A Review on Optimal Allocation of Distributed Generation to Minimize Loss in Distribution System

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Abstract: In order to reduce power losses caused by high current and improve the voltage profile in the network distribution, the introduction of distributed generations also called productions decentralized in distribution network plays a prominent role. The placement and sizing of DGs is essential because wrong choice may jeopardies the system behaviour. To solve this combinatorial problem, a meta-heuristic algorithm known as artificial bee colony (ABC) algorithm is proposed in this paper. The paper illustrates the artificial bee colony (ABC) algorithms for optimal location and sizing of distributed generation in a distribution network. Distributed generation is an approach that employs small scale technologies to produce electricity close to the end users of power. Here the total real power loss has been reduced by allocating two Distributed Generations in an IEEE 34 Bus Radial Distribution System using ABC technique and the results are obtained through MATLAB coding.

Keywords: Artificial Bee Colony technique (ABC), Distributed Generation (DG), Distribution System, loss reduction.

I. INTRODUCTION

The increase in demand of energy has brought many challenges on power systems. Distributed generation (DG) is an alternative to solve these problems. DG is integration of small generators in a distribution system in order to meet required load demand by improving the voltage profile, increasing life of system, increase of reliability, minimization of power loss and improving in efficiency. DG is much economic than running a power line to remote areas and DG-unit requires less installation time and the investment risk is not so prominent. It provides power backup during system outages. The DG-unit capacity is ranges from 15 kW to 50 MW and it gains more importance when it uses of renewable energy sources such as Fuel Cells, Small wind turbines, Solar cells and Small Hydro Turbines as well as some unconventional energy sources. Significant influence of embedded distributed generators on load demand, voltages profile, power loss, economy and system reliability make a key issues for distribution system planning in the deregulated power system environment. To achieve maximum benefits the optimization of DG unit is necessary. The application of DG unit is a nonlinear optimization problem which is the determination of the size and optimal location for DG-unit to be installed on a network. It includes minimizing power loss and cost and maximizing voltages. DG-unit placement and sizing has been solved by using different approaches. A classical approach second order algorithm method used in to allocate DG-units for minimal power loss. In analytical approaches the location of DGs are determined for the load profiles in radial systems. As another analytical method in optimal placement is obtained with unity power factor in networked and radial system as well. An analytical method is introduced based on the equivalent injection of current techniques without use of jacobian matrix, admittance matrix or inverse of admittance matrix which are proved to be problematic for the networked systems. In this paper presents an optimization technique called Artificial Bee Colony (ABC) Algorithm to find the optimal location of distributed generators in the distribution system such that the total real power loss of the radial distribution system is minimized.

The new optimization approach called Artificial Bee Colony algorithm is another meta-heuristic method to solve combinatorial problems. The Artificial Bee Colony algorithm is Meta heuristic approach inspired by foraging behavior of honeybee swarm. As in the case of genetics and differential evolutions the external parameters such as mutation rate and cross over rate are required but as in case of Artificial Bee colony algorithm external parameter as mentioned above is neglected. This paper discuss the optimal allocations of DG are identified by Artificial Bee Colony algorithm to determine the optimal size(s) of DG to minimal the real power losses which takes the number and location of DGs as input in distribution systems. The advantages of implementation of Artificial Bee Colony method from determination of locations of DGs are less computational time and improved converged characteristics with thermal and voltage constraints are considered.

II. DG SYSTEM

Electricity is produced and delivered through generation, transmission and distribution systems. Distribution system must deliver electricity to each customer's service entrance. This system may consist of distribution substations, primary distribution systems, distribution transformers and secondary distribution systems.

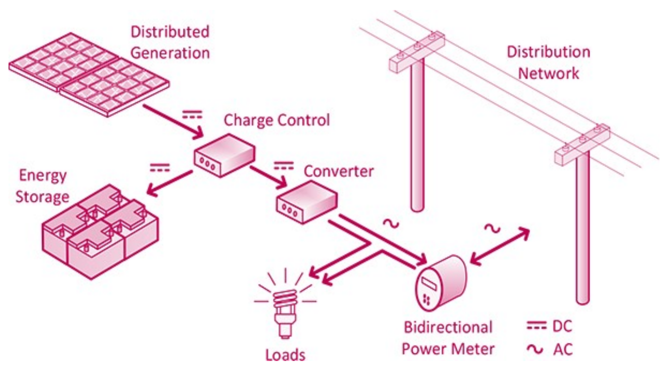

Figure 1: Distribution System

A. *Types of DG Technologies*

The technologies for DG are based on reciprocating engines, photovoltaic, fuel cells, combustion gas turbines, micro turbines and wind turbines. The technologies are also called alternate energy systems as they provide an alternative to the traditional electricity sources i.e. oil, gas, coal, water etc. and can also be used to enhance the current electrical system. Some of them are conventional such as the diesel generators and some are new technologies such as the micro-turbines.

Fuel Cells: A fuel cell is an electrochemical device that converts chemical energy directly into electrical energy. The fuel cell unit uses hydrogen and oxygen to perform the required chemical reaction and produce power. Fuel cells are inverter interfaced DGs, meaning the unit produces dc power that is converted to ac power via a 3-phase converter.

Micro-Turbine: Micro-turbines are small gas fired turbines rotating at a very high rate of speed (90,000 rpm). A high rpm DC generator is used to generate dc power. The DC generator is coupled to a dc/ac power converter to produce voltages at the rated frequency.

Reciprocating Engines: The most common form of distributed generation. This is a mature technology that can be fueled by either diesel or natural gas, though the majority of applications are diesel fired. The technology is capable of thermal efficiencies of just over 40 percent for electricity generation, relatively low capital costs, but relatively high running costs. The technology is also suitable for back-up generation as it can be started up quickly and without the need for grid-supplied power. When fueled by diesel, this technology has the highest nitrogen oxide (NOx) and carbon dioxide (CO2) emissions of any of the distributed generation technologies considered in this entry. In Malaysia, The promotion of energy efficiency and renewable energy resources by the Malaysian government have contributed to an increasing number of distributed generation (DG) connection applications. Most of these applications are from developers of renewable energy, mainly mini-hydro & Biomass (Palm Oil Waste) and industrial customers, who are migrating to cogeneration for energy efficiency.

B. ***Benefits of DG [15]***

- Connection of DG is intended to increase the reliability of power supply provided to the customers, using local sources, and if possible, reduce the losses of the transmission and distribution systems.
- The connection of DG to the power system could improve the voltage profile, power quality and support voltage stability. Therefore, the system can withstand higher loading situations.
- The installation of DG takes less time and payback period. Many countries are subsidizing the development of renewable energy projects through a portfolio obligation and green power certificates. This incentives investment in small generation plants.
- Some DG technologies have low pollution and good overall efficiencies like combined heat and power (CHP) and micro-turbines. Besides, renewable energy based DG like photovoltaic and wind turbines contribute to the reduction of greenhouse gases.

C.*Drawbacks of DG [15]*

- Many DG are connected to the grid via power converters, which injects harmonics into the system.
- The connection of DG might cause over-voltage, fluctuation and unbalance of the system voltage if coordination with the utility supply is not properly achieved.
- Depending on the network configuration, the penetration level and the nature of the DG technology, the power injection of DG may increase the power losses in the distribution system.

- Short circuit levels are changed when a DG is connected to the network. Therefore, relay settings should be changed and if there is a disconnection of DG, relay should be changed back to its previous state.

III. LITERATURE REVIEW

This literature survey presents the definition of DG and various methods such as network reconfiguration, DG allocation to minimize the losses. Influence of a DG in a distribution network is also studied.

Civanlar*et al.* [1] presented a method to decrease the losses by feeder reconfiguration. Losses could be decreased by altering the on/off states of the sectional and tie-line switches.

The proposed method suggested a methodology to vary the states of the switches that could reduce the losses. This filtering mechanism significantly reduces reducing the computational time.

Fan *et al.* [2] suggested that in order to reduce the losses by network reconfiguration, single loop optimization technique could be used. This methodology solved a linear programming problem by simplex method. The author described a heuristic approach for optimizing the switch plan to reach the optimal configuration.

Barker and Mellow [3] considered the impact of distributed generation in power system that could drastically affect power flow and voltage at customers-end and utility equipment. The benefits of distributed generation include reduction in losses, reliability, voltage support and improved power quality. The factors that determined system impacts included not only the size, but also the dynamic characteristics of the generator and various else parameters.

Losi and Russo [4] proposed an object oriented algorithm based on Newton-Raphson technique. This type of tactic added flexibility to the system. In the proposed technique used a set the convergence criteria emphasis during mapping the electrical parameters to the mathematical parameters.

Acharya *et al.* [5] presented the analytical approach to shrink the losses with help of DG. This paper also described the effect on losses with respect to size and location. The comparison between exhaustive load-flow and loss sensitivity method was analyzed. In that method the exact loss formula was considered in order to compute the whole methodology.

Beroni*et al.* [6] presented the particle swarn optimization (PSO) algorithm on the given test system. The proposed algorithm was applied to radial distribution network to improve the voltage profile. It also gave additional benefits like loss reduction and THD. They inferred that PSO gave better results when compared to GA in terms of solution quality and calculation complexities.

Sagar and Prasad [7] studied the impact of DG in RDN. The author distinguished the DG from the conventional generating units as DGs would experience more derated states. The inference were drawn from the reliability indices, load point indices and performance indices calculated through the proposed analytical technique.

Mouti and El-Hawary[8] compared the three techniques named as modified artificial bee colony (MABC), ABC and the analytical methodology on various bus systems. On comparison modified ABC algorithm approach gave the optimal solution in the least computation time and yield high quality solution among all.

Shukla *et al.* [9] presented a multi-location distribution generation problem in order to trim down active power losses of radial distribution system using the genetic algorithm based solution. The loss sensitivity, to change active power injection, was used in order to select an optimal node for DG placement.

Dent *et al.* [10] explained the impact of the size of DG to a RDN. In that method, the voltage step constraints had been integrated with the OPF method to examine the capacity of network to allocate the DG unit.

Khodr*et al.*[11] presented a probabilistic approach in order to aid the engineers of system planning in the selection of location of distributed generator, considering hourly load changes or daily load cycle. The location selected was according to their load magnitude, and used to calculate best probability distribution.

Singh and Goswami[12] suggested a new methodology which was based on nodal pricing to allocate DG unit for optimized results for loss reduction and voltage profile improvement. The method was carried out for time variant and time invariant loads, as well, by incorporating single and multiple DG units in an existing Indian rural distribution network.

Koutroumpezis and Safigianni[13] gave a suitably modified and optimized scheme by intriguing a real network with already installed DG unit. The method was used to determine the optimally placing the multiple DG units in a pre-determined bus as well as the other buses without changing their network structures.

Akorede*et al.*.[14] proposed a valuable method to guide the electric utility distribution companies to determine the optimal position and size of DG unit used in the distribution system. This proposed approach considered system constraints and maximized the system profit of the distribution companies and loading margins.

IV. BUS CLASSIFICATION

A bus is a node at which connects lines, loads and generators. In a power system, four quantities are specified which are voltage, phase angle, active and reactive power. To run a load flow 2 quantities must be specified 2 are required to be determined through the solution of equation. Depending on the quantities that have been specified, the buses are classified into 3 categories. For load-flow studies it is assumed that the loads are constant and they are defined by their real and reactive power consumption. The main objective of the load-flow is to find the voltage magnitude of each bus and its angle when the powers are generated and loads are pre-specified. The buses are classified as:

i) Load Buses (P, Q specified)

In these buses load is connected and therefore the generated real power PGi and reactive power QGi are considered as zero. The load drawn by these buses are defined by real power PLi and reactive power $-QLi$ in which the negative sign signifies for the power flowing out of the bus. This is why these buses are called as P-Q bus. The objective of the load-flow is to find the bus voltage magnitude V and its angle δ.

ii) Voltage Controlled Buses (P,V specified)

The buses that have generators are connected to them are known as voltage controlled buses. Hence the power generation in such type of buses are controlled through a prime mover while the terminal voltage which is controlled through the generator excitation. Here the input power constant is kept constant through turbine-governor control and to keep the bus voltage constant automatic voltage regulator is used, constant PGi and| Vi | are specified for these buses.

iii) Slack or Swing Bus (V, specified)

Generally this bus is referred as the reference thus numbered "1" for the load-flow studies. This bus also sets the angular reference for all the other buses. Since it is the angle difference between two voltage sources that dictates the real and reactive power flow between them, the particular angle of the slack bus is not important. However, it sets the reference against and the angles of all other bus voltages are measured. For this reason the angle of this bus is usually chosen as 0.

V. ARTIFICIAL BEE COLONY

The Artificial Bee Colony Algorithm was introduced by Karaboga in 2005. The bee colony consists of three types of bees namely: employed bee, onlooker bee, and scout bee. The employed bee goes in search for food source randomly and they share the information regarding the nectar amount of food source with onlooker bees waiting in the hive by dancing. The nectar amount of the food source determines the time period of the dance. The onlooker bee selects the best food source position by watching the dance of the employed bee which is the measure of the nectar amount. The onlooker bee compares the dance of an employed bee with that of its neighbor and selects the food source of the employed bee which dances for a longer duration as the optimal solution. Once the food source is selected the onlooker and scout bees change to become employed bees and an employed bee after abandoning the food source becomes a scout bee. The scout bee again searches a new food source. This search process continues until the best food source position is found. There are three parameters in ABC algorithm namely: colony size or number of population (NP), maximum cycle number and limit value. The colony size (CS) represents the total number of bees present. The bee colony has equal number of employed bees and onlooker bees. Each food source has been given an employed bee and thus the number of food source positions equals the number of employed bees. The maximum number of times the search process has to be repeated is given by Maximum Cycle Number (MCN). Limit value gives the number of trials after which a food source becomes exhausted. In this technique, the best food source is selected by comparing the nectar amount of the current food source with that of the previous best food source position stored by the onlooker bee. If the nectar amount of the current food source is higher than that of the previous one, then the best food source position stored by the onlooker bee is modified as the current one or it will remain the same. In this manner the search process will go on until the best food source position is found. The same principle can be used for finding the optimal location of DG units. The DG units are placed at different locations in the IEEE 34 bus radial distribution system with varying sizes and the power loss is calculated for each combination using Newton Raphson load flow. The power loss of the successive combination is compared with the previous one and the best solution is retained. The combination that gives the minimum power loss gives the optimal location and size of DG units. Thus the total real power loss minimization after DG incorporation is found.

VI. CONCLUSION

In this paper, a two-stage methodology of obtaining optimal allocations and sizes of DGs for maximum loss reduction of distribution systems. The DG placement method is proposed to find the optimal DG allocations and Artificial Bee Colony algorithm is proposed to find the optimal sizes of DG. The ABC algorithm is simple in nature than PSO and GA so it takes less computation time. The total power loss of the system has been reduced drastically and the voltage profile of the system is also improved, by installing DGs at all the potential locations. The future scope of this work is insertion of the real time limits such as time varying loads, discrete DG unit sizes and different types of DG units into the proposed algorithm.

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