Abstract

Cost based reliability enhancement in a power system is a critical and complex combinatorial optimization problem. This enhancement is much necessary when deregulated business environment is developing very fast particularly in microgrid sector. Actually these business domains these days may be very small in size say in the range of a few megawatts or in moderate form in the range of a few tens of megawatts. Whatsoever be the size the reliability of a power system especially of a microgrid type radial distribution system can be enhanced by incorporating distributed generators and applying shunt capacitors at suitable locations as line losses will be substantially reduced by such incorporation. Reliability can also be improved by performing network reconfiguration. Obviously these activities have economical implications. Here in this work reliability has been found to be increased economically by incorporating shunt capacitors and distributed generators at the proper locations in a microgrid type radial distribution system. Appropriate planning has been performed for selecting proper value and location for capacitor as well as distributed generation (DG). Distributed generations have been incorporated considering these are catering 10%, 15% and 20% of the total active power load. Study has also been performed considering DG integration at 50% of total real power load keeping a futuristic plan in mind. Standard thirty four bus and sixty nine bus microgrid type radial distribution systems have been chosen for simulation. On the other hand, reliability indices' studies have been performed considering two common reinforcement schemes. One is applying only disconnects or isolator between two buses and the other one is based on introducing lateral protection with disconnects. These reinforcement schemes have been chosen to make the microgrid radial distribution system realistic. Furthermore, those schemes have been considered to study any kind of contingencies leading to failure of distribution line. It is well known that failure of electric line can be reduced by decreasing the real power loss of it. Distributed generator integration reduces the real power loss by decreasing the loading effect of electric line thereby improving reliability. On the other hand, reactive power compensation by shunt capacitor has the objective of reducing real power loss. This also helps to reduce failure rate of electric line improving reliability. Here distribution system reliability indices viz. *system average interruption frequency index* (SAIFI), *system average interruption duration index* (SAIDI), *customer average interruption duration index* (CAIDI), *average system unavailability/ availability index* (ASUI/ASAI), *average energy not supplied* (AENS) and a newly developed *cost based reliability index* (CBRI) have been thoroughly investigated in connection to the microgrid radial distributed system. To perform reliability improvement vis. a vis. cost minimization, single objective optimization study has been exercised. Additionally a few important reliability indices viz. SAIFI, SAIDI and AENS have been found to be improved while performing minimization. The total cost, loss, SAIFI, SAIDI and AENS are generally conflicting objectives. It is also observed that single objective optimization can't always give the clear picture of the problem under question. Therefore the stated five conflicting objectives have been studied in multi-objective environment having either two or five objectives competing with each other. The selection of the appropriate solution has been done providing equal importance to five conflicting objectives for thirty four bus microgrid type radial distribution system. On the other hand, for sixty nine bus microgrid type radial distribution system unequal weightage values for objectives have been considered for different customers to observe variance in solutions between these two microgrid based radial systems. The total number of customers has been selected based on realistic distribution system data for sixty nine bus microgrid type radial distribution system.

On the other hand, for 34 bus microgrid type system lump sum values of loads has been assigned to buses for selection of number of customer. Actually the number of customers is related to different reliability indices. Justification for choosing different weight values for various customers viz. rural, urban, hospital, office/building, industrial, commercial etc has been provided. Load enhancement has been exercised in 69 bus microgrid type radial distribution system to have a reflection of futuristic load growth. Studies related to cost reduction, energy loss minimization and improvements of SAIFI, SAIDI and AENS have been performed in this enhanced load model considering the deregulated business environment. In the soft computing front, two novel algorithms have been mathematically developed. This is the significant thing of this research work.

To have the optimal solution for single objective as well as multi-objective environment soft computing methods especially novel evolutionary techniques have been developed inspired from natural phenomena. Fish's electro location phenomenon has been considered to be taken as the concept for algorithm. Elephant nose fish *Gnathonemus petersii* and shark fish's active and passive electro location have been mathematically mimicked as fish electrolocation optimization (FEO) as novel evolutionary technique. On the other hand, a well established algorithm called cultural algorithm has been effectively modified to apply in this cost based reliability enhancement problem. The said modification to original cultural algorithm evolved as a modified cultural algorithm which has given the desired strength and potential to solve the mentioned critical and complex combinatorial optimization problem. The interesting thing in this work is to study the competitiveness amongst the newly developed and chosen evolutionary techniques for achieving the highest cost based reliability enhancement. Comparative studies have been performed amongst particle swarm optimization (PSO), real coded genetic algorithm (rcGA), fish electrolocation optimization (FEO) and modified cultural algorithm (MCA). It has been observed that total cost has been reduced from its initial value i.e. without DG and capacitor connectivity after suitably placing capacitors and distributed generators by the application of rcGA, PSO, MCA and FEO techniques in 34 bus microgrid type radial distribution system. The best total cost values have been achieved by FEO technique at a maximum of 10% and 20% DG penetration considering reinforcement scheme as disconnects with lateral protection. Reliability improvements have been conceived by the application of four considered algorithms after performing minimization of SAIFI, SAIDI and AENS. The SAIFI value has been observed to be reduced from 5.240010 interruption/customer yr to 5.052301 interruption/customer yr by the implementation of FEO technique after suitably placing DG and capacitor at a maximum of 10% DG penetration in 34 bus microgrid type distribution system. The least AENS value has been obtained by FEO technique at 1.956178 kWh/customer yr amongst all the chosen algorithms considering DG penetration up to 20% in 34 bus microgrid type distribution system. The best outcomes related to real power loss minimization, total cost reduction and improvement of SAIDI and AENS have been achieved by MCA technique considering a maximum of 50% DG penetration in 34 bus microgrid type system. Five and eleven pareto-optimal solutions have been obtained by the implementation of MCA and FEO techniques after performing multi-objective optimization in 34 bus microgrid type system considering five conflicting objectives and a maximum of 50% DG penetration. On the other hand, fifteen and twenty one non-dominated solutions have been achieved by the application of FEO and MCA techniques after performing multi-objective optimization in 69 bus microgrid type distribution system considering five conflicting objectives and DG penetration up to 50%. Finally total cost, energy loss, SAIFI, SAIDI and AENS have been observed to be reduced from intial values i.e. without placing DG

and capacitor by the application of rcGA, PSO, MCA and FEO techniques in enhanced load 69 bus microgrid type system considering a maximum of 20% DG penetration. The results showed that reliability improvement as well as cost reduction and loss minimization have been successfully achieved by appropriate planning considering optimal capacitor allocations and DG integrations for present and futuristic situations.