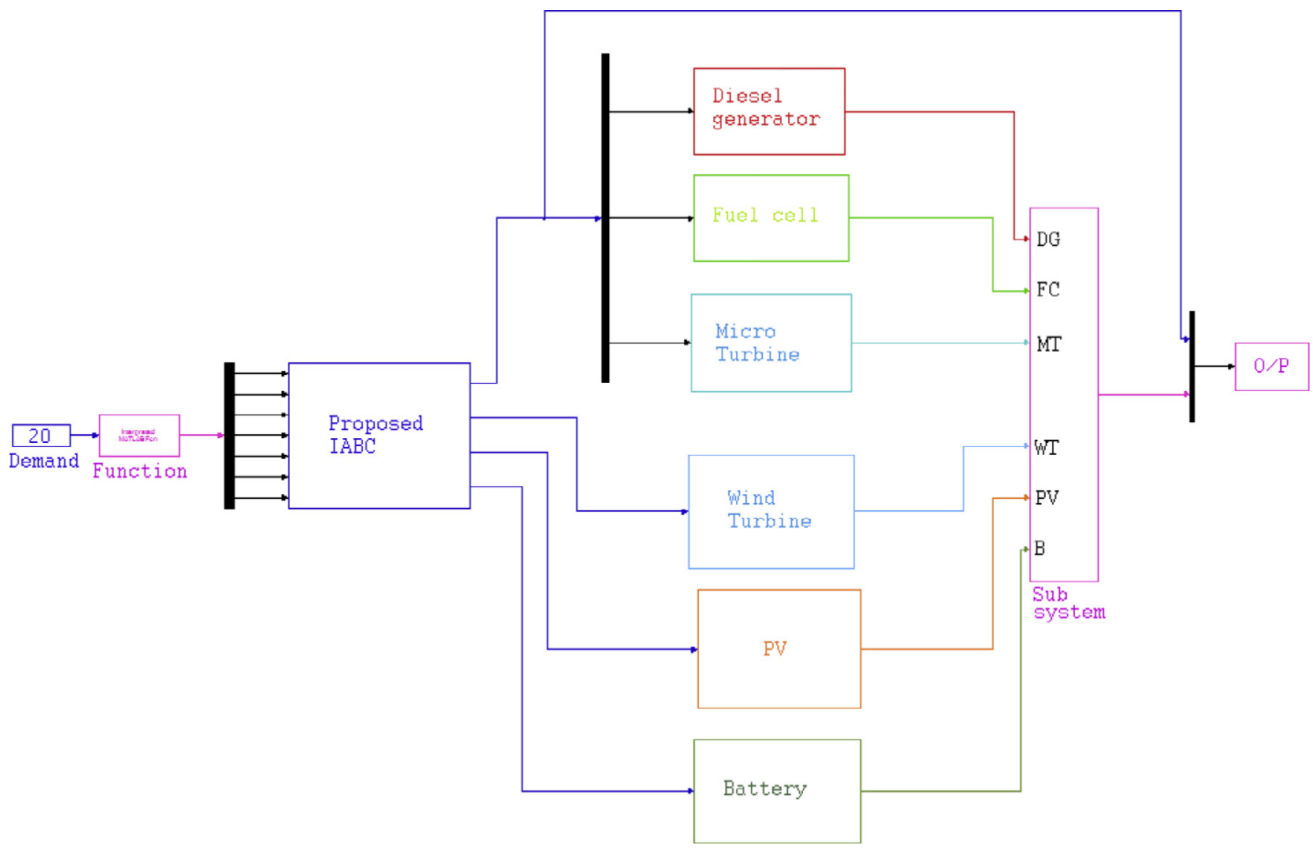


Figure 5.8: Convergence of cost and emission by the proposed method

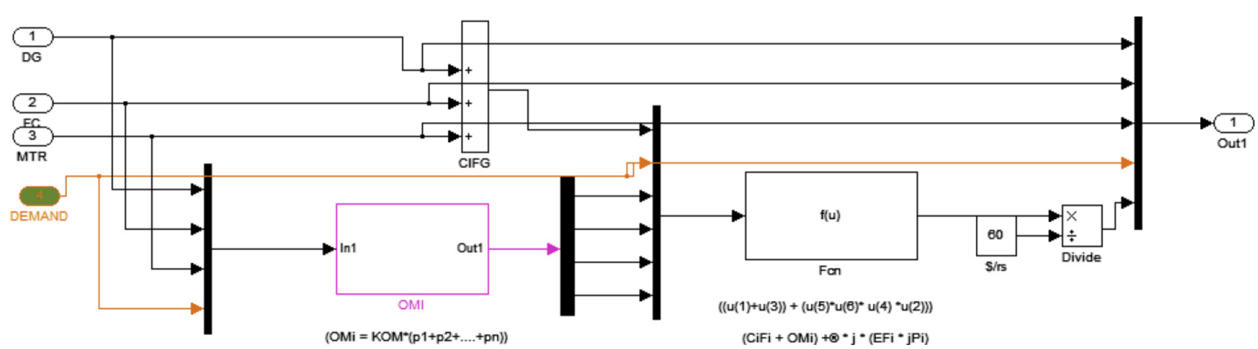
Figure 5.3 represents the optimum configuration of micro grid sources like Diesel Generator (DG), FC, MT and battery storage in 24 hours. The cost of operation as well as maintenance cost of the MG is taken into consideration as it has an effect from various methods like online optimum management of the micro grid, ABC as well as proposed method. Figure 5.4 signifies the fuel cost of online management of MG, which is the fuel cost function in each hour. The selection of the generated power of micro grid sources depends upon the demand load. Also the fuel cost of ABC is accessible in Figure. 5.5. Figure. 5.6 signify the fuel cost of proposed method. In Figure. 5.5 and 5.6, it is perceives the proposed method is optimum manages demand load through select optimum of the generating power in micro grid on least cost. Utilizing minimal fuel cost, the operation as well as maintenance cost or entire cost of the selecting micro grid is examined in Figure. 5.7. In Figure 5.8, the convergence of cost with emission is explained. The proposed hybrid method is compared with ABC approach. Lastly, overall cost evaluation is proved and the proposed hybrid method is effective for managing micro grid in the require demand utilize reduce cost as well as emission.

(B) MODELING AND MANAGING OF MICRO GRID CONNECTING SYSTEM UTILIZING IABC

The MG construction consists of a group of radial feeders along point of common coupling, i.e., PCC. The feeders are connected to sensitive and non-sensitive loads. Furthermore, the feeder has micro sources like WT, PV, DG, FC and MT. For DG, FC & MT, the fuels were needed for generating power but for WT and PV, the fuel comes from environment with no cost. The IABC is performed on MATLAB/Simulink platform. Here, demand load is worked out by PV, WT as well as battery sources. The load demand which determines through chosen optimum conformation of micro grid sources utilizing different techniques as IABC, ABC and ABC–ABC. The system is verified and shown below through several demand load curve, that is, the load demand graph varies from 4 kW up to 14 kW and the generating capability of micro grid sources, corresponding emission factors are defined in Table 5.3. MATLAB model of the micro grid construction utilizing IABC is depicted in Figure. 5.9. The formation is utilized to design micro grid along with overall cost, that is, fuel, emission and operational & maintenance cost which is to be determine as per the cost factors. The IABC is allowed in 100 iterations along 20 bees. It consumes lesser computing time, that is, 5.95s, while ABC computing time is7.89s, ABC–ABC computing time is 6.94s. The randomized day-to-day demand load is presumed as demonstrated in Figure. 5.10 by proposed method. The randomized day-to-day demand load required demand load value is varied as of 4kW up to 14 kW. It depicts that essential demand load is mainly resolved utilizing renewable energy sources viz PVas well as WT. The balancing demand load is meeting up in rest micro grid sources like MT, FC and DG. An optimal arrangement of micro grid to satisfy the remaining demand load at each period is portrayed in Figure 5.11. The 24 hour demand load is resolved by utilizing OM method that assembles the MT, FC and DG according to demand load. Cost of fuel utilizing OM is illustrated using Figure 5.12 where fuel cost of each time is calculated. The related demand load is applied for both the ABC as well as ABC–ABC, which is assembling micro grid model.



(a)



(b)

Figure 5.9: (a) Structure of the Micro grid using proposed method (b) Structure of subsystem

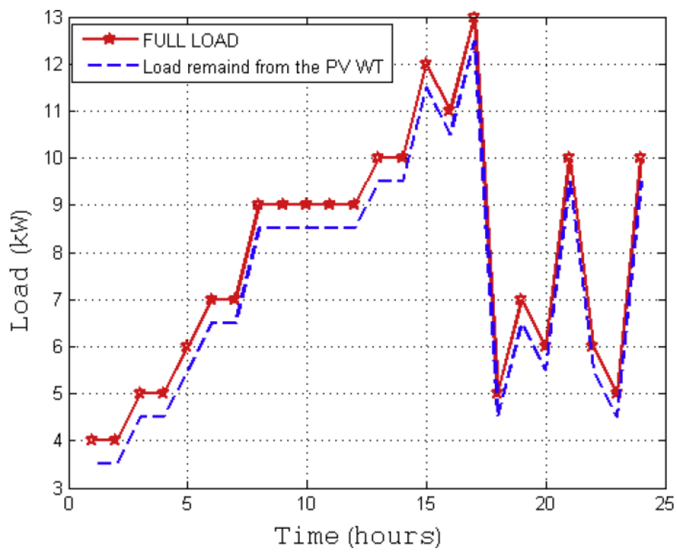


Figure 5.10: Load demand for hours

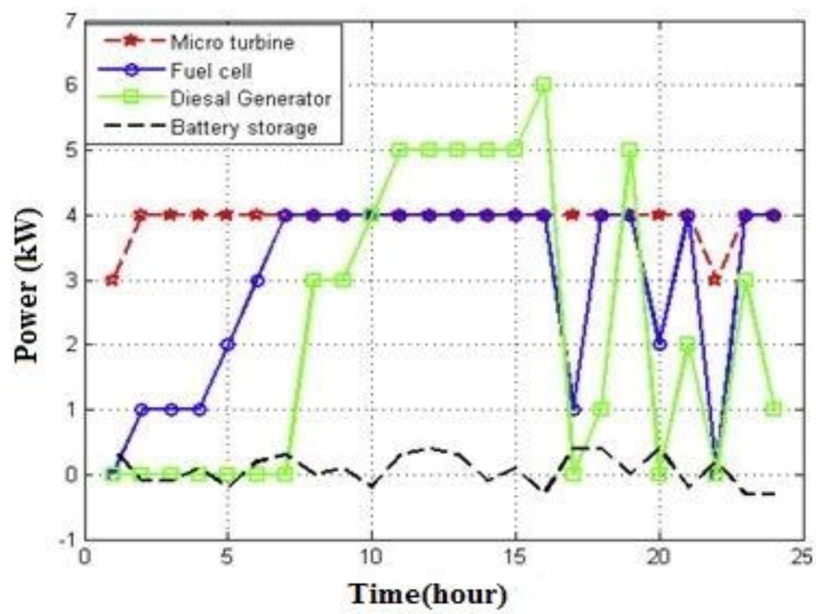


Figure 5.11: Micro grid power for hours

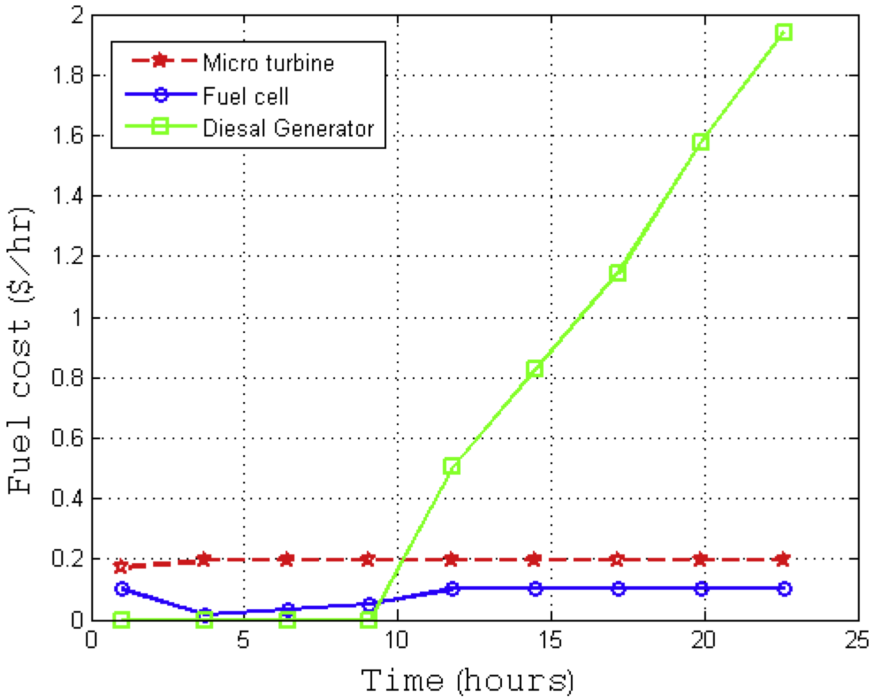


Figure 5.12: Fuel cost using OM method

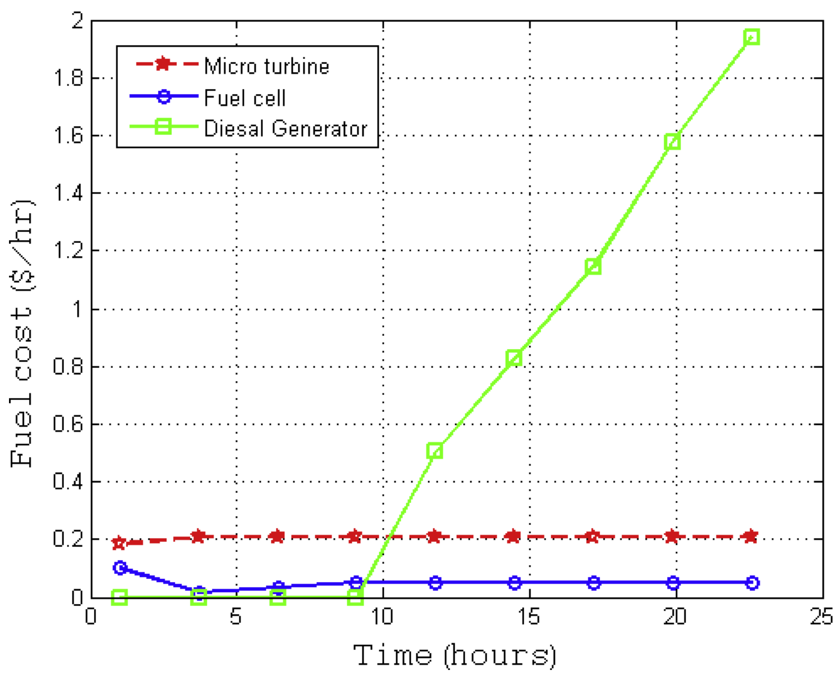


Figure 5.13: Fuel cost utilizing ABC method

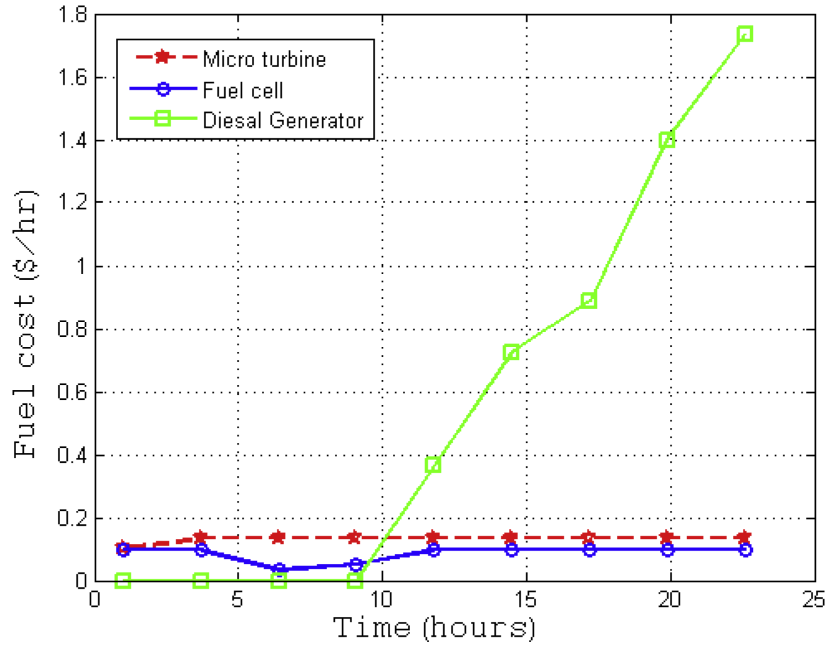


Figure 5.14: Fuel cost utilizing ABC–ABC method

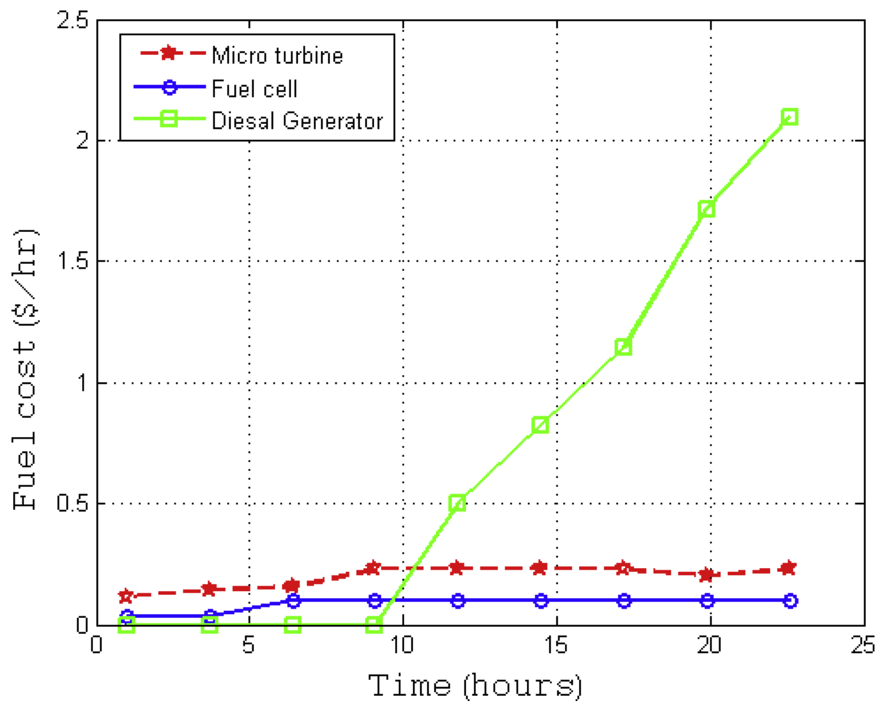


Figure 5.15: Fuel cost utilizing proposed method

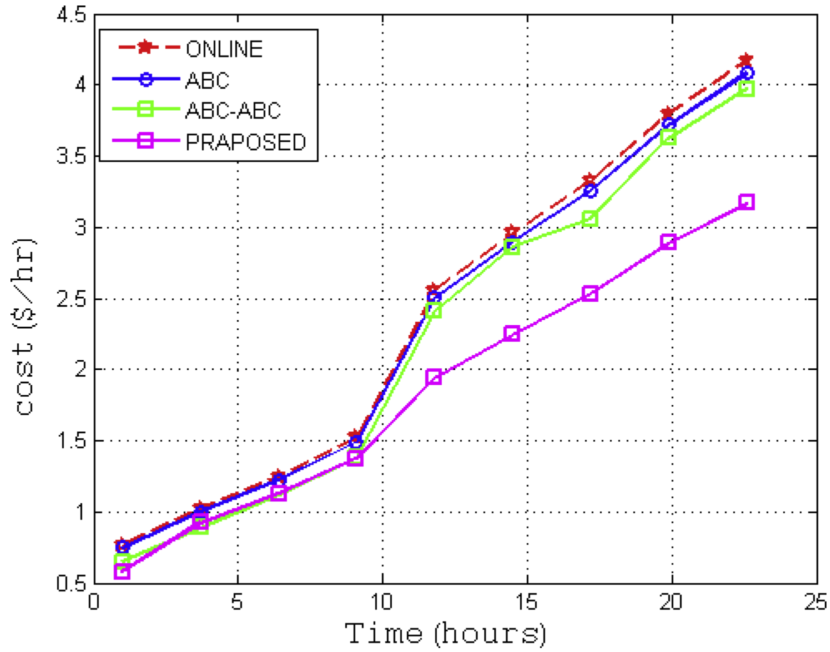


Figure 5.16: Total cost comparison

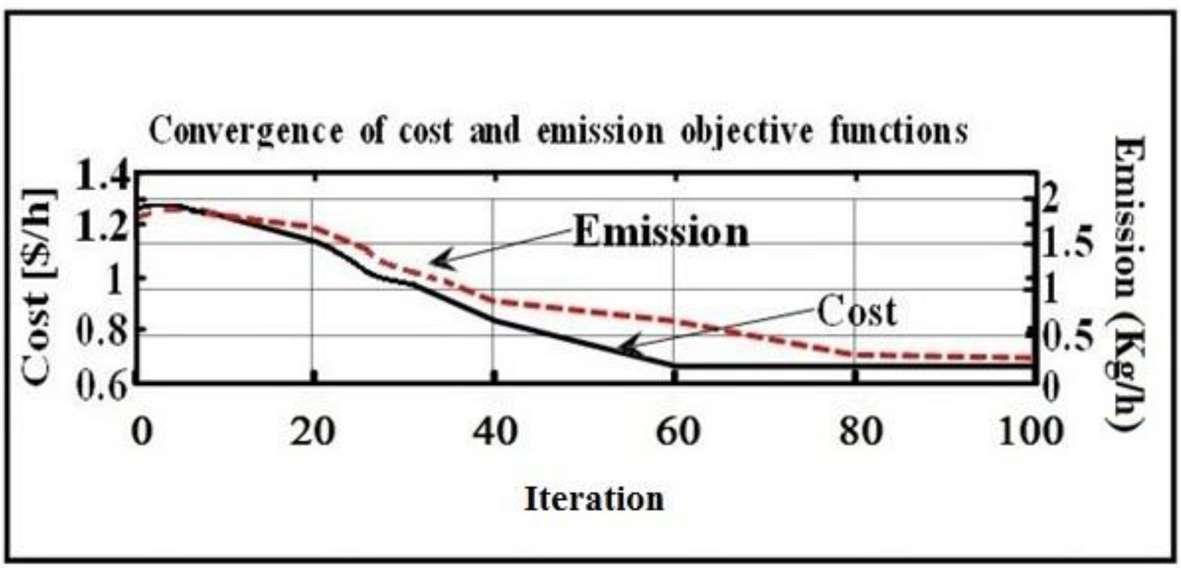


Figure 5.17: Convergence of cost and emission with proposed method

Table 5.4: Selection of optimum MG combination utilizing various methods

Demand Load/kW	FC/kW	MT/kW	DG/kW	Overall cost/($\$h^{-1}$)			
				OM	ABC	ABC-ABC	IABC
3.5	0.00	3.50	0.00	0.7648	0.7507	0.6511	0.5758
4.5	0.50	4.00	0.00	1.0212	1.0001	0.9231	0.8895
5.5	1.50	4.00	0.00	1.2477	1.2218	1.1287	1.1218
6.7	2.70	4.00	0.00	1.5194	1.4878	1.3822	1.3754
8.3	4.00	4.00	0.30	2.5541	2.5002	2.4086	1.9391
9.6	4.00	4.00	1.60	2.9575	2.8951	2.8623	2.2458
10.8	4.00	4.00	2.80	3.3303	3.2601	3.0571	2.5295
12.3	4.00	4.00	4.30	3.7967	3.7168	3.6235	2.8864
13.5	4.00	4.00	5.50	4.2703	4.1825	3.9690	3.7716

Table 5.5: Statistical comparison of Micro grid management after 100 iterations

Load demand /kW	MEAN			MEDIAN			STANDARAD DEVIATION			MAXIMUM		
	S1	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
3.5	0.802	0.654	0.586	0.801	0.685	0.586	0.028	0.017	0.006	0.848	0.711	0.595
4.5	1.053	0.982	0.899	1.057	0.952	0.899	0.029	0.018	0.006	1.099	0.988	0.911
5.5	1.271	1.172	1.129	1.274	1.174	1.159	0.026	0.025	0.020	1.321	1.213	1.199
6.7	1.553	1.406	1.382	1.554	1.407	1.383	0.030	0.014	0.004	1.599	1.430	1.389
8.3	2.588	2.438	1.970	2.592	2.436	1.970	0.046	0.018	0.017	2.658	2.468	2.001
9.6	2.948	2.880	2.261	2.944	2.880	2.262	0.027	0.010	0.009	3.001	2.899	2.271
10.8	3.334	3.134	2.612	3.335	3.141	2.618	0.037	0.046	0.044	3.398	3.213	2.684
12.3	3.818	3.665	2.909	3.819	3.665	2.908	0.058	0.024	0.011	3.909	3.709	2.929
13.5	4.221	4.044	3.856	4.220	4.041	3.830	0.022	0.045	0.028	4.256	4.131	3.871

Here S1, S2, S3 are the solution techniques such as ABC, ABC-ABC and IABC.

Table 5.6: Performance comparison of the various methods

Methods	Bc	Wc	CAP
OM	0.7648	4.1703	4.44
ABC	0.7507	4.0825	4.56
ABC–ABC	0.6511	3.9690	5.08
IABC	0.5758	3.7716	5.53

Here, Bc: Best cost, Wc: Worst cost & CAP: Cost accuracy percentage.

ABC, ABC–ABC based MG optimum formation fuel charges is designated in Figure 5.13 and Figure 5.14 respectively. The fuel charge for the optimum configuration of micro grid combination at 24 hour demand load utilizing proposed method is shown in Figure 5.15. Here, the micro grid model combination is designated to the cost factors since the micro grid of low cost priority for solving the demand load through arranging of MT, FC and DG. Optimum formation of micro grid method have chosen utilizing fitness functions such as entire cost, that is, the cost of fuel, emission, operation as well as maintenance cost. The overall cost attains by using several methods are compared in Figure 5.16. It depicts the proposed method which is having less the total cost, on comparison to the other methods. In Figure 5.17, the convergence of cost with emission is explained. The optimum formation of micro grid combination and the corresponding overall cost utilizing various methods are designated in Table 5.4. The first order of statistics measures like Mean, Median, Standard Deviation, and maximal cost consummate in the proposed and previous method is designated in Table 5.5, where, S1, S2, S3 are the solution techniques like ABC, ABC–ABC, IABC. It observes the proposed method is covering in the optimum solutions utilizing minimum deviation. Then the efficiency of IABC is analyzing the utilizing Cost Accuracy Percentage (CAP) in Table 5.6. In Table 5.6, we have to find the percentage accuracy of the results during the process because the low CAP value between the best cost and the worst cost provides inefficient performance. Here, the ABC is 4.57% CAP value from the best cost as well as worst cost, while ABC–ABC is somewhat upper CAP value than the other methods, that is, 5.09% CAP. It takes place ABC–ABC is CAP value as 5.09% from both the best cost along the worst cost. Never the less, the IABC provides high CAP value in the optimizing process, i.e., 5.54%. This comparative outcome is demonstrated with effectiveness of the proposed method.

(C) MULTIPLE-OBJECTIVE FUNCTION OF SYSTEM MODELING ALONG OPTIMUM MANAGEMENT OF MG: A HYBRID METHOD

At the MATLAB platform, the CS-BAT hybrid system is implemented and designed specifically for research purposes in MG sources like PV, WT, MT, FC, DG, battery. Micro-grid source distribution for various loads is utilized on cost minimization by CS-BAT method. The proposed method utilizes cost factors with estimates of sources according to research work. CS-BAT is executed in 100 iteration utilize 20 input populations. The advantage of CS-BAT has been demonstrated by comparing its performance utilizing existing methods.

A. PERFORMANCE ANALYSIS

Here, it defines optimizing algorithm of micro grid combination based on generalized objective function. First, the demand load value is considered from the input of the proposed approach.Depending on load value of the input, requirement for an optimum combination of micro grid with minimum cost by the proposed method. The load demand is displayed in Figure 5.18 where in the optimizing algorithms are applied to the system which utilizes variable demand load from 2 kW up to 18 kW. Here, renewable energy sources are utilized maximum to meet the demand after that balanced demand load is utilized by MT, FC, DG. In Figure 5.19, an hourly demand load are achieved via optimum allocation of Micro grid sources is shown. It is perceptibly explanation of left behind load after the usage of PV and WT is driven obtainable through employed additional MG sources such as MT, FC, DG and battery.

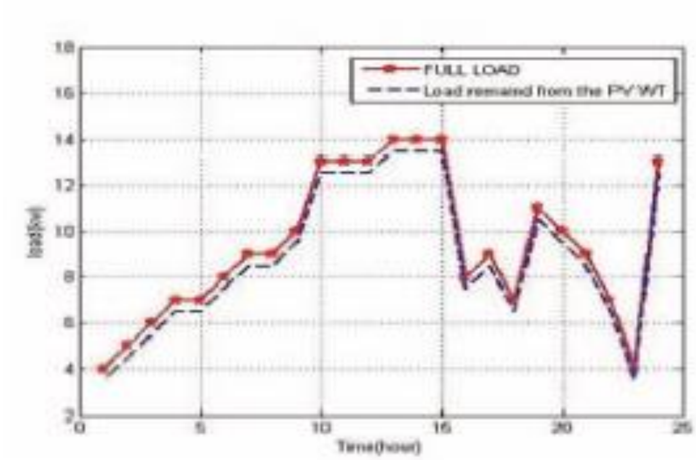


Figure 5.18: Hourly load demand curve

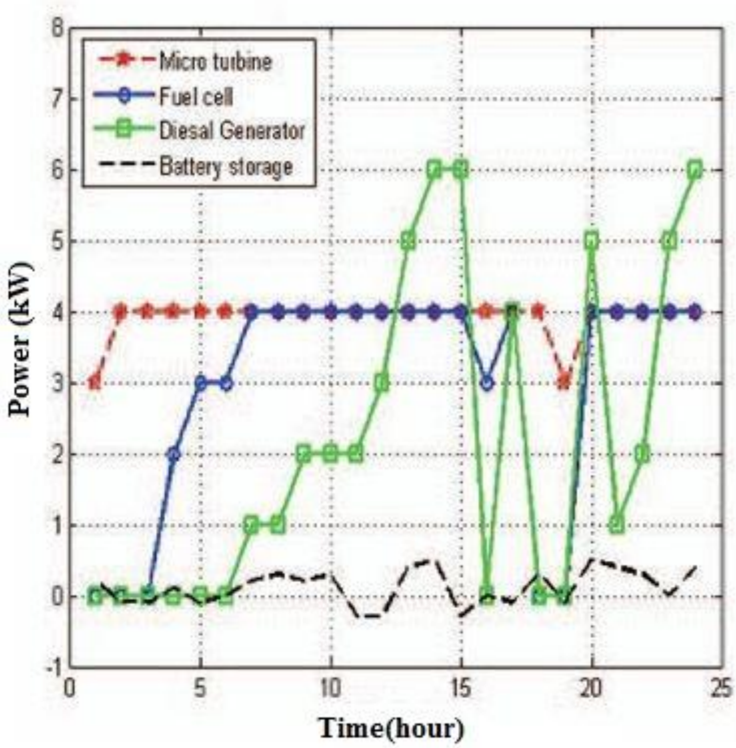


Figure 5.19: Hourly power curves of several MG sources

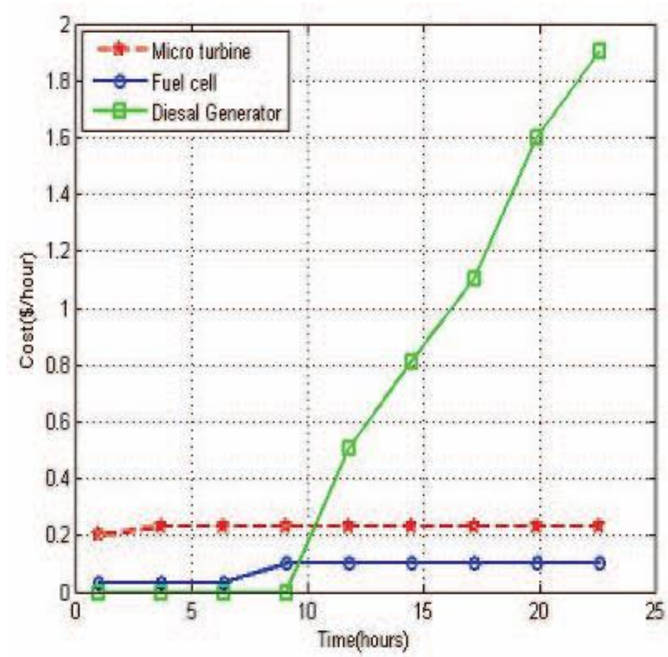


Figure 5.20: Fuel cost analysis of Micro grid sources utilizing proposed approach

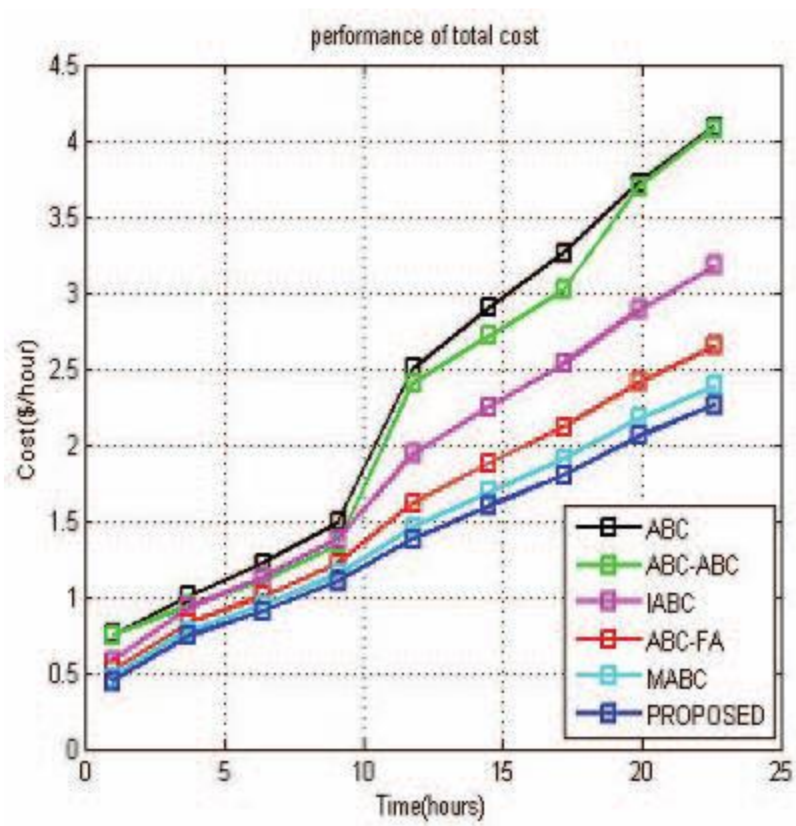


Figure 5.21: Cost comparison analysis of the proposed method with other techniques

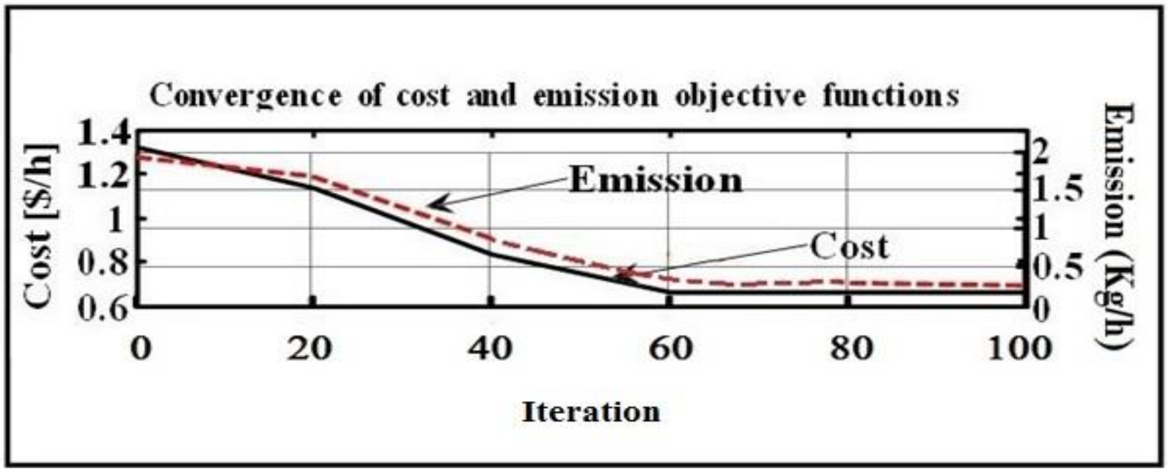


Figure 5.22: Convergence of cost and emission with proposed method.

Table 5.7: Cost comparison results for various methods

Load demand (kW)	Total cost ($/hr.)					
	OM	**ABC**	**ABC-ABC**	**IABC**	**ABC-FA**	**CS-BAT**
3.5	0.7649	0.7508	0.6512	0.5759	0.5185	0.4414
4.5	1.0213	1.0002	0.9232	0.8896	0.8224	0.74074
5.5	1.2478	1.2219	1.1288	1.1219	1.0041	0.9043
6.7	1.5195	1.4879	1.3823	1.3755	1.2233	1.1017
8.3	2.5542	2.5003	2.4087	1.9390	1.6188	1.3784
9.6	2.9576	2.8952	2.8624	2.2459	1.8755	1.5973
10.8	3.3304	3.2602	3.0572	2.5296	2.1129	1.7994
12.3	3.7968	3.7169	3.6236	2.8865	2.4124	2.0538
13.5	4.2704	4.1826	3.9691	3.7717	2.6514	2.2562

The load demand along the total cost of several methods is given in Table 5.7. Overall optimizing algorithms including OM, ABC, IABC, ABC-FA is implemented to 100 random trials with participation of MT, FC, DG sources based on the hourly load requirements. The proposed approach utilized management of micro grid with minimization of fuel charge is labeled in Figure 5.20. In Figure 5.21, the fuel cost comparison is displayed by different methods. In Figure 5.22, the convergence of cost with emission is explained. The entire analyses of optimum selection of MG sources with minimization fuel cost in several load conditions are attained. For minimization of total cost, the proposed method is efficiently chosen optimum micro source with fitness function.

5.2.2. CASE STUDY-2 (ENERGY MANAGEMENT OF ENERGY STORAGE BASED MG CONNECTED SYSTEM: AN SOGSNN MODEL)

The MG construction consist a group of radial feeders along point of common coupling, i.e., PCC. The feeders are connected to sensitive and non-sensitive loads. Furthermore, the feeder has micro sources like WT, PV, DG, FC and MT. For DG, FC & MT, the fuels were needed for generating power but for WT and PV, the fuel comes from environment with no cost. The Gravitational search algorithm based artificial neural network and squirrel search algorithm (SOGSNN) is used to minimize the entire generating cost as well as maximizing the power. For meeting the demand load PV, WT and battery sources are utilized. The increased load demand in the MG has been met utilizing optimum formation of micro grid sources. GSA based ANN is utilized for predicting the demand load of micro grid. SSA highlights the squirrel in optimizing MG based demand load. It is represented in the MATLAB/Simulink platform and the performance is verified utilizing other methods. Parameters in energy resources are displayed in Table 5.8.

Table 5.8: Parameters of Energy Resources

Resources	Description	Ranges
WT	Wind speed (m/s)	5.7
	Cut in speed (m/s)	3.5
	Cut out speed (m/s)	18
PV [73]	Irradiance (W/m^2)	1000
	Temperature (^{0} C)	25
	Cell temperature (^{0} C)	55
Battery	System voltage (Volts)	200
	Capacity (mAH)	6.5
	SOC max	100
DG [73]	d_i	0.4333
	e_i	0.2333
	f_i	0.0074
FC	Cost ($/kW)	0.00175

The parameters of MT are obtained from the data sheet [171].

ANALYSIS OF GENERATING POWER

The optimal combination of Micro grid utilizing different methods is presented in Table 5.9. In Figure 5.23, the generating power of battery, MT, FC, DG, PV and WT is explained.

Table 5.9: Optimal selection of MG combination utilizing various methods

Load demand (kW)		3.5	5.5	8.3	10.8	13.5
FC (kW)		0.00	1.50	4.00	4.00	4.00
MT (kW)		3.50	4.00	4.00	4.00	4.00
DG (kW)		0.00	0.00	0.30	2.80	5.50
Total cost ($/hr.)	ABC	0.72	1.21	2.49	3.25	4.16
	BFO	0.63	1.12	2.39	3.04	3.95
	ANFASO	0.55	1.10	1.91	2.50	3.70
	Proposed	0.31	1.01	1.86	2.12	3.49

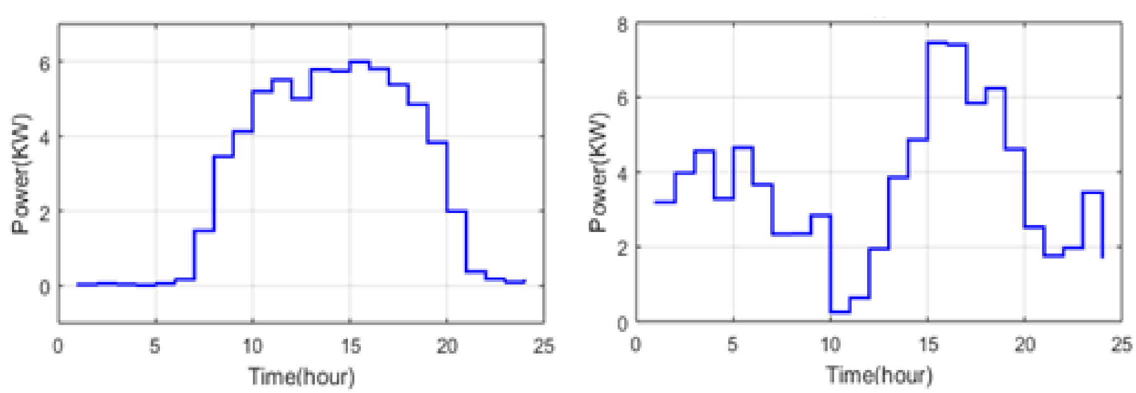


Figure 5.23(a): Generated power of PV and WT utilizing proposed method

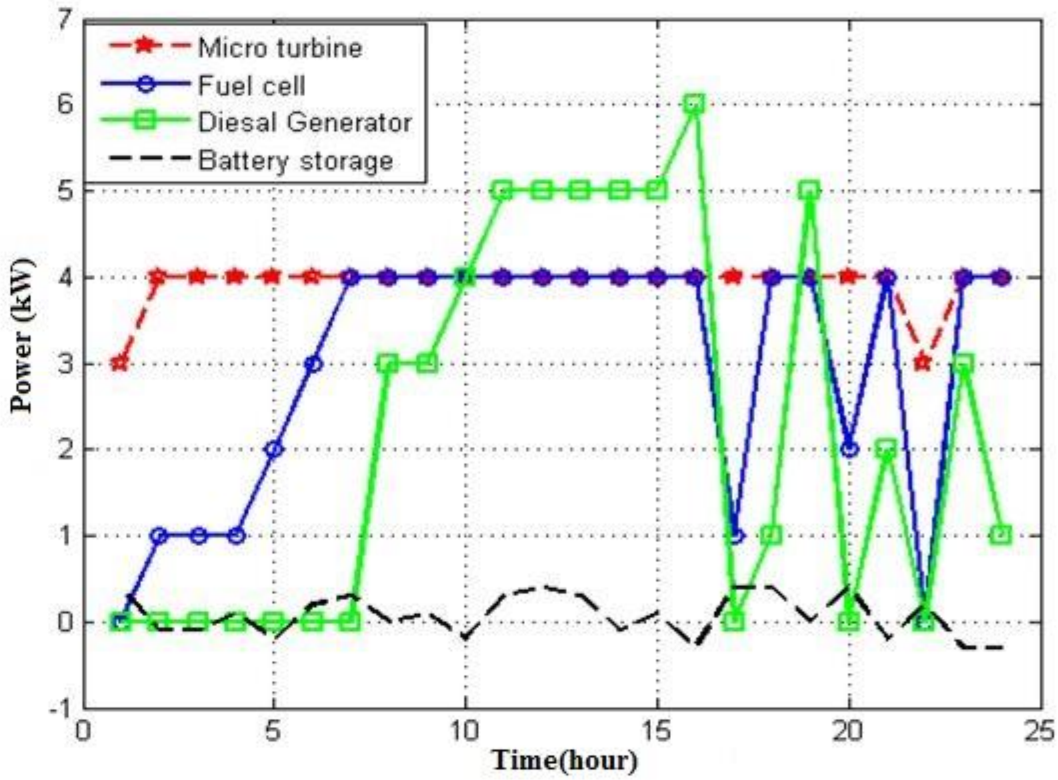


Figure 5.23(b): Generated power of MT, FC, DG and Battery utilizing proposed method

In Figure 5.23(a), the generating power of PV is implemented in 24 hour time. The PV power achieves the maximal power as 1.8 kW in the time instant of t=1-7 hour, at the time moment t=8-17 hour, it is raises to 6 kW and after t=18-24 hour, it is decreases to 0.65 kW. In this figure, it also depicts the generating power for WT in 24 hour time. The generating power of WT is decreased from 3.5 kW up to 2.5 kW in t=1-7 hour of time. At t=8-17 hour of time moment the power is increased to 7.6 kW. Again the power is decreased from 5.2 kW to 1.8 kW as t=18-24 hour of time. The optimal configuration of MG sources to meet the hourly load demand is delineated in Figure. 5.23 (b).

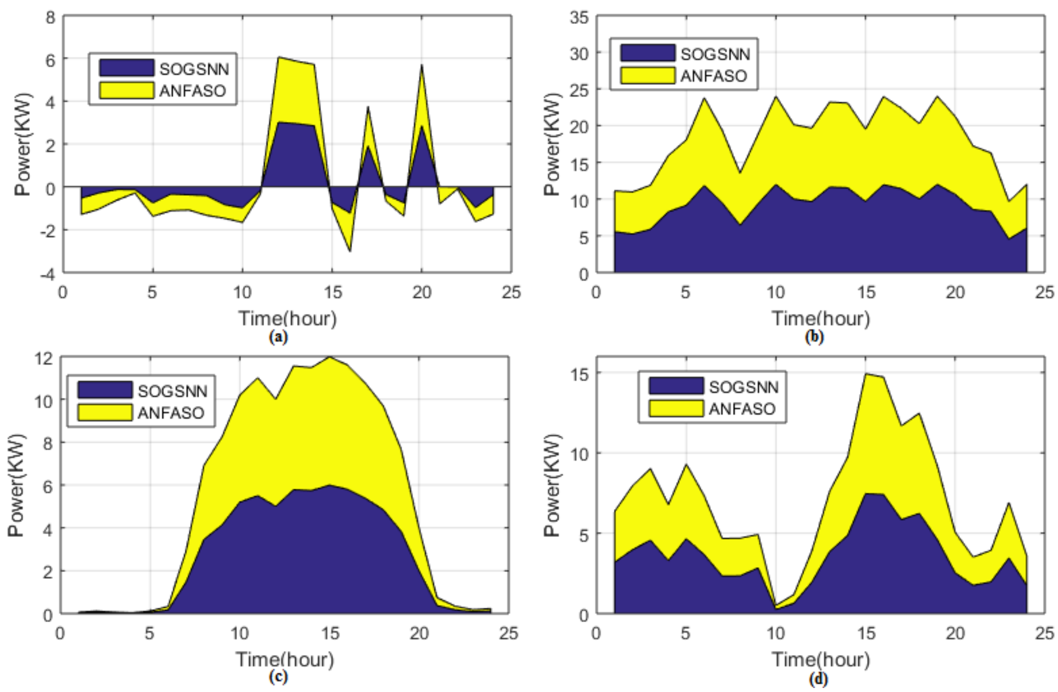


Figure 5.24: Analysis of generating power by (a) Battery (b) MT (c) PV (d) WT utilizing proposed and ANFASO method

In Figure 5.24, it depicts the analysis of generating power in several sources. Figure 5.24(a), it is demonstrated in the initial period, in t= 1-12 hour of time, the battery is charging. The battery is in discharging mode at t= 12-16 hour of time moment and that time the battery power is utilized. But, MT power is utilized to charge the battery. In Figure 5.24 (b), the generating power of MT is analysed in 24 hour time. It attains the maximal power as 12 kW in the t=8-17 hour of time moment. In Figure 5.24(c), it depicts the generating power of PV in 24 hour time. PV attains maximal power as 2.5 kW at t=1-7 hour of time moment. At t=8-17 hour of time moment, it raised to 5.8 kW. Then, t=18-24 hour of time moment, generating power of PV decreases to 0.65 kW. In Figure 5.24(d), the generating power of WT is analysed in 24 hour time. The generating power decreases from 3.5 kW to 2.5 kW at t=1-7 hour time period. At t= 8-17 hour time the WT power increases to 7.6 kW. Over the period at t=18-24 hour, the power reduces from 5.2 kW-1.8 kW. Total analysis of generating power as of sources utilized proposed method is more efficient than other methods.

ANALYSIS OF SOC (State of Charge)

In Figure 5.25, the state of charge (SOC) is analysed utilizing proposed and other methods. The overall power demands by the load are assisted through MT. If the MG is not able to completely supply the load demand, the battery is fully discharged. In particular interval time, the battery activates in charging modes. However, proper selection of MT and battery tends to reach the SOC of battery to 85% by the proposed method.

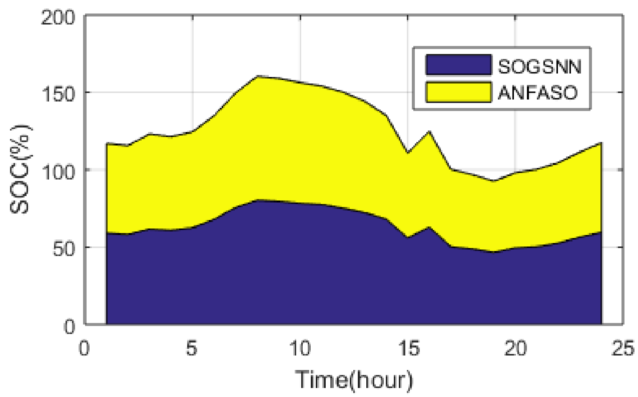


Figure 5.25: Analysis of SOC (%) utilizing proposed and ANFASO method

ANALYSIS OF COST

The operational cost is identified utilizing renewable energy sources, along with the battery in charging as well as discharging mode at 24 hour time in micro grid connected system. In Figure 5.26, it depicts the comparison analysis of cost of proposed method with the other techniques. It is clearly shown that the proposed method gives low cost in comparison with other methods. The aggregated cost of the MG is high in all the other method with respect to proposed method. The charging mode of BS is mainly in the time interval of 1 to 12 hour. Comparing with ABC, BFA, ANFASO method, the aggregating cost is abundantly lessened utilizing the proposed method.

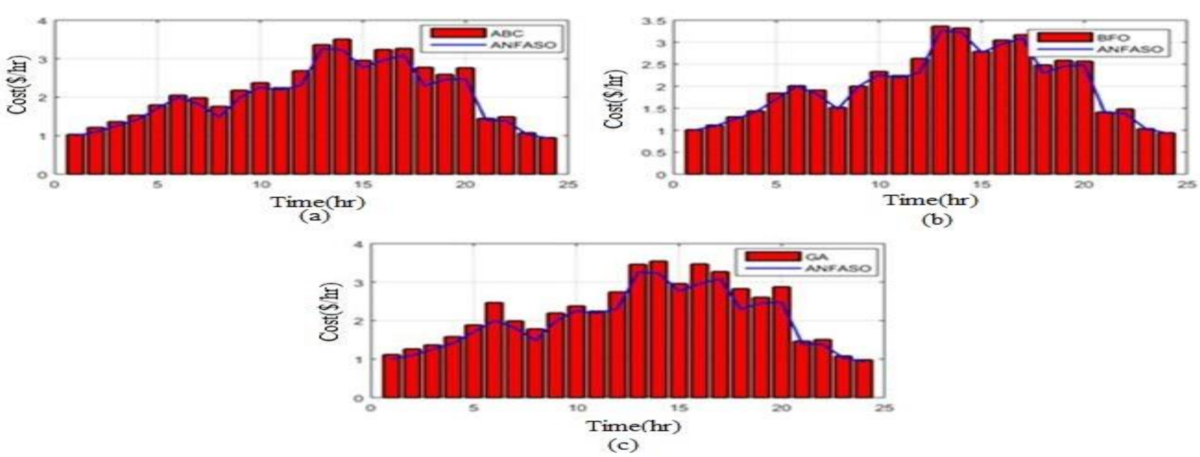


Figure 5.26: Cost($/h) analysis for proposed with existing methods (a) ABC-Proposed (b) BFO-Proposed (c) ANFASO- Proposed

Table 5.10: Comparison analysis of elapsed time of the proposed method with other methods

Solution Methods	Time in sec
ABC	37.11
BFO	36.96
ANFASO	38.08
SOGSNN	36.47

Table 5.11: Statistical analysis of market clearing price (MCP) for proposed method with other methods

Market clearing price ($/kWh) (MCP %)			
Methods	**Mean**	**Median**	**Std. deviation**
ABC	2.152	2.114	0.798
BFO	2.066	2.004	0.767
ANFASO	2.210	2.220	0.817
Proposed	1.990	1.997	0.734

For evaluating the effectiveness of the proposed method, the elapsed time is determined with the proposed method as well as existing methods that are shown in Table 5.10. The proposed method achieves less computational time when compared with the other techniques. The MCP of the proposed method is analysed with respect to the other techniques. The mean, median as well as standard deviation of the proposed method as 1.991, 1.998, 0.735 respectively which is lesser than other methods that is shown in Table 5.11. Figure. 5.26 depicts comparison analysis of cost of proposed method with other methods. This proposed method provides low cost while comparing with existing techniques. Its effectiveness can calculated in terms of cost accuracy percentage (ECAP) in the following equation:

$$ECAP = \frac{best - worst}{best} \times 100$$

The percentage accuracy of the proposed method and the other existing methods is determined. Table 5.12 shows the performance evaluation of different methods of the proposed method with other methods.

Table 5.12: Performance evaluation for different methods

Solution methods	Best	Worst	ECAP
ABC	0.71	4.15	4.76
BFO	0.62	3.94	5.25
ANFASO	0.55	3.70	5.71
Proposed	0.31	3.48	10.24

Table 5.13: Evaluation of SOC utilizing different techniques

SOC (%)			
Solution Methods			
Proposed Method	**ABC**	**BFO**	**ANFASO**
82%	78%	70%	63%

In Table 5.12, It is showed the percentage accuracy of the various methods have less ECAP. The ECAP value of proposed method is high with respect to the other methods. The ECAP of proposed method is estimated as 10.25%. The other methods like ABC, BFO, ANFASO with different demand load as well as the entire cost are compared with the proposed method and tested the effectiveness. Comparison Analysis of SOC (state of charge) utilizing various methods is presented in Table 5.13. The SOC of proposed method is greater than the existing techniques. The SOC is of 82% of proposed method, ABC as of 78%, BFO as of 70%, ANFASO as of 63%.

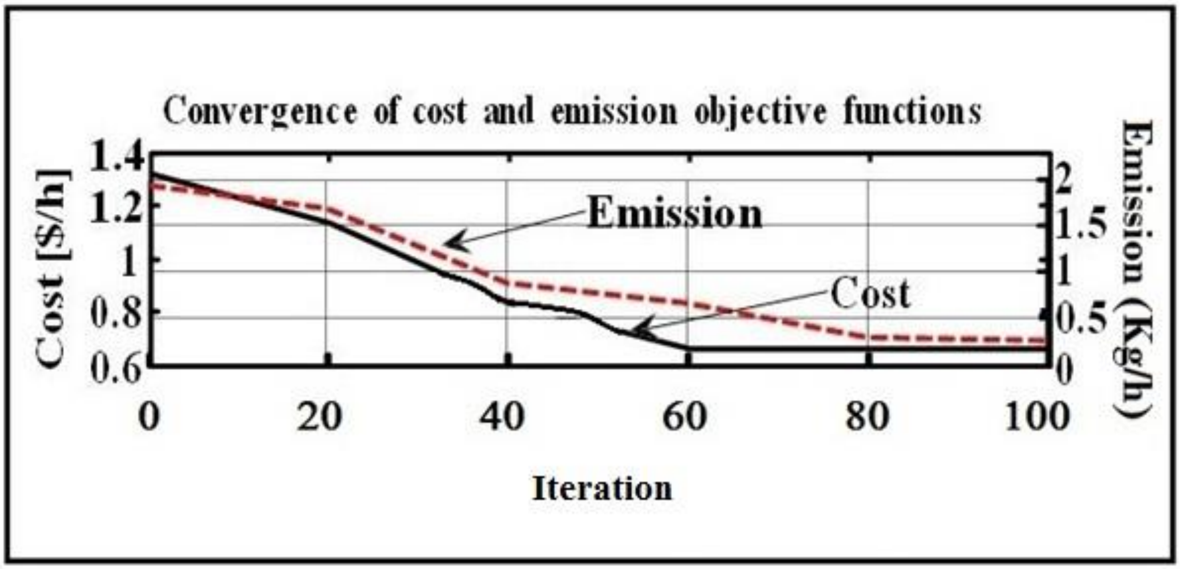


Figure 5.27: Convergence of cost and emission with proposed method.

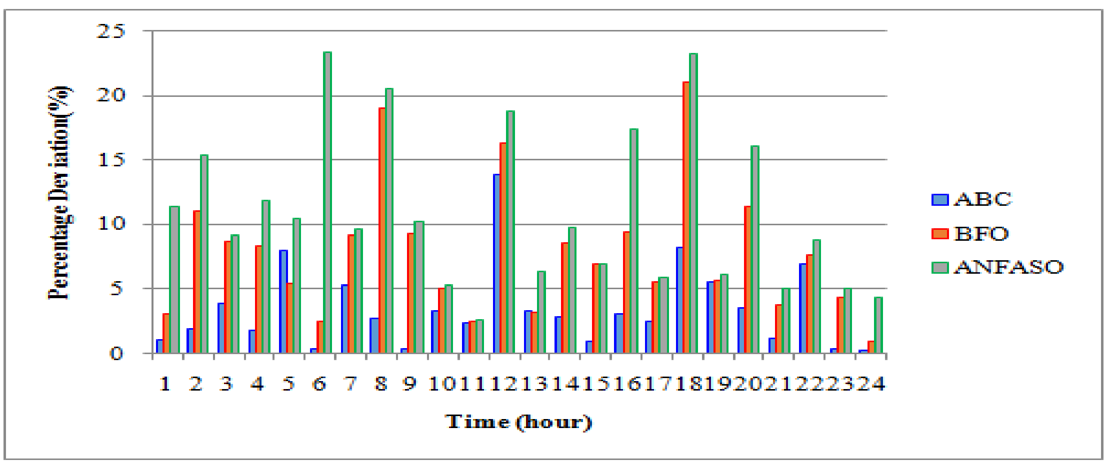


Figure 5.28: Percentage deviation for the proposed method with the existing methods

In Figure 5.27, the convergence of cost with emission is explained. Figure 5.28 depicts the percentage deviation of the proposed method with other methods like ABC, BFO and ANFASO. Here the generating power of battery, MT, PV and WT is shown by the proposed method as well as ANFASO. The maximal power of battery is produced by the proposed method. The maximal power of battery, MT, PV and WT is as 8 kW, 9.5 kW, 16 kW, and 5 kW. The SOC of proposed method achieved as of 80%. In ANFASO generating power of battery, MT, PV, WT is as 7.5 kW, 9 kW, 15 kW, and 4.5 kW correspondingly. It depicts the proposed method gives the maximal power and the total generating cost is minimal. The computation times, entire generating cost (Table 5.10) are evaluated and compared with other methods like ABC, BFO and ANFASO for evaluating the effectiveness of the method. Lastly, it depicts the proposed method gives optimum outcomes with compared to ANFASO method.

5.2.3. CASE STUDY-3

(A) CASE STUDY-3a (ANALYSIS OF ENERGY MANGEMENT IN MICROGRID- A HYBRID BFOA WITH ANN)

Here, a hybrid method is proposed for minimizing total generating cost as well as maximizes the utilization of power of MT, WT, PV and battery storage (BS). The hybrid method is a combination of ANN as well as Bacterial Foraging Optimization Algorithm (BFOA), which is utilized for an optimal operation of micro grid. Here, the MG consists of photovoltaic (PV), Wind turbine (WT), Micro turbine (MT) as well as energy storage system. ANN utilizes to predict the load demand of MG. Micro grid has two non-dispatch able resources such as PV as well as WT, a dispatch able resource as MT, energy storage device as ES with some responsive load as electric water heater (EWH), demand response (DR). Depending on the DR, the WT, PV, and MT along with Battery power is estimated utilizing ANN. Then the generating cost of MG is minimized by the BFOA. The inputs consider as PV, WT, ES, MT powers with minimal, maximal limits by the proposed method is implemented in the MATLAB platform. The effectiveness of the proposed method is evaluated and compared with the proposed method with the previous techniques like GA, ABC respectively. Overall cost is analyzed in several load demand. The forecasting data of PV, WT, load demand & specification of power of PV, WT, MT, battery and also implementation parameters are tabularized in Table 5.14(a), 5.14(b) and 5.14(c) respectively. The system data including forecasting data are obtained from the data sheet [175- 178].

Table 5.14 (a): Forecasting data of PV, WT & Load demand [96]

Time (hr.)	Load demand	PV Power	WT Power
1	0.2888	0.0631	2.8923
2	3.8858	0.0355	4.2461
3	4.0516	0.0510	3.2615
4	4.6801	0.0241	3.8461
5	3.8998	0.0420	3.0769
6	5.5938	0.0687	4.5538
7	6.5048	0.9130	0.8000
8	7.6443	3.8801	2.9538
9	6.1626	3.9534	2.0615
10	7.7066	5.3813	0.2461
11	8.3539	5.4774	0.6153
12	8.6906	5.6435	2.4000
13	9.3762	5.8129	2.6153
14	7.9100	5.6770	6.5538
15	7.8562	6.0144	7.7538
16	9.7148	5.8163	7.7846
17	10.2866	5.6104	5.2615
18	11.9492	5.0086	7.7846
19	12.4620	4.2409	4.3076
20	14.4698	2.5171	2.8307
21	13.0139	0.0923	1.7230
22	7.9529	0.0726	1.1692
23	5.5947	0.0783	3.4461
24	3.8537	0.0924	2.1539

Table 5.14 (b): PV, WT, MT & battery power range

PV Power	WT Power	Battery Power	M T Power
0 kW (min) 6 kW (max)	0.45 kW (min) 8 kW (max)	0.81 kW (min) 3.84 kW (max)	3.6 kW (min) 12 kW (max)

Table 5.14 (c): Implementation parameters

S.No	Description	Values
1	Dimension of search space	3
2	Number of bacteria	10
3	Length of swim	4
4	Count for reproduction steps	4
5	Elimination of dispersal events	2
6	Number of hidden layers	20

PERFORMANCE ANALYSIS

In 24 hour of time intervals, WT, PV, MT as well as ES power values are determined utilizing the suggested method. It is presented in Figure 5.30. In Figure. 5.29, ANN is used to analyze the data in the training and testing period. From their performance, the error value is evaluated which is used to prove the effectiveness of ANN and obtained optimal results. In the initial period, during the charging of battery in 1-12 hour the state of charge is evaluated. In discharging mode, the battery power is used in t = 12 to 16 hour. But, the power needs to charge ES provides through MT. Finally, state of charge (SOC) is reached up to 70% at the end of this time interval. More SOC causes the increase of the ability to supply the loads in the rest of the system day-to-day operation. Also, the remaining interval time, the ES is utilized to supply the shortage of power, while utilizing the proposed approach is operated in charging mode and continuing to reach SOC in maximum. Similarly, present methods like GA as well as ABC are utilized to acquire optimum results and compare with the proposed method.

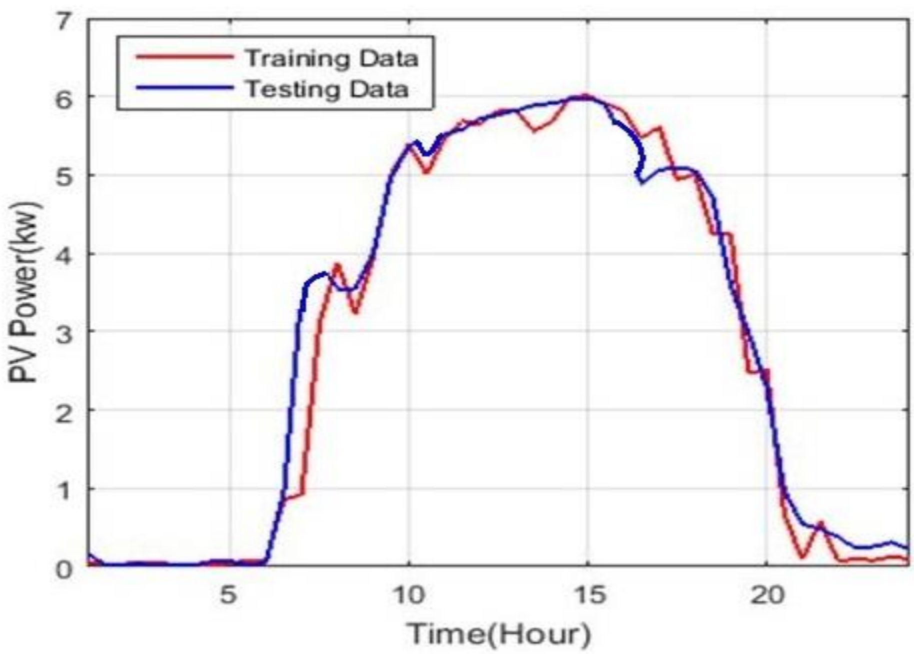


Figure: 5.29(a)

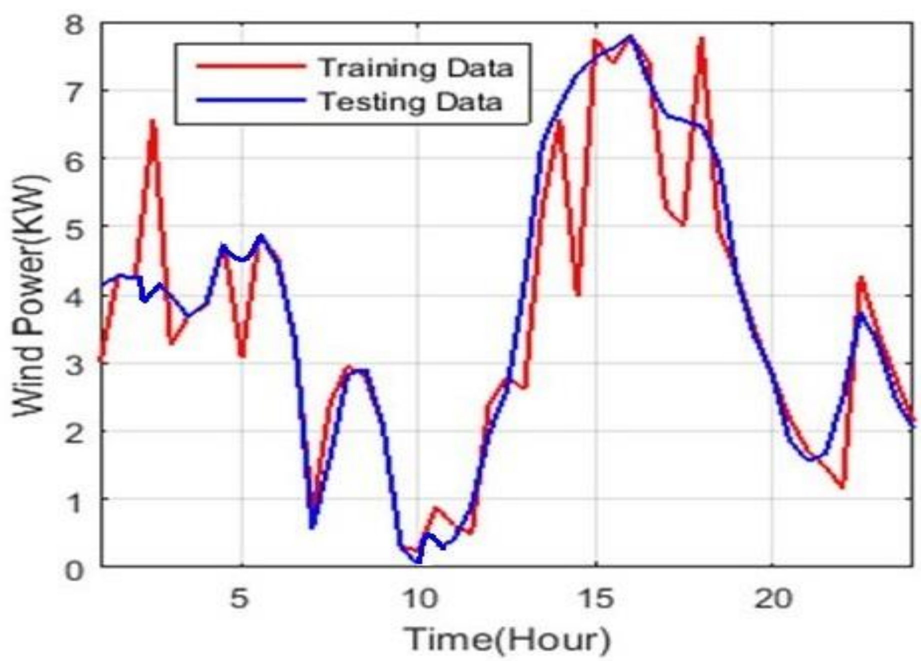


Figure: 5.29(b)

Figure: 5.29: Analysis of ANN training and testing in (a) PV (b) Wind

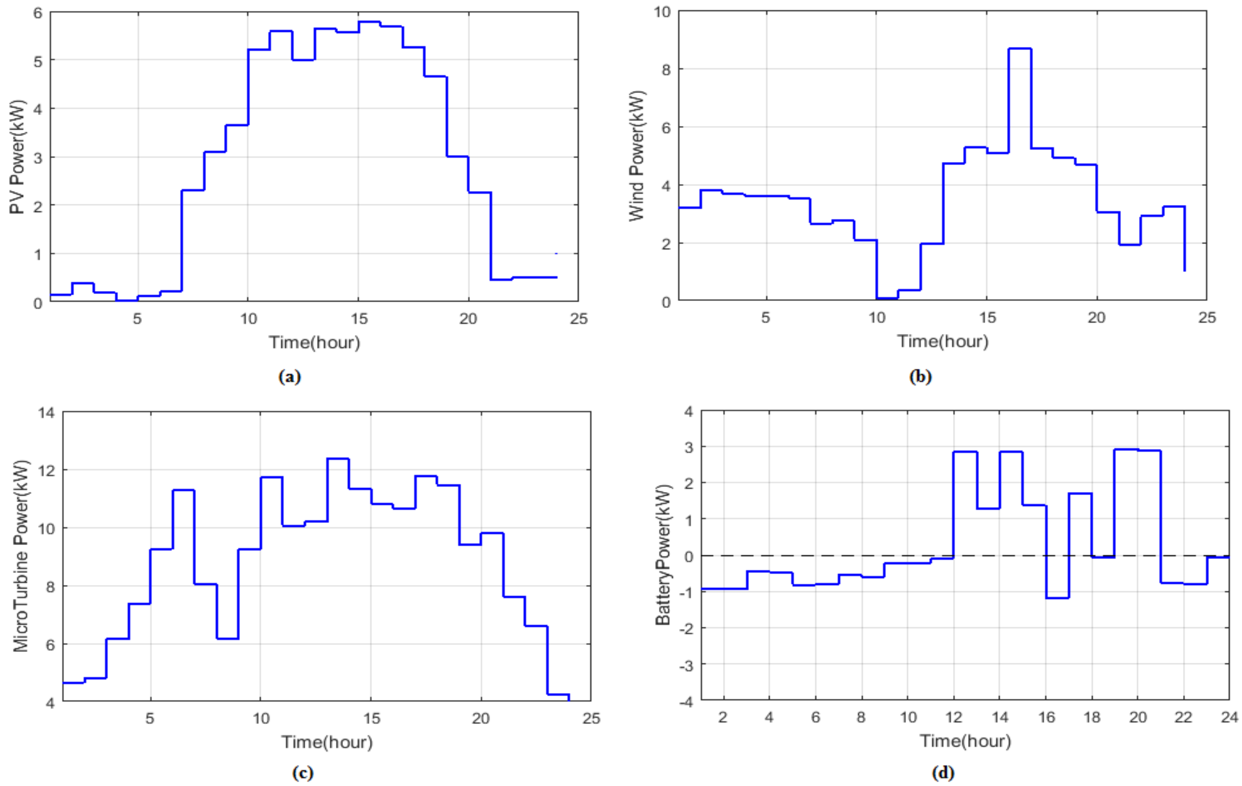


Figure 5.30: Generated power through (a) PV (b) WT (c) MT (d) battery utilizing proposed method

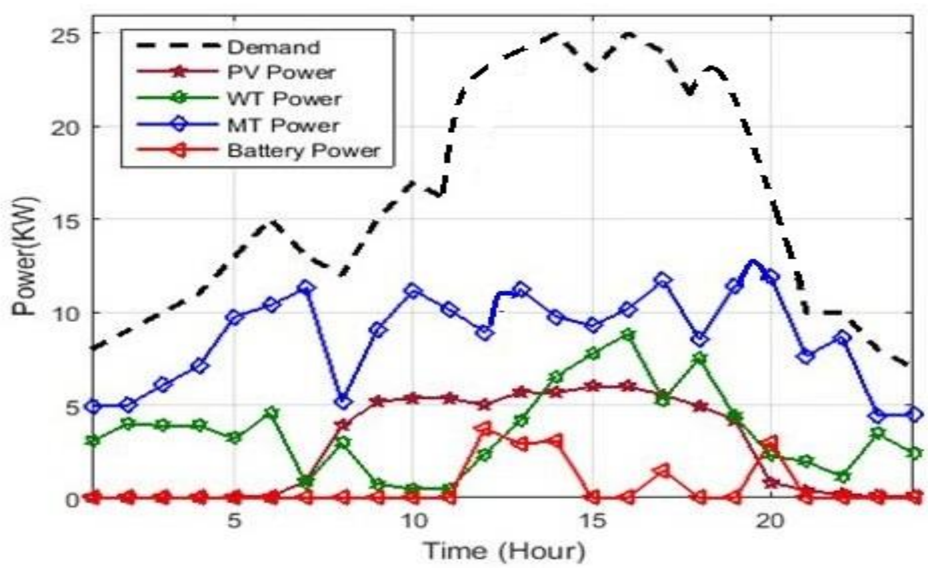
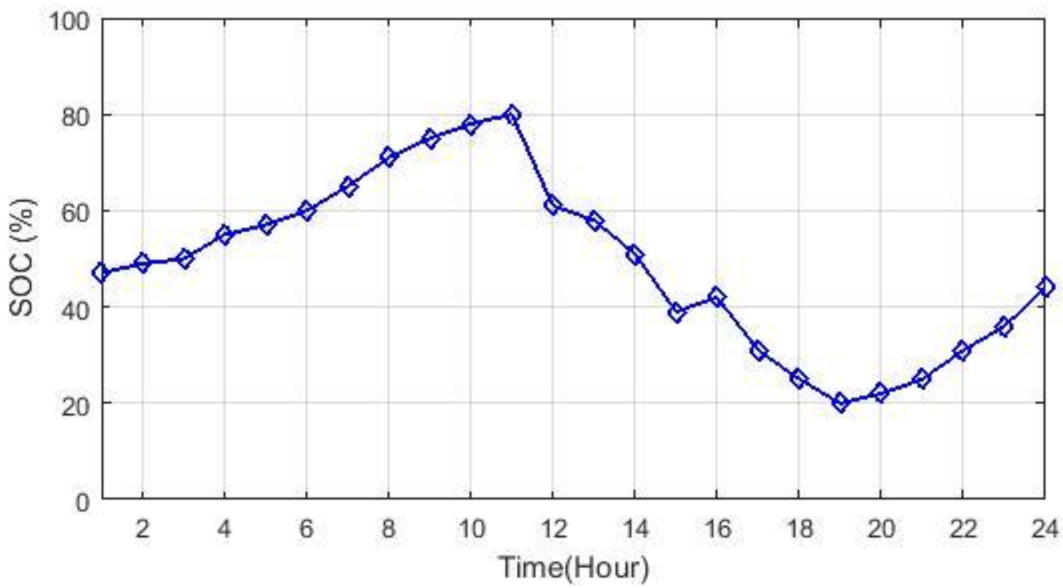
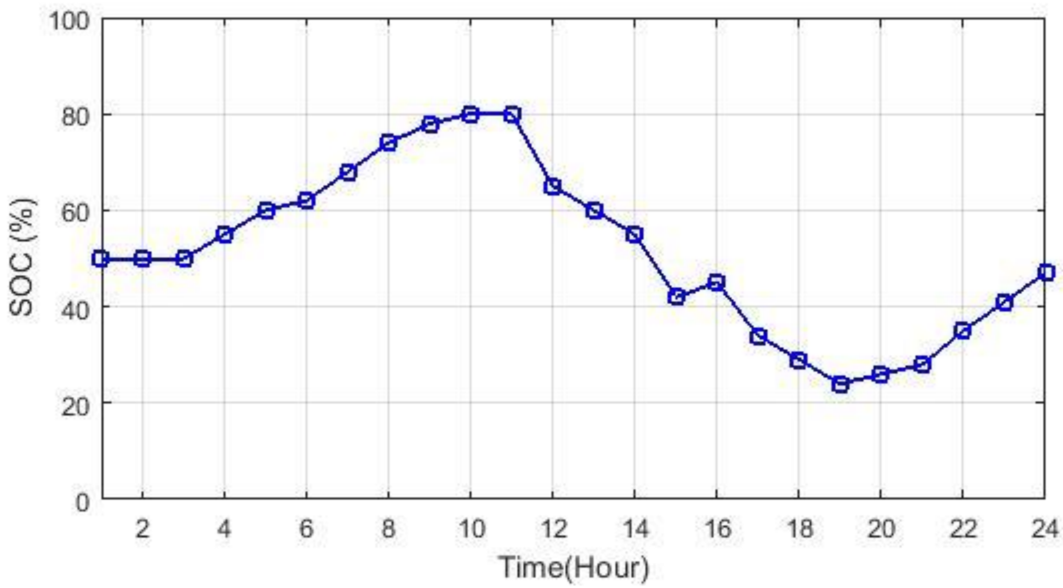


Figure. 5.31: Analysis of Demand Vs PV, WT, MT and Battery power using proposed method

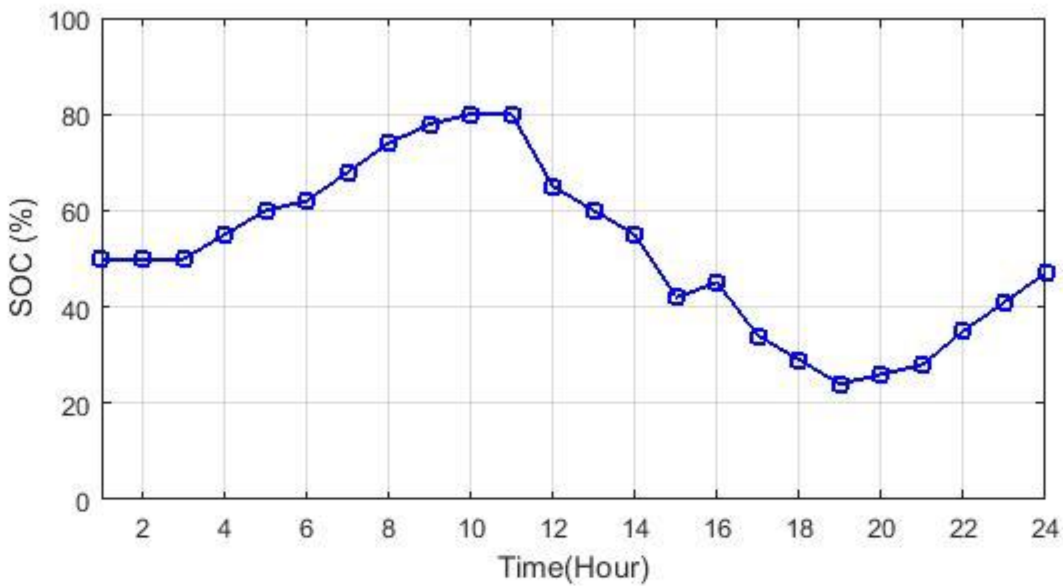
In Figure 5.30, the generating power of MG is considered in 24 hours. During peak hours (t=10 to 17 hours), the maximal generating PV power is utilized, that is displayed in Figure 5.30(a). In case of WT, the maximal generating power based on the wind speed. Utilizing the proposed approach, at the time (t=16-20 hour) maximal power is generated. Likewise, other dispatch able as well as non-dispatch able resources is analyzed. In Figure 5.30(a), the power generated byPV is considered utilizing the proposed approach. The instant time (t=1 up to 7 hour), Attains maximal power as of 2.3 kW and in peak hours (t=8 to 17 hour) it increases to 5.8kW. It is decreased to 3.5 kW after the instant of time (t=18 to 24 hour), after again it is reduce to 0.6kW. In case of wind power, in the time period (t=1 to7 hour), generating power is decreased from 3.5 kW to 2.5 kW. Then, the power is increased to 8.5 kW in instant period (t=8 to 17 hour). Again, the power is reduced by 4 kW (5.5 kW to 1.5 kW) in time period (t=18 to 24 hour). To analyze MT generating power, it is reached maximal power (11.9 kW) in time period (t=8 up to 17 hour). Then the rest of the time periods, differences are observed. In case of the battery power, the battery is charging in the instant of period (t=1 up to 12 hours). Then, in the time period (t=13 up to 16 hour) maximal power (2.95 kW) is evaluated from the battery, that is in the discharging mode. Likewise, other approaches are utilized to analyze the generating power of MG. Furthermore, maximal generating power by the proposed method is evaluated and compared with the other methods. After that, the total generating cost is considered and compared with the other methods. In Figure 5.31, the maximum utilization of MT, WT, PV and battery is analyzed based on their demand values. In Figure 5.32, it depicts analysis of state of charge using the proposed method as well as existing methods. The evaluation analysis in generating power, SOC (state of charge) and the cost of MG is considered and depicted in the following figures. Comparison analysis of generating power utilizing PV is displayed in Figure 5.33. Comparison analysis of generating power utilizing WT is displayed in Figure 5.34. Comparison analysis of generating power utilizing MT is displayed in Figure 5.35.



(a)



(b)



(c)

Figure 5.32: Analysis of SOC utilizing (a) GA (b) ABC (c) proposed method

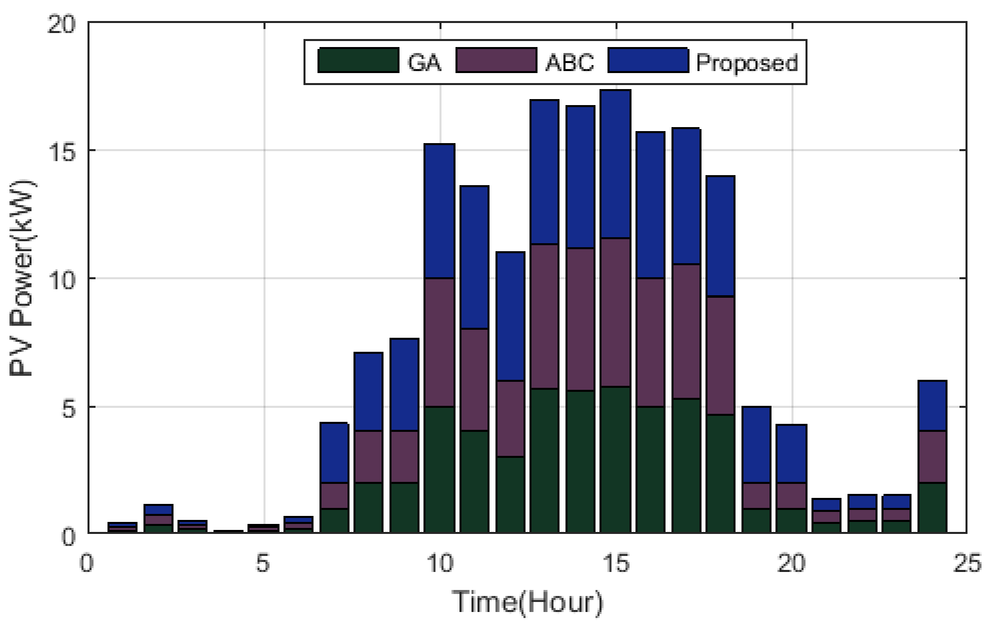


Figure 5.33: Comparison analysis of generated power with PV

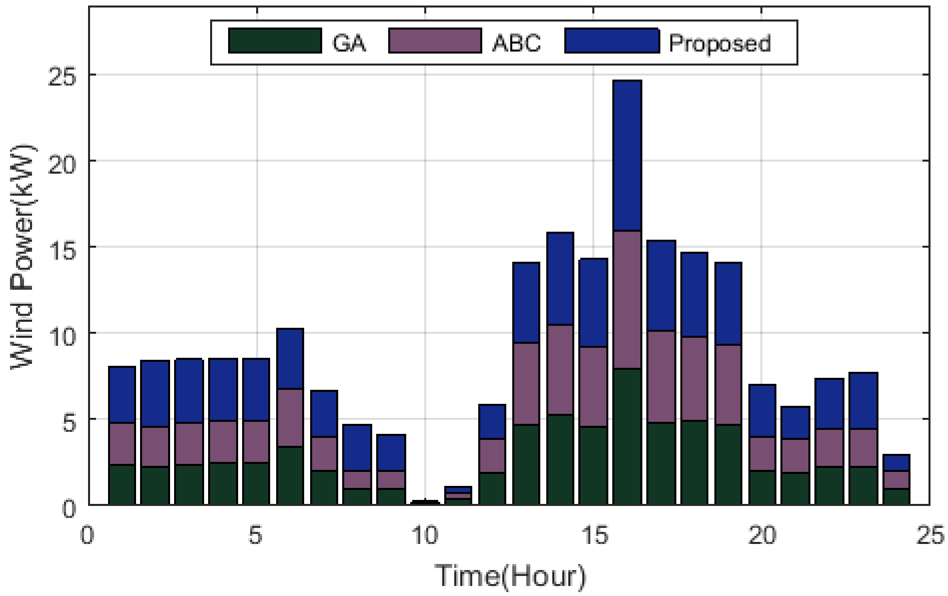


Figure 5.34: Comparison analysis of generated power utilizing WT

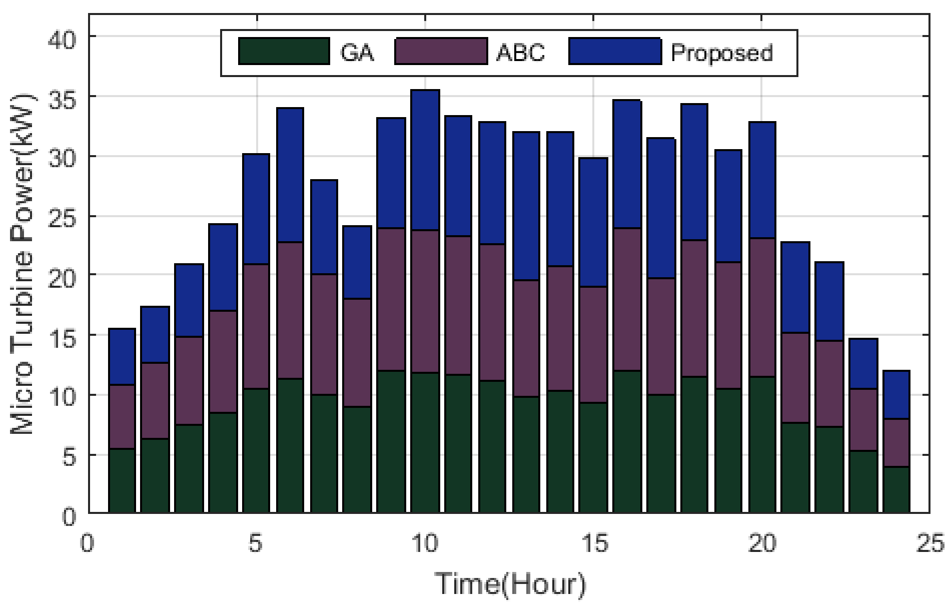


Figure 5.35: Comparison analysis of generated power utilizing MT

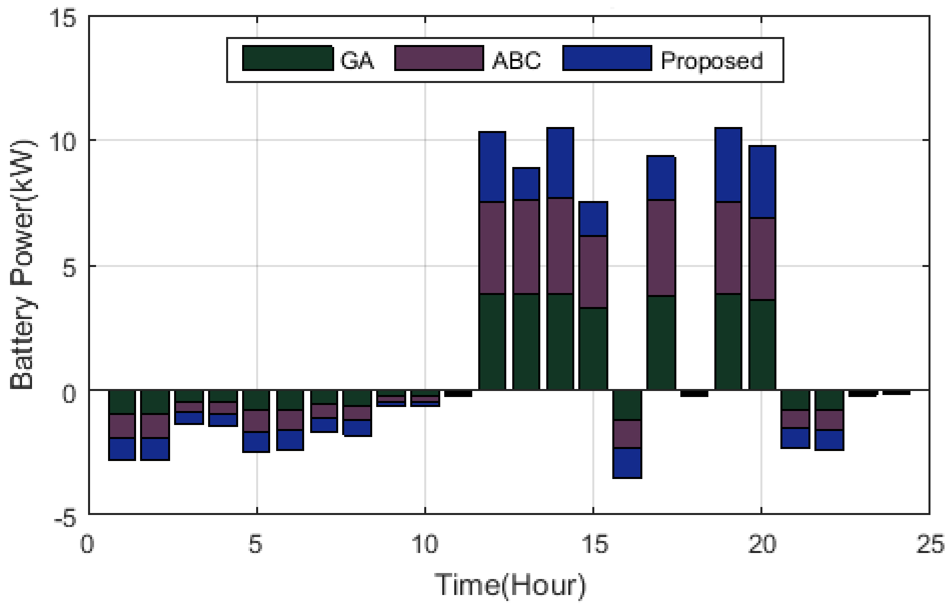


Figure 5.36: Comparison analysis of generated power utilizing battery

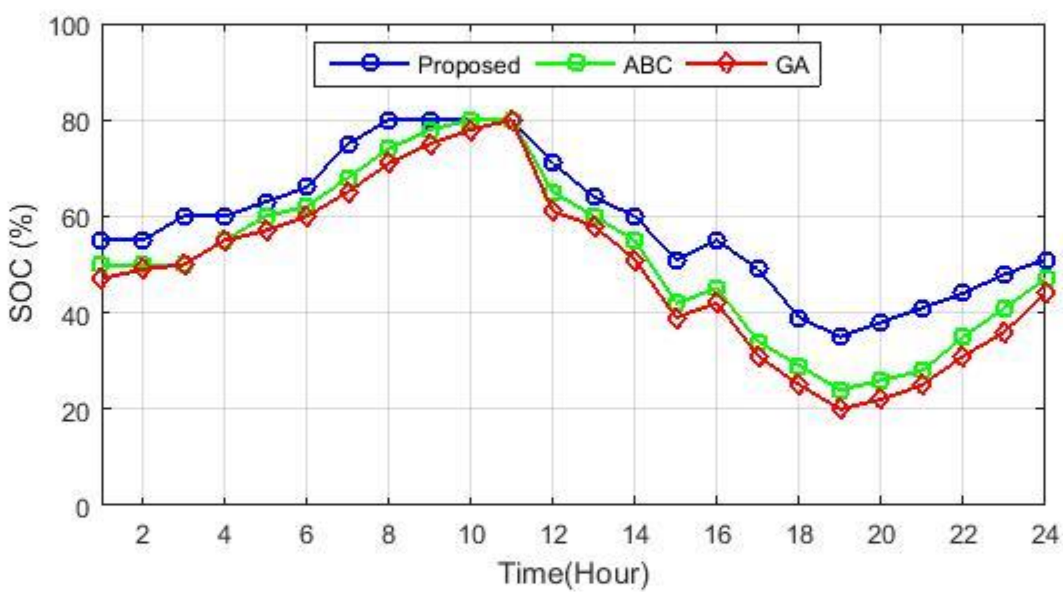


Figure 5.37: Comparison analysis of SOC utilizing various methods

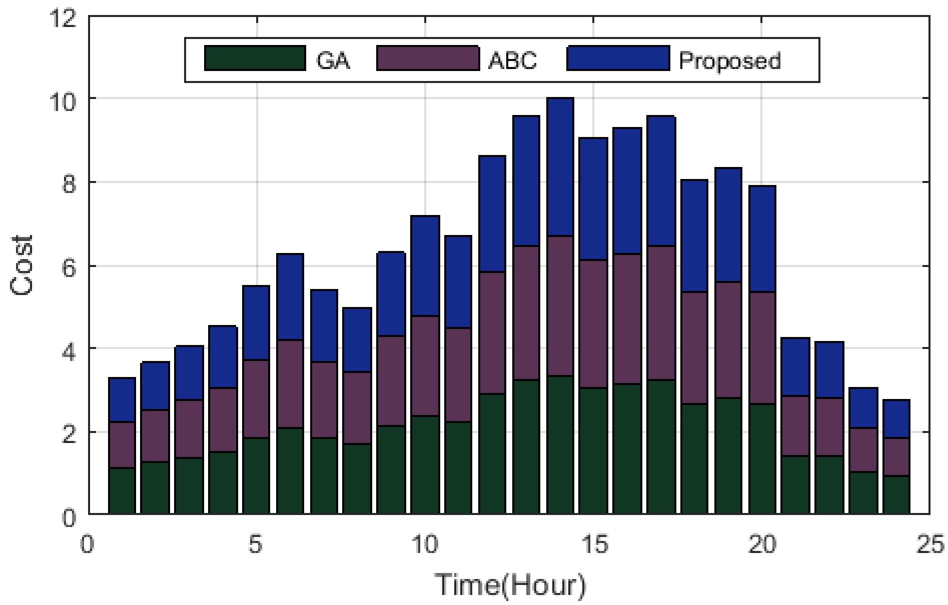


Figure 5.38: Comparison analysis of costs ($/h) utilizing various methods

In the figure, the system can meet the load demand in normal condition even though the MT is assisted as well as ES completely discharging; the MG is not able to supply the complete load demand. In time periods (t= 18 to 24 hour). ES operates in discharging mode like as SOC. Then, the ES is operated in charging mode in specific time intervals. But, the optimum configuration of MT, ES in the charging mode in EMS by the proposed method and SOC reached to 80%. Even though higher MT is compared with ES, the proposed approach is predictable to utilize the MT to compensate the shortage of power and rest of the generating power for charges the ES, the entire generating cost is minimized. Additionally, for lessening the cost, ES tries to store more energy to supply the loads. The bar charts of ES charging/ discharging, state of charge (SOC (%)) is portrayed in Figure. 5.36. Throughout the system operation, the SOC is considered. Also, WT, PV and Battery power [kW] is considered utilizing the proposed approach along with existing approaches. Comparison analysis of SOC utilizing several methods is illustrated in Figure. 5.37. Comparison analysis of costs is displayed utilizing several methods in Figure 5.38.

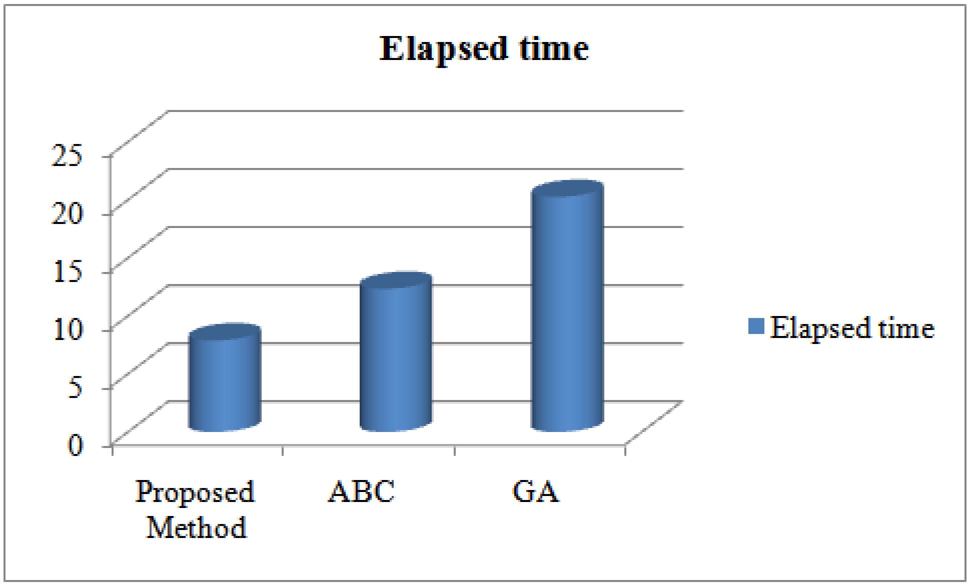


Figure 5.39: Comparison analysis of elapsed time utilizing various methods

Analysis of generating powers for PV, WT, MT and battery power is analyzed in the proposed method along with existing approaches. The maximal generating power of PV, WT, MT and battery power are 7.5 kW, 9 kW, 15.5 kW and 4.5 kW correspondingly. The SOC is considered around as of 80%. In ABC, the generated powers are 6 kW, 7.5 kW, 13 kW, and 3.5 kW respectively. Utilizing GA, the generating powers are 5.5 kW, 7.5 kW, 11 kW, and 3.5 kW correspondingly. It shows maximal generating power of PV, WT, MT and battery. Then, whole generating costs is assessed. In order to have an effectiveness of proposed method, the computational time, the entire generation charge along with fitness graphs are assessed and compared with the other methods. The elapsed time is shown in Figure 5.39. The proposed method has the efficiency of minimum cost based on load demand. It highlights the proposed method attains optimum outcomes with compare to the other methods.

(B) CASE STUDY-3b (ANT-LION OPTIMIZER ALGORITHM (ALO) AND RECURRENT NEURAL NETWORK FOR ENERGY MANAGEMENT OF MG CONNECTED SYSTEM)

Here, RNN as well as ALO is utilized for minimizing overall generating cost along with the maximum use of PV and WT power. The proposed technique is employed for optimum operation of micro grid, which does consider the renewable energy sources along with energy storage system. By utilizing RNN, the load demand of the MG is attained with two non-dispatch able resources (PV and WT), a dispatch able resource (MT), ES integrates with some responsive load (EWH and DR). Firstly, the WT, PV, MT and Battery power are determined utilizing RNN to achieve DR. Then, the generating cost of the micro grid is minimized utilizing ALO. The proposed method is executed in MATAB/Simulink platform. The performance of the proposed method is evaluated and compared with the other techniques like, GA, ABC, BFA correspondingly, that is helpful to identify effectiveness of the proposed approach. The forecasting data of PV, WT, load demand & specification of power of PV, WT, MT, battery and also implementation parameters are tabularized in Table 5.15(a), 5.15(b) and 5.15(c) respectively. The system data including forecasting data are obtained from the data sheet [175-178].

Table 5.15 (a): Forecasting data of PV, WT & Load demand [96]

Time (hr.)	Load demand	PV Power	WT Power
1	0.2888	0.0631	2.8923
2	3.8858	0.0355	4.2461
3	4.0516	0.0510	3.2615
4	4.6801	0.0241	3.8461
5	3.8998	0.0420	3.0769
6	5.5938	0.0687	4.5538
7	6.5048	0.9130	0.8000
8	7.6443	3.8801	2.9538
9	6.1626	3.9534	2.0615
10	7.7066	5.3813	0.2461
11	8.3539	5.4774	0.6153
12	8.6906	5.6435	2.4000
13	9.3762	5.8129	2.6153
14	7.9100	5.6770	6.5538
15	7.8562	6.0144	7.7538
16	9.7148	5.8163	7.7846
17	10.2866	5.6104	5.2615
18	11.9492	5.0086	7.7846
19	12.4620	4.2409	4.3076
20	14.4698	2.5171	2.8307
21	13.0139	0.0923	1.7230
22	7.9529	0.0726	1.1692
23	5.5947	0.0783	3.4461
24	3.8537	0.0924	2.1539

Table 5.15 (b): PV, WT, MT & battery power range

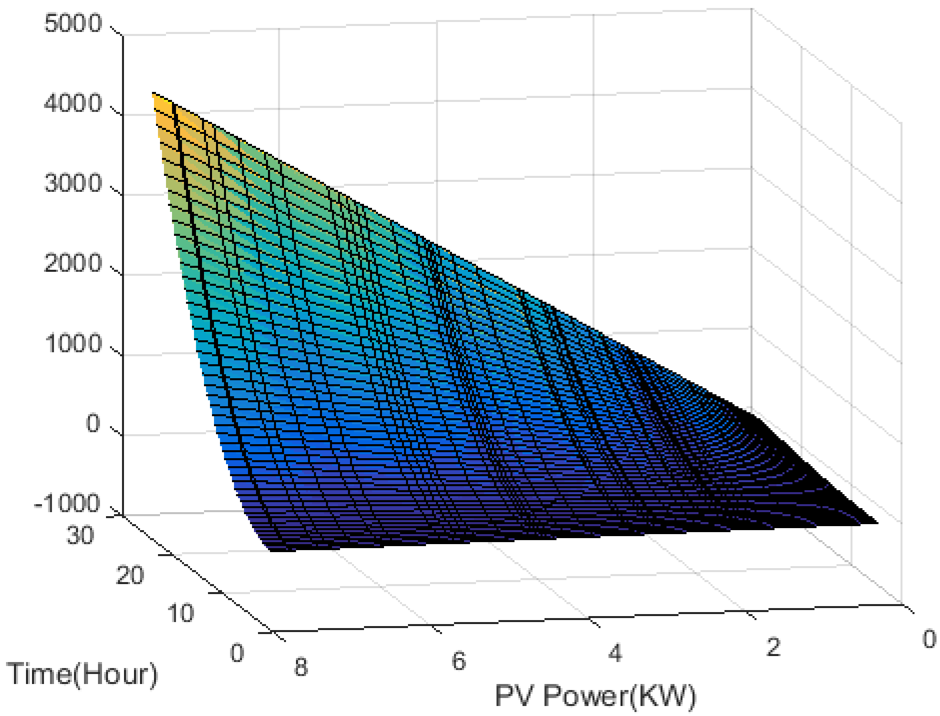
PV Power	WT Power	Battery Power	M T Power
0 kW (min) 6 kW (max)	0.45 kW (min) 8 kW (max)	0.81 kW (min) 3.84 kW (max)	3.6 kW (min) 12 kW (max)

Table 5.15 ©: Implementation parameters

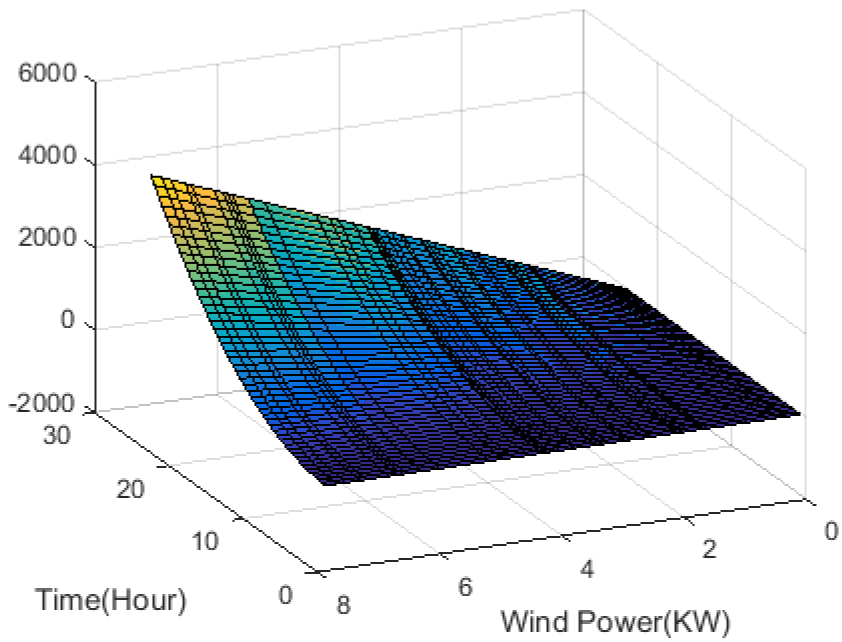
S. No	Description	Algorithm	Values
1	Maximal iteration	ALO	100
2	Populace size (n)		10
3	Ratio (I)		1
4	Number of Bacteria (s)	BFA	4
5	Number of chemotactic (Nc)		4
6	Length of a swim (Ns)		4
7	Elimination of dispersal events (Ned)		2
8	Probability		0.25
9	Crossover rate	GA	0.01
10	Mutation rate		0.03
11	Maximum iteration		100
12	Bee Length	ABC	4
13	Population Size		10

Using the proposed approach, overall costs are analyzed for the several load demand. The proposed model based DR is optimized the sources in 24 hour time, such perceived in the following Figures. Firstly, the 24 hour of data [175- 178] is analyzed and sent to the input of RNN. RNN is utilized for analyzing the data in training process as well as testing periods. Then, the error is calculated and that utilized to prove efficiency of RNN as well to get the optimum outcomes. The training and testing process of the data and the prediction of error is illustrated in

Figure 5.40 and 5.41. Similarly, the inputs connected to proposed approach are energy price, the contract related with DR, the parameter linked to DER considered in the system. Here, multiple inputs are considered, including the information that connects the forecast data with the non-dispatch able energy sources, battery, MT and loads, the parameters of the equipment and analyzed and the maximum capacity of the power are determined in the 24 hour time periods.

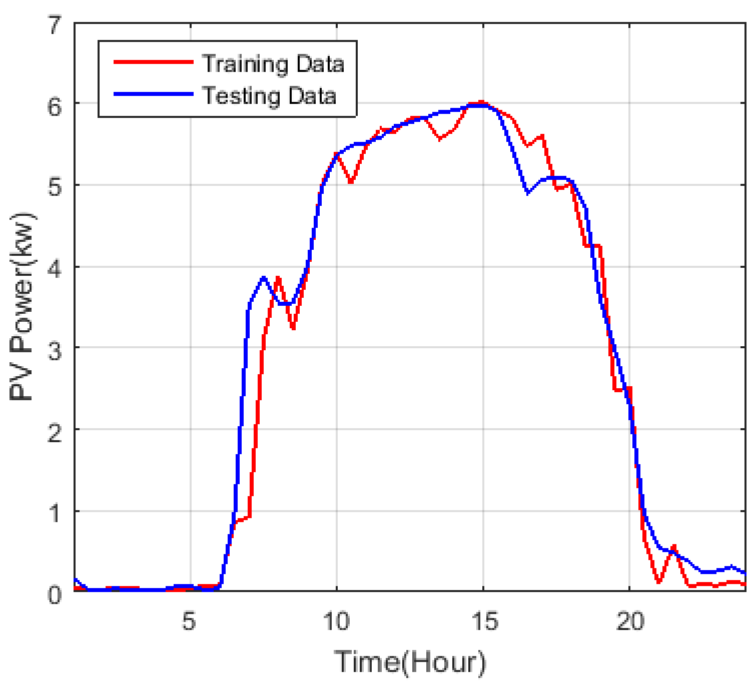


(a)

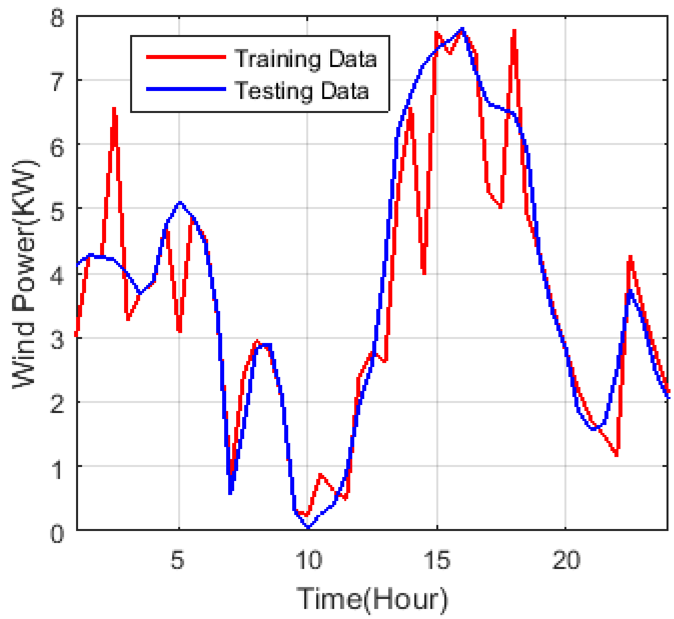


(b)

Figure 5.40: RNN testing performances in (a) PV (b) WT power-3D representation



(a)



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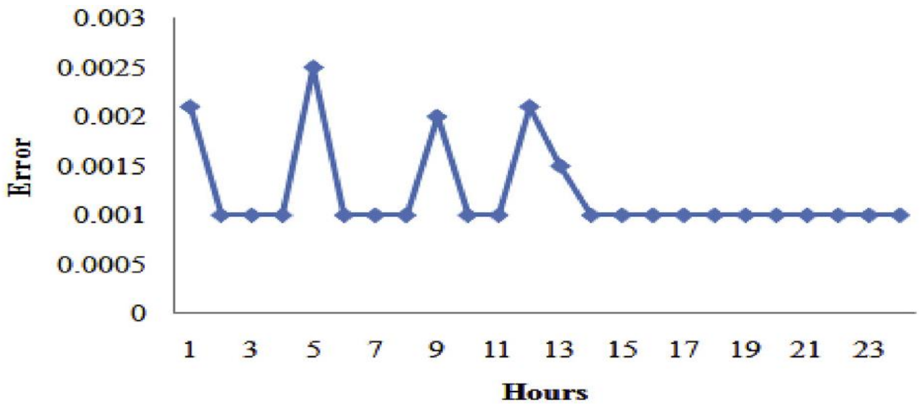

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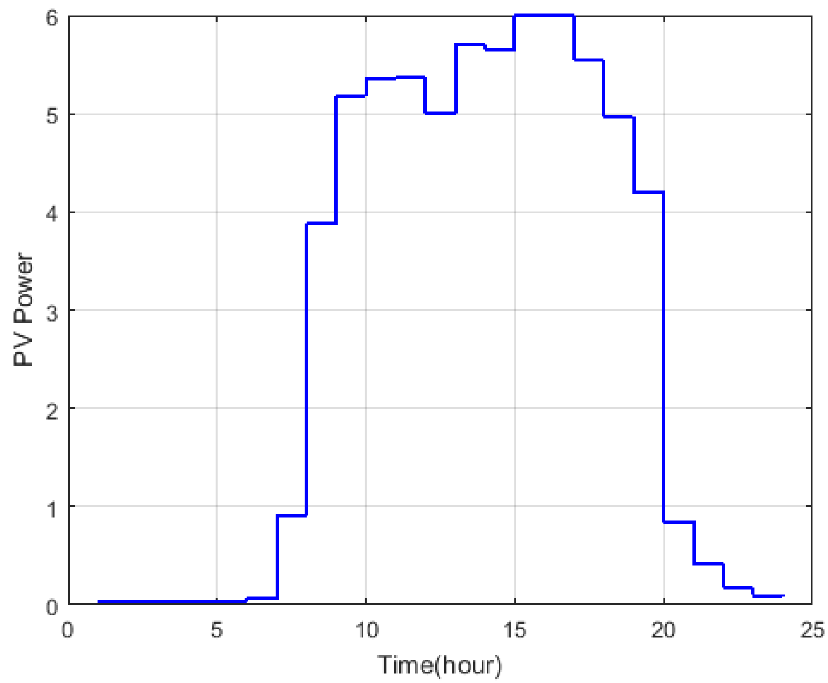
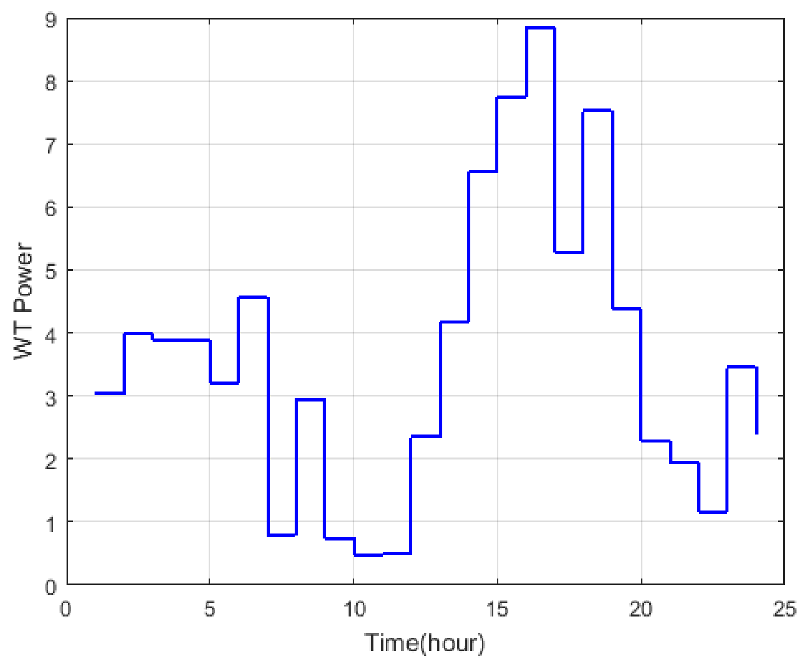
Figure 5.41: Analysis of RNN training and testing in (a) PV (b) WT (c) Error



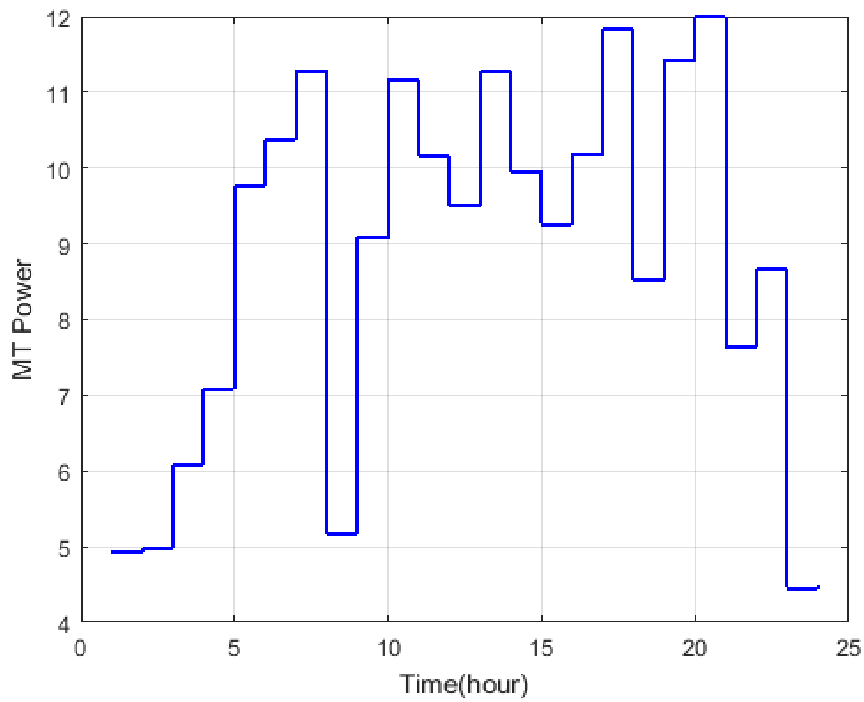
PV Power
Time(hour)
0
1
2
3
4
5
6
0
5
10
15
20
25

(a)

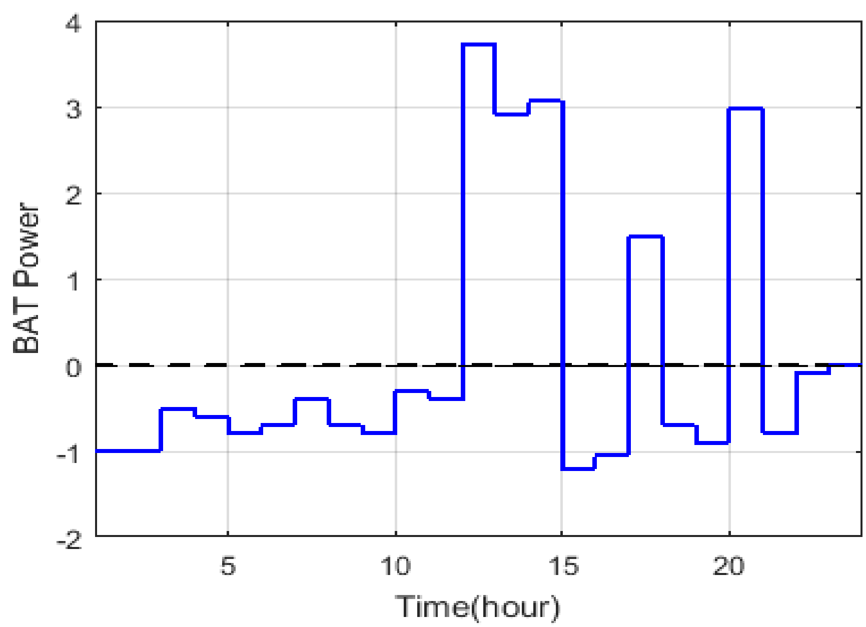


WT Power
Time(hour)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
25

(b)



(c)



(d)

Figure 5.42: Analysis of (a) PV (b) WT(c) MT and (d) Battery power using proposed method

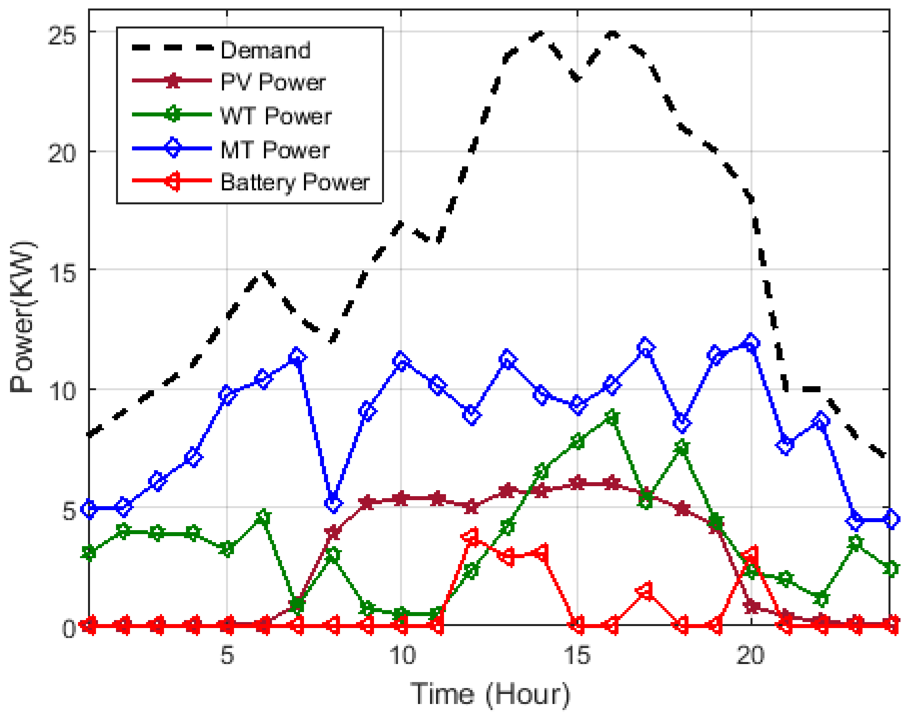
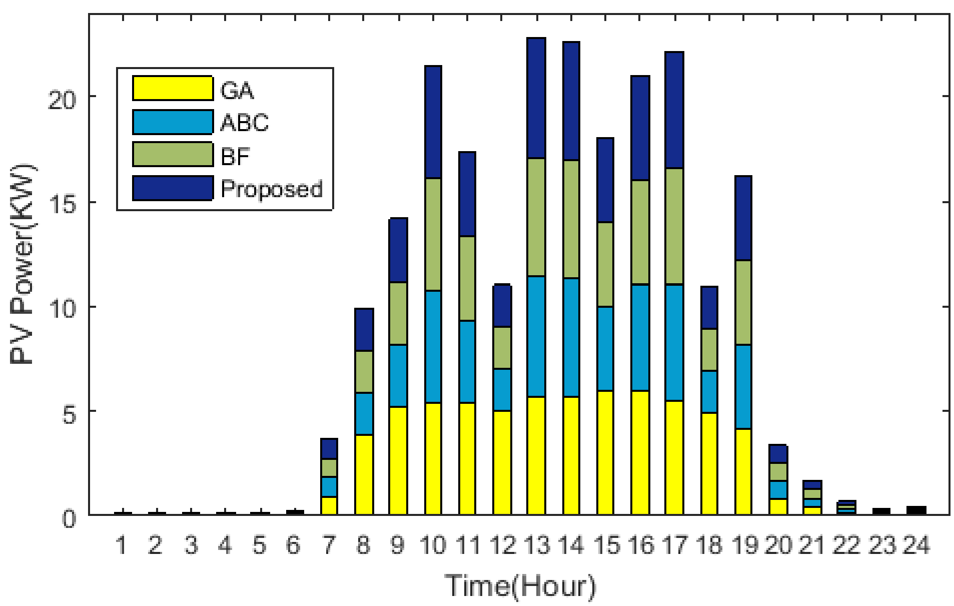


Figure 5.43: Analysis of Demand vs. PV, WT, MT and Battery power utilizing proposed method

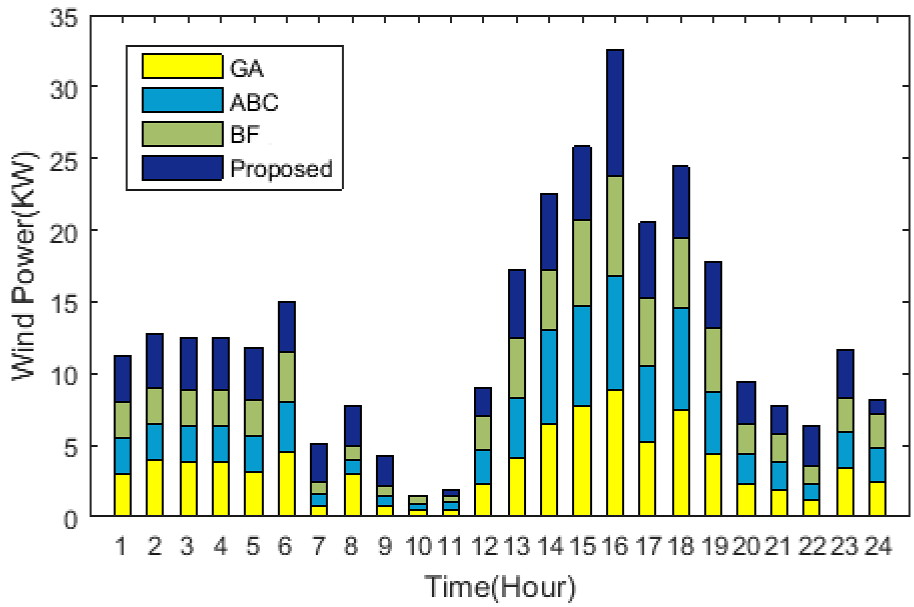
(a) PV (b) WT(c) MT (d) battery utilizing proposed approach is shown in Figure 5.42. The maximum utilization of PV, WT, MT along with battery power is utilized by the proposed approach are shown in Figure 5.43. In the 24 hour time, the WT, PV, MT, ES power values are determined utilizing the proposed method. It is observed the maximal use of MT, WT, PV and battery power considering load demand. The battery is charging in 1-12 hour time. After that, the SOC is determined at the end of the operation. In discharge mode, the battery power is utilized for t= (12-22) hour. The power is needed to charge ES provided by MT. Also, at the time of remaining period, ES is evaluated to supply the amount of power shortage, when the proposed method is operated in charging mode along continue to reaches SOC. The analysis of proposed approach is reached maximal power for meeting the request power. Similarly, the existing approach like GA and ABC is utilized for acquiring optimum outputs and compare with the proposed approach.

(a) COMPARISON ANALYSIS

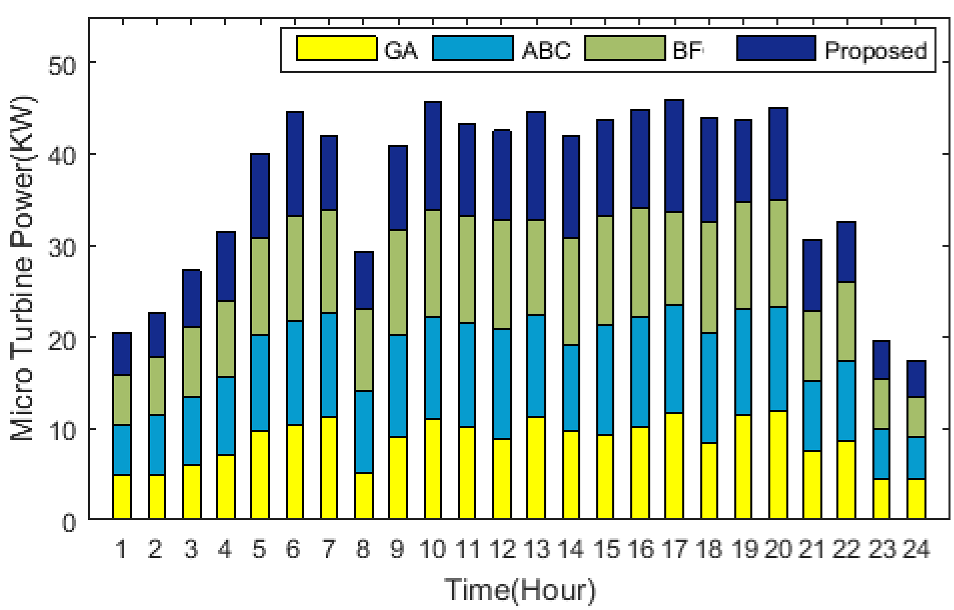
Here, the PV, WT, MT and battery power are presented in Figure. 5.44(a), (b), (c) and (d). Here, the generating power of MG is considered in 24 hour time. In peak hour (t=10 to 17 hour), maximal generating power of PV is utilized in Figure 5.44(a). Whereas utilizing WT, the maximal power is generated based on wind speed. Through using the proposed approach, at the time (t=16-20 hour) maximal power is generated. In Figure 5.44(a), generating power of PV is considered utilizing the proposed approach. In the instantaneous time (t=1 to 7 hour), the PV is attained maximal power 3.20kW, in peak hours (t=8 to 18 hour) increases to 8.83 kW. It is decreased up to 5.62 kW and again it is reduced almost 2.38 kW. Whereas for the WT, in the time (t=1 to 7 hour), generating power of WT is reduced from 3.03 kW to 0.79 kW and there is an improvement in power. Again, the power is reduced up to 4.55 kW in the specific instant time (t=18 to 24 hour). Also, the other dispatch able as well as non-dispatch able resources evaluated.



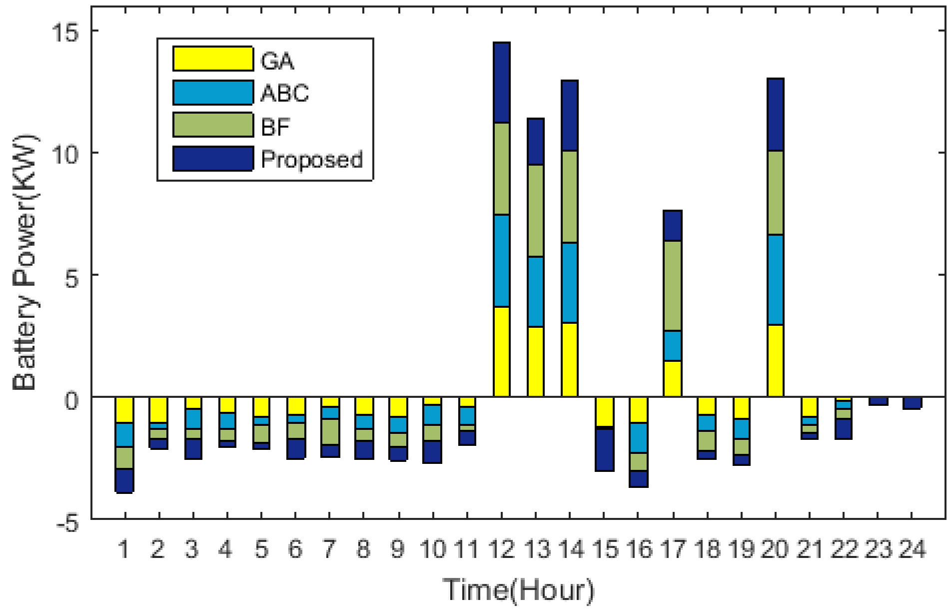
(a)


35
30
25
20
15
10
5
0
Wind Power(KW)
GA
ABC
BF
Proposed
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time(Hour)

(b)


50
40
30
20
10
0
Micro Turbine Power(KW)
GA
ABC
BF
Proposed
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time(Hour)

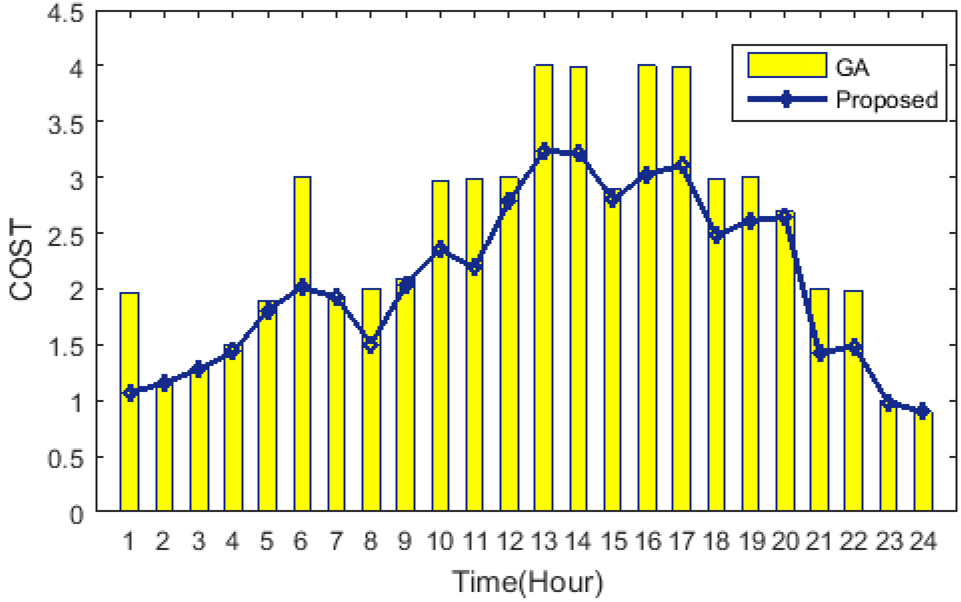
(c)



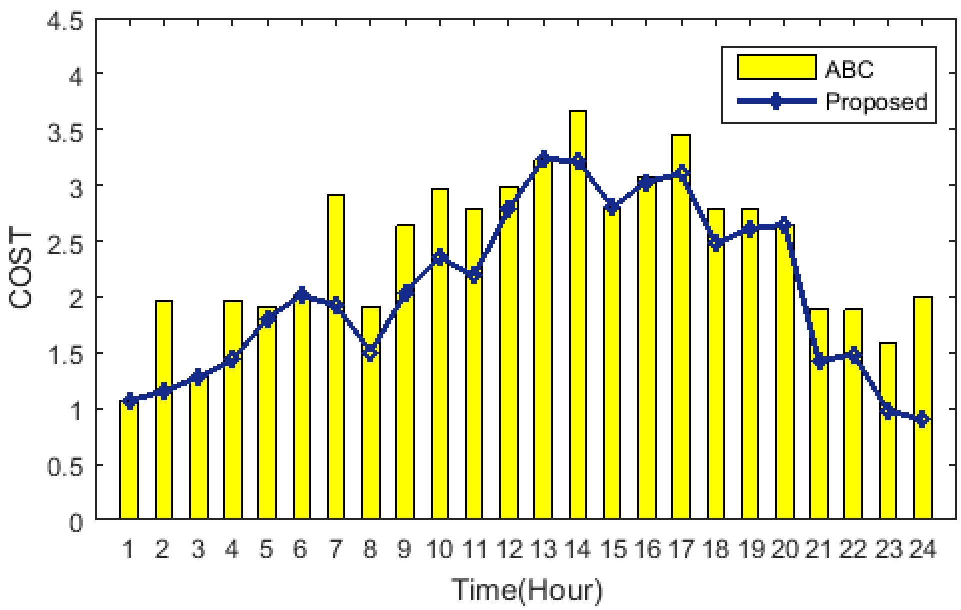
(d)

Figure 5.44: Comparison analysis of (a) PV (b) WT (c) MT (d) Battery power

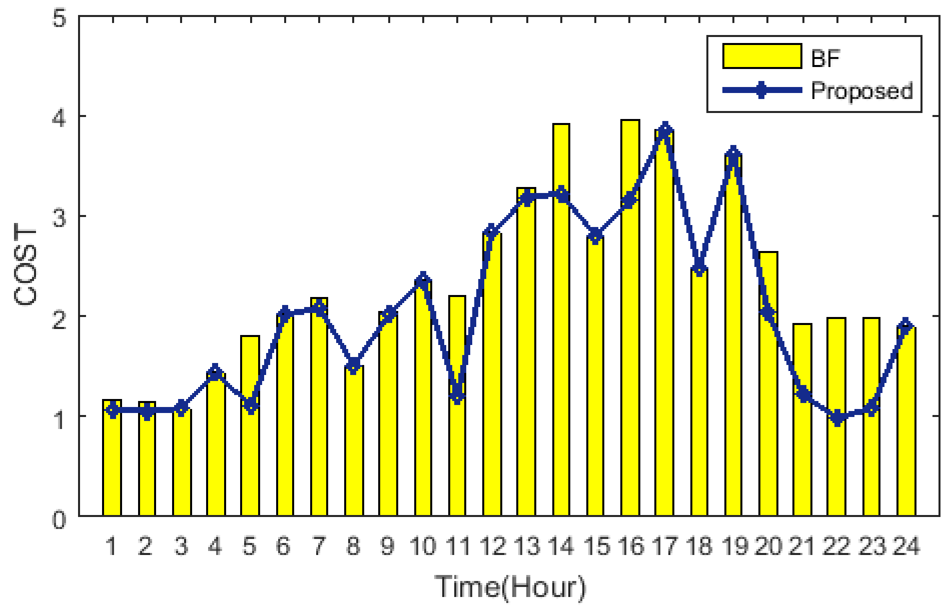
However, the battery is employed in the charging mode in time (t = 1 to 12 hour). When, the time (t=13 to 16 hour) maximal power (3.7289 kW) is to be calculated from battery, that is in the operation of discharging mode. Under this situation, an amount of essential power required by the load is met up by ES and MT. As it is observed, when some amount of power are required by load, that are not supplied. The extra power of PV & WT is utilized to feeds ES, DR and EWH. Also, the previous methods are utilized for analyzing the generating power of micro grid. Furthermore, maximum generated power as well as utilized power is analyzed in the proposed approach with the other methods. Then, the overall generating cost is evaluated along with the existing methods like, GA, ABC and BFA. The comparison analysis of generating power as well as cost of micro-grid is evaluated and that is portrayed in the succeeding Figures.



(a)



(b)



(c)

Figure 5.45: Cost ($/h) analysis of proposed method utilizing (a) GA (b) ABC (c) BFA

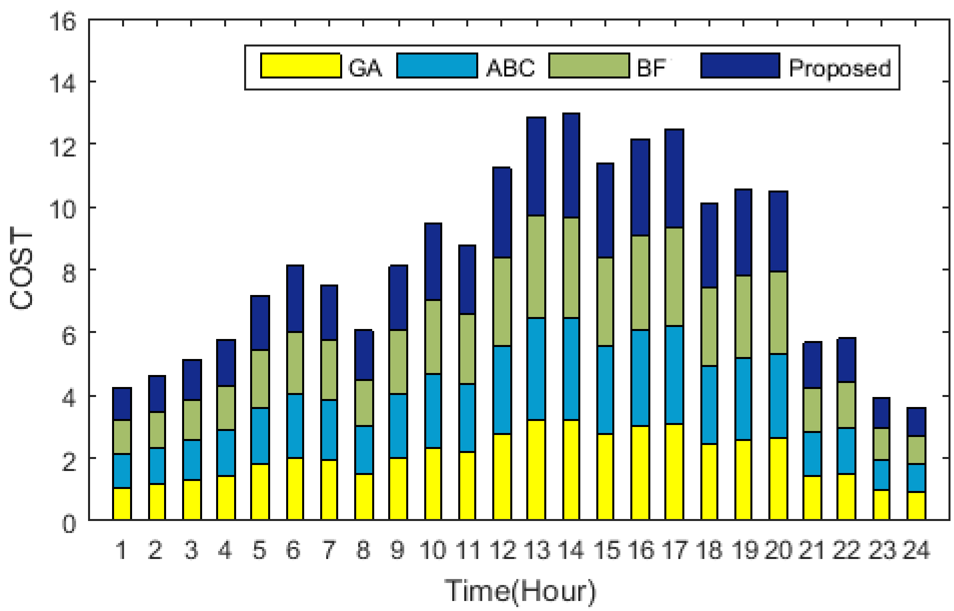


Figure 5.46: Comparison Analysis of Cost function

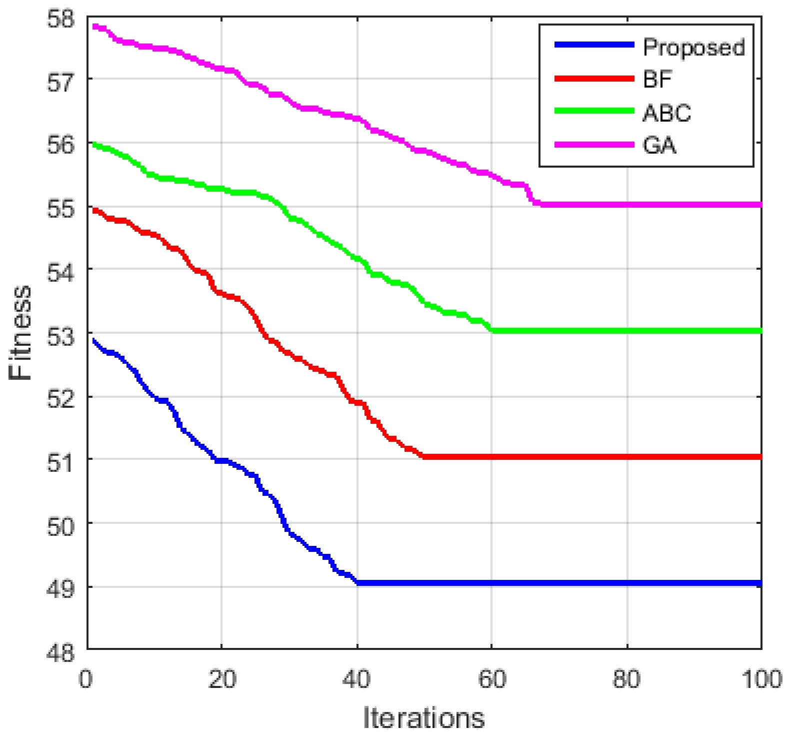


Figure 5.47: Convergence Analysis graph

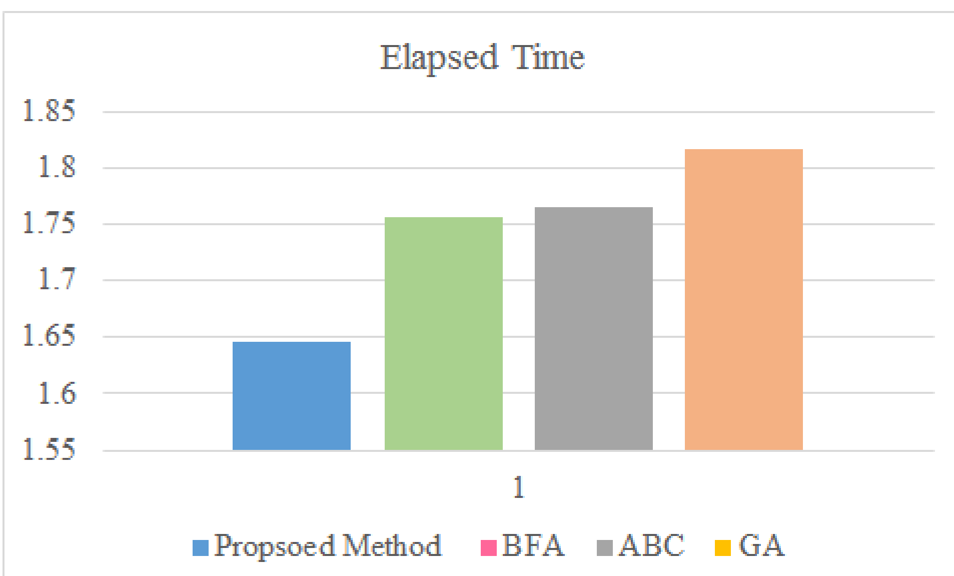


Figure 5.48: Comparison Analysis of Elapsed Time in sec

In the 24 hour, the ES is perceived in consistent power utilization, cost of MG. In peak hour, the maximal power use of MG is about 75% in 85% of time interval, which stored extra energy compare with the other optimizing algorithms. In Figure 5.45 the bar charts linked to the cost according to PV, WT, MT and charging as well as discharging of battery are displayed. In Figure. 5.45(c), maximum time period, of the ES is operated in charging mode. The charging periods are mostly focused in 1to 11 hour time. In rest of the time, ES is frequently discharged. Lastly, the average cost attained through the proposed method is the lowest compare with GA, ABC and BFA methods. The, optimizing techniques provides lower costs compare to the conventional EMS with comparing the performance of the proposed method with the other methods. Additionally, the value of objective functions of the proposed approach is actually nearby reference values. Then the convergence analysis of the proposed approach is determined and compared with the other methods. It depicts the proposed approach is attained lesser cost of MG when compared to other approaches. Comparison analysis of cost function is shown in Figure 5.46. Convergence analysis graph is shown in Figure 5.47 and comparison analysis of elapsed time is shown in Figure 5.48.

(C) CASE STUDY-3c (PRESENTATION OF ANFASO APPROACH FOR OPTIMUM ENERGY MANAGEMENT OF MICRO GRID CONNECTED SYSTEM WITH ENERGY STORAGE)

Here, the MG consists of photovoltaic (PV), wind turbine, micro turbine (MT) as well as energy storage system. Here, the optimal results of the proposed method with the existing methods like GA, ABC and BFA algorithms are presented. In Table 5.16, it is portrayed the simulating data of energy sources. The system data are obtained from the data sheet [175-178].

Table 5.16: Simulating data of energy sources

Sources	Minimal	Maximal
PV(kW)	0.0304	5.9989
WT(kW)	0.2535	7.4600
MT(kW)	5.04757	12
Battery(kW)	-0.01420	3.83
SOC of battery (%)	46	81.04

ANALYSIS OF THE PROPOSED METHOD

The proposed method through 24 hour of periods is inspected. For identifying the effectiveness of the recommended method it is assessed and contrasted to other existing methods.

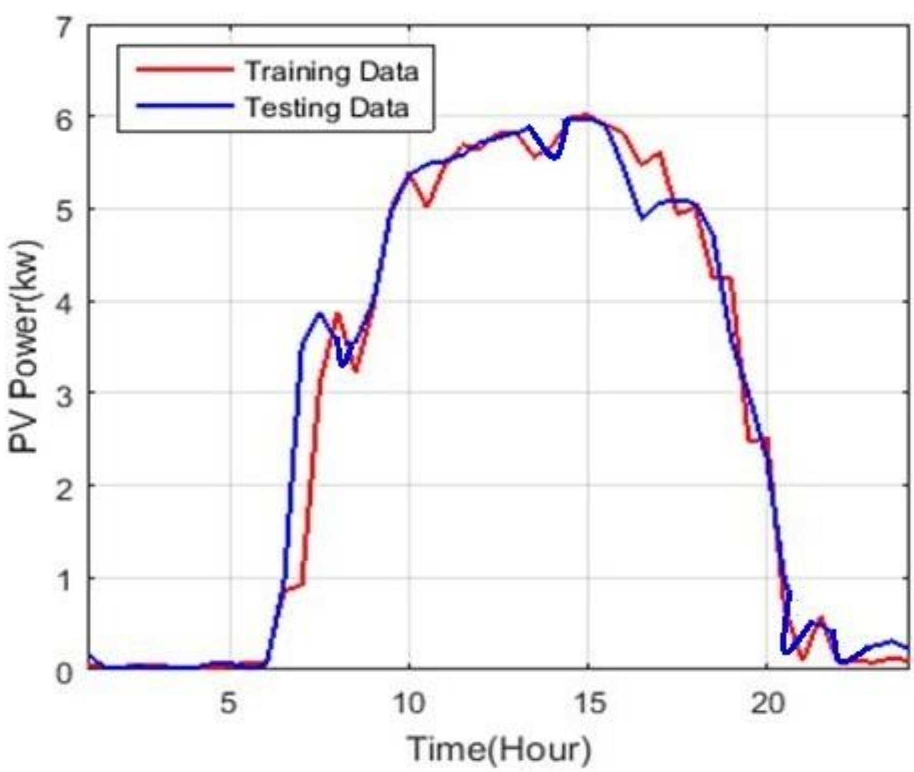


Figure: 5.49(a)

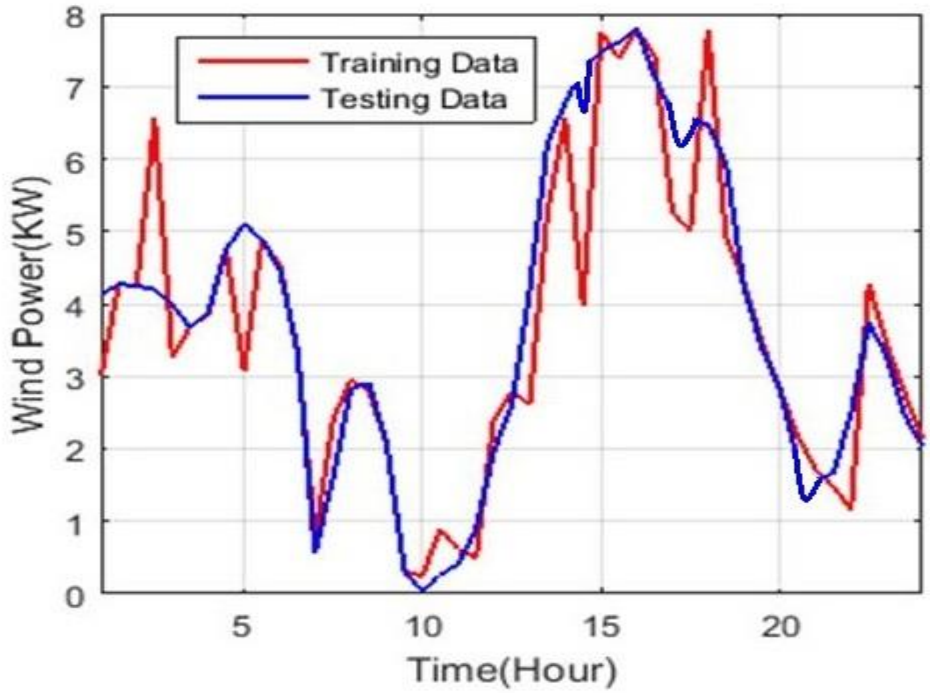


Figure: 5.49(b)

Figure 5.49: Analysis of ANFIS training and testing in (a) PV (b) Wind

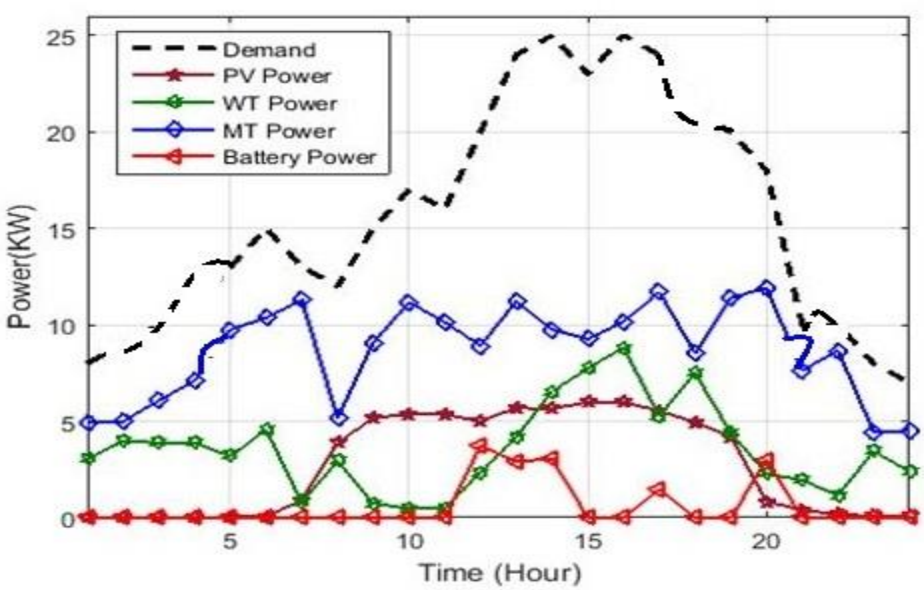


Figure. 5.50: Analysis of Demand Vs PV, WT, MT and Battery power using proposed method

In Figure 5.49, ANFIS is used to analyze the data in the training and testing period. From their performance, the error value is evaluated which is used to prove the effectiveness of ANFIS and obtained optimal results. In Figure 5.50, the maximum utilization of MT, WT, PV and battery is analyzed based on their demand values.

a) ANALYSIS OF COST

In order to manage the MG system, operational cost is demonstrated to utilize RES and battery under charging as well as discharging mode in 24 hour time. In Figure 5.51, it depicts the cost analysis of proposed method with existing methods. It is seen from; total MG cost is high in all existing methods. The BS is working in charging mode in interval ranges as of 1 to 12 hour time. The rest of the duration the BS is normally discharging. The overall cost is extremely reduced by proposed method on compare with other methods like ABC, GA and BFO. The Overall graph of cost comparison is displayed in Figure 5.52.

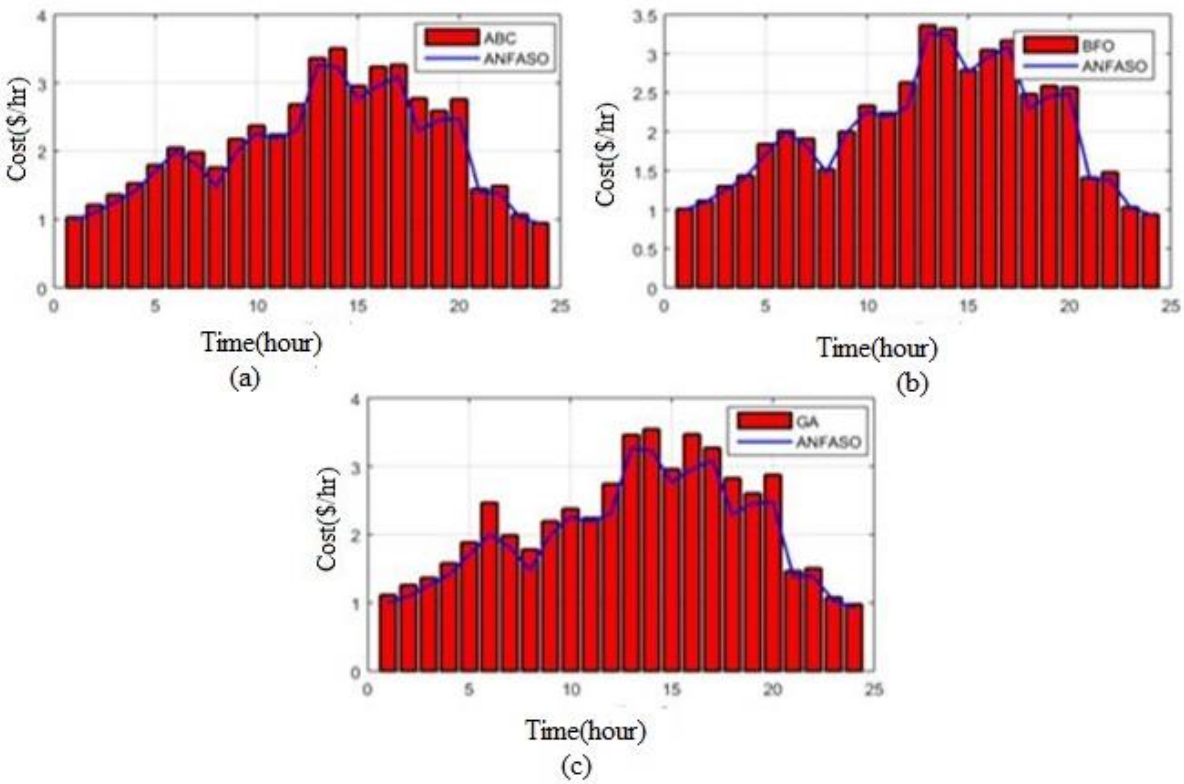


Figure 5.51: Cost analysis of proposed method with the existing methods (a) ABC-ANFASO (b) BFO-ANFASO (c) GA-ANFASO

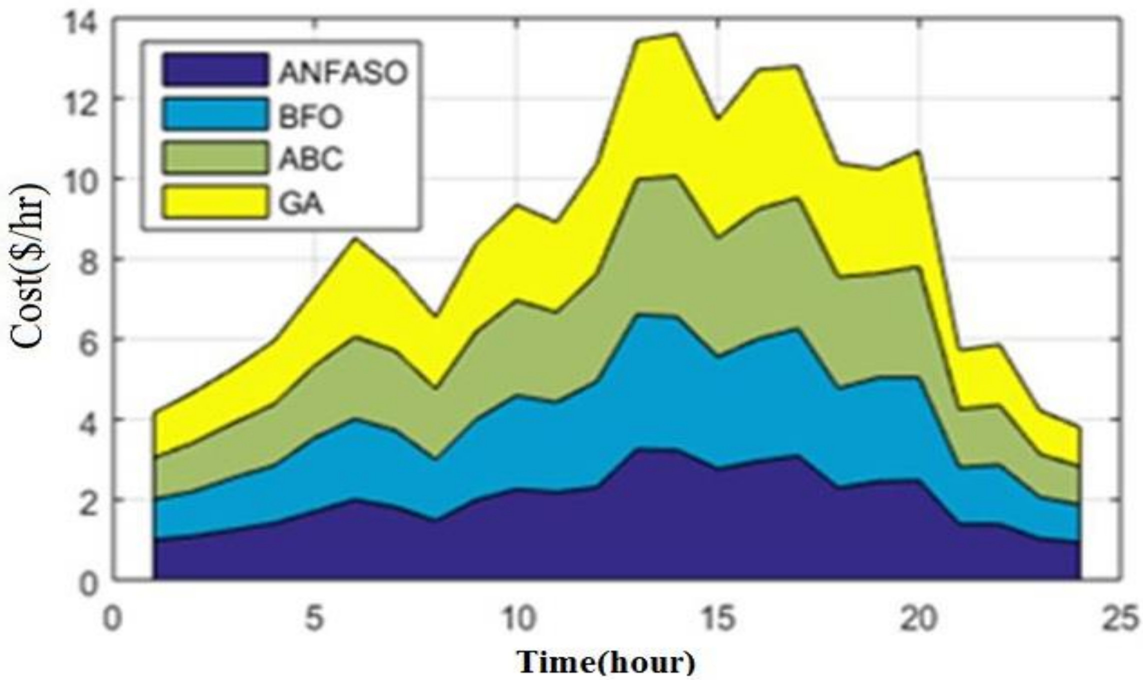


Figure 5.52: Analysis of cost ($/h) comparison of proposed with existing methods

b) EVALUATION OF SOC

Battery power is used in mode of discharging at time 12 to 16 hour. For charging BS the power is required and it is provided by MT. Thus, SOC is reached to 70% toward the end of this time interval. During the remainder of the system the capacity for providing the loads is additionally expanded when the SOC gets increased. Due the shortage of power and to providing it, BS is assessed for the rest of the timeframe. Under the charging mode the proposed method is used while it is worked and continues to achieve the SOC. So for acquiring the optimum outputs, the proposed method is utilized and compared with the existing methods. Utilizing the proposed method and the other methods the SOC of the system is appeared in Figure 5.53. The comparison analysis of SOC of battery with proposed and existing techniques is delineated in Figure 5.54.

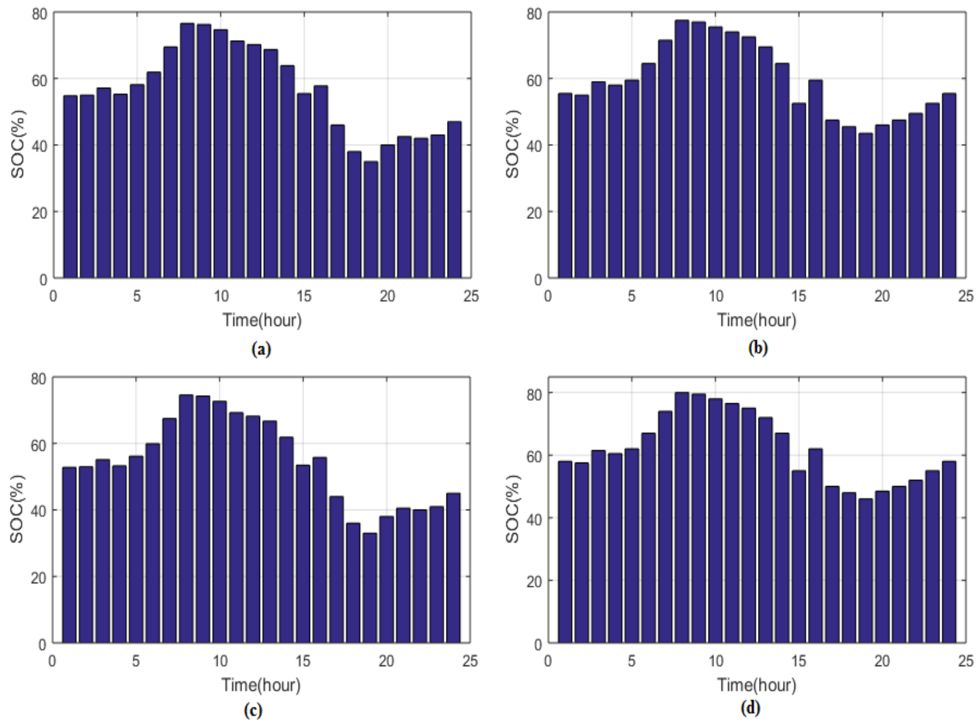


Figure 5.53: SOC analysis of (a) ABC (b) BFO (c) GA (d) proposed methods

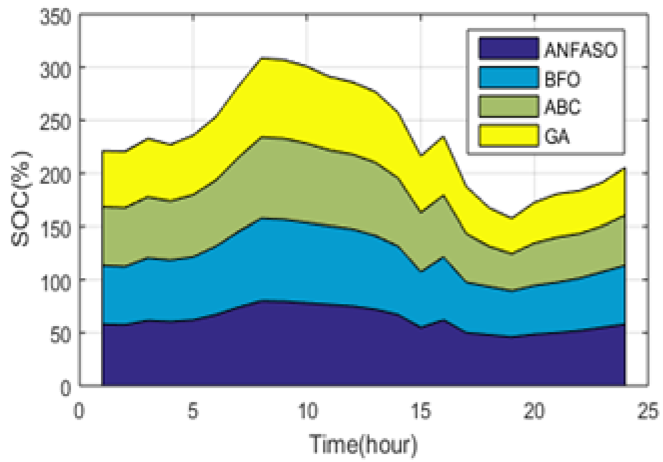


Figure 5.54: Comparison of SOC analysis of proposed with the existing methods

c) ANALYSIS OF BATTERY STORAGE (BS) POWER

In 1 to 12 hour of time the battery is in charging mode, which is perceived after evaluating battery power. The discharging operational mode, maximal battery power is assessed as of 13 to 16 hour of time period. Battery power by proposed method is appeared in Figure 5.55.

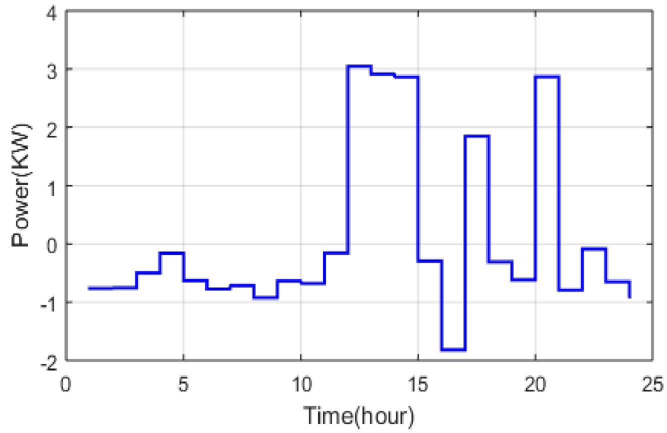


Figure 5.55: Battery power generated by the proposed method

d) ANALYSIS OF MT POWER

The part of required power is supplied by MT in the discharging mode of battery operation. In Figure 5.56, the power of MT by the proposed method is shown below.

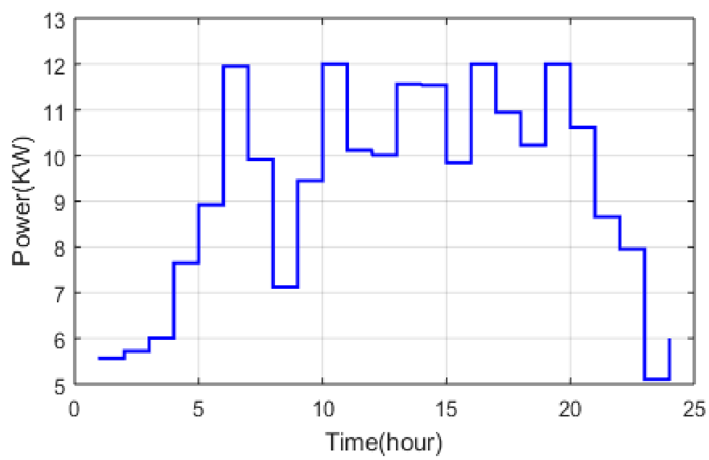


Figure 5.56: MT power generated by the proposed method

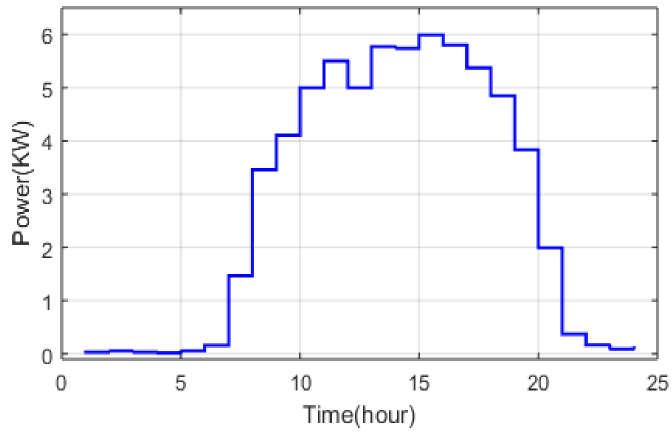


Figure 5.57: PV power generated by the proposed method

e) EVALUATION OF PHOTOVOLTAIC (PV) POWER

The maximal PV power are produced at the peak hours of time t= 8 as 20 hour. The generating power of PV is examined using the proposed method which is shown in Figure 5.57. PV can consume maximum power as 3.5 kW and in peak time during t=8.5 hour it is extended to 6 kW and then the power is decreases gradually and attains of 0.1 kW.

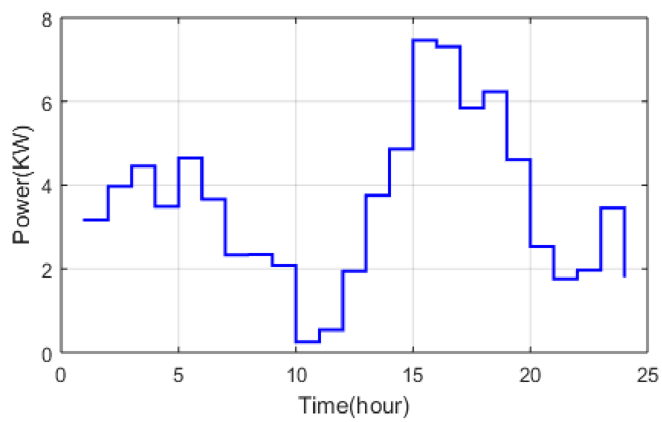


Figure 5.58: WT power generated by the recommended technique

f) ANALYSIS OF WIND TURBINE (WT) POWER

In case of WT power, the maximal power attained mainly depends on wind speed. In Figure 5.58, during time t= 15 to 20 hour, maximal power is produced by utilizing the recommended approach. The generating power is decreased from 4.2 kW to 2 kW during the time t= 5 to 10 hour. After that the power is increased up to 7.8 kW. During the time t= 11 to 15 hour. After the peak hours again power reaches to 2 kW in *t*= 16 to 24 hour of time.

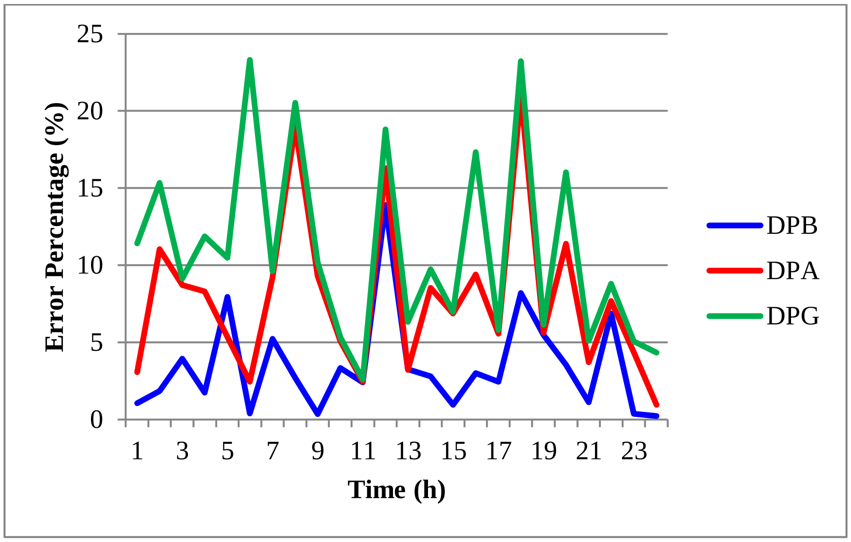


Figure 5.59: Percentage deviation error of proposed with existing methods

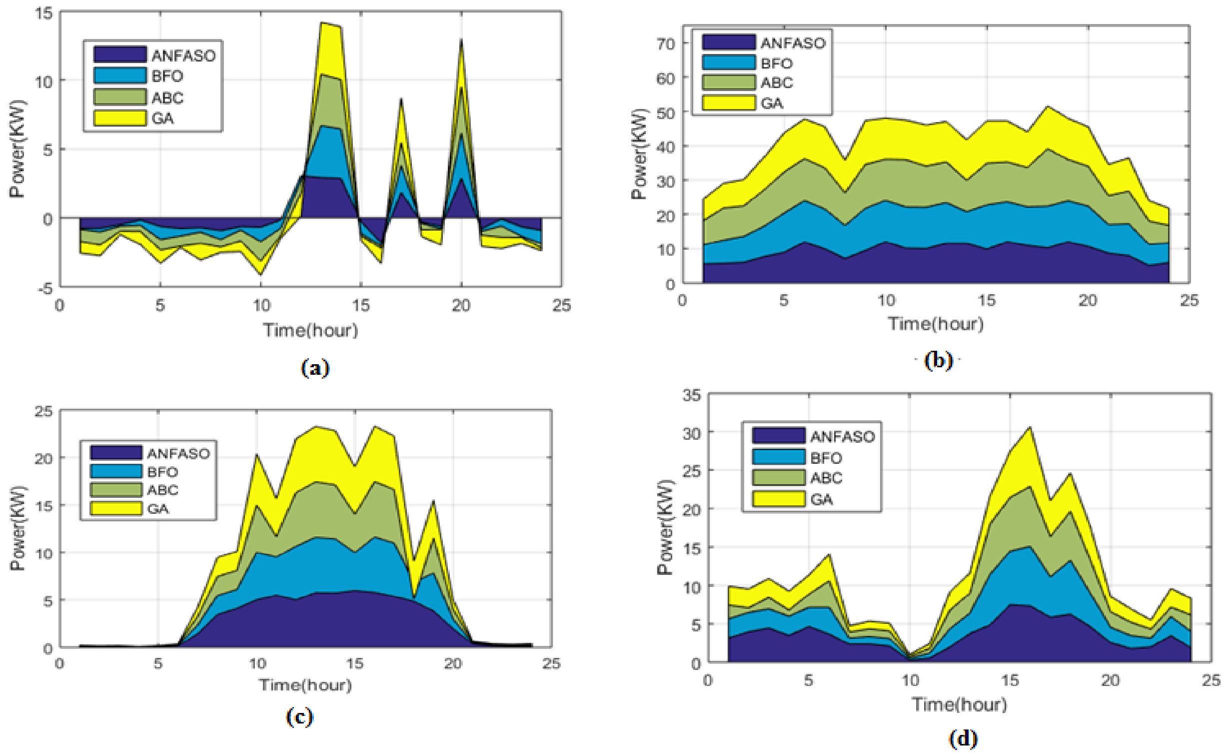


Figure 5.60: Comparison analysis of power of proposed method with existing methods for (a) Battery (b) MT (c) PV (d) WT

Table 5.17: Comparison Analysis of elapsed time of proposed with the existing methods

Solution Techniques	Time in seconds
ABC	37.11
BFA	36.95
GA	38.07
Proposed	36.46

Table 5.18: Statistical Analysis of Market Clearing price of proposed method with the existing methods

Market Clearing Charge (%)			
Methods	**Mean**	**Median**	**Std. deviation**
ABC	2.151	2.115	0.799
BFA	2.065	2.005	0.768
GA	2.211	2.221	0.818
Proposed	1.991	1.998	0.735

In Table 5.17, the elapsing times are evaluated and compared with the existing methods to validate the proposed method. It is shown in table that the proposed method has less computational time with respect to other methods. The market clearing charge of the proposed method is examined with existing methods in order to validate the proposed method. In Table 5.18, the statistical analysis of the proposed method in terms of market clearing charge is ported.

Mean, median and standard deviation of the proposed method is 1.991, 1.998 as well as 0.735 which is smaller than the existing methods. In Figure 5.59, the deviation error of proposed method utilize deviation percentage error with BFA (DPB),proposed method utilize deviation percentage error with ABC (DPA), proposed method utilize deviation percentage with GA (DGA) methods are designed. Since the deviation percentages are greater in certain time frame, the entire cost of the generating unit is reduced through the proposed method. The separate power analysis of the proposed with the existing methods is represented in Figure 5.60.

5.2.4. CASE STUDY-4

(A) CASE STUDY-4(a) (A HYBRID RFCRO METHOD FOR ENERGY MANAGEMENT OF GRID CONNECTED MG)

The system data of this model are obtained from the data sheet [175- 178].

Here, the random forest based coral reefs optimization (RFCRO) method is executed on MATLAB/Simulink platform. For checking the efficiency of proposed method, the output power of PV, Wind and Battery is evaluated. Through various working modes along with its occurrences, the system is screened to check its efficiency. Here, the simulating outcomes of the proposed methods are assessed. The energy related assessment of PV, WT, MT and Battery is presented in Figure 5.61. The peak power is produced up to 6 kW in subplot 5.61(a), in the time as of 0-15 hour. The RFCRO is utilized to retain the ability of proposed method. The subplot 5.61(b) depicts WTs individual ability. The proposed method produces the peak WT energy (4.5 kW) in 0-5 hour of time. The subplot 5.61(c) depicts MT's individual strength. The interval time as of (0-25 hour), the RFCFA stored the maximal power (8.5 kW). In Figure 5.61(d), it demonstrates the chart of battery power with respect to time. The battery is charging at the extended period of (0.7 kW), 0-24 hour of interval time. During discharging of battery, the power is extended up to (0.4 kW), in 0-23 hour of interval time. In Figure 5.62, it depicts power comparison of RFCRO and existing technique vs. time. Power comparison of PV, wind, grid, MT and ESS are demonstrated in Figure 5.62. Here, the power is shown indiscrete form at 10 sec of time instant at the power instance of 11 kW. During the 1-24 hour period of time, the maximal generating power is (11 kW). The power is generated through proposed method with respect to the other methods. In this chart, the time in hour is represented at x-axis and power in kW at y-axis.

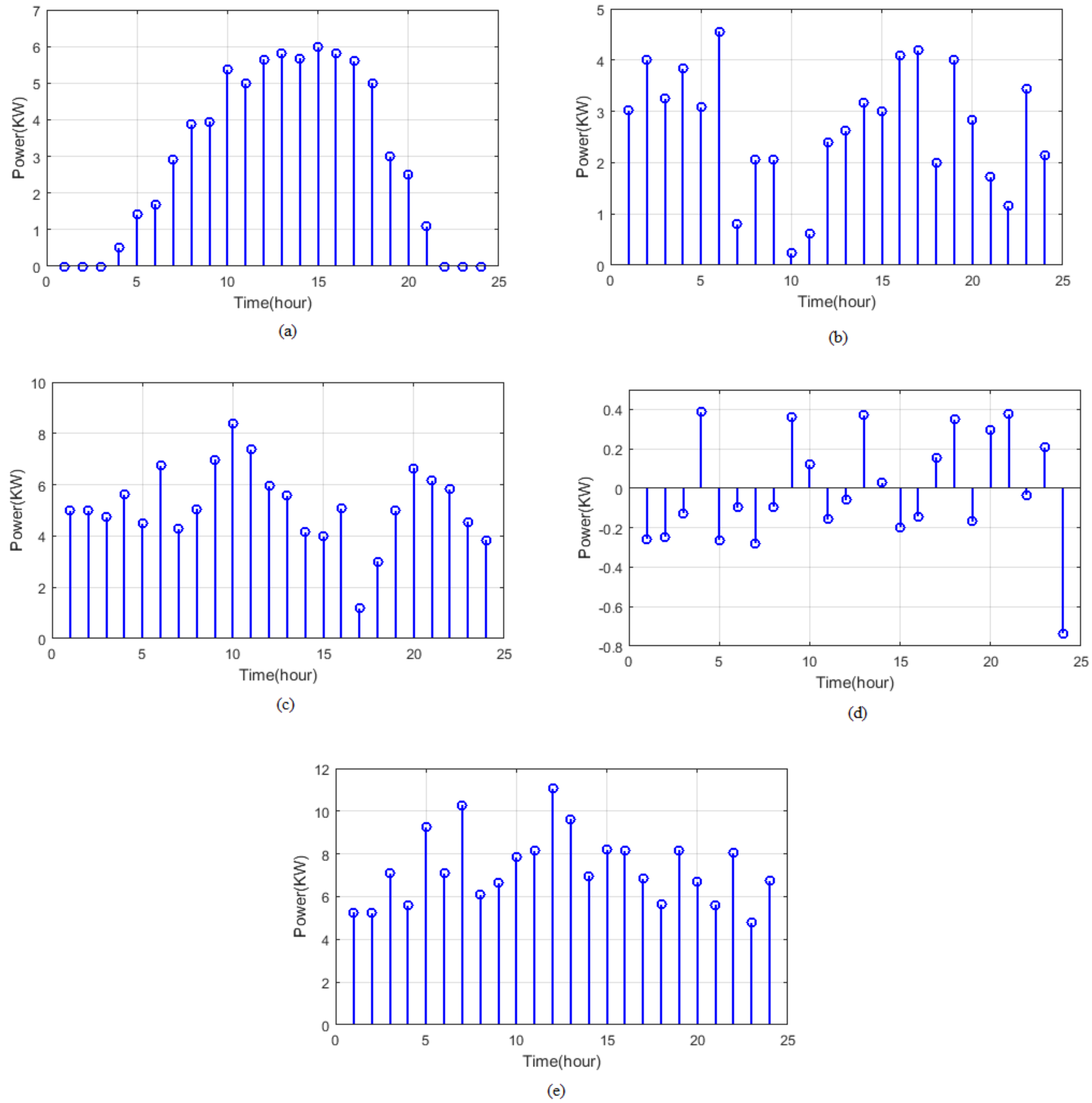


Figure 5.61: Analysis of Power of (a) PV (b) WT (c) MT (d) Battery (e) Grid

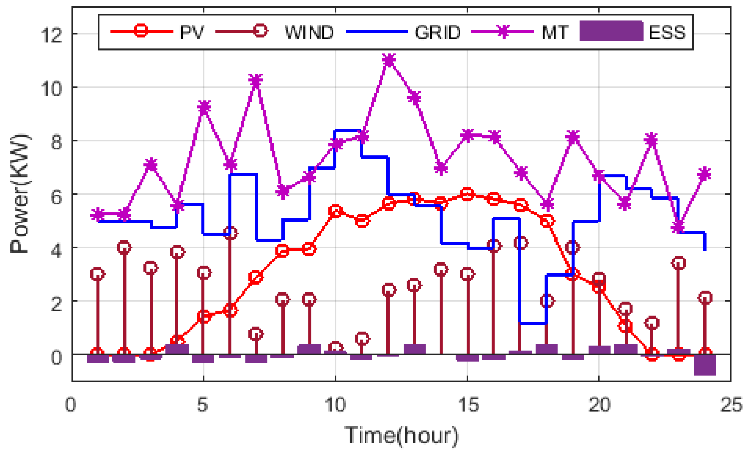


Figure 5.62: Power comparison of proposed method

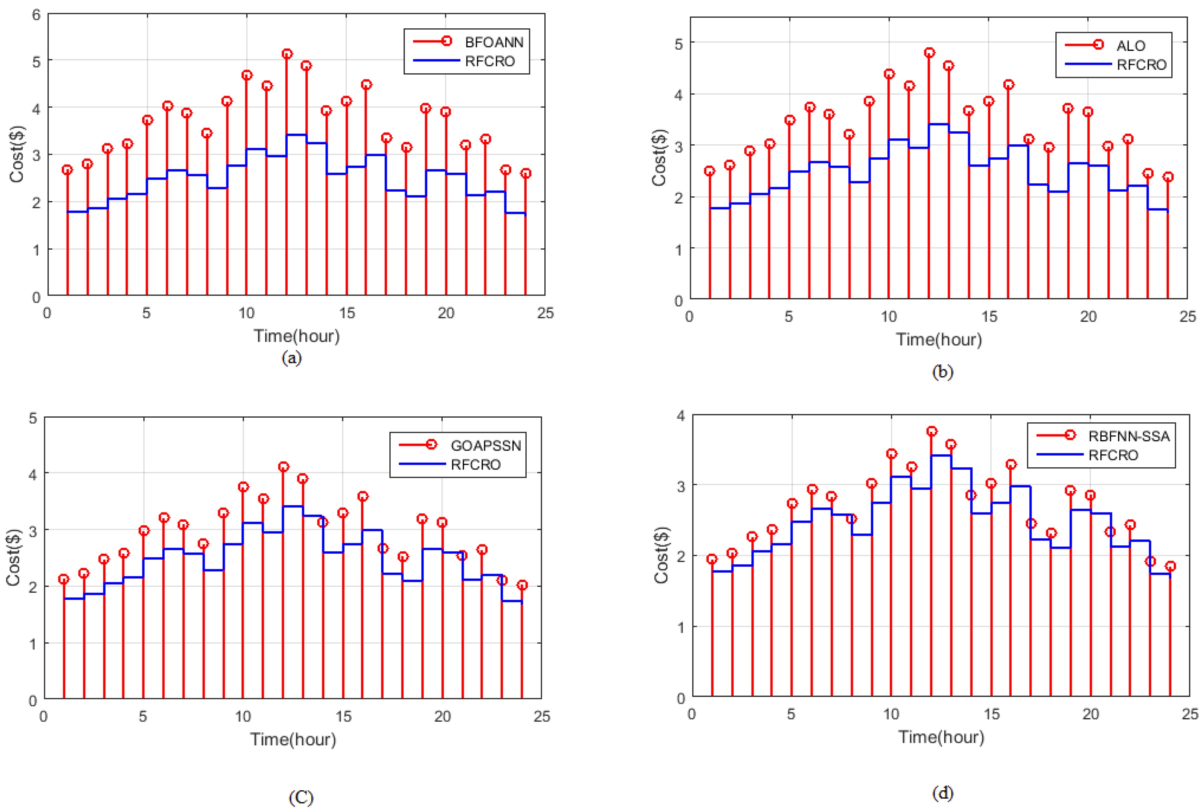


Figure 5.63: Cost comparison of (a) BFOANN and proposed (b) ALO and proposed (c) GOAPSSN and proposed (d) RBFNN-SSA and proposed

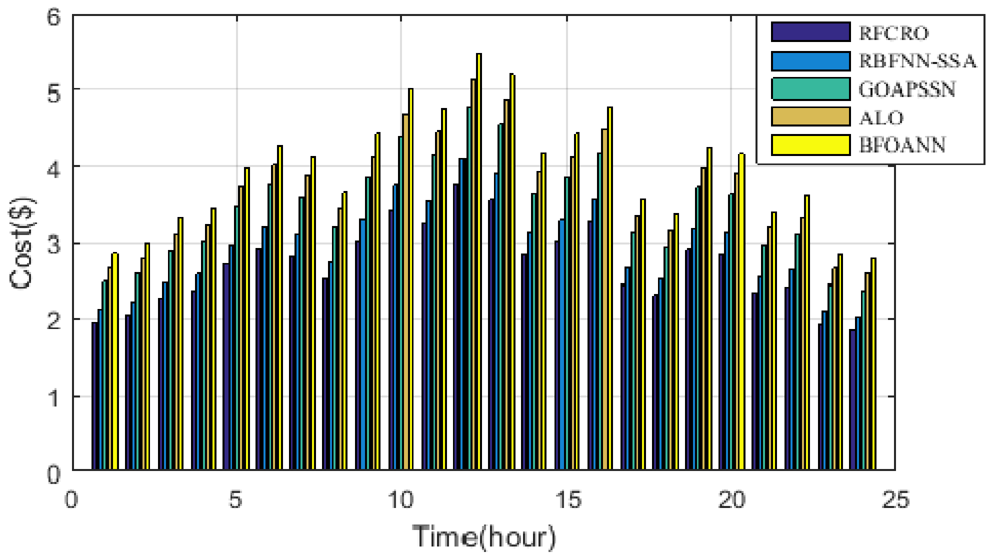


Figure 5.64: Cost comparison of proposed and existing methods

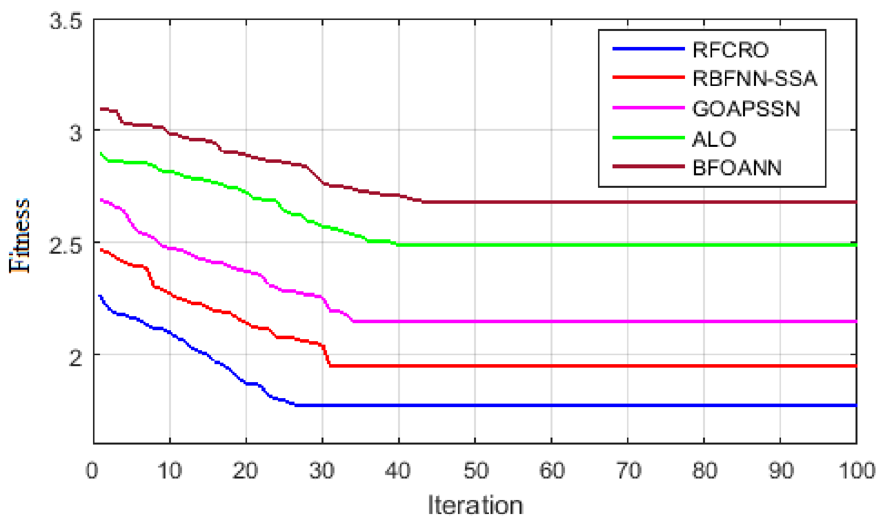


Figure 5.65: Fitness comparison ($/h)

In Figure 5.63, it depicts the cost comparison of proposed and existing techniques. In subplot 5.63(a), the maximum cost is generated at 5 sec, at 1-24 hour of time period. Here, for maintaining the cost, the proposed with existing method is utilized with Bacterial Foraging Optimization Algorithm-Artificial Neural Network (BFOANN) method. In subplot 5.63(b) the maximum cost is produced at (4.7 hour), in x-axis time interval of 0-24 hour. The current methodology is used in this subplot with ALO method. The cost is at Y-axis along time in X-axis. In subplot 5.63(c), it demonstrates the maximum generated cost of 4.1hour in 24hour of time period with the existing and Grasshopper Optimization Algorithm and partical swarm optimization with Artificial Neural Network (GOAPSSN) method. In subplot 5.63(d), the maximal cost is produced at (3.9 hour) in 1-24 hour of interval period with proposed and the existing method of Radial Basis Function Neural Network- Squirrel Search Algorithm (RBFNN-SSA). In Figure 5.64, it demonstrates the cost comparison of proposed and existing methods. In this method the maximum cost is generated at 1-24 hour of time period and the cost is extended at (5.5 hour). For maintaining the cost, the proposed RFCRO method is utilized. The existing techniques utilized are RBFNN-SSA, GOAPSSN, ALO, and BFOANN. In Figure 5.70, it demonstrates the fitness comparison. Here the BFOANN method converged in 45 range of iteration; ALO method converged at 40 range of iteration; GOAPSSN method converged at 35 of iteration range; RBFNN-SSA method converged at 31 of iteration range. But the proposed technique meets rapidly at 28 of iteration range and in Figure 5.65 the graph finally depicts that the proposed method is easily converged than existing techniques.

(B) CASE STUDY-4(b) (SMART ENERGY MANAGEMENT FOR OPTIMUM ECONOMIC OPERATION IN GRID-CONNECTED HYBRID POWER SYSTEM BY RBFNN-SSA METHOD.

Here, the MG consists of photovoltaic (PV), wind turbine, micro turbine (MT) as well as energy storage system. Here, the simulation outcome of the Radial Basis Function Neural Network-Squirrel Search Algorithm (RBFNN-SSA) is designated, where, RBFNN-SSA method is implemented to maximize use of all energy sources and reduce the operating costs. It is implemented on the MATLAB / Simulink platform and the proficiency are evaluated by RBFNN-SSA techniques with existing methods.

PERFORMANCE ANALYSIS OF SOURCES POWER

In Figure 5.66, it illustrates the performance analysis of energy source like PV, WT, MT, battery and grid utilizing RBFNN-SSA method. In Figure 5.66 (a-e), it demonstrates the WT, PV, MT, battery power values in 24 hour time by the RBFNN-SSA method. In Figure 5.66 (a), it illustrates the PV power vs. time. Here, x-axis is drawn at 24 hour of time interval and the y-axis is drawn at power in kW. Initially, PV power produces 0 kW in the absence of the sun. In 5 to 22 hour time PV power produces a maximum of 6 kW.

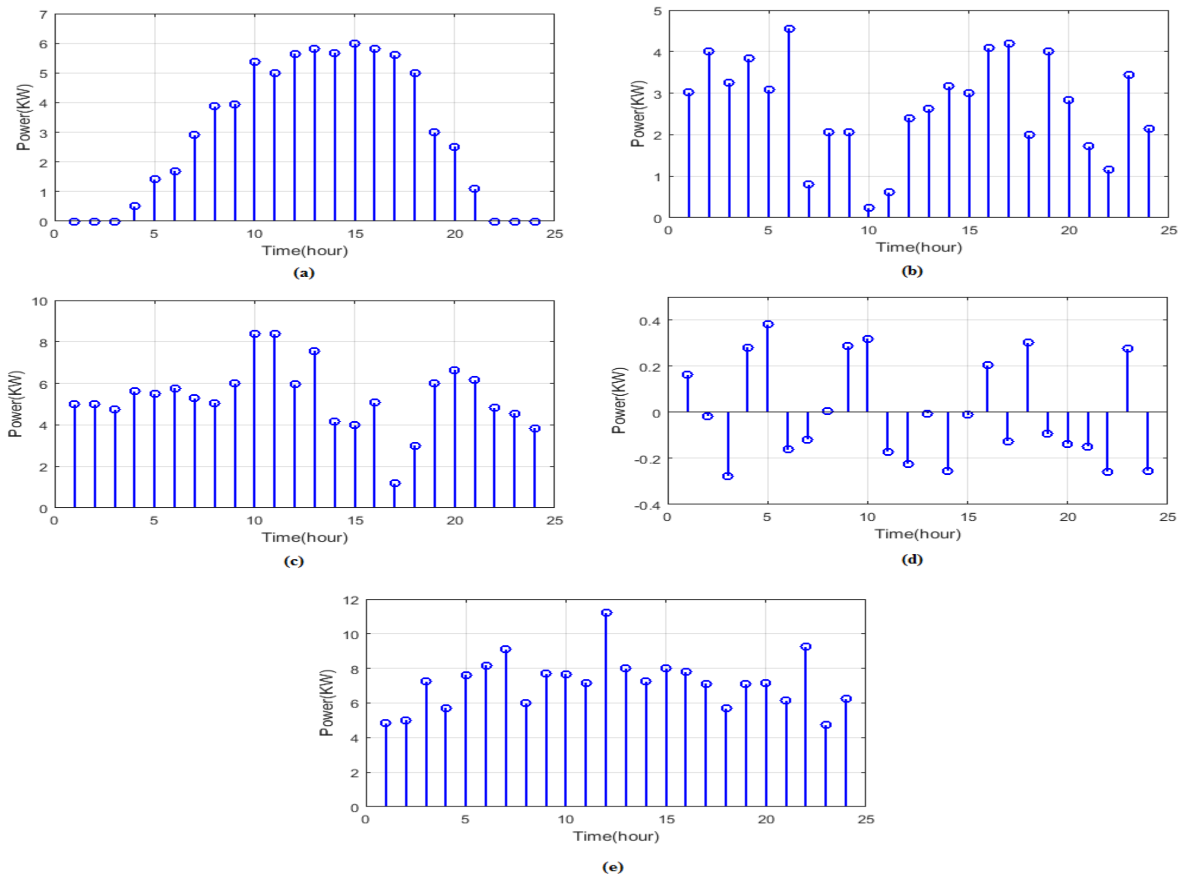


Figure 5.66: Power performance of (a) PV (b) WT (c) MT (d) Battery (e) Grid

In Figure 5.66 (b), it illustrates WT power performance over time. Here, the generating power by the WT is 4.7 kW in an instant of 7hrs of time. In Figure 5.66 (c), it shows the MT power vs. time. Here, the MT produces 8.2 kW in 10 hour of time. In Figure 5.66 (d), it shows the battery power performance over time. During the initial period, the battery is charged at 1-12 hour time period. At the instant of time, maximum SOC is reached at the operation end. At t = 12-16 hour time period the power of battery is utilized at discharging mode. However, power to the battery is provided through MT when power is needed to charge the ES. By the end of the day, the SOC reaches 70% of its maximum value and have the ability to deliver rest of the system and higher SOC loads in daily operation. Similarly, ES is rated for delivering a portion of the storage power and the remaining period, then the use of RBFNN-SSA system to activate in charging mode and constantly reaches the SOC. In Figure 5.67, it illustrates the comparison of individual power source utilizing the RBFNN-SSA and the efficiency to produce the optimal generated power is proved.

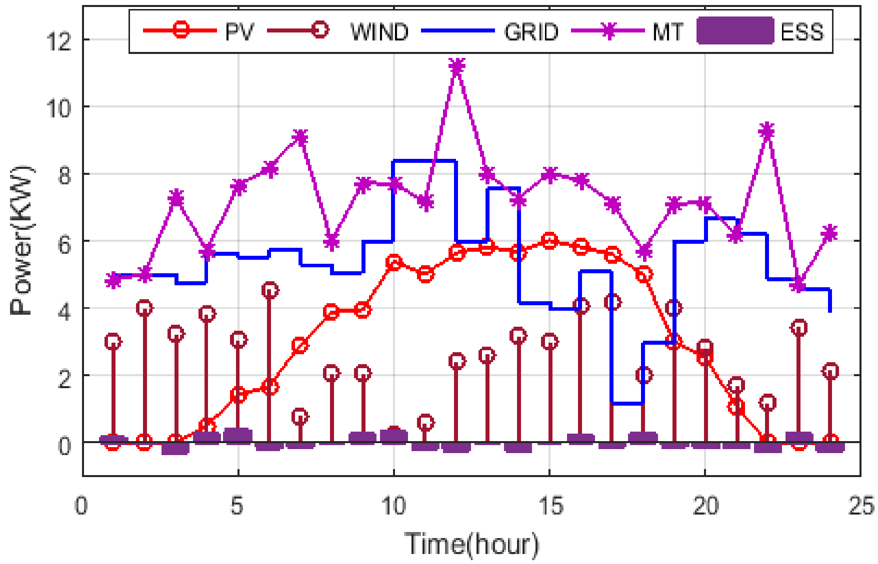


Figure 5.67: Individual power comparison of sources

COMPARISON ANALYSIS OF COST

In Figure 5.68, it represents cost analysis of Radial Basis Function Neural Network- Squirrel Search Algorithm (RBFNN-SSA) method with existing techniques. In Figure 5.68 (a), it illustrates the analysis of cost of RBFNN-SSA with Improved Artificial Bee Colony (IABC) method. Here, it illustrates for IABC reaches a high cost as of $ 5.5, while the RBFNN-SSA attains a low cost as of $ 3.8 at 13-hour. In Figure 5.68 (b), it illustrates the analysis of cost of RBFNN-SSA with Bacterial Foraging Optimization Algorithm-Artificial Neural Network (BFOANN) method. Here, BFOANN attains a maximum cost of $ 5.1, while the RBFNN-SSA attains a low cost of $ 3.8 at 13-hour. In Figure 5.68 (c), it illustrates the analysis of cost of RBFNN-SSA with ALO method. Here, the ALO technique attains a high cost of $ 4.9, while the RBFNN-SSA attains a low cost of $ 3.8 at 13-hour. In Figure 5.68 (d), it illustrates the analysis of cost of RBFNN-SSA with GOAPSNN method. Here, Grasshopper Optimization Algorithm and particle swarm optimization with Artificial Neural Network (GOAPSNN) attains a maximum cost of $ 4.1, while the RBFNN-SSA attains lesser costs $ 3.8 less at 13-hour. Figure

5.69 illustrates the cost comparison of RBFNN-SSA with the existing methods.

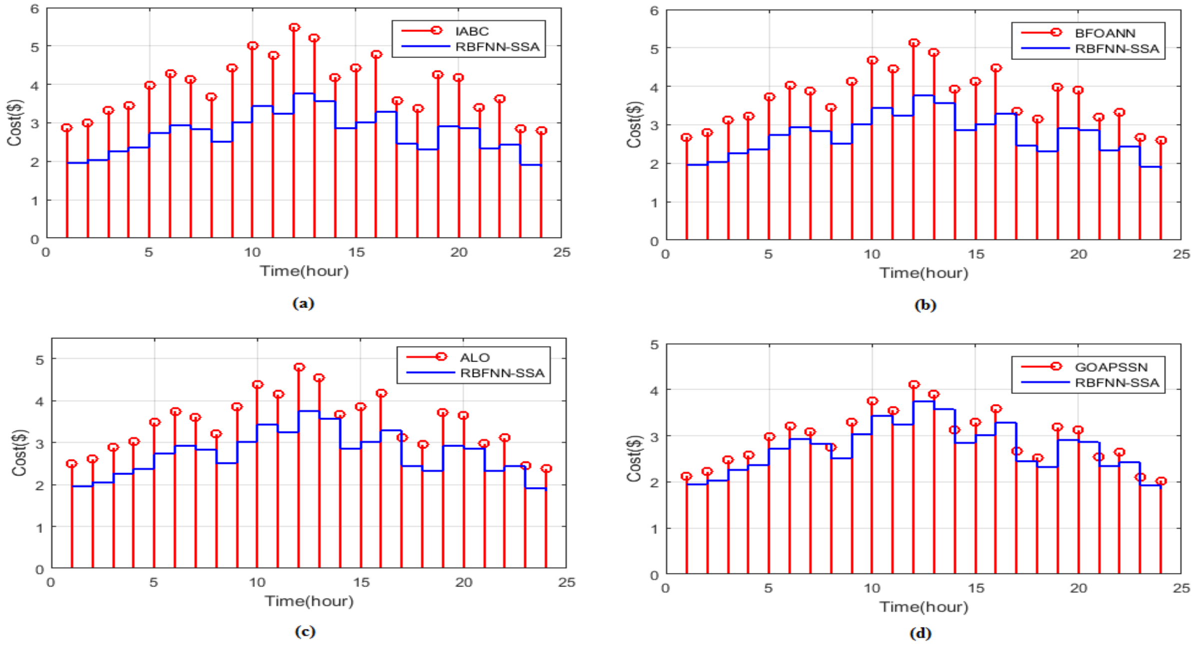


Figure 5.68: Cost analysis of (a) Proposed-IABC (b) Proposed-BFOANN (c) Proposed-ALO (d) Proposed-GOAPSNN

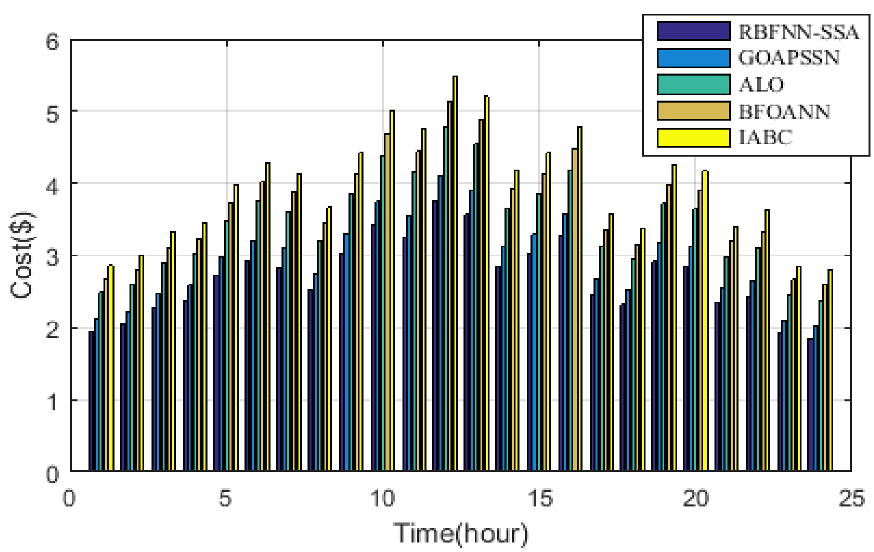


Figure 5.69: Cost comparison of RBFNN-SSA with existing methods

PERFORMANCE OF PROPOSED AND EXISTING METHODS FOR ONE YEAR

Here, the performance of proposed and existing method is estimated in one year, i.e. 12 month. In Figure 5.70, it depicts a comparison of each power in one year. The graph is formulated for several sources such as PV, WT, MT and ESS using RBFNN-SSA method for one year. In Figure 5.71, it illustrates the cost analysis of RBFNN-SSA method with other existing approaches. In Figure 5.71 (a), it illustrates the chart of IABC with RBFNN-SSA method. Here, for RBFNN-SSA method offers lesser cost at $ 1510 l, for IABC method offers cost at $ 1690. In Figure 5.71 (b), it illustrates the cost analysis of BFOANN with RBFNN-SSA method. Here, for BFOANN method offers cost at $ 1630. In Figure 5.71 (c), it illustrates the cost analysis of ALO with RBFNN-SSA method. Here, for ALO method offers cost at $ 1560. In Figure 5.71 (d), it illustrates the cost analysis of GOAPSNN with RBFNN-SSA method. Here, for GOAPSNN method offers cost at $ 1600. In Figure 5.72, it illustrates the analysis of cost between RBFNN-SSA method and existing methods over one year. In the 1^{st}month of year, the RBFNN-SSA system offers cost at $ 1660.

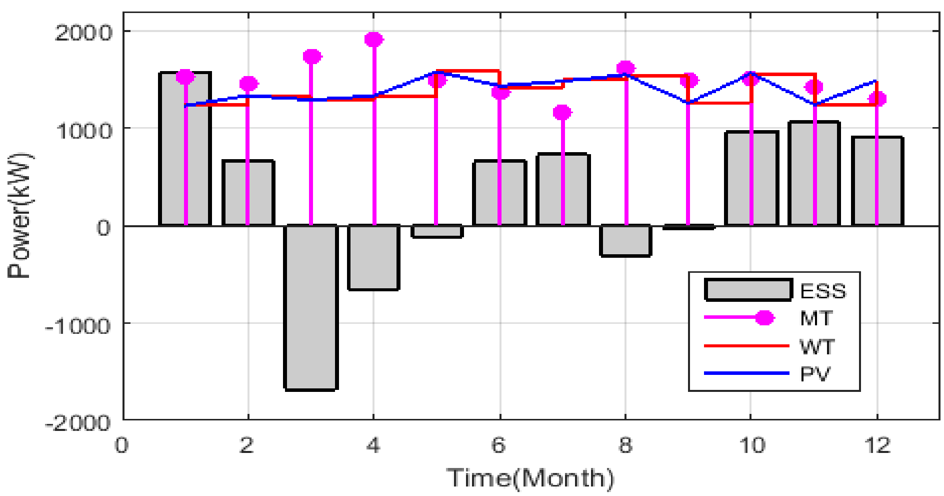


Figure 5.70: Comparison of Individual power for one year

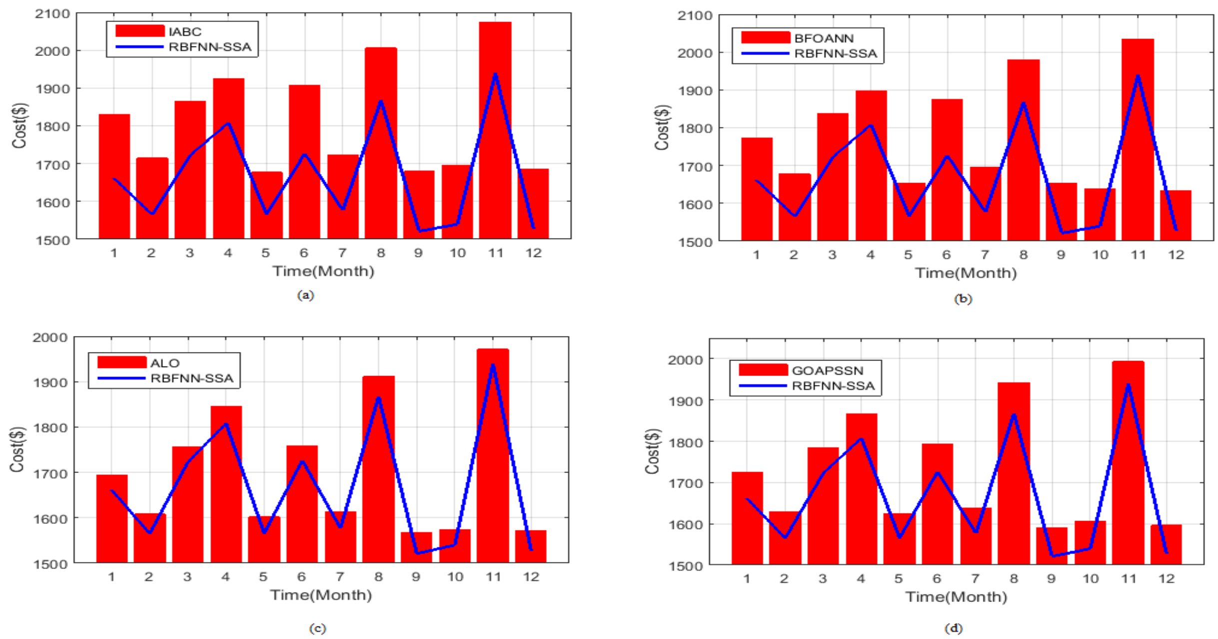


Figure 5.71: Cost analysis of (a) IABC - proposed (b) BFOANN - proposed (c) ALO - proposed (d) GOAPSNN - proposed

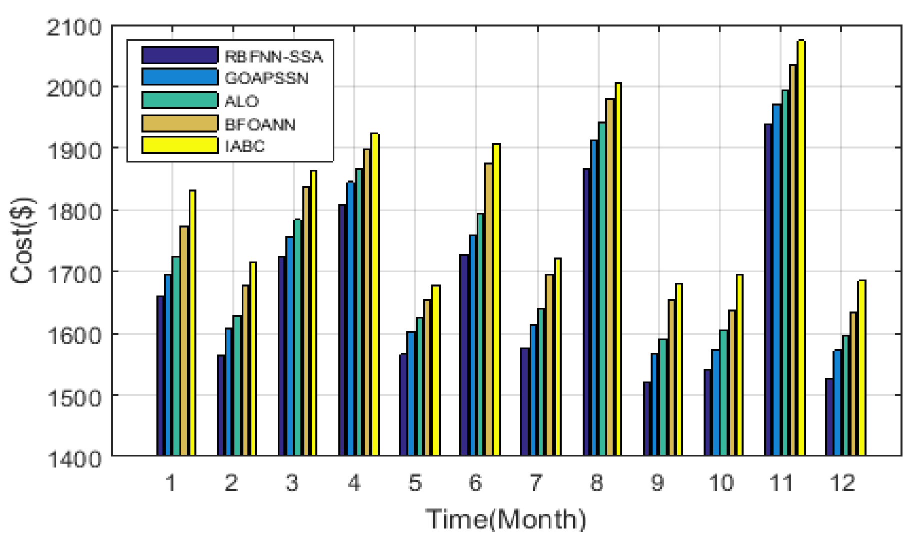


Figure 5.72: Cost comparison of RBFNN-SSA with existing methods

At the 3rd month, RBFNN-SSA system offers cost at $ 1710. At the 5th month, the RBFNN-SSA system offers cost at $ 1580. At the 7th month, the RBFNN-SSA system offers cost at $ 1580. At the 9th month, the RBFNN-SSA system offers cost at $ 1510. At the 12th month, the RBFNN-SSA system offers cost at $ 1520.

ANALYSIS OF FITNESS

In Figure 5.73, it represents fitness comparison of RBFNN-SSA with existing methods. In RBFNN-SSA method, the fitness is a cost reduction i.e. the cost calculation based on the 24 hour period. The system cost is determined for the entire period and then the optimal cost is obtained. The Cost varies with each hour, and the solution reaches a steady value (i.e. the minimum cost) in a certain number of iteration. After attaining the minimum cost value, the iteration is stopped. The IABC method offers a maximum cost value 3.3 at iteration 46, for BFOANN method offers 3.1 cost value at iteration 42, for ALO method offers 2.9 cost value at iteration 40, for GOAPSNN method offers 2.7 cost value at iteration 33 and lastly for RBFNN-SSA method offers 2.5 cost value at iteration number 31.

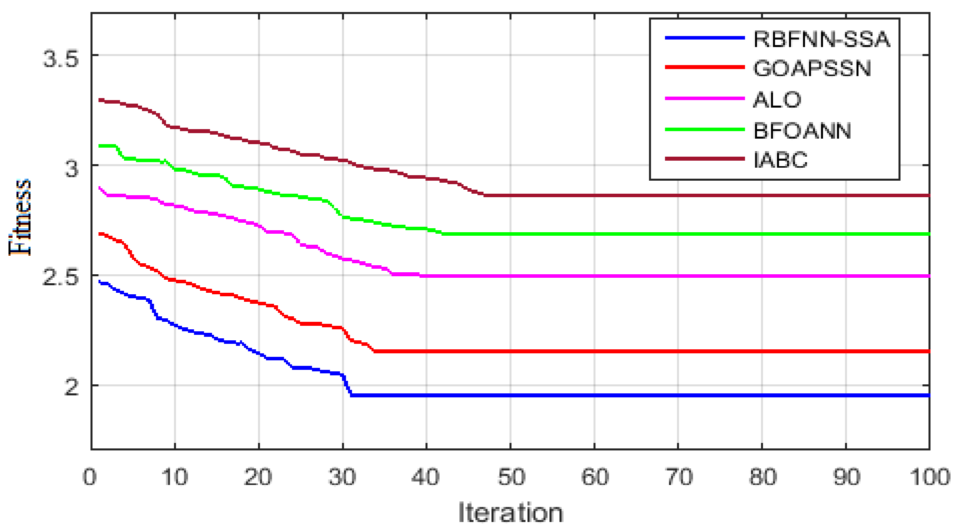


Figure 5.73: Fitness comparison ($/h)

STATISTICAL ANALYSIS

Root mean square error (RMSE), Mean bias error (MBE) and Mean absolute percentage error (MAPE) are the statistical analysis in the subgroup. The performance of RBFNN-SSA is integrated with existing techniques like IABC, BFOANN, ALO and GOAPSNN. The productivity indicator of predictive system is defined as RMSE. The normal deviation maker is defined as MBE. The precision pointer is defined as MAPE. The performance parameter along with statistical analysis is derived into 50 and 100 number of iterations.

Table 5.19: Statistical comparison of RBFNN-SSA with existing methods for 50 numbers of iterations

Model	IABC	BFOANN	ALO	GOAPSNN	Proposed
RMSE	25.3	19.8	22.4	22.537	9.2
MAPE	18.1	9.3	12.0	12.97	4.1
MBE	7.0	2.8	5.2	5.32	2.6

Table 5.20: Statistical comparison of RBFNN-SSA with existing methods for 100 numbers of iterations

Model	IABC	BFOANN	ALO	GOAPSNN	Proposed
RMSE	29.3	21.8	26.4	30.74	13.4
MAPE	18.1	7.3	14.0	15.22	3.8
MBE	10.2	5.8	8.2	6.44	5.6

Table 5.21: Statistical analysis of RBFNN-SSA with existing methods

Solution Strategies	Mean	Median	Standard Deviation
IABC	1.2144	0.9722	0.3252
BFOANN	1.1537	0.9415	0.2857
ALO	1.0642	0.9301	0.2067
GOAPSNN	1.0514	0.9212	0.2052
Proposed method	0.9681	0.9063	0.1098

Table 5.22: Elapsed time of RBFNN-SSA with existing methods

Solution Strategies	Time in sec
IABC	37.12
BFOANN	36.95
ALO	38.07
GOAPSNN	36.46
Proposed	30.14

In Table 5.19, it shows a statistical analysis with 50 numbers of iterations of proposed method with other existing methods. IABC's RMSE reaches up to 25.4, for BFOANN reaches up to 19.9, for ALO reaches up to 22.5, for GOAPSNN designates at 22.5, although it receives 9.3 for RBFNN-SSA method. The MAPE of IABC reaches up to 18.2, for BFOANN reaches up to 9.4, for ALO reaches to 12.0, for GOAPSNN reaches up to 12.9, for RBFNN-SSA reaches up to 4.2. The MBE of IABC reaches up to 7.1, for BFOANN reaches up to 2.9, for ALO reaches up to 5.1, for GOAPSNN reaches up to 5.3, then for RBFNN-SS reaches up to 2.7. In Table 5.20, it shows a statistical analysis with 100 numbers of iterations of proposed with other existing methods. The RMSE of IABC reaches up to 29.4, for BFOANN reaches up to 21.9, for ALO reaches up to 26.5, for GOAPSNN reaches up to 30.75 but for RBFNN-SSA reaches to 13.5. The MAPE for IABC attains as 18.2, for BFOANN reaches up to 7.4, for ALO reaches up to 14.0, for GOAPSNN reaches up to 15.23, but for RBFNN-SSA attains to 3.9. The IABC's MBE reaches up to 10.1 the BFOANN reaches up to 5.9; for ALO reaches up to 8.1, for GOAPSNN reaches up to 6.45, but for RBFNN-SSA attains to 5.7. In Table 5.21, it tabularizes the statistical analysis of RBFNN-SSA method with the existing methods. The mean of IABC reaches to 1.2145, for BFOANN reaches to 1.1538, for ALO reaches to1.0643, for GOAPSNN reaches to 1.0515, but for the RBFNN-SSA attains to 0.9681.The median of IABC reaches to 0.9723, for BFOANN reaches to 0.9416, for ALO reaches to 0.9302, for GOAPSNN reaches to 0.9213, but for RBFNN-SSA attains to 0.9062. The SD of IABC reaches to 0.3253, for BFOANN reaches to 0.2858, for ALO becomes up to 0.2065, for GOAPSNN attains to 0.2053, but for RBFNN-SSA becomes to 0.1099. For assessing the performance of RBFNN-SSA method, the elapsed time is estimated comparison with the existing methods shown in Table 5.22. In RBFNN-SSA method, it reaches lesser computational time with compare to the existing approaches. Lastly, the comparison results demonstrate the superiority of RBFNN-SSA method in terms of optimal energy management with the existing methods.

DISCUSSION OF OBTAINED RESULTS AND MAIN ACHIEVEMENTS

Performance of RBFNN-SSA system is better with PV, WT, MT, battery power, grid power, overall cost and fitness function with the other existing methods.

5.3. SUMMARY

In this chapter, the optimal results obtained by the corresponding optimization algorithms for every case study have been presented in details. The presented results have also been compared with other state-of-the-art meta-heuristic algorithms to check the effectiveness and superiority of the proposed algorithm. Along with this comparative study, the results have also been statistically tested to prove their robustness.

As per the results mentioned in case study 1, the CS-BAT technique seems to be superior as compared to other techniques likes online management, ABC, ABC-ABC, IABC, ABC-FA in case of different load demands of the system.

In case-study 2, a novel proposed SOGSNN algorithm has been implemented and found to be most superior compared to other meta-heuristic algorithms likes ABC, BFO & ANFASO in every scenarios and for all types of forecasted load demands of the system. The superiority and robustness of the proposed algorithm have been checked statistically.

This statistically tested the ANFASO algorithm with other meta-heuristic algorithms likes GA, ABC, BFA, has also been implemented in case study 3, where the combination of ANFIS and ASOA approach has been formulated, to reduce overall fuel cost and increase the use of RES with considering the generation cost of PV & wind power for maximum techno-economic benefits.

The optimal multi-objective problem has been solved by the proposed RBFNN-SSA algorithm and presented the optimal results in case study 4. It is seen that for forecasted load demands, the proposed algorithm can produce superior results. The obtained results are also compared with other state-of-the-art algorithms like IABC, BFOANN, ALO and GOAPSNN and it is found that the proposed RBFNN-SSA algorithm can produce better precise and hence that can produce better optimal results.

6 Conclusion and Future Scopes

6.1. CONCLUSION

Micro Grid (MG) is one of the important and needful strategies to expand the existing power system to tackle the increasing load demands. Nowadays, MG penetration becomes the prerequisite strategy for the planners due to negative environmental impacts and fuel crisis of the coal based conventional power plants, and the continuous technological advancements in the small scale generating technologies especially in the field of renewable. MG penetration can have both positive and negative impacts on the system depending on the planning strategies. The optimal use of MG systems in the existing system with proper planning strategies may leads to several technical, economical, operational and environmental benefits. So, the main aim of this research work is focused on to find the optimal energy management and control of MG units in the different network systems for getting maximum techno economic benefits initially obviously by simulation studies. Again, this can only be ascertained most effectively by novel soft-computing techniques.

The research work has been carried out in different stages and presented in form of case-studies. In case-study 1, a simple multi-objective function has been formulated to minimize the fuel cost as well as operation and maintenance cost by the optimal energy management of MG sources. Here, a hybrid ABC strategy, the IABC and CS-BAT based modeling and management of Micro grid System (MG) has been presented. The ABC algorithm is designed in two phases based on objective functions. The initial phase of ABC demonstrates that MG's optimal configuration at low fuel costs. By least cost functionality, the second phase of ABC has been achieved with minimal OM costs. At IABC, the scout bee phase has been relocated with GSA technology that promises for enhancing the search capability of scout bees. At hybrid CS-BAT here, the configuration of optimal MG is acquired by solving the proposed multi-objective function depends on load requirement. The performance of proposed system is examined with previous systems, viz online management, ABC, ABC-ABC, IABC and ABC-FA. The comparative outcomes portrays that proposed system to identify optimal identifying of parameters is the most effective technique when meeting the load requirement at the lowest fuel cost and it is more efficient than existing techniques.

In case-study 2, a novel SOGSNN algorithm has been proposed to solve the similar objective function as mentioned in the previous case-study but this time with different operating scenario of MG units with optimal load forecasting. The proposed SOGSNN method is the combined performance of GSA-ANN and SSA, hence it is named SOGSNN. The purpose of the SOGSNN method is “reduce fuel costs, reduce emissions and operating with maintenance costs, also makes optimal use of RES”. The optimization issue involves a kind of energy sources that can be performed in the MG like, photovoltaic, wind turbine, micro turbine, BESS. Control operations needs to the optimization issue to reflect few extra considerations with optimal load forecasting. The proposed hybrid technique is activated in MATLAB/Simulink platform along its proficiency is assessed utilize various current approaches. The efficacy of the SOGSNN method is tested to other exiting techniques such as ABC, BFO and ANFASO technique. The comparative result provides the proposed method is more efficient than other previous methods.

In case-study 3, the problem has been made more complex for better techno-economic analysis by considering multi objective problem formulation. The recommended hybrid technique is in terms of a combination of ANFIS and ASOA approach. The intention of the proposed technique is to reduce overall fuel cost and increase the use of RES with considering the generation cost of PV & wind power. The optimization issue involves maximum uses of energy sources that can be found in the MG like battery storage, photovoltaic, micro turbine and wind turbine sources. The control operations have been added to the optimization issue to reveal few another considerations that are mostly found in the smaller generation scheme. The proposed method is activated in MATLAB/Simulink, also their effectiveness is analyzed utilize different existing methods. From the experimental outcomes, it clearly shows that the use of optimum power generating costs and energy sources for micro grid that the optimization works best and provides the optimum power scheme for the generators after carry out the objective functions. The proposed approach is likened utilize other previous methods like GA, ABC, BFA. Furthermore, the use of the proposed technique has led to a minimization of almost 25% in the entire cost of generating power.

In the fourth case-study of the work, a novel RBFNN-SSA method has been proposed for solving the multi objective problem in order to avoid premature convergence. For maximum techno-economic benefits, the multi objective problem has been formulated in such a way that it can minimizing various objectives including yearly economic loss which includes annual capital cost, annual replacement cost, annual fuel cost, annual operation and maintenance cost as well as optimal forecasting load demand. Here, maximizing usage of MG sources and minimizing the operational cost is performed by the RBFNN-SSA method. The proposed RBFNN-SSA is implemented in MATLAB/Simulink platform and then the proficiency is assessed and tested with the exiting techniques viz IABC, BFOANN, ALO and GOAPSNN methods.

6.2. FUTURE SCOPE

- Extension of this proposed micro grid system with the introduction of additional DERs like Electrical vehicle (EV), Fly wheel, and CHP.
- Multiple MGs can be studied to investigate the effect on grid frequency.
- Biologically inspired optimization algorithms can be employed in place of FLCs for PHS and LM to optimize their operations.
- Deploying optimization techniques for load forecasting and management.
- Chattering of battery energy storage can be taken care of by operating it based on understanding the trend in the dynamic energy management systems decisions.
- Enhancing the Power capacity to next level for catering bigger community.
- Interlinking of multiple micro grids complex networks with loads.
- Minimization of entire energy consumption.
- Enhanced the reduction of environmental impact.
- Improvement of energy system consistency.
- Improvement of benefits of the network.
- Cost efficiency power infrastructure replacement.
- Enhanced incorporation of distributed and renewable energy system.
- Cost Comparative and proficient.
- Enables smart grid technology integration.
- Locally controlling power quality.

- Lessen carbon foot print with greenhouse gas emissions through rising hygienic local energy generation.
- To increases customer contribution.

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RESEARCH ARTICLE

Kallol ROY, Kamal Krishna MANDAL

Hybrid optimization algorithm for modeling and management of micro grid connected system

Abstract In this paper, a hybrid optimization algorithm is proposed for modeling and managing the micro grid (MG) system. The management of distributed energy sources with MG is a multi-objective problem which consists of wind turbine (WT), photovoltaic (PV) array, fuel cell (FC), micro turbine (MT) and diesel generator (DG). Because, perfect economic model of energy source of the MG units are needed to describe the operating cost of the output power generated, the objective of the hybrid model is to minimize the fuel cost of the MG sources such as FC, MT and DG. The problem formulation takes into consideration the optimal configuration of the MG at a minimum fuel cost, operation and maintenance costs as well as emissions reduction. Here, the hybrid algorithm is obtained as artificial bee colony (ABC) algorithm, which is used in two stages. The first stage of the ABC gets the optimal MG configuration at a minimum fuel cost for the required load demand. From the minimized fuel cost functions, the operation and maintenance cost as well as the emission is reduced using the second stage of the ABC. The proposed method is implemented in the Matlab/Simulink platform and its effectiveness is analyzed by comparing with existing techniques. The comparison demonstrates the superiority of the proposed approach and confirms its potential to solve the problem.

Keywords micro grid (MG), multi-objective function, artificial bee colony (ABC), fuel cost, operation and maintenance cost

1 Introduction

For subsequent generation, the distributed power generation system is probably an important electric power supply system [1]. The requirement for more flexible electrical systems, changing regulatory and economic scenarios, energy savings and environmental brunt are offering momentum to the enhancement of micro grids (MGs) [2]. A micro grid (MG) is an element of a power system which includes one or more diesel generator (DG) units efficient of performing either in parallel with or self-governing from a large service grid, while presenting persistent power to multiple loads and end-users [3–5]. The consumption of small-modular residential or commercial units for onsite service is one of the important applications of the MG units [6].

A MG contains a low-voltage distribution network with allocated energy resources that can work either interconnected or remote from the foremost allocation grid as a controlled entity [7–9]. Distributed energy resource (DER) is a method to enhance the power quality of the distribution system [10]. For working out several matters facing electric utilities, DER is applied [11]. The basic idea of DER is to suggest for a more robust transmission system, constraints decreased, and energy efficiency increased, power quality enhanced and developed local dependability [12]. More than a few ideas of the MG systems have been suggested and learned since they have an opportunity to present high quality and/or economical electric power [13].

MGs may differ in sizes [14]. The administration of the MG units requires an accurate economic model to describe the working cost [15]. For the MG operation, special protection, control and energy management systems must be intended so as to make specific dependable, safe and inexpensive function in either grid-connected or stand-alone mode [16]. The setback of energy management in micro grids consists of the determination of the optimal (or near optimal) unit commitment (UC) and the transmission of the obtainable generators so that certain chosen purposes are accomplished [17]. Therefore, to reduce the operating costs to the minimum, optimization devices are needed.

The study devices must model the system with its three

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Kallol ROY (✉), Kamal Krishna MANDAL
Faculty of Electrical Engineering, University Institute of Technology, University of Burdwan, Burdwan 713104, India
E-mail: kallolroy0181@gmail.com

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Modeling and managing of micro grid connected system using Improved Artificial Bee Colony algorithm

Kallol Roy [a,*,1], Kamal Krishna Mandal [b,1], Atis Chandra Mandal [c,2]

[a] Department of Electrical Engineering, University Institute of Technology, Burdwan University, India
[b] Department of Power Engineering, Jadavpur University, Kolkata 700098, India
[c] Department of Physics, Burdwan University, India

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ABSTRACT

This paper introduces an Improved Artificial Bee Colony algorithm for modeling and managing Micro Grid (MG) connected system. IABC differs from ABC because of its inclusion of Gravitational search algorithm (GSA) in the scout bee phase. Hence, the scout bee phase is substantially improved as the gravitational constant of GSA increases searching accuracy. As already ABC works with memory, IABC tackles drawbacks occur due to memory-less search entertained by GSA. In the proposed technique, optimal MG's configuration is determined based on load demand by reducing the fuel cost, emission factors, operating and maintenance cost. By using the input of MG's configuration such as Wind Turbine (WT), Photovoltaic array (PV), Fuel Cell (FC), Micro Turbine (MT), Diesel Generator (DG) and battery storage and the corresponding cost functions, the proposed method achieves the required multi-objective function. The performance of the proposed method is examined by comparing with other techniques that are recently reported in the literature. The comparison results demonstrate the superiority of the proposed technique and confirm its potential to solve the problem.

Introduction

For the upcoming generation, Distributed power generation systems are usually supposed to become a crucial electric power supply system [1]. The necessity with regard to more elastic electrical systems, transforming regulatory and also economical predicaments, energy savings and also environmental friendly impact are providing traction for the enhancement associated with Micro-Grids (MGs) [2]. The MG is a part of a power system which in turn contains a number of DG devices effective at working often within parallel using or self-governing from the large service grid, and will be offering incessant power to several loads and also end-users [3–5]. The intake of small-modular residential or industrial devices with regard to onsite assistance is just about the major apps on the MG devices [6].

Any micro grid incorporates a low-voltage submission system along with allocated power resources (DERs) that may perform either interrelated or maybe rural through the main allocation grid like a controlled entity [7–9]. Distributed energy resource (DER) is usually an approach to increase the submission system's a higher level power quality [10]. For working out numerous concerns facing electrics utilities, DER is usually utilized [11]. The fundamental perception of DER should be to provide for the more robust transmission process, restrictions decreased, energy performance improved, electric power quality improved along with boost local stability [12]. Many tips regarding micro grid system are recommended along with figured out simply because possess enable to provide premium quality and/or economical electric power [13].

MGs might consist of lots of different sizes along with types [5]. The particular administration from the MG products needs an exact economical model to explain the actual working cost [14]. To the micro grid operations, Unique protection, control along with energy management systems must be prepared so as to ensure that dependable, safe and inexpensive function along with affordable operate throughout sometimes grid-connected or perhaps stand-alone mode [15]. The particular problem of energy management throughout micro grids consists about finding the optimal (or close to optimal) unit commitment (UC) along with dispatch from the obtainable generators so that specific chosen motives are generally achieved [16]. Thus to diminish the actual operating costs to a minimum level, optimization devices are important.

The study units need to type the system having its a few stages, the particular neutral conductors, the ground conductors and the connections to ground [17]. Such units really should contain firm

* Corresponding author.
E-mail addresses: kallolroy0181@gmail.com (K. Roy), mandal_atis@yahoo.co.in (A.C. Mandal).
[1] Assistant Professor.
[2] Associate Professor.

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Letter to the Editor

Analysis of energy management in micro grid – A hybrid BFOA and ANN approach

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ABSTRACT

This paper introduces a hybrid strategy for an ideal operation programming of electrical frameworks through minimization of production cost and in addition better usage of renewable energy resources. The hybrid technique is the combined performance of bacterial foraging optimization algorithm (BFOA) and artificial neural network (ANN) technique. Here, the photovoltaic (PV) system, wind turbine (WT) and storage system are considered in micro gird (MG) system. The proposed control strategy is to manage the power flows between the energy sources and the grid. To achieve this point, demand response (DR), customer response, offer priority, DR magnitude, duration, and minimum cost of energy (COE) is determined. The proposed method is implemented in MATLAB/Simulink working platform and compared with the exiting methods such as, genetic algorithm (GA) and artificial bee colony algorithm (ABC) respectively. In the proposed method, the maximum generated power of PV, WT, MT and battery is 7.5 kW, 9 kW, 15.5 kW and 4.5 kW respectively. By using GA, the generated powers are 5.5 kW, 7.5 kW, 11 kW and 3.5 kW respectively. The SOC of the proposed method is analyzed and is about 80%. The proposed method has less cost effective based on their load demand.

1. Introduction

This century is expected to witness unprecedented growth and challenges in power generation, delivery, and usage. Environmental friendly power generation technologies will play an important role in future power supply [3]. These technologies include power generation from renewable energy (RE) resources, such as wind, PV, micro hydro (MH), biomass, geothermal, ocean wave and tides, and clean alternative energy (AE) power generation technologies [1]. The benefits of renewable energy penetration include a decrease in external energy dependence, decrease in transmission and transformation losses and further improve the system reliability, etc [4,16]. To increase the energy reliability, wind and solar energy are used as dual energy sources. However, seasonal climatic conditions and geographic conditions affect the wind-solar energy output [8]. Therefore, a third energy system is needed to improve the energy supply reliability. Thus, the PEM fuel cell ideally fulfills the need for any start up power. When the wind-solar system energy output is insufficient, the fuel cell backups the supply system [9]. A general power system uses battery energy storage to avoid a power outage or power surges caused by natural environmental factors.

The recent trend of renewable energy development is a combination of distributed power sources and energy storage subsystems to form a small micro-grid that can reduce loss of energy from power transmission lines over long distances [7]. A renewable-based micro grid can be understood as a particular case of a more general concept called a ‘smart grid’ [2]. The modern concept of micro grid is highly promising as a solution to the problem due to scarcity of fossil fuel in future in conventional power generation. Micro grid is a platform to integrate DERs into distribution network. The DERs may include DGs and distributed storage (DS) [12]. Micro grids operate in grid-connected or island mode, and may entail distribution networks with residential or commercial end-users, in rural or urban areas [14,19]. Operation of micro grid depends on successful integration of DERs which is related with several factors like power quality issues. The PQ issues should be carefully dealt with to achieve satisfactory values of voltage and frequency. These are tested under the grid connected and islanded mode of micro grid in steady state and as well as, during dynamic state [6,20].

The energy obtained from the RES is clean and creates no pollution, but on the other hand it is stochastic and consequently difficult to control. Due to this drawback, a high penetration of the RES can create stability, reliability and power quality problems in the main electrical grid. Thus, an optimum way of integrating the energy obtained from the RES must be designed [10,17]. In this respect, the hybrid system, formed by interconnecting small, modular generation and storage devices. It has proved to be the best means of meeting the energy demand with high reliability, flexibility and cost effectiveness [5,11]. Energy management of hybrid energy systems is essential for ensuring optimal energy utilization and energy sustainability to the maximum extent [13,18]. Dynamic interaction between the load demand and the renewable energy source can lead to critical problems of stability and power quality. Therefore, managing the flow of energy throughout the hybrid system is essential to increase the operating life of the membrane and to ensure the continuous energy flow. The increasing number of renewable energy sources and distributed generators requires new strategies for their operations in order to maintain the energy balance between the renewable sources and utility grid or micro-grid [15]. Therefore, an efficient hybrid BFOA and ANN technique is proposed in the paper. The main objective of the process was the optimum operation of micro-sources for decreasing the electricity production cost by hourly day-ahead and real time scheduling. The algorithm was based on BFOA method and was able to analyze the technical and economic time dependent constraints. In the document, Section 2 brings out a bird's eye-view of the most modern research works related to the subject. Section 3, on the other hand, offers a fascinating summary of the innovative technique. The performance of the proposed method is well-illustrated in Section 4. The conclusion part of the document enriches the contents of Section 5 with deductions and recommendations.

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Ant-Lion Optimizer algorithm and recurrent neural network for energy management of micro grid connected system

Kallol Roy [a, *], Kamal Krishna Mandal [b], Atis Chandra Mandal [c]

[a] Assistant Professor of Electrical Engineering, University Institute of Technology, University of Burdwan, India
[b] Professor Department of Power Engineering, Jadavpur University, Kolkata 700098, India
[c] Department of Physics, Burdwan University, India

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ABSTRACT

In this paper, an intelligent technique for EMS based on Recurrent Neural Network (RNN) with aid of Ant-Lion Optimizer (ALO) algorithm is presented to find energy scheduling in MG. The optimal operation programming of electrical systems through the minimization of production cost as well as better utilization of renewable energy resources, such as the PV system, WT, and storage system. The objective of the proposed method is utilized to the optimum operation of micro-sources for decreasing the electricity production cost by hourly day-ahead and real-time scheduling. The proposed method is able to analyze the technical and economic time-dependent constraints. The proposed method attempts to meet the required load demand with minimum energy cost. To accomplish this aim, demand response (DR) is evaluated by utilizing the RNN and additional indices for evaluating customer response, such as consumers information based on the offered priority, DR magnitude, duration, and minimum cost of energy (COE). Finally, the ALO algorithm is developed to solve the economic dispatch issues for determining the generation, storage, and responsive load offers. The proposed method is implemented in MATLAB/Simulink working platform and their performances are tested with the existing methods such as GA, ABC, and BFA respectively.

1. Introduction

This century is relied upon to witness extraordinary development and difficulties in force era, conveyance, and utilization. Ecologically cordial (renewable and clean choices) power era innovations will assume a critical part in future force supply because of expanded worldwide open consciousness of the requirement for natural security and yearning for less reliance on fossil powers for vitality creation [3]. These advancements incorporate force era from renewable energy (RE) assets, for example, wind, photovoltaic (PV), micro hydro (MH), biomass, geothermal, sea wave and tides, and clean alternative energy (AE) power era innovations, for example, fuel cells (FCs) and micro turbines (MTs) [1]. The advantages of renewable vitality infiltration incorporate an abatement in outer vitality reliance, diminish in transmission and change misfortunes and further enhance the framework dependability, and so forth [4,16]. To build the vitality unwavering quality, wind and sun based vitality are utilized as double vitality sources. In any case, occasional climatic conditions and geographic conditions influence the wind-sun powered vitality yield [8]. Consequently, a third vitality framework is expected to enhance the vitality supply unwavering quality. Therefore, the PEM energy unit in a perfect world satisfies the requirement for any start up force. At this point, when the wind-close planetary system vitality yield is inadequate, the energy unit reinforcements supply framework [9]. A general force framework utilizes battery vitality stockpiling to dodge a force blackout or force surges brought on by common natural components.

The late pattern of renewable vitality advancement is a mix of circulated force sources and vitality stockpiling subsystems to frame a little smaller scale network that can decrease loss of vitality from force transmission lines over long separations [7]. A renewable-based smaller scale network can be comprehended as a specific instance of a more broad idea called a 'shrewd lattice', which is an interdisciplinary term for an arrangement of innovative answers for electric force framework administration [2]. The present day idea of small scale network is profoundly encouraging as an answer for the issue because of lack of fossil fuel in future in

* Corresponding author.
E-mail address: kallolroy0181@gmail.com (K. Roy).

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METHODOLOGIES AND APPLICATION

Energy management of the energy storage-based micro-grid-connected system: an SOGSNN strategy

Kallol Roy[1] · Kamal Krishna Mandal[2] · Atis Chandra Mandal[3]

Abstract

In this paper, a novel hybrid algorithm is implemented for the system modelling and the optimal management of the micro-grid (MG)-connected systems with low cost. The increasing number of renewable energy sources and distributed generators requires new strategies for their operations in order to maintain the energy balance between the renewable sources and MG. Therefore, an efficient hybrid technique is proposed in the paper. The main objective of the process was the optimum operation of micro-sources for decreasing the electricity production cost by hourly day-ahead and real-time scheduling. The proposed hybrid technique is to manage the power flows between the energy sources and the grid. To achieve this point, demand response and minimum cost of energy are determined. The proposed hybrid technique is the combined performance of both the gravitational search algorithm (GSA)-based artificial neural network (ANN) and squirrel search algorithm (SSA), and it is named as SOGSNN. This technique is involved with the mathematical optimization problems that necessitate more than one fitness function to be optimized simultaneously. By using the inputs of MG-like wind turbine, photovoltaic array, fuel cell, micro-turbine, diesel generator and battery storage with corresponding cost functions, the GSA-based ANN learning phase is employed to predict the load demand. SSA clarifies the squirrel in optimizing the configuration of MG based on the load demand. The proposed hybrid technique is implemented in MATLAB/Simulink working platform and compared with other solution techniques like ANFASO method. The comparison result reveals that the superiority of the proposed technique confirms its ability to solve the problem.

Keywords Battery · Cost function · DG · FC · Load demand · MG · MT · PV · SOGSNN · WT

1 Introduction

Electric power distribution systems are considered as the promising concepts for the next generation (Kaundinya et al. 2009). Constantly delivering power and extending nature of demand is the difficult and challenging task for the developed and developing countries. Usage of power, exhaustible nature of petroleum derivatives and the increasing state of environment have made interest in renewable energy sources (RESs) (Dali et al. 2010; Ahmed et al. 2008). The RESs like solar and wind energy are non-depletable and non-polluting, are littler in estimate, and can be installed nearer to load centres and attainable (Deshmukh and Deshmukh 2008). The growth of wind and photovoltaic (PV) power generation systems has exceeded the most optimistic estimation. For consumers, a multi-source hybrid alternative energy system is higher than a single resource based on the higher reliability and power quality in multi-source hybrid alternative energy system (Dursun and Kilic 2012; Hajizadeh and Golkar 2007). The integrated approach makes a hybrid system more appropriate for isolated communities, for example remote islands (Bajpai and Dash 2012; Palizban et al. 2014). In the upcoming generation, the distribution network will need smart grid ideas (Figueiredo and Martins 2010). Flexible micro-grids (MGs) are able to work in all the ecological conditions. For both grid-connected and

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✉ Kallol Roy
kallolroy0181@gmail.com

[1] University Institute of Technology, Burdwan University, Bardhaman, West Bengal, India

[2] Power Engineering Department, Jadavpur University, Kolkata, West Bengal, India

[3] Physics Department, Burdwan University, Bardhaman, West Bengal, India

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Application of ANFASO for optimal power flow management of MG-connected system with energy storage

Kallol Roy[1] | **Kamal K. Mandal**[2] | **Atis C. Mandal**[3]

[1]Department of Electrical Engineering, University Institute of Technology, Burdwan University, Bardhaman, India
[2]Power Engineering Department, Jadavpur University, Kolkata, India
[3]Physics Department, Burdwan University, Bardhaman, India

Correspondence
Kallol Roy, Department of Electrical Engineering, University Institute of Technology, Burdwan University, Bardhaman, India.
Email: kallolroy0181@gmail.com

Summary

The power flow management scheme for a microgrid (MG)-connected system utilizing a hybrid technique is suggested in this dissertation. An MG-connected system includes photovoltaic, wind turbine, micro turbine and battery storage. Due to the use of this resource, power production is intermittent and unpredictable, as well as unstable, which causes fluctuation of power in hybrid renewable energy system. To ensure the fluctuation of power, an optimal hybrid technique is suggested. The suggested hybrid technique is joint execution on ANFIS and ASOA. ANFIS stands for adaptive neuro fuzzy interference system, and ASOA stands for advanced salp swarm optimization algorithm, thus it is commonly known as the ANFASO method. In the established method, ANFIS is applied to continuously track the MG-connected system's required load. ASOA optimizes the perfect combination of MG in terms of predicted required load. The suggested methodology is used for optimal cost and to increase renewable energy sources (RESs). Constraints are RES accessibility, power demand and the storage elements. Using the MATLAB/Simulink work site, the ANFASO approach is executed and implemented compared with existing methods. The suggested method is compared with genetic algorithm (GA), BFA and the artificial bee colony algorithm (ABC), and the observed elapsed time of ABC is 37.11 seconds, BFA is 36.96 seconds and GA is 38.08 seconds. The elapsed time of the proposed technique was found to be lower (36.47 seconds) compared to existing techniques. Significant improvements regarding utilization of RES and total generation cost accuracy are attainable by utilizing the proposed approach.

KEYWORDS

battery storage, constraints, micro turbine, photovoltaic, power demand, power generations, wind turbine

Abbreviations: ABC, artificial bee colony algorithm; ANFIS, adaptive neuro fuzzy interference system; ASOA, advanced salp swarm optimization algorithm; BFA, bacterial foraging algorithm; BS, battery storage; EMS, energy management system; GA, genetic algorithm; MG, microgrid; MT, micro turbine; PV, photovoltaic; RES, renewable energy source; WT, wind turbine.

1 | INTRODUCTION

Electricity is the main focus of the economic development of many countries.[1] For the developed and developing countries, optimally producing electricity and solving the load requirement are complicated because of increasing

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A hybrid RFCRO approach for the energy management of the grid connected microgrid system

Kallol Roy[1] | **Kamal Krishna Mandal**[2] | **Atis Chandra Mandal**[3]

[1]Department of Electrical Engineering, University Institute of Technology, Burdwan University, Bardhaman, India

[2]Power Engineering Department, Jadavpur University, Kolkata, India

[3]Physics Department, Burdwan University, Bardhaman, India

Correspondence
Kallol Roy, Department of Electrical Engineering, University Institute of Technology, Burdwan University, Bardhaman, India.
Email: kallolroy0181@gmail.com

Summary

Energy management of the grid connected microgrid (MG) systems with low cost using a novel hybrid algorithm is implemented in this paper. The novel proposed hybrid technique is the combined performance of both the Random Forest (RF) and Coral Reefs Optimization (CRO) algorithm and in this way it is named as RFCRO. Optimum operation of micro-sources for decreasing the electricity production cost by hourly day-ahead and real-time scheduling is the main objective of the paper. The proposed hybrid technique is to manage the power flows between the energy sources and the grid. To achieve this point, demand response and minimum cost of energy are determined. This technique is involved with the mathematical optimization problems that necessitate more than one fitness function to be optimized simultaneously. By using the inputs of MG-like wind turbine, photovoltaic array, battery, and fuel cell with corresponding cost functions, the RF is employed to predict the load demand. CRO clarifies the squirrel in optimizing the configuration of MG based on the load demand. The proposed hybrid technique is implemented in MATLAB/ Simulink working platform and compared with other solution techniques like

List of symbols and abbreviations: $P_{B-\mathrm{Ref}}$, reference battery power that is utilized to charge the battery; P_{pv} as well as P_{wind}, generated power through PV as well as wind turbine; P_{Load}, load power; P_{FC-Ref}, reference power of the FC; $P_{Battery}$, power distribution through battery; T, time; *Price* (k), function of time electricity price; P_{PC2L}, FC power supplied for load; P_{Grid2L}, grid power supplied for load; P_{Load_max}, maximum requirement of load; SOC_{max}, maximal battery SOC; $P_{\mathrm{PV}2B}$, transferred power from PV to battery; P_{B2G}, transferred power from battery to utility grid; $P_{Discharge}(K)$, battery discharge power; $P_{\mathrm{PPV}-Max}$, limits of upper power on PV; P_{W2G}, transferred power as wind turbine through grid; P_{FC2G}, transferred power as FC through grid; P_{PV}, generated PV power; $\varphi^{c(tr)}$, out-of-bag trail specimen to peculiar tree; T, total amount of tree; X_a, a, b, sample value represent the amount of trail specimens per tree exit as well as amount of trail specimens per tree at forest; P_{Wind}, wind power; P_{pv} , PV power; P_{FC}, FC power; P_B, battery power exchanged to load as well as grid utility; P_{Grid}, utility grid power through smart grid transferred to different components; P_{W2L}, power supplied through wind turbine for load; P_{PV2L}, PV power supplied for load; P_{B2L}, power supplied through battery for load; $P_{Loss(K)}$, loss of power transmission; SOC_{min}, minimum SOC of the battery; P_{W2B}, transferred power of wind turbine through battery; P_{FC2B}, transferred power from FC to battery; P_{charge}, charging power needs through battery; $P_{Wind-Max}$, limits of upper power on wind; $P_{\mathrm{FC}-Max}$, limits of upper power on FC; P_{PV2G}, transferred power as PV through grid; P_l, power demand; P_{WT}, generated WT power; tr, number of tree; $C_a^{(tr)}$ and $C_{a,\pi z}^{(tr)}$, forecasted class for every specimen of trail; Z_{output}, set of training; ALO, ANN-BP, artificial neural network - feed-back propagation; ANFIS, adaptive neuro fuzzy inference system; ANFMDA, adaptive neuro-fuzzy interference system - modified Dragonfly algorithm; BESS, battery energy storage system; BFOANN, bacterial foraging optimization - artificial neural network; CHP, combined heat and power; COE, cost of energy; CRO, coral reefs optimization; DER, distributed energy resources; DR, demand response; EMS, energy management system; ESS, energy storage system; FC, fuel cell; GSCs, grid side converters; GOAPSNN, Grasshopper optimization algorithm Pi sigma neural network; HOMER, hybrid optimization model for electric renewables; HRE, hybrid renewable energy; HRES, hybrid renewable energy system; LM, Leven berg Marguardt; MDA, modified Dragonfly algorithm; MG, microgrid; MMG, multi micro grid; MOPSO, modified particle swarm optimization; MT, micro turbine; Ni-MH, nickel-metal-hydride; PCC, point of common coupling; PMS, power management systems; PQ, power quality; PSO, particle swarm optimization; PV, photovoltaic; RBFNN-SSA, radial basis function neural network - Salp swarm algorithm; RF, random forest; RES, renewable energy source; SG, smart grid; SOC, battle charging status; SOFC, solid oxide fuel cell; RFA, random forest algorithm; RNN, recurrent neural network; VRFB, vanadium redox flow battery; WT, wind turbine.

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Smart energy management for optimal economic operation in grid-connected hybrid power system

Kallol Roy [a], Kamal Krishna Mandal [b], and Atis Chandra Mandal [c]

[a]Department of Electrical Engineering, Assistant Professor,University Institute of Technology, Burdwan University, India; [b]Professor, Power Engineering Department, Jadavpur University, Kolkata India; [c]Professor, Physics Department, Burdwan University, India

ABSTRACT

This manuscript presents a hybrid method for smart energy management (EM) in grid connected microgrid (MG) system. The grid connected micro grid system consists of photovoltaic (PV), wind turbine (WT), micro turbine (MT), and battery. The proposed method is the combined execution of Radial Basis Function Neural Network (RBFNN) and Squirrel Search Algorithm (SSA), hence it is called RBFNN-SSA method. Here, the necessary load demand of grid-connected MG system is constantly monitored by AI strategy. SSA has developed the perfect combination of MG considering the forecast load demand. The major intention of the RBFNN-SSA method is fuel cost involvement, grid power hourly power variation, operation with maintenance cost of grid connected micro grid system. The constraints are the accessibility of renewable energy sources (RES), power requirement and state of charge (SoC) of storage elements. Batteries are used as an energy source, to stabilize and allow the renewable power system units for maintaining constant output power. The proposed method is activated in MATLAB/Simulink working site. Then, the efficiency is assessed with existing methods such as improved artificial bee colony (IABC), bacterial foraging optimizer and artificial neural network (BFOANN), ant lion optimizer (ALO), grasshopper optimization algorithm with particle swarm optimization including artificial neural network (GOAPSNN). The root mean square error (RMSE), mean absolute percentage error (MAPE), and mean bias error (MBE) of proposed and existing methods under 50 and 100 count of trails are also analyzed. The proposed technique achieves the RMSE is 9.3, MAPE is 4.2, and MBE is 2 for 50 number of trails. For 100 count of trails, the proposed method achieves the RMSE is 13.5, MAPE is 3.9 and MBE is 5.7. The mean, median and standard deviation of RBFNN-SSA method achieves 0.9681, 0.9062 and 0.1099. The elapsed time of RBFNN-SSA method attains 30.15 s.

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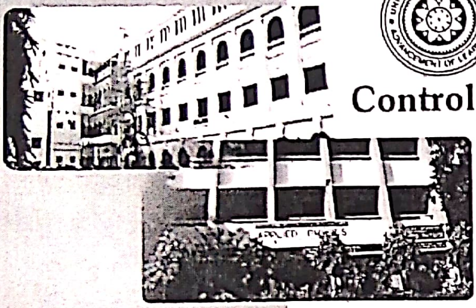
Energy Management; power flow; grid connected MG system; micro turbine; squirrel search algorithm

Introduction

Recently, integration of distributed generation (DG) units, system of storage energy and loads controllable in a network of low voltage may operate either the mode of grid-connected or standalone (Zhou et al. 2010). The MG adjusts the distribution power balance as well as requirement in grid-connected mode, either by getting power from the main grid or by selling power to the main grid for maximizing working profits. From the upstream distribution grid, the MG is separated and targets to offer reliable power to customers who use DG bids in standalone mode. Many control schemes are applied in MGs to mitigate the fluctuation of power of DG units non-dispatch able adding power of every dispatch able DG unit, load shedding, including energy storage system (ESS) charging and

CONTACT Kallol Roy kallolroy0181@gmail.com Assistant Professor, University Institute of Technology, Burdwan University, India



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