STATE OF THE ART TECHNIQUES FOR OPTIMUM ALLOCATION AND SIZING OF DISPERSED GENERATION UNITS IN POWER SYSTEM NETWORK

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ABSTRACT

Distributed Generation (DG) also known as dispersed generation is small scale generation units directly coupled with the distributed system. There has been great interest in the installation of dispersed generation sources close to the consumer load centre. The DG technologies comprise of both conventional and non-conventional sources of energy to generate power in order to satisfy the demand of ever rising energy demand. Optimum position and size of DG units can aid the performance of active power system network. Integration of DG units of optimum capacity at ideal locations improves the voltage profile of the system and minimizes the active losses and reactive losses of the system. In this paper, state of the art techniques for optimum placement and sizing of DG have been suggested. This paper provides an overview of the various methods implemented for determining optimal location and capacity of DG units to maximize the benefits of DG units in the system network.

Keywords*: *Distributed Generation, Loss Minimization, Optimum Location, Optimization Techniques, Voltage Profile Improvement

I. INTRODUCTION

The deregulation of the electricity sector has created many opportunities to develop new technologies. Dispersed generation is one of those technologies to meet the ever increasing demand of electricity. The term "Dispersed Generation" refers to small electric generation units close to the point of consumption. Integration of DG sources in the existing power system network can result in various advantages. Dispersed generation resources can improve the voltage profile of the network, lessen system losses and enhance the reliability and efficiency of the system. These advantages could be maximized by proper positioning of DG units at optimum location with ideal capacity and suitable type of DG unit. The benefits of integrating DG are segregated into technical, economical and environmental benefits. Technical advantages comprise of voltage improvement, minimization of real losses and reactive power losses, enhancement of system efficiency, increase in system reliability, improving power factor of the system and therefore improving power quality of the system.

The economical benefits include the reduction of transmission and distribution congestion, decrease in electricity transmission pricing and better performance of network system in deregulated utilities. The environmental benefits constitute the reduction in the emission of pollutants, less noise pollution and extra saving of fuel [1-5]. An overview of the different methods for integrating DG in the system has been suggested in this paper. Several researchers have been working this area to avail the maximum benefits from the integration of DG units in the power system. With the deregulation of the power system network, it is important for the electrical utilities to maximize the positive effects of DG [6]. Numerous methods have been proposed to determine the optimum location and size of DG in order to improve the voltage level and for loss minimization. Improper location and non-optimum capacity of the DG unit can have negative impact on the active power system network. It may cause the voltage to rise above a pre-determined voltage level, increase of fault current in the system, poor efficiency and elevation of system losses. Therefore, it is necessary to find out the optimum location and size of DG units along with its type to enhance the working and planning of active network. This paper suggests various techniques to determine the ideal location and optimum size of DG units for voltage level improvement and loss minimization.

II. DIFFERENT DG TECHNOLOGIES

Different DG technologies are available in the market today. DG size ranges from a few kilowatts to less that 10 Megawatts. Distributed generation resources (DER) can be classified into renewable DG resources and conventional DG resources. Several DG technologies along with their size and applications are shown in Table 1.

TABLE 1: DG Technologies and its applications

No.	DG Type	Size	Applications
1	Micro-Turbines	A few kW to several hundred MW	Peak load shaving.
2	Fuel cells	A few tens of kW to a few MW	Base load applications, used as a module to serve large loads.
3	Photovoltaic cells	A few W to several hundred kW	Stand alone and base load applications.
4	Wind turbines	A few hundred W to a few hundred MW	Remote homes, farms, industry application.
5	Combustion diesel engines	A few hundred MW	Peak load shaving and backup operation

III. PROBLEM FORMULATION

The problem of optimum allocation and size of distributed generation units comprise of various parameters. The objective functions and operation constraints should be well defined in order to attain maximum benefits by integrating DG units in the system network.

3.1 Objective Function

The problem objective of optimum placement and sizing of DG can be single or multi objective. The single objective functions could be real loss minimization, reactive loss minimization, voltage level enhancement, maximization of DG capacity, reduction of cost of generation and minimization of voltage deviations. Multi objective functions are attained by combining single objective functions using weighting factors.

3.2 Constraints

The most popular constraints to solve the problem of sizing and location of DG units are voltage limits, real power limits, reactive power limits, power flow limits, short circuit level ratio limits, maximum number of DG units and size of DG units.

3.3 Number of DG units

The problem of sizing and placement of distributed generators is categorized into single DG unit and multiple DG units.

3.4 Types of DG units

The problem of optimum deployment of DG units may consist of different types of DG units described as follows:

- DG delivering real power only.
- DG delivering reactive power only.
- DG delivering both real power and reactive power.
- DG delivering real power and absorbing reactive power.

IV. METHODS FOR OPTIMUM LOCATION AND SIZING OF DG UNITS

There are numerous methods invented to determine the optimum location and size of DG units for voltage profile improvement and loss minimization. However, other objectives like reliability, maximization of DG capacity, cost minimization have also been discussed in many research papers. Fig. 1 shows the classification of different techniques for solving the problem of allocation and sizing of DG units in the network system.

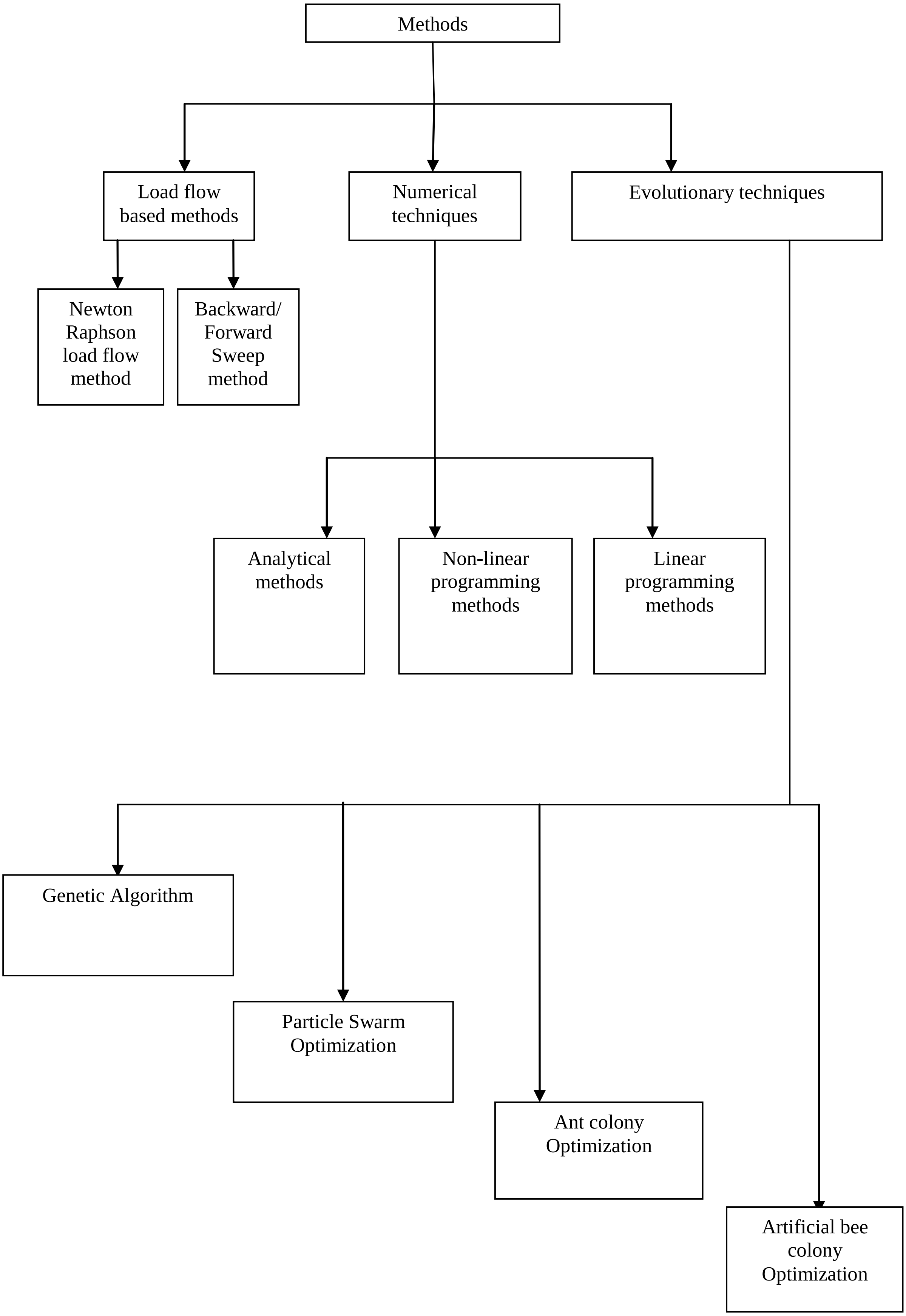

Fig. 1. Classification of different methods for DG sizing and placement

4.1 Load Flow Based Methods

4.1.1 Newton Raphson load flow based method

A simple conventional Newton Raphson method is used to solve the problem of optimal location of a single DG unit which is delivering only real power in the system [7]. A load flow based method for optimal location of dispersed generation unit delivering only real power for voltage profile improvement has been presented in [8]. A load flow based approach for optimum allocation of DG units for voltage profile improvement and loss minimization has been suggested in [9]. A Newton Raphson load flow method for optimal sizing and placement of DG units using weighting factors has been proposed in [10]. The cost and loss factors are minimized in this paper.

4.1.2 Forward/Backward load flow method

A forward/backward load flow technique for optimal placement of DG units has been presented in [11]. An approach for optimal allocation and sizing of DG units using forward/backward sweep method has been presented in [12].

4.2 Numerical Techniques

4.2.1 Analytical techniques

The 2/3 rule has been proposed to determine the optimum location and size of radial feeder with uniformly distributed load in [13]. An analytical technique based on exact loss formula has been suggested in [14]. Three analytical approaches using different power loss expressions to determine optimal size and power factors have been proposed in [15]. A loss sensitivity calculation based approach to determine optimal location of DG units has been presented in [16].

4.2.2 Non-linear programming methods

A mixed integer non-linear programming method for optimal placement of DG units has been presented in [17]. A non-linear programming method has been employed for optimal allocation of different types of DG units considering electricity market fluctuations in [18].

4.2.3 Linear programming methods

A linear programming method has been used to solve the problem of optimal placement and sizing of DG units to attain maximum DG energy harvesting has been proposed in [19].

4.3 Evolutionary Algorithms

4.3.1 Genetic Algorithm

It is an artificial intelligence technique which has been applied in various optimization problems such optimal DG placement. The Genetic Algorithm (GA) is an optimization technique based on natural selection and genetics [20]. In case of DG placement, fitness function can be loss minimization, voltage profile improvement and cost reduction. A combined GA and tabu search is suggested in [21].

4.3.2 Particle Swarm Optimization

Kennedy and Eberhart proposed the first Particle Swarm Optimization (PSO) in 1995 [22]. Applications, developments of PSO method have been suggested in [23]. A PSO based method with variable load models for optimal allocation of different types of DG units has been suggested in [24]. An improved PSO and clonal algorithm based method for optimum allocation of DG units has been explained in [25]. A hybrid GA and PSO is suggested in [26].

4.3.3 Ant Colony Optimization

It is an optimization technique obtained from the behavior of real ants. The procedure of the Ant Colony algorithm controls the scheduling of three activities. The first step comprises of initialization of the pheromone trail. In second step, each ant constructs a complete solution to the problem according to a probabilistic state transition rule. The third step updates quantity of pheromone. This process is iterated until a stopping criterion is obtained. An ant colony algorithm has been proposed to solve the optimum placement and optimum sizing of DG units in radial distribution system network in [27].

4.3.4 Artificial Bee Colony Algorithm

It is a new meta-heuristic technique introduced by Karaboga in 2005. An extended version of the Artificial Bee Colony Algorithm has been proposed. An Artificial Bee Colony algorithm to find the optimum placement of DG units has been suggested in [28].

V. CONCLUSION

This paper has suggested an overview of state of the art techniques implemented to solve the problem of sizing and position of DG units in the network system. The solution methodology implemented to solve the problem of optimal allocation and size of DG units are categorized as load flow based techniques, numerical methods, analytical methods, evolutionary algorithms such as GA, PSO etc. This problem may include various objective functions, numerous constraints to solve the location issues of DG units. The most common objective function is the reduction of real losses, reactive power losses and voltage profile improvement. It can be concluded that the numerical and analytical methods are time consuming and not very efficient to solve the problem of placement and size of DG sources in the system. Evolutionary algorithms such as PSO, GA, Ant Colony Optimization etc are very feasible and easy to implement.

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