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OPTIMAL LOCATION AND SIZING OF PHOTOVOLTAIC GENERATOR USING SIMULATED ANNEALING ALGORITHM

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Abstract— Recently growing of global energy demands and load expansion leads to increasing of consumer's distance in distribution networks which causes increasing in power losses and also led to voltage profile decreases. Therefor the need for using of distributed generation (DG) is important to enhance and solve these problems. This article concerns with a photovoltaic generator based on using of suitable optimize strategyto get the optimal location and sizing of DG in the distribution network to minimize the real power losses and improving of voltage profile at all busses by placing of a Photovoltaic generator with optimum size at the best location where unchecked place for a Photovoltaic generator may lead to an increase in loss and also not enhance the voltage profile. To optimize in a 39 bus New England system based on artificial intelligence method, simulated annealing algorithm (SAA) programmed under MATLAB software has been suggested. The analysis of results clearly indicates that when optimal sizing Photovoltaic generator is putted in the optimal location, power losses in the networkdecrease and also, at the same time, voltage profile is improved.

Index Terms— Photovoltaic generator, Voltage profile, Power losses, optimal location, optimal sizing and simulated annealing algorithm.

1 INTRODUCTION

The interest in Distributed Generation (DG)has been increased rapidly to overcome the local and regional environmental issues generated from rising inthe demand of electrical energy[1],thereforeDG placement or reconfiguration in distribution networks by replacement of conventional fossil based generation with clean renewable generation resources is a proper solution to solve and improve the issue in the network [2].the DG placement has positive impacts to the network some of which are decrease in lines losses, voltage profile improvement, network security progress, power quality improvement, increasing of distribution and transmission systems capacity and delaying investment fornetwork development, spinning reserve to support generation outages and improvement in reliability through backup generation [3-4].DG placement may be a small power plant connected close to the supply side or demand side or renewable energy sources based micro hydro, wind turbines, photovoltaic, etc[3].Photovoltaic (PV)electric power generation is one of the consequences of competitive electricity markets and solar generation is among those resources that have been at the center of attention. These resources currently more expensive (in $/MW installed comparison) are environmentally friendly, renewable and it the clean sources of the energy and it gives us the solution to the problems such assolid wastes, greenhouse gas effects[5].In the other hand, the price of the combustible fossils is increasing because of the increasing worldwide demand for the energy Therefore,replacing the conventional generation with large scale renewable units such PV generation has been one of the major aspects characterizing smart grids[6].With the extensive growth in the deployment of the photovoltaic resources, power system operators are expected to deal with a new generation of power system issues due to the different nature of the newly added power generation resources. The ability to reverse the flow of the power from the loads towards the transmission system and the reduced reactive power generation are some of the unique characteristics of the PV units that addto the complexity of power systems [5]. Now, connecting the PV generation to the already existing power system is going to affect the stability of the system positively or negatively. So, the study of the impact of this solar generation on the stability is important. Solar power plant consists of the solar cell and DC to AC inverters. Hence, they do not possess inertia which the traditional synchronous generators prossess. In addition, their behavior and interaction with the power system depend on the dynamics of the inverter. Therefore, it is important to study the effect of the penetration of the PV on the power system dynamic performance, where there are not many references available on the small signal stability of the power system considering high PV penetration [6]. This paper is organized as follows: At first, modeling of Photovoltaic generator, then in thenext section, simulated annealing algorithm(SAA) is discussed After that, a proposed method is tested on a 39-bus network, and the impact of Photovoltaic generator on voltage profile and real power losses is illustrated. finally, Conclusions that can be drawn from these analyses are presented in last section.

2. PHOTOVOLTAIC MODEL

This model is based on a current source converter as in [7], where there are two models used for photovoltaic generator based on PQ and PV control models. Also according to Different possibili-

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ties for inverter model, first order transfer function with steady state gain and closed loop Control transfer functions are the most appropriates. Since both models yield similar results, the first order transfer functions are adopted here, where figure (1) and figure (2) Present the block diagram of the photovoltaic PQ and PV models respectively. In these models the current set points can be obtained based on the desired active power and reactive power and also current measurements in the d-q reference frame. In this paper, photovoltaic generator as PV modelis used and data of proposed model will be provided [8].

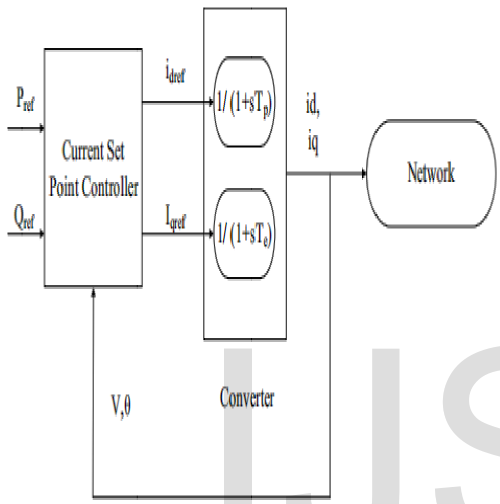


Fig.1 photovoltaic PQ model

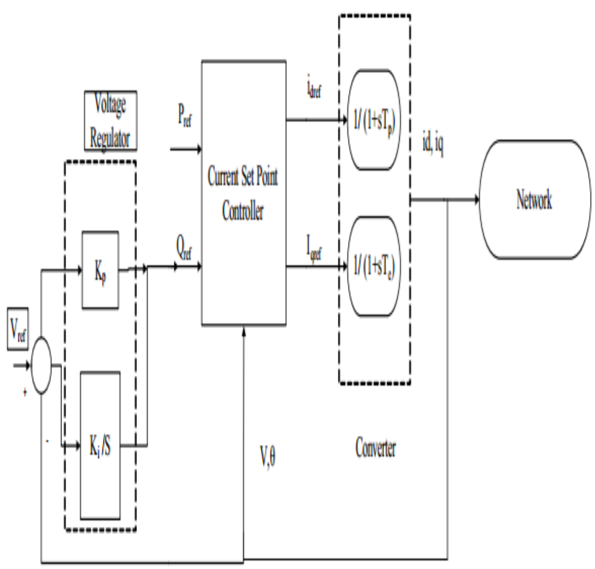


Fig.2 photovoltaic PV model

3. SIMULATED ANNEALING ALGORITHM (SAA)

Many problems in engineering, planning and manufacturing can be modeled as that of minimizing or maximizing a cost function over a finite set of discrete variables. The placement of DG should be carried out with the consideration to its size and location, where the worst placement in some situations can reduce system benefits so the placement should be optimal in order for maximum benefit of DG implemented to the system. For that reason, the use of an optimization method capable of indicating the best solution for a given system and this is very useful for the system planning when dealing with the increase of DG penetration that is happening nowadays, also using of optimization method Contributes in solve the network reconfiguration problem in a distribution systemand find a configuration with the minimum power loss while all system constraints are satisfied [4-9].

DG unit location and sizing problem in networks is a multi-objective function. To solve the problem of optimization in distribution networks different algorithms have been used but this article concerns with using of simulated annealing algorithm (SAA) which particularly well suited for a large combinatorial optimization problem.

Simulated Annealing (SA) is motivated by ananalogy to annealing in solids. The idea of SA
Comes from a paper published by Metropolis
etc al in 1953 [Metropolis, 1953). Simulated annealing algorithmis a random investigation mechanism for global optimization problems, and it simulate the annealing process in material processing when a metal cools and freezes into a crystalline case with the minimum energy and considerable crystal size so as to minimize the impurity in metallic frame [9].

The basic idea of the simulated annealing algorithm is to use random search in terms of a Markov chain [8]. The simulated annealing will concur to its global optimality if sufficient randomness is used in combination with cooling very slowly.

3.1 THE COOLING SCHEDULE.

The cooling schedule of a simulated annealing algorithm contains four components [8].

A. STARTING TEMPERATURE

The starting temperature must be hot enough to allow a move to almost any neighborhood state. If this is not done, then the ending solution will be the same (or very close) to the starting solution. However, if the temperature starts at too high value then the search can move to any neighbor and thus transform the search (at least in the early stages) into a random search. Effectively, the search will be random until the temperature is cool enough to start acting as a simulated annealing algorithm.

B. FINAL TEMPERATURE

It is usual to let the temperature decrease until it reaches zero. However, this can make the algorithm run for a lot longer, especially when a geometric cooling schedule is being used. In practice, it is not necessary to let the temperature reach zero because as

ISSN 2229-5518

it approaches zero the chances of accepting a worse move are almost the same as the temperature being equal to zero. Therefore, the stopping criteria can either be a suitably low temperature or when the system is “frozen” at the current temperature (i.e. no better or worse moves are being accepted).

C. Temperature Decrement

Starting and stopping temperature isneeded to get from one to the other. That is, decrement temperature is needed so that it eventually arrives at the stopping criterion. One way to decrement the temperature is a simple linear method and geometric decrement is an alternativeway, where

$$t = t\alpha$$

Where, $\alpha < 1$

Also, experience has shown that α should be between 0.8 and 0.99, with better results being found in the higher end of the range. Therefore, the higher value of α, the longer it will take to decrement the temperature to the stopping criterion.

D. Iterations at each temperature

The final decision is how much iteration at each temperature, where a constant number of iterations at each temperature are an obvious scheme. Another method, first suggested by (Lundy, 1986) is to only dooneiteration at each temperature, but to decrease the temperature very slowly. The formula used is

$$t = t/ (1 + \beta t)$$

Where, β is a suitably small value.

3.2 (SA) Solution algorithm for Network Reconfiguration.

In this optimization the simulated annealing algorithm is used to find the global minimum of a function of several variables, where this paper applying simulated annealing to determine the optimal location and optimal size of Photovoltaic generator which lead to reduce power losses and improve voltage profile.

Methodology of using simulated annealing algorithm is summarized in detail as follows steps and also flowchart in figure (3) show these mentioned steps [9]:

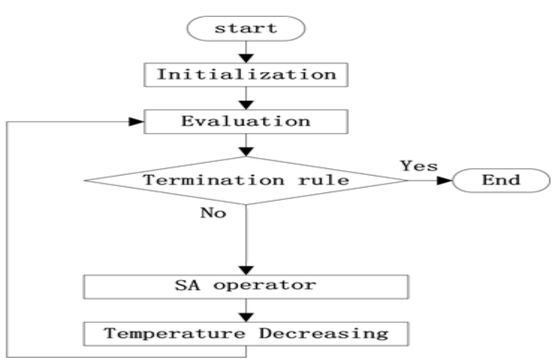


Fig. 3: Flow chart for optimum DG placement based on SAA

SAA Steps are:

a) Choose a random Xi.
b) Select the initial temperature.
c) Specify the cooling schedule.
d) Evaluate F(Xi).
e) Obtain Xi+1.
f) Evaluate F(Xi+1)
g) If F(Xi+1)<F(Xi), then accept Xi+1as a new current solution.
h) Else, then accept Xi+1as a new current solution with probability
i) Reduce the system temperature according to the cooling schedule.
j) Loop until some termination criteria is satisfied.

4.Case Study and Results

4.1 The39-bus New England system

The test system is 39-bus New England system is shown in figure (5),wheresystem data are based on a 100 MVA, also the system has 21 loads have totaling powers equal to 6254.23 MW, 1387.1 MVAr, real and reactive power loads, respectively.The proposed algorithm in this paper was programmed in MATLAB software.According to the results obtained from load flow, the active and reactive power losses of the system are calculated as 120.761 MW and 1096.05MVAR, respectively, also Voltage magnitudes of the system buses are also noted and shown in figure (4). It is seen that many buses incur with low voltage problem and bus 15 having a voltage lower than 0.95 P. U value.

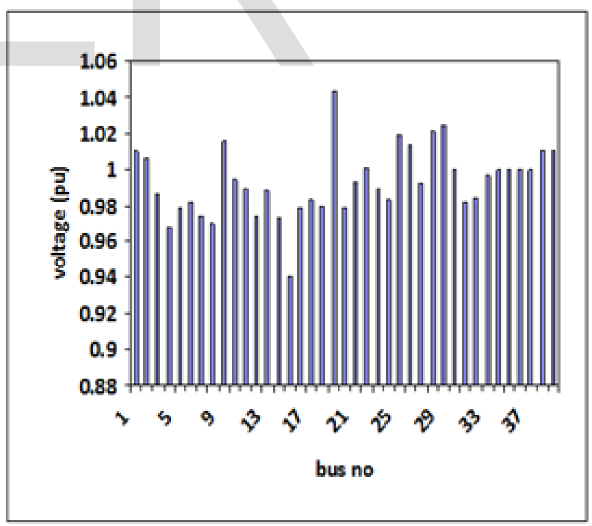
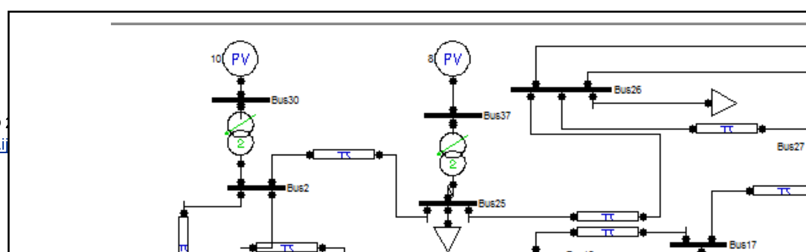


Fig 4: voltage at each bus without Photovoltaic generator.



4.2 Optimal location and sizing of (Photovoltaic generator).

Applying (SAA) and run the code under MATLAB software with a specific value of a Photovoltaic generator to determine the best location for it based on the values of power losses. A minimum power loss occurs when Photovoltaic generator located at bus 8 and the size of the Photovoltaic generator should not be so small or so large and has a range compared tothe total load value. Therefore; the Photovoltaic generator range is between 640.6 MVA (10% of total load) and 1601 MVA (25% of total load) for this system. The optimal size of the Photovoltaic generator is also quantified to get minimum power losses and the appropriate sizing of the Photovoltaic generator at bus-8 which calculated by using simulated annealing algorithmis 760.23MVA, i.e., 11.86% of the total load. After the allocation of the Photovoltaic generator at bus-8, it is seen that the voltage profile for all system buses are raised above 0.95 p.u as shown in Figure (6). It is seen that the voltage magnitudes of bus-15 are increased to 0.953 p. u, represent the minimum bus voltage after placing Photovoltaic generator.

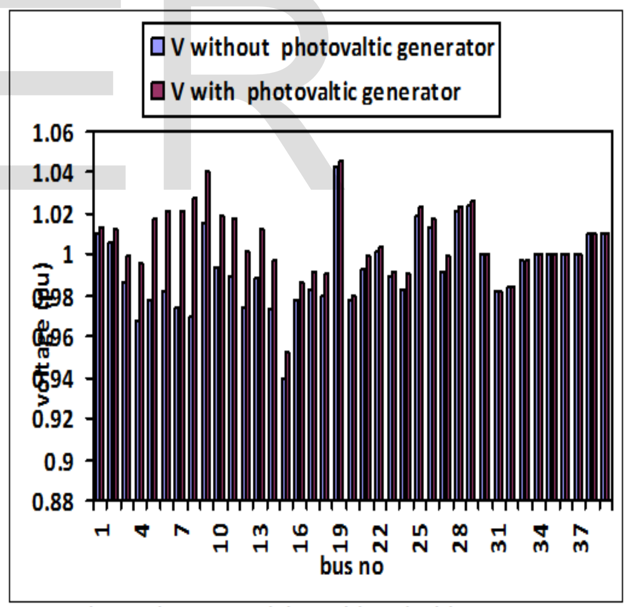


Fig 6: voltage at each bus with and without Photovoltaic generator.

After the proper allocation and size of a Photovoltaic generator in the test system, the results are noted thatthe active and reactive power losses of the network are reduced significantly as shown in Table 1. Where the active power losses are reduced by 7.92% and the reactive power losses are reduced by 20.85%.

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TABLE 1.
COMPARATIVE STUDY OF POWER LOSSES WITH AND WITHOUT PHOTOVOLTAIC GENERATOR.

	ACTIVE POWER LOSS(MVAR)	REACTIVE POWER LOSS(MVAR)
Without Photovoltaic generator	120.761	1096.05
With Photovoltaic Generator at optimal location	111.1953	867.5
Reduction of losses after allocation of DG unit	7.92%	20.85%

5. CONCLUSION

This article presents an efficient process of optimization based onsimulated annealingalgorithm (SAA) which illustrated through the 39-bus system to solve the DG placement and sizing problemin distribution network with reconfiguration ability in order to reduce the losses and increase the voltage profile improvement index, where the appropriate location and size of the Photovoltaic generator has been done easily using suggested method for the determination based on simulated annealing algorithm (SAA) programmed which give results with high accuracy, where the best locationat bus-8 and implemented optimal size of the Photovoltaic generator improve the voltage profile at all buses and also the minimum power loss of the system is obtained.

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