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Transforming an Existing Distribution Network Into Autonomous MICRO-GRID using particle swarm optimization (Review)

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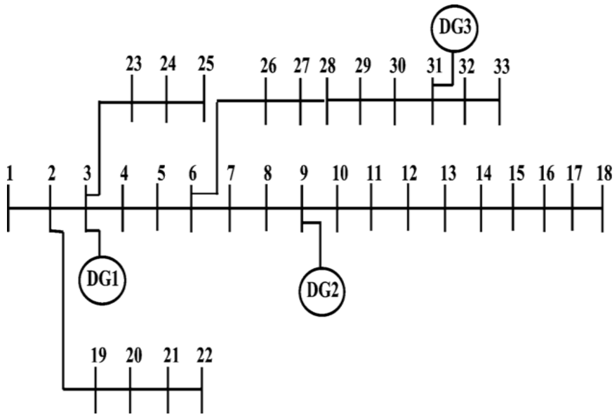
Abstract
A distribution network with renewable and fossil-based resources can be operated as a micro-grid, in autonomous or nonautonomous modes. Autonomous operation of a distribution network requires cautious planning. In this context, a detailed methodology to develop a sustainable autonomous micro-grid is presented in this paper. The proposed methodology suggests novel sizing and siting strategies for distributed generators and structural modifications for autonomous micro-grids. This paper introduces the Particle Swarm Optimization (PSO) algorithm to solve the optimal network reconfiguration problem for power loss reduction. The PSO is a relatively new and powerful intelligence evolution method for solving optimization problems. It is a population-based approach. The PSO was inspired from natural behavior of the bees on how they find the location of most flowers. The proposed PSO algorithm is introduced with some modifications such as using an inertia weight that decreases linearly during the simulation. This setting allows the PSO to explore a large area at the start of the simulation.
Keywords- Distributed power generation, load flow, power generation planning. microgrid, distributed generation (DG), siting and sizing, reliability. particle swarm optimization, Systems Reconfiguration, Power Loss Reduction.

I. INTRODUCTION

IN modern power distribution systems, integrating small nonconventional generation sources has become attractive.These technologies have less environmental impact, easy siting, high efficiency, enhanced system reliability and security,improved power quality, lower operating costs due to peak shaving, and relieved transmission and distribution congestion[1]. The distributed generator (DG) units used are highly modular in structure as well as helpful in providing continuous power supply to the consumers.

The distribution network is generally designed in closed loop and operated in open loop, and it involves large quantity of section switches and a small amount of tie switches. the distribution network reconfiguration (dnr) is to change the network topology through opening and closing these switches in order to optimize network operation parameters. dnr is an effective way to reduce losses in the distribution network, and it also helps balance load, improve voltage quality and enhance system security [1].However, depending on the rating and location of DG units, there is also a possibility for voltage swell and an increase in losses. In this scenario, to exploit the complete potential of distributed generation, proper siting and sizing of DGs become important. This paper, therefore, attempts to develop a sizing

algorithm that transforms an existing distribution network to a sustainable autonomous system. In such an operation, the generation and corresponding loads of the distribution network can separate from the feeder network and form a micro-grid without affecting the transmission grid's integrity.



This paper focuses on siting of the DGs and suggests a minimum-loss configuration for the network. There are many options available for reducing losses at the distribution level: reconfiguration, capacitor installation, load balancing, and introduction of higher voltage levels [10], [11]. Nevertheless, a heuristic approach in choosing the sites for the DG units has been attempted in this paper for autonomous micro-grids. Souza Ribeiro *et al.* proposed an architecture for isolated micro-grids [12]. They have proposed programmed switching of already existing switches to reconfigure the distribution network for stable operation as micro-grid. Two types of switches are used in primary distribution systems viz., sectionalizing switches (normally closed) and TIE switches (normally open) [13], [14]. These switches are designed for both protection and configuration management resulting in cost minimization.

II. PLANNING OF AUTONOMOUS MICRO-GRID

It is evident that transformation of an existing radial distribution system into a sustainable autonomous micro-grid, requires DGs to be integrated into the network. The exact size of these generators and the optimal placement of the same in the network are necessary for its autonomous operation. Hence a hierarchical and partially heuristic methodology is attempted for determining the optimal sites and sizes of the generators and for reconfiguring the network.

Power losses in distribution systems vary with umerous factors depending on the system configuration, such as level of losses through transmission and distribution lines, transformers, capacitors, insulators, etc. [9]. Power losses can be divided into two categories: real power loss and reactive power loss. The resistance of lines causes the real power loss, while reactive power loss is produced due to the reactive elements. Normally, the real power loss draws more attention for the utilities, as it reduces the efficiency of transmitting energy to customers

The major technical benefits are:

- Reduced line losses
- Voltage profile improvement
- Reduced emissions of pollutants
- Increased overall energy efficiency
- Enhanced system reliability and security
- Improved power quality
- Relieved T&D congestion
- Deferred investments for upgrades of facilities
- Reduced O&M costs of some DG technologies
- Enhanced productivity
- Reduced health care costs due to improved environment
- Reduced fuel costs due to increased overall efficiency
- Reduced reserve requirements and the associated costs
- Lower operating costs due to peak shaving
- Increased security for critical loads
- Improved the efficiency of the distribution system

III. PARTICLE SWARM

Kennedy and Eberhart first introduced particle swarm optimization (PSO) in 1995 as a new heuristic method. The original objective of their research was to graphically simulate the social behavior of bird flocks and fish schools. As their research progressed, they discovered that with some modifications, their social behavior model can serve as a powerful optimizer. The first version of PSO was intended to handle only nonlinear continuous optimization problems. However, many advances in PSO development elevated its capabilities to handle a wide class of complex optimization

Considering a real distribution network, the network scale is normally very large. If the binary PSO algorithm is dopted, the quantity of the switches to be optimized will be very large, and it will also easily generate long code and invalid particles.

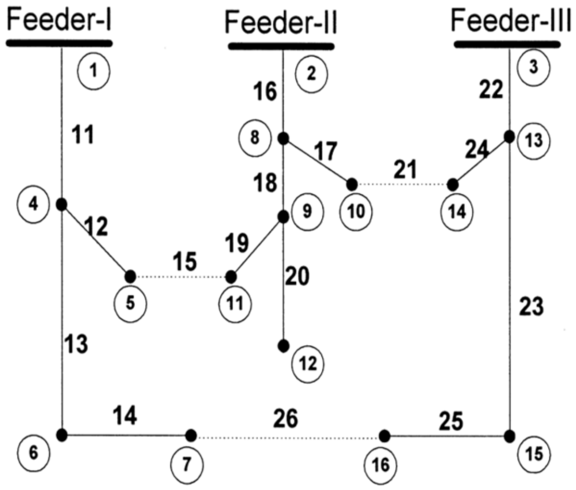
To overcome these problems, this paper proposes an algorithm to simplify the distribution network. This algorithm not only reduces the dimensionality problem but also avoids the generation of many invalid particles. The distribution network is simplified through grouping the branches, and then each group of branches is represented by one dimensional coding. Based on the DNR necessary condition summarized in this paper, particles are evolving regularly, and this improves the efficiency of the search process

A. Basic PSO Algorithm

In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles.Each particle keeps track of its coordinates in the problem space which are associated with the best solution it has achieved so far. This value is called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the neighbors of the particle. This location is called lbest. When a particle takes all the population as its topological neighbors, the best value is a global best and is called gbest. The particle swarm optimization concept consists of, at each time step, changing the velocity of each particle toward its pbest and gbest locations .Acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward pbest and gbest locations

IV. PROBLEM FORMULATION

Generally, there are two types of switches in distribution systems: tie switch and sectionalizing switch. As shown in Fig., switches in dotted branches connecting nodes (10-14), (5-11), and (7-16) are tie switches, and switches in other continuous branches are sectionalizing switches. The tie switches are normally open and the sectionalizing switches are normally closed. When the operating conditions have been changed, feeder reconfiguration is performed by the opening / closing of these two types of switches to reduce resistive line losses



That is, a tie switch may be closed for the purpose of transferring loads to different feeders, and, at the same time, a sectionalizing switch should be opened to maintain the radial structure of the distribution network. For example, in Fig. 1, when the loads of feeder 2 become heavy under normal operating conditions, the tie switch connecting nodes (5-11) may be closed to transfer the load at bus 11 from feeder 2 to feeder 1 and at the same time the sectionalizing switchconnecting nodes (9-10) must be opened to maintain the radial structure of the network.

The objective of the reconfiguration is to minimize the distribution losses with turning on / off sectionalizing switches. The reconfiguration problem has the following constrains:

1. Power flow equations.
2. Upper and lower bounds of nodal voltages.
3. Upper and lower bounds of line currents.
4. Feasible conditions in terms of network topology.

I. PROBLEMS INVOLVED IN ENGINEERING AND SCIENCE.

Use either SI (MKS) or CGS as primary units. (SI units are strongly encouraged.) English units may be used as secondary units (in parentheses). An exception is when English units are used as identifiers in trade, such as "3 $\frac{1}{2}$ in disk drive." Avoid combining SI and CGS units. If you must use mixed units, clearly state the units for each quantity in an equation.

V. CASE STUDY

The standard 33 bus distribution system with a demand of 3.715MW and 4.456 MW respectively in summer & winter has been used for validating the proposed algorithm to improve voltage profile.

A. Load flow analysis

It has been determined that for three numbers of DGs the optimal location is viz., **3rd bus, 9th bus & 31st bus** to attain minimal distribution losses without violating the voltage constraints. The power factor at each DG bus has been considered 0.85 lagging. The base MVA and voltage adopted for the load flow analysis are 100MVA & 12.66kV respectively. Forward & Backward sweep based load flow analysis has been adopted for determining the losses for summer demand and the optimal size has been obtained by applying the non-conventional optimization techniques namely GA and PSO and the values are tabulated in table 1 and 2. Each optimization technique based minimization program has been run for ten times and the best solution has been adopted as the final optimal sizing of the generator units.

VI. CONCLUSION

This paper has proposed the PSO algorithm, as a new evolutionary technique, for reconfiguration of distribution systems. The main advantage of solving such problems using PSO over the conventional mathematical methods is its simplicity. The results obtained during simulation showed that the proposed PSO algorithm is capable of finding an optimal or a near-optimal solution to the two cases studied in this paper. Moreover, the algorithm is capable of finding a feasible solution to the 32-bus system. a methodology for reconfiguring the nonautonomous and autonomous micro-grids has been proposed based on ranking of the buses. A ranking algorithm has also been proposed depending upon the capability of the buses to with stand maximum real and reactive power loadabilities. Based on the ranking of the buses, the strongest and weakest bus has been determined to decide locations for the sectionalizing

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