Study on Energy Consumption pattern changes in Domestic Area and Role of Natural Refrigerants based Solar Air-Conditioner in Energy System

SYNOPSIS OF THESIS

Submitted

by

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Synopsys of Thesis

on

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Climate change nowadays is a global concern and a mounting threat to our well-being all over the world. In India, particularly in the northern region, temperature exceeds up to 50 degrees Celsius mark. Since the last two decades, the Temperature of summer months in India has broken all the previous records of rising temperatures. It is evident that India will be the World's third largest energy-consuming country by the year 2030, keeping behind the European countries, thanks to rising income and improving standard of living.

With the increasing demand for home appliances, India's Air Conditioner market needs to grow more units, as it is already estimated to reach 9.7 million units within this financial year 2023-24. Subsequently, the electricity consumption by residential homes is expected to increase from 8TWh in 2010 to 239 TWh by 2030 due to the installation of air conditioning machines.

Such Increasing demand for electricity has a significant impact on the Indian power sector and there is an urgent need for new power plants. We have already seen 40% of the energy consumed for domestic purposes could be saved by introducing solar power-based Green (with natural refrigerants) Air conditioners which will be cost-effective as well as efficient. This power transform to a potential energy saving of 118TWh at bus-bar or a peak demand saving of 60GW by 2030. And this energy saving is possible through the implementation of Solar power-based Air conditioners with natural refrigerants. Natural refrigerants are used mainly to reduce Global warming potential (GWP) at the same time.

The use of solar energy in recent years has an alarming result in global warming and its depletion of the ozone layer. So effective natural refrigerants is the best alternative to face zero ozone depletion potential (ODP) in place of higher ODP base synthetic refrigerants.

Tropical countries like ours have an abundant source of solar radiation. It increases ambient temperature and we have to use the Air conditioner to reduce excess heat to make room ambient temperature in a comfortable zone. So, we can use solar photovoltaic power to run Air conditioners for domestic and industrial purposes and maintain Solar Energy Ecosystem by judiciously using solar radiation.

The whole system would be operated on Solar Power (DC) with natural refrigerant for vapour compression based domestic scale air conditioning system and for implementing the technique, more theoretical analysis is needed to have the energy optimization in this regard. Therefore, in the present work, software based theoretical analysis is carried out along with some experimental work and presented in the form of thesis.

This thesis presents sustainable and low-Power consumption drives to get environmental comfort. Air conditioning units are used as a low-carbon alternative. It can be possible in three ways: i.e. solar thermal, solar PV technologies, and application of natural refrigerants so that solar energy can be implemented as solar thermal technology to reduce compressor rating by superheating refrigerants when required and also by using electricity generated from the PV panel (Photo voltaic) and use of natural refrigerants (R290 & R600a), instead of synthetic refrigerants (R134a, R32, R22, and R152a).

Aim and objective:

This research proposal will be ready to serve comfort with less power consumption using natural resources in Air conditioning units. Therefore, the main aim and objectives of the present work are enlisted as follows;

a) To make comprehensive review of energy consumption pattern changes in the domestic sector in India for adaptation air conditioning system
b) To develop a model of solar air conditioning operating units as a green energy application with least power consumption
c) To develop a unique approach for cooling using solar thermal and solar Photovoltaic power with natural organic refrigerants
d) To compare the compressor power consumption and COP of different cooling capacity Air conditioning system operated with various types of refrigerants (synthetic as well as natural/organic) to understand the feasibility and identifying the best suited refrigerant option considering environmental aspect and energy savings in concern using cool pack software & EES Software
e) To analyze and evaluate the performance of different natural refrigerants to make the best performance for a solar AC by Cool pack software
f) To propose a novel technique for the implementation of R600a natural refrigerants by introducing Solar thermal and
g) To analyze energy optimization and its application on solar air-conditioning systems based on five major climatic conditions in India.

Actually, air conditioning and the effect of load on air conditioning systems on energy consumption, and pattern of load changes are studied in detail, and try to develop renewable energy-based air conditioning systems operated with natural refrigeration. The whole work is presented in the form of a thesis consists of the following sections.

The thesis is started with the major objective to create a model for solar air conditioning that runs throughout years long using green energy. The authors try to annualize a 20-year energy consumption pattern for solar air conditioning system in domestic sector and its impact on energy sector and environmental aspects. This thesis assessed and compared the effectiveness of various natural and synthetic refrigerants to provide the better performance

in terms of energy saving and sustainable environment. Accordingly, the main objectives of the work are fixed and presented in Chapter-1.

Rigorous literature review was conducted in Chapter-2. The knowledge gap identified as normal AC is now available with high power usage. Inverter ACs can help to reduce power consumption. There are natural solar powered (DC) air conditioners with low power requirements; however they are not yet on the market. The main focus is the developing of a natural solar powered (DC) air conditioner utilizing solar thermal technology to use the least amount of compressor power.

In Chapter-3 the authors made several assumptions for the study including data analysis on gathering demand information based on per capita income growth, weather information, and calculated hourly, monthly, and yearly solar radiation; calculating the cooling load to ascertain the type and quantity of cooling required. The components of the AC system can be developed and scaled using specific design conditions. The designed system should be optimized to use the least amount of energy possible. Performance assessment and economic analysis was done. The system's economic viability has been assessed. In order to be competitive in terms of price and thermal efficiency for household applications, the lifetime costs for solar cooling systems are evaluated. The results are examined, and potential solutions are identified.

In Chapter-4 a preliminary experimental setup employing R-290 as a natural refrigerant is set up on the roof of the School of Energy Studies building at Jadavpur University. Different solar AC with DC compressor setup components indicates indoor and outdoor units to observe solar thermal impact. The experimental result reveals significant changes of refrigerant pressure by introducing solar thermal energy at the compressor inlet to reduce compression energy consumption.

Software called CoolPack1.50 is used to conduct the current analysis and is discussed in Chapter-5. For developing, dimensioning, analyzing, and optimizing refrigeration and air conditioning systems, a group of simulation software programs is available in whichCoolPack1.50 is chosen for the same. A 1 Ton capacity solar air conditioner is taken into account while analyzing the system initially. It uses various synthetic as well as natural refrigerants as its working medium and runs on a vapor compression cycle powered by DC solar photovoltaic energy. The natural refrigerants R290 and R600a were chosen because they have no potential to deplete the ozone layer and very little GWP in comparison to other refrigerants currently in use. The various qualitative parameters of natural refrigerants show that R290 has a high Latent heat of vaporization at a lower boiling point temperature. While R718 and R123 cannot be chosen due to their high boiling point temperatures at atmospheric pressure, as well as R114 & R502 having high molar masses, R600a also has more or less comparable attributes to those of R290. As a result, it is determined that R290 and R600a are the best candidates for use as natural refrigerants in air conditioning and refrigeration systems. Reheating is also offered in order to maintain a realistic working cycle for R600a.

The same analysis also carried out with other different cooling capacity (2 Ton, 3 Ton and 5 Ton) with R290 and R600a (with super heating and without superheating) which justified the result with similar pattern.

For the purpose of designing vapor compression cycle air conditioning systems with a capacity of 1 Ton and natural refrigerants (R 290 and R600a with 5 ^{0}C reaheating), the authors took into account various climate zones in India which is discussed in Chapter-6. They then compared the compressor capacity and its full load power consumption based on various condenser temperatures in the various climate zones with respect to the readily available standard system for all locations. The evaporator temperature is held constant at 10°C, while the condenser temperature and humidity are changed according to the zone's maximum temperature and humidity in order to comprehend the techniques better. Since the compressor is the system's main power-consuming component, solely its power consumption is calculated here. The Cool Pack (Version 1.50) and EES Software are utilized for analysis. Summary, discussion and concluding remarks of the whole work is given in Chapter-7

The main conclusion of this thesis along with avenue of future work will be discussed in the following Chapter-8.

The authors of the current work provide guidance for the micro design of the air conditioning system based on various climatic conditions in India by downsizing all essential parts like the compressor, evaporator, and condenser for the best possible power consumption and financial aspect. The potential for energy savings is calculated using the CoolPack version 1.50 software, and the results are cross-checked with those from the EES Software Professional V9.478 version 11.319, which also show the same results. Here, the environmental behavior of the natural refrigerant R290 is taken into account. The system's COP and compressor work, in particular, are approximated using comfortable climatic conditions like a temperature of 25°C and a 50% relative humidity. The results show that changing the evaporator and condenser temperatures in accordance with the various climatic zones may significantly reduce the energy consumed by the compressor. Specifically, 12.99% of the area is in a hot and dry climate zone, 41.73% is warm and humid, 44.36% is temperate, 54.41% is cold (sunny/cloudy), and 19.17% is in a composite climate zone. In order to have the best possible power usage, this effort emphasizes downsizing air conditioning system components, particularly the compressor system.

Using R600a refrigerant instead of refrigerant R290 has also huge energy-saving possibilities i.e., 12.97 % in a Hot and Dry Climate Zone; 40.89% in a Warm and Humid Climate Zone; 43.35% in a Temperate Climate Zone; 59.77% in a Cold (Sunny/ Cloudy) Climate Zone; 23.65% in Composite Climate Zone. From the present analysis, the authors suggested resizing compressor capacity based on the different climatic zone to achieve the best performance of the system with optimized energy consumption.

One of the major important points that due to application of R600a(with 5^{0}C superheat) we can able to save in compressor power consumption comparing with R290 on standard consideration(without superheating) is 6.24% extra whereas in case of superheating for both

the cases, R600a shows better performance by reducing 5.28% compressor power consumption comparing with R290.

The output from the analysis considering different climatic zones author found possible decrease in compression capacity 27-40% indicated lower consumption of energy compared to the standard design. In case of R600a with 5 ^{0}C author obtained better results compared to R290. Further, using DC compressor can help to reduce energy consumption by 30%. This thesis also discusses on the use of solar thermal (superheating for R600a) and photovoltaic energy to power air conditioners in the future. Therefore, in this work the authors propose to save energy consumption by pre-size designing of domestic air conditioning system on the basis of different climatic zones of India.

Future Scope of the Work:

In this present work the patterns of energy consumption in domestic air conditioning systems are studied rigorously and try to find out the alternatives in energy savings and environmental sustainability. For that the authors try to climate-based design of air conditioning system with different natural refrigerants.

The whole work is carried out experimentally as well as theoretically analysis but the experimental part of the work cannot be elaborated with different types of refrigerants at different locations. But the theoretical analysis is carried out considering natural refrigerants R 290 and R600a considering different climatic zones. Further experimentation is needed to validate the results obtained theoretically for different climatic zones. So that can be the avenue of the future work.

Further analysis of heat balancing for different components of standard air conditioning systems can be carried out while using solar energy to drive (DC) the systems with other different natural refrigerants (R 290 and R600a).

If the temperature of air can be maintained at low temperature at inlet of the condenser (outdoor) unit, the overall energy consumption can be reduced further that can be done by placing the condenser unit at cool place with proper shading and an arrangement can be made for cooling the air flow by using some evaporative cooling.

For this purpose, optimum designing of the evaporative cooling systems can be done considering different types of materials (i.e., clay pot) that may be another avenue of the future work.

Another analysis on power savings opportunities for using solar based air conditioning systems can be analyzed for the whole country and the load forecasting analysis by using different optimization techniques like artificial neural network (ANN), deep learning, etc. for air conditioning systems can be done. Based on that a proper load management can be ensured.

So, the present work has a large importance as it shows directions on future research on air conditioning systems towards sustainable goals.

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Synopsis of Thesis

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Plagiarism_check_R. Naskar_2023.pdf

ORIGINALITY REPORT

01%

SIMILARITY INDEX

INDEX NO: D-7/ISLM/94/18

1. Title of Thesis:

"Study on Energy Consumption pattern changes in Domestic Area and Role of Natural Refrigerants based Solar Air-Conditioner in Energy System"

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3. LIST OF PUBLICATIONS (Journal):

1. Naskar R, Ghosh A & Mandal R: Design & New Development of Solar Air Conditioner. ***International Journal of Scientific Research in Multidisciplinary Studies (IJSRMS)***, 2018; 4(6):19-23. **ISSN No.: 2454-9312**. **(UGC Care listed Journal during publication time).**

2. Naskar R, Ghosh A & Mandal R: Advancement of Solar Refrigeration Technology and its Impact in Society**.** ***Science And Culture*****,** 2019; 85(9–10): 323-330**, ISSN No.: 0036-8156. (SCI Indexed).**

3. Naskar R & Mandal R, "Energy Optimization of Natural Refrigerant-based Air-Conditioning System for a Sustainable Environment on the Basis of the Major Five Climatic Zones in India", ***Industrial Engineering Journal***. 2023; 52(5): 2. **ISSN: 0970-2555**. (**UGC CARE Group-1**).

4. Naskar R & Mandal R: Studies and Analysis on Feasibility of Two Different Natural Refrigerants Based Solar Powered Air-Conditioning System of One Ton Capacity. ***Journal of Nanomaterials & Energy****. 2023;* **(SCOPUS Indexed) Communicated***

5. Naskar R & Mandal R, "A Competitive study of all Natural refrigerants Implementation on 1.5-ton Domestic Air Conditioners using cool pack software", Industrial Engineering Journal. 2023; **Industrial Engineering Journal. September, 2023; 52(9): 1. ISSN: 0970-2555. (UGC CARE Group-1).**

4. LIST OF PATENTS: NIL

5. List of Presentation in National/ International/ Conferences/ Workshop

LIST OF PUBLICATIONS (Conference)

1. Naskar R, Ghosh A & Mandal R: Some Studies on energy conservation by use of Natural Refrigerants in Solar Thermal & Photovoltaic powered Air-conditioning and Refrigeration Systems. ***Proceedings of International Conference on Sustainable Water Resources Management under Changed Climate.*** **2020. Title of the book: Water Resources: Current and Future Challenges and Research, Directions. ISBN No.: 978-8-19-410094-2.**

2. Naskar R, Ghosh A & Mandal R: Integration Analysis on Impact of Using Natural Refrigerants in Solar powered Air-conditioning and Refrigeration Systems: An Overview. Proceedings of 1st**National Conference** on Innovations in Mechanical Engineering. December **2021**, Heritage Institute of Technology, Kolkata-700107, West Bengal, India

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