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Effect of DG Installation in Distribution System for Voltage Monitoring Scheme

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Abstract**—**Loss minimization is a long progressing issue mainly in distribution system. Nevertheless its effect led to temperature rise due to significant voltage drop through the distribution line. Thus, compensation scheme should be proper scheduled in the attempt to alleviate the voltage drop phenomenon. Distributed generation has been profoundly known for voltage profile improvement; provided that over-compensation or under-compensation phenomena are avoided. This paper addresses the issue of voltage improvement through different type DG installation. In ensuring optimal sizing and location of the DGs, pre-developed EMEFA technique was made use for this purpose. Incremental loading condition subjected to the system is the concern such that it is beneficial to the power system operator.

Keywords**—**Distributed generation, EMEFA, power loss, voltage profile.

I. Introduction

VOLTAGE drop problem may cause insecure power delivery to consumer. The consequence of voltage drop is loss increment in the whole system. Thus it requires compensating scheme such as static var compensation (SVC) [1], compensating capacitor [2] and distributed generation (DG) [3]. Nowadays, DG is the most commonly used scheme in distribution system. This requires optimization processes such as Genetic Algorithm (GA) [4], Evolutionary Programming (EP) [5], Particle Swarm Optimization (PSO) [6], [7] and Firefly Algorithm (FA) [8].

DG can be categorized as renewable and nonrenewable energy resources. Renewable energy resources comprise of biomass, wind power plants, solar or photovoltaic (PV) generation while technologies that utilize nonrenewable or conventional energy resources included hydro power, gas turbines (GT), fuel cells (FC) and microturbines [9], [10]. DG can be divided into four categories based on the rating of generation source including micro DG (1 W–5 kW), small DG (5 kW–5 MW), medium DG (5 MW–50 MW), and large DG (50 MW–300 MW).

Generally, distribution systems are significantly designed to operate without any generation on the customer sites or at the distribution line. By incorporating DG into distribution systems, it can affect the voltages and power flows and may also contribute towards loss reduction. The increased interest in DG has influenced the development in DG technologies, grid support and expansion of network in distribution system. Decision or determining on DG placement and sizing are to be considered as important factor to ensure maximum benefits. Although the installation and exploitation of DGs to solve network problems has been debated in distribution networks; in most cases, the distribution system operator (DSO) has no control or influence about DG location and size below a certain limit [3]. If the implementation of DG placement is not appropriately done, it may increase the losses which lead to temperature rise on the cable and can cause low or over voltage to the system. It can eventually result an increase in costs of operation [11].

Most studies in the determining the optimal output of DG has only focused on loss minimization without considering the types of DG. This paper presents the effect of DG installation in distribution system for voltage monitoring scheme. It addresses the issue of voltage improvement and loss reduction through different type of DG installation in distribution system. In achieving optimal parameters of the compensating devices, a pre-developed EMEFA was employed. Results from the study revealed the robust capability of EMEFA in making sure that the compensating process does not cause over-compensated and under-compensated.

II. The Evolution of DG Technologies

Along with the rapid development of DG technology into the distribution system, it is important to study the different types of DG.DG can be modeled as voltage controlled bus (PV) or complex power injection bus (PQ)[12]. The different types of the DGs can be characterized in four types as shown in Fig. 1. Fig. 2 illustrates the specific topics on DG types for PV and GT from the year 2000 till year 2013. The increasing number of published papers on the DG installation in distribution system shows that this study is still relevant in power system.

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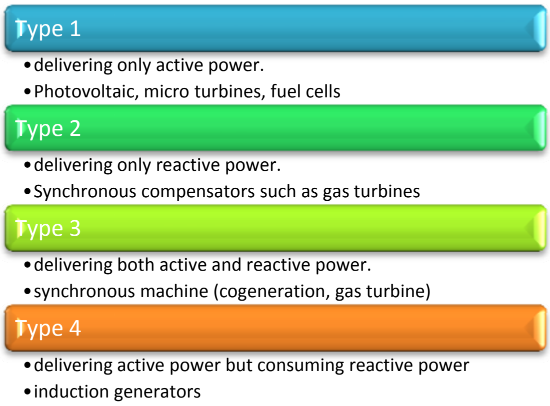

Fig 1 Types of DG

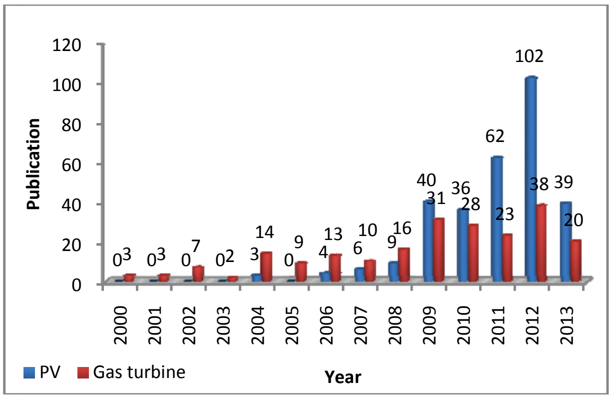

Fig. 2 The number of published papers on the DG types (source: web of knowledge October 2013)

III. Problem Formulation

Many researchers proposed several of techniques for loss minimization and allocation of DG due to improper placement and sizing for DGs which can cause the low or over voltage in the system. For loss minimization of DG, it is necessary to consider the reduction of I^2R loss. This is to ensure and improve the overall efficiency of power delivery in the distribution system. This parameter I^2R loss can be divided to active and reactive components of branch currents. The total I^2R loss in the distribution system with n number of branches is given in (1). The loss associated with the active and reactive power components of branch currents is given by (2) and (3).

$$P_{loss} = \sum_{j=1}^{n} I_j^2 R_j \quad (1)$$

$$P_{L_a} = \sum_{j=1}^{n} I_{aj}^2 R_j \quad (2)$$

$$P_{L_r} = \sum_{j=1}^{n} I_{rj}^2 R_j \quad (3)$$

where;
I_j= current magnitude
R_j = resistance at branch I
I_{aj} = active current component at branch I
I_{rj}= reactive current component at branch I

There are two different types have been considered to show the effectiveness of the proposed method in the investigation of the DG installation problem. The installation of DG was reported as a method of minimizing the loss and could affect both the active and reactive power losses in the system [2]. In this study, the DGs are modeled as type I (PV) and type II (GT). The total real power loss and voltage profile for the base case of the system are calculated, where no DG is installed in the system. In order to study the impact of DG installation on the system, the following two cases are considered:

Case 1. The objective (f_1) is to minimize loss while improve voltage profile in the presence of PV.

Case 2. The objective (f_1) is to minimize loss while improve voltage profile in the present of GT.

Case 3. Comparing the system performance between the installation of PV and GT.

The objective function is proposed to minimize active power loss shown in (4).

$$f_1 = Min\left(\sum_{j=1}^{n} I_j^2 R_j\right) \quad (4)$$

In this study, IEEE 69-bus test system is used as the test specimen. In order to evaluate the effectiveness of the proposed technique, the test was conducted at various loading conditions ranging from 60% to 200% of the base load. The load variation was considered at all buses and also the total loading of the systems.

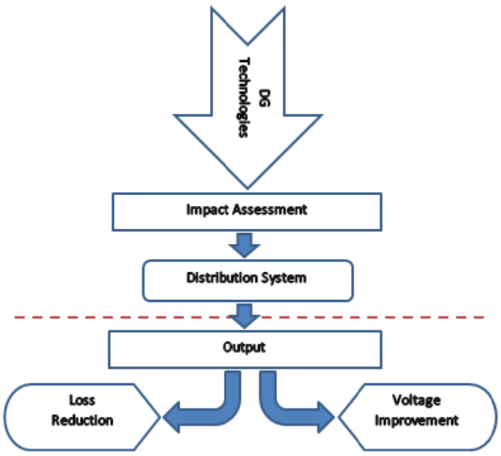

Fig. 3 Conceptual configuration for optimal sizing of different type of DG sources

Step 1 Generate control variable
Initialization process was conducted by generating the control variable using a uniformly distributed random number generation, X_i. The random numbers represent the value of x_i and η_i as the variable to be optimized.
Step 2 Constraint violation test and fitness calculation
Test the value of X_i. The evaluation of the fitness value (y_i) of each population was calculated.
Step 3 Mutation process
A new population is formed by mutating the initial existing population using the mutation operator. Mutation is the only variation operator used for generating the offspring (x_i', η_i') from the each parent. The fitness of the offspring was calculated using same objective function and represent as y'. The mutation formula for MEP is shown in (5) and (6)

$$\eta'_i(j) = \eta_i(j)\exp(\tau' N(0,1) + \tau N_i(0,1)) \quad (5)$$

$$B'_i(j) = B_i(j) + \eta'_i(j) N_i(0,1) \quad (6)$$

Step 4 Combine and sort population
The offspring produced from the mutation process were combined with the parents to undergo the selection process using ranking scheme. The data was rank and sort based on the objective function set in equation (4).
Step 5 Selection process for 'n' fireflies
Based on the ranking data, the best 'n' population was selected as initial location of 'n' numbers of fireflies.
Table I tabulates the FA characteristic.

TABLE I
FA CHARACTERISTIC

Number of fireflies: 20
Maximum iteration: 50
Number of DG unit: 1
α(scaling parameter): 0.25
Minimum value of β(attractiveness): 0.2
γ(absorption coefficient): 1

Step 6 Calculate distance and attractiveness
Move firefly i towards j in d-dimension. Attractiveness varies with distance r via exp[−γr]. Evaluate new solutions and update light intensity. The firefly attractiveness, β can be defined by (7). The distance between any two fireflies i and j are calculated using the Cartesian distance in (8). The movement of firefly i is attracted to another more attractive (brighter) firefly j, determined by (9).

$$\beta = \beta_0 e^{-\gamma r^2} \quad (7)$$

$$r_{ij} = \left\| x_i - x_j \right\| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \quad (8)$$

$$x_i = x_i + \beta_0 e^{-\gamma r^2}(x_j - x_i) + \alpha(\text{rand} - 0.5) \quad (9)$$

Step 7 Fitness calculation
The evaluation of the fitness value (y_i) of each population was calculated.
Step 8 Convergence test
The convergence criterion is specified by the difference between the maximum and minimum fitness to be less than 0.0001. If the convergence condition is not satisfied, the processes will be repeated again until the convergence criterion is met.

$$maximum_{fitness} - minimum_{fitness} \le 0.0001$$

Fig. 4 Complete algorithm of the EMEFA technique

The conceptual configuration designed for the effect of different DG type installation voltage monitoring scheme is shown in Fig. 3. In order to produce the best performance of DG installation in the system, the outputs of this study are loss reduction and voltage improvement.

IV. METHODOLOGY

The EMEFA technique was developed with an objective to minimize the distribution losses while improving the voltage profile in the system. The EMEFA is developed based on embedded FA properties into the Meta Evolutionary Programming (MEP). Based on the literature study, it is found that hybridizing them together with other algorithms could improve the performance and become faster, efficient, and more robust [13]. The complete algorithm of the EMEFA is explained in the following procedural form in Fig. 4.

V. RESULTS AND DISCUSSION

The proposed EMEFA technique was simulated and tested on the IEEE 69-bus test system. The effect of the DG installation using different types of DG is observed by installing the DG at bus 61. The idea is to minimize distribution losses with the proposed EMEFA. In the simulations, two conditions are addressed which are without DG and with DG installed in the system. The analysis was conducted based on two cases which are discussed below.

A. Effect of DG Type in Loss Profile

The effect of DG type in loss profile was tested and analyzed for case 1 and case 2 using EMEFA technique with the objective function is defined as in (4).The analysis was conducted by looking into variation in loading conditions at the load buses ranging from 60% to 200%of the base load condition**.** The results are discussed below.

Case 1:

In this case, the loss profile was calculated while optimal output of PV is determined with PV install at bus 61. The results are shown in Fig. 5. It is clear that the total power loss has been reduced with the PV installed in the system compared to without PV. Fig. 6 indicates the optimal PV output for loss minimization in the system for overall load increase in the system. The graph also shows that the PV output is higher as the loading increased from 60% to 200%.

Case 2:

Similar study was performed with GT install at bus 61. The results are shown in Fig. 7. It is clear that the total power loss has been reduced with the GT installed in the system compared to without GT.

Fig. 8 indicates the optimal GT output for loss minimization in the system for overall load increase in the system. The graph also shows that the GT output is higher as the loading increased from 60% to 200%.

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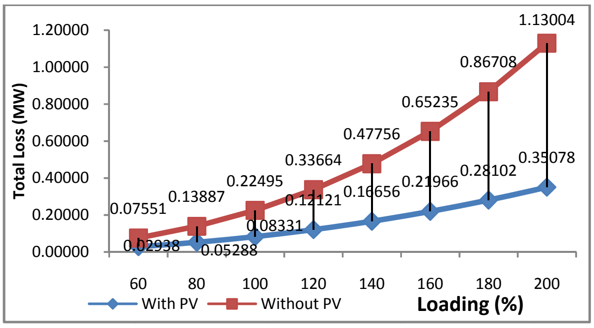

Fig. 5 Total losses with installation of PV for overall load increase in the system

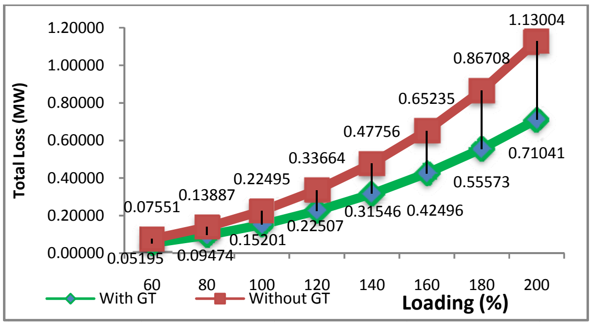

Fig. 7 Total losses with installation of GT for overall load increase in the system

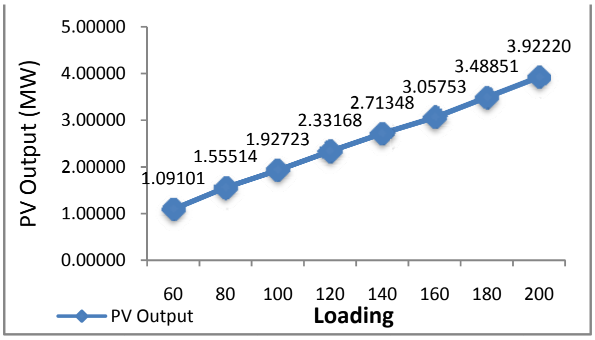

Fig. 6 Optimal PV output for loss minimization in the system for overall load increase in the system

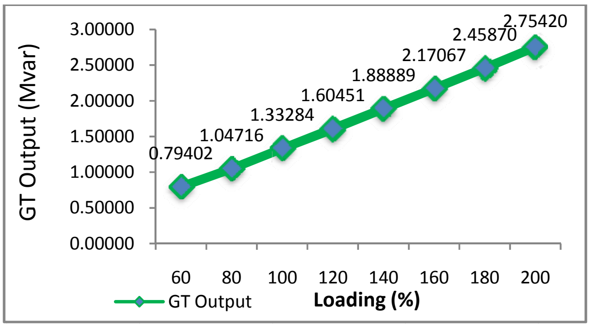

Fig. 8 Optimal GT output for loss minimization in the system for overall load increase in the system

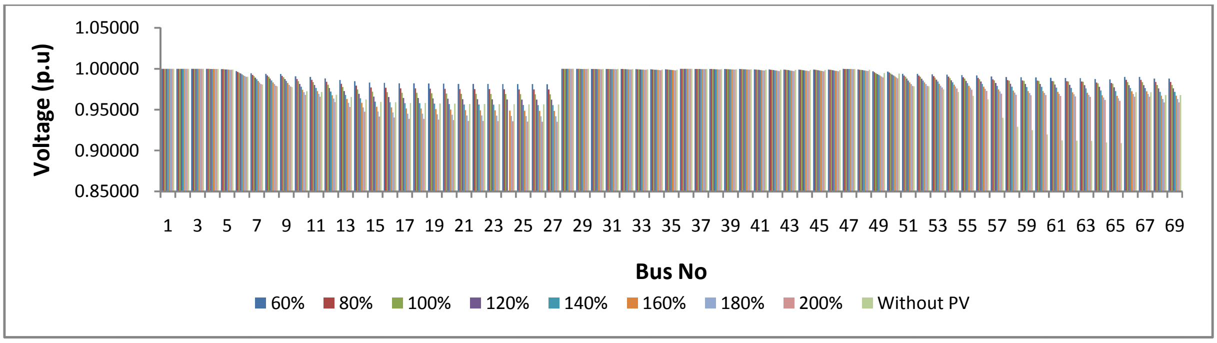

Fig. 9 Voltage performance with installation of PV for overall load increase in the system

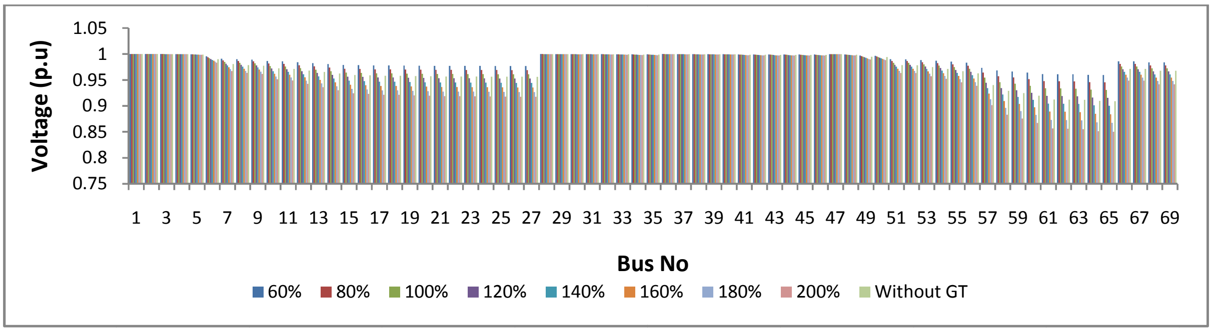

Fig. 10 Voltage performance with installation of GT for overall load increase in the system

B. Effect of DG Type in Voltage Performance

The effect of DG type in voltage performance was tested and analyzed for case 1 and case 2. Fig. 9 indicates the voltage variation when the optimal PV install at bus 61 for overall load increase in the system. It could be observed that allocating PV at bus 61 has given better voltage improvement and the voltage profile of the system is maintained at an acceptable range compared to without DG. Similar study is conducted with GT installed at bus 61. Fig. 10 displayed the voltage variation when the optimal GT installed at bus 61. It can be observed that allocating GT at bus 61 has given better voltage improvement.

C. Comparative Study on the System Performance between the Installation of PV and GT

The comparison in the system performance in terms of loss reduction between installation of PV and GT at bus 61 could be observed in the graphs shown in Fig 11. The results were compared to the base case to show the performance with the installation different types of DG in the system. From this graphs, it can be concluded that the installation of PV gives better loss minimization in the system as compared to GT. Fig 12 indicates the comparison on optimal PV and GT output for loss minimization and voltage improvement in the system for overall load increase in the system. The graph shows that the PV output is higher than GT output as the loading increased from 60% to 200%.

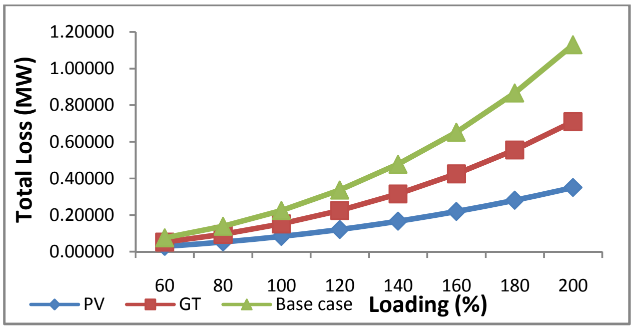

Fig. 11 Comparison on total losses for overall load increase in the system

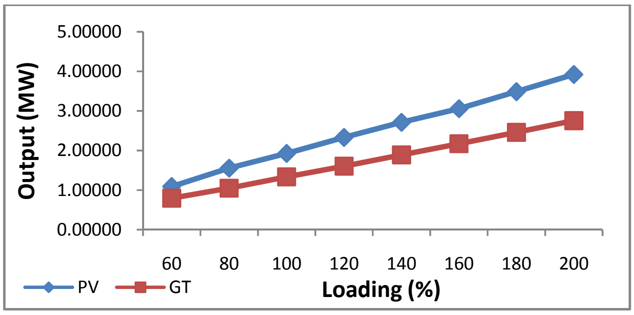

Fig. 12 Comparison on optimal output for PV and in the system for overall load increase in the system

VI. Conclusion

In this paper, EMEFA approach for DG installation which considers the minimization of power loss and the voltage performance was successfully implemented and tested on IEEE 69 bus test system. This technique is developed to determine the optimal output of PV and GT with the load variation from 60% to 200% of the base load condition. The proper placement and sizing for DGs is very important to avoid the low or over voltage in the system. This is to ensure and improve the overall efficiency of power delivery in the distribution system. Comparative studies have been conducted in order to highlight its strength in terms of its ability to achieve optimal solution. It can be revealed that the proposed EMEFA has successfully reduced the loss profile and improving the voltage performance.

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