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Optimum locating and Sizing of Distributed Generation Based on Artificial Ant Colony Algorithm

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Abstract

Recent advances in the field of renewable sources technology, and increasing demanding to clean and cheap energy cause importance of distributed generation (DG). Correct and suitable installation DGs in power system can help to system stability and reliability, moreover reduction of loss and final cost of generation. In this paper a method based on ant colony for optimal locating of DGs due to cost and loss minimization is presented. Proposed method is tested on the 32 bus system and optimal location, size, and number of DGs is determined. The results show that DGs have considerable effect on the cost and loss minimization of power systems.

Keywords: Distributed generation, ant colony, optimal location, power systems, stability.

Introduction

The large amount of capital cost needed to install large power stations, abnormal operation conditions which can lead to black out added with economic and environmental pressures, changed the generation approaches of traditional electric power utilities in the recent past[1]. The alternative after considering the above factors is to introduce distributed and dispersed generation which can be conveniently located closer to load centers. The main idea behind the Distributed Generation (DG) is that generation in small scale and can be easily placed closer to the point of consumption[2]. Distributed generation is an electric power source connected directly to the distribution network or customer side of the meter[3]. It may be understood in simple term as small-scale electricity generation. The definition of distributed generation takes different forms in different markets and countries and is defined differently by different agencies[4]. International Energy Agency (IEA) defines Distributed generation as generating plant serving a customer on-site or providing support to a distribution network, connected to the grid at distribution-level voltages[5]. CIGRE defines DG as the generation, which has the following characteristics[6]: It is not centrally planned; it is not centrally dispatched at present; it is usually connected to the distribution network; it is smaller than 50–100 MW. Other organization like Electric Power Research Institute defines distributed generation as generation from a few kilowatts up to 50 MW[7]. In general, DG means small scale generation. There are a number of DG technologies available in the market today and few are still in research and development stage. Some currently available technologies are reciprocating engines, micro turbines, combustion gas turbines, fuel cells, photovoltaic, and wind turbines[8]. Each one of these technologies has its own benefits and characteristics. Among all the DG, diesel or gas reciprocating engines and gas turbines make up most of the capacity installed so far. Simultaneously, new DG technology like micro turbine is being introduced and an older technology like reciprocating engine is being improved[9,10]. Fuel cells are technology of the future. However, there are some prototype demonstration projects. The costs of photovoltaic systems are expected to falling continuously over the next decade[11]. This all underlines the statement that the future of power generation is DG. Supplying peaking power to reduce the cost of electricity, reduce environmental emissions through clean and renewable technologies (Green Power), combined heat and power (CHP), high level of reliability and quality of supplied power and deferral of the transmission and distribution line investment through improved load ability are the major applications of the DG[12]. Other than these applications, the major application of DG in the deregulated environment lies in the form of ancillary services. These ancillary services include spinning and non-spinning reserves, reactive power supply and voltage control etc.[13]. DG also has several benefits like reducing energy costs through combined heat and power generation, avoiding electricity transmission costs and less exposure to price volatility. Though the DG is considered as a viable solution to most of the problems that today's utility are facing, there are many problems (e.g. DG integration into grid, pricing, change in protection scheme, nuisance tripping etc.) that need to be addressed. Furthermore, the type of DG technology adopted will have significant bearing on the solution approach[14,15]. The planning of the electric system with the presence of DG requires several factors to be taken into considerations, such as: the best technology to be used, the number and the capacity of the units, the best location, the type of network connection, etc. The impact of DG in system operating characteristics, such as electric losses, voltage profile, stability and reliability needs to be appropriately evaluated[16]. The problem of DG allocation and sizing is of great importance. The installation of DG units at non-optimal places can result in an increase in system losses, implying in an increase in costs and, therefore, having an effect opposite to the desired. For that reason, the use of an optimization method capable of indicating the best solution for a given distribution network can be very useful for the system planning engineer. The selection of the best places for installation and the preferable size of the DG units in large distribution systems is a complex combinatorial optimization problem[17]. The artificial intelligence techniques are the most widely employed tool for solving most of the optimization problems. The optimum DG allocation can be treated as optimum active power compensation, like capacitor allocation for reactive power compensation. DG allocation studies are relatively new, unlike capacitor allocation. In Chiradeja P. and Ramakumar R.[18] power flow algorithm is presented to find the optimum DG size at each load bus assuming every load bus can have DG source. Such methods are, however, inefficient due to a large number of load flow computations. The genetic algorithm (GA) based method to determine size and location is used in Chiradeja P. and Ramakumar R.[19], Dugan R.C. and Price S.K.[20].

GA is suitable for multi-objective problems like DG allocation and can give near optimal results, but they are being computationally demanding and slow in convergence. In Dugan R.C. and Mcdermont T.E.[21] reported analytical method to place DG in radial as well as meshed systems to minimize power loss of the system is presented. In this method separate expressions for radial and network system are derived and a complex procedure based on phasor current is proposed to solve the location problem. However, this method only optimizes location and considers size of DG as fixed. The optimal power flow problem is solved based on the use of a Genetic Algorithm load flow[22]. GA could have trouble in finding the exact global optimum and they require a large number of fitness functions evaluations. It is very difficult to achieve analytic relationship between sensitivity of simulated power system and the parameters values to be optimized. Since Ant Colony (ACO) method don't need this kind of information, it is suitable in our optimization task.

The scientific contributions of this paper are: i. minimum loss will be obtained when supplying of loads is done in location of consumption. ii. the best location, size, and number of the DG is determined simultaneously iii. the objective function which is a cost function is minimized properly.

In section II proposed method for solving problem is presented, In section III the problem is defined and solved with ACO method, In section IV simulation results is presented. Finally, in section V conclusions is given.

Material and Methods

Proposed method for solving problem: The ACO algorithms form a class of meta-heuristic to solve hard combinatorial optimization problems. It has been introduced to solve the travelling salesman problem. The basic idea is to imitate the behaviour of real ants foraging for food. In fact, the real ants can found the shortest path from a food source to their nest without visual cue. Indeed, they communicate, in a local and indirect way, through an aromatic essence called "pheromone", deposed on the ground as they move about. Being very sensitive to this substance, an ant seeking food choose, in a randomly way, the path comprising a strong concentration of this substance. Thus, as more ants take the same path, more than ants will be attracted by this path. By analogy, in ACO algorithm, artificial ants build a solution by applying a probabilistic decision to choose a next destination. The generation of solutions is guided by pheromone trail and information related on the problem specification. Then, the ACO can be defined as an extension of traditional construction heuristics which have to adapt the pheromone quantity during the execution of the algorithm to take into account, the experiment of research. We note that, in addition to the real ants characteristics, the artificial ants are equipped with a memory, are not completely blind, and the used time is discrete.

Ant colony method: In this paper optimal locating of distributed generations for determination location, size and number of them is done based on ACO. In this method load variation in hours of days and months of a year, annual growth of load, and electrical energy cost is considered. Also by a cost function, minimization is done using ACO. In this section, a network with 32 buses is presented for locating studies. The network with 32 buses is a real feeder with nominal voltage of 24.9kv, and in a section of that by using a transformer some loads are feed with nominal voltage of 4.16kv. This feeder has long distance and light loading. Therefore for voltage stability two parallel capacitor and two voltage regulators is used. Loads of this network has different characteristics. A number of loads are balanced and some of them are unbalanced. This network has three types of loads: constant power, constant current, constant impedance and these loads are connected in star and triangle three phase, single phase. In addition to constants loads there are distributed loads in this network.

All of constant current loads and constant impedance loads are converted to power constant and triangle loads are changed to star loads. Also distributed loads are divided between first and last loads. Characteristics of transmission lines and parallel capacitors are not changed. But voltage regulators are eliminated from network for setting after solving of DG locating problem. This network is shown in figure-1.

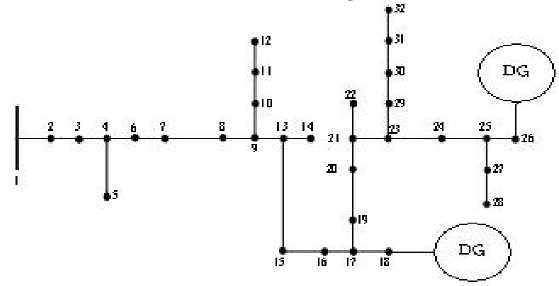

Figure -1
Studied Network

Daily load diagram: Maximum daily load at the first day of first month is equal to base load which is presented in table-1 daily load diagram at the first day of first month is shown in figure-2.

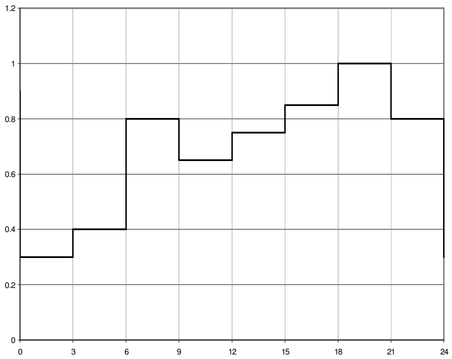

Figure-2
Daily load diagram

As it is seen variation of load is liberalized for every three hours. With considering cost variation at time of load peak by using a factor supposed to load at peak time is consumed more. In this way if a cost consider for all hours a day, the cost of energy in peak hours is the same. Peak factor is 1.2.

Table-1
Factor of load variation in different months of a Year

Months	Months factor
January	1.05
February	1.05
March	1.15
April	1.2
May	1.15
June	1.1
July	1.2
September	1.05
October	1.1
November	1.1
December	1.15

Load growth is considered 0.03 percent and growth of electrical energy cost is the same. For calculating load flow, variations and growth of load equation (1) is used.

Load=Loadbase.*K.year *K.month.*K.load.*K.peak (1)

For every three hours load flow is done and related losses is calculated. Therefore cost at peak time and annual growth of and load behavior in different months of year in addition to annual growth of energy cost for salving locating problem in proposed method are considered.

Objective function: Objective function which should be minimized in this study is a cost function included loss cost and distributed generation unit cost. This function is presented in equation (2).

$$f(x) = C(loss) + C(DG) \quad (2)$$

Where C (loss) is loss cost of total lines, and C (DG) is included installation cost, fuel cost, maintenance cost. For calculating loss cost at first, load flow is done and from its results is used for calculating losses finally loss cost will be multiplied. This cost for the first year is equal to 0.03C.kwh and for every year 0.03 percent, cost growth is considered. DG cost included primary cost, fuel cost, maintenance cost. Cost function of DG is defined as below:

$$C(DG) = a + bP \quad (3)$$

Where P is nominal active power of DG and a, b are calculated from equations (4) and (5).

$$a = \frac{Capital\ Cost(\$/kW) \times Capacity(kW) \times Gr}{Life\ Time(Year) \times 365 \times 24 \times LF} \quad (4)$$

$$b = Fuel\ Cost(\$/kWh) + O\ \&\ M\ \text{Cost(\$/kWh)} \quad (5)$$

Where Gr is rate of annual gain, LF is load factor of DG.

Ant colony method: In this paper ant colony method in discrete state for optimal locating of distributed generations is used. In this locating in addition to optimal locating and sizing of DG optimal number of them is determined. Size of every distributed generation is considered from zero to one megawatts and for discretion of DG size. There is changed in 50kw steps. Therefore 20 steps for variations of every generation unit in program are considered. For limiting space of search maximum number of generation units is considered to 3 units. With notice that without first bus we have 31 buses, there are 31 options for determining optimal bus. For determining optimal size, location and number DG pheromone matrix is defined figure-3.

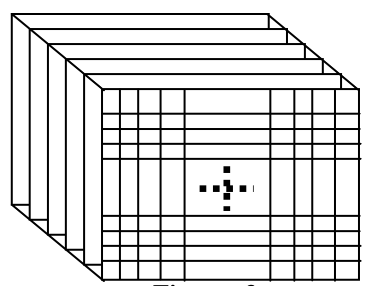

Figure- 3
Three dimensional pheromone matrixes

This matrix has 20 rows and 31 columns. The third dimension of this matrix is equal to six (z=6). Rows, columns and z of this matrix are for determination of size, location and number distributed generation respectively. In simulations if number of optimal DG is one then size and location of DG will be selected form two dimension matrix with z=1. While number of optimal DG is two, size and location of two generation units will selected from two dimension matrix with z=2 and z=3. If number of optimal DG is three , size and location of three generation units will be selected from two dimension matrix with z=4 and z=5,z=6. For example if maximum pheromone is on these elements: (A,B,4), (C,D,5), (E,F,6), it means that optimal number of DG is 3 and optimal size of them are 20×A, 20×C,20×E on buses B , D, F , respectively. In proposed method optimal element is selected based on average of maximum pheromone. Actually in cases that number of DG is more than one average pheromone is used.

Results and Discussion

Simulation Result: In this paper Sinusoidal PWM method is selected for In this paper by MATLAB/mfile a program based on ACO for optimal locating of DG is proposed. This program can determine location, size and number of DG in the described network. In this section result of optimal locating of DG in different power factors is presented. In table-2 the results of DG locating with PF=0.85lag is shown.

Table-2
The Results of DG Locating With PF=0.85lag Is Shown

DG	Location	Size
1	9	250KW
2	22	550KW
3	29	600KW

Loss cost of network in this condition is 1.3518 million dollar. The results show that cost function will be minimized when DG units are closer to center of loads. Of course effect of power factor should be considered. If DG operates with lag power factor, it will produce active power and consume reactive power. In this condition contradiction between closing to center of active power consumption concept and closing to reactive power supplier (substation) concept will choose location of DG units. Actually closing to center of load will decrease loss but due to DG is reactive power consumer closing to load center causes long distance from reactive power supplier which loss will be increased. On the other side, due to DG restrictions generation of active power of them is more than consumption of reactive power. With notice that line resistance in distribution system is more than reactance of them effect of active power generation will be increased. As a result closing to load center has stronger effect on locating of DG and optimal location of DG is in load center. With increasing number of DG loss of network will be decreased more. With considering restriction for this network three DG is selected. In table-3 the results with PF= 0.9lag and in Table-4 the results with PF= 0.95lag are shown.

Table-3
The Results of DG Locating With PF=0.9lag Is Shown

DG	Location	Size
1	11	250KW
2	20	500KW
3	26	550KW

Network loss cost in condition is 1.3236 million dollar.

Table-4
The Results of DG Locating With PF=0.95lag Is Shown

DG	Location	Size
1	11	250KW
2	20	500KW
3	26	550KW

Network loss cost in condition is 1.2683 million dollar. In Table-5 the results for PF=0.95 lead is shown.

Table-5
The Results of DG Locating With PF=0.95lead Is Shown

DG	Location	Size
1	13	250KW
2	21	500KW
3	30	600KW

Network loss cost in condition is 1.1372million dollar. In table-6 the results for PF=0.85 lead is shown.

Table-6
The Results of DG Locating with PF=0.85Lead is Shown

DG	Location	Size
1	9	250KW
2	22	550KW
3	29	600KW

Network loss cost in condition is 1.0523million dollar. Also active power in different buses of studied network is shown in figure-4.

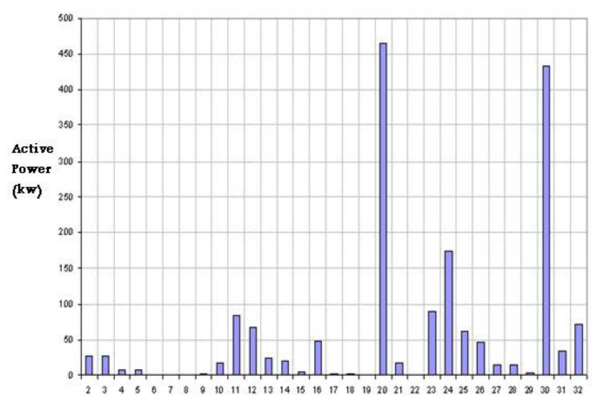

Figure- 4
Active power in different bus

Conclusion

Ant Colony can be used as a better tool than traditional methods to enable the planners to choose the best size and location of DGs to distribution system. ACO method is faster, easier, and smooth accurate size. The results emphasize that minimum loss will be obtained when supplying of loads is done in location of consumption. In fact if every load has a generating unit loss will be minimized due to current passing through network lines is minimized. But from economical view this is impossible, but it might be possible in the future.

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