International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

March 2014	Issue 18	Volume 6	Number 1	Pages 125-130

OPTIMAL ALLOCATION OF DG UNITS AND VAR COMPENSATORS SUSPECT TO GA BASED REACTIVE POWER FOR POWER LOSSES DECREASING AND VOLTAGE STABILITY AND PROFILE IMPROVEMENTS

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Abstract- Distributed Generation (DG) systems are considered an integral part in future distribution system planning. The active and reactive power injections from DG units, typically installed close to the load centers, are seen as a cost effective solution for distribution system voltage support, energy saving, and reliability improvement. This paper proposes first to optimal allocate of DG units (suppose of unity power factor) by GA aspect of active power to decrease of power losses and improve of voltage profile with DG then proposes to compare of various technology of DG units instance of synchronizes generation by 0.8 lag power factor and wind turbines by 0.98 lead power factor. Same of expected, if wind turbine units connected to grid this units consumer of reactive power of grid so occasion of increase of power losses and decrease of voltage stability of grid, while these units connected to the grid. In this paper second propose to while the wind turbine units connected to the grid allocate of VAR compensator units by GA aspect of reactive power to decreases of power losses and improve of voltage stability. In this paper case study is a 34-bus IEEE distribution system finally indicate of results and compare of results.

Keywords: DG, Voltage Stability, Voltage Profile, Power Losses, Genetic Algorithm (GA), Compensation.

I. INTRODUCTION

Renewable Distributed Generation (DG) systems, with dispatchable and non-dispatchable generation patterns, exhibit techno economic benefits to various stakeholders. The grid integration of dispatchable renewable DG units such as biomass generators has been seen as one of the attractive options to meet the ever increasing load demands while significantly improving customer reliability and reducing the overall emissions. In recent years, an increasing number of renewable DG units having intermittent generation patterns are being interconnected into the distribution system.

The integration of these renewable DG units such as wind and solar photovoltaic (PV) based units provides an opportunity to further support the distribution system while possibly reducing fuel cost associated with the fuel based DG units. However, integration of non-dispatchable renewable DG units cannot guarantee fixed power output due to the uncertainties in power availability. Therefore, it is important to assess and quantify the relative system performance with the integration of non-dispatchable renewable DG units.

In [1] proposed a novel distribution system expansion planning strategy encompassing renewable DG systems with schedulable and intermittent power generation patterns. The reactive capability limits of different renewable DG systems covering wind, solar photovoltaic and biomass based generation units are included in the planning model and the system uncertainties such as load demand, wind speed, and solar radiation are also accounted using probabilistic models.

The problem of distribution system planning with renewable DG is formulated as constrained mixed integer nonlinear programming, wherein the total cost will be minimized with optimal allocation of various renewable DG systems. A solution algorithm integrating TRIBE Particle Swarm Optimization (TRIBE PSO) and Ordinal Optimization (OO) is developed to effectively obtain optimal and near optimal solutions for system planners. TRIBE PSO, OO, and proposed algorithm are applied to a practical test system and results are compared and presented.

In [2] Reactive Power Planning (RPP) is proposed here as a three objective optimization as reactive compensation investment, system loss, and the active power stability margin after critical contingencies. A two level optimizer with Improved Non-dominated Sorting Genetic Algorithm (NSGAII) and Interior Point Algorithm is proposed to obtain Pareto front of RPP. NSGAII performs optimization in planning stage to find optimal compensation scheme (locations and sizes of VAR devices).

According to the compensation scheme, operation oriented stage adjusts the output of the VAR devices to optimize the economic aspect (system loss) and security (post-contingency stability margin). A simulation was conducted on New England 39-bus system and a three-dimensional Pareto front was obtained, showing the decrease of system loss and the increase of stability margin with gradual addition of VAR support. Solutions under different compensation level are given, among which suitable solutions can be selected for RPP.

Reference [3] has analyzed the impact of distribution power quality, especially unbalancing and triplen harmonic, on DG interconnection protection. We explored that the unbalanced single phase loads increase neutral current at DG interconnect transformer by analysis of measured data and simulation of PSCAD/EMTDC. An impact of triplen harmonic on DG interconnection transformers, which are grounded wye (utility)-delta (DG) was also studied in same method. We confirmed that the power quality should be considered carefully for setting of ground overcurrent trip pick up level.

In [4] reactive power planning (RPP) is one of the most important task in operation and control of power systems. This paper presents a methodology, based on genetic algorithms (GA), for optimal placement of DG units in power networks to achieve both effects, to guarantee the voltage profile and to maximize the voltage loadability under normal and/or contingency conditions. The methodology aims in finding the configuration, among a set of system components, which meets the desired system reliability requirements taking into account stability limits.

Results shown in the paper indicate that the proposed formulations can be used to determine which the best buses are where the addition of small distributed generator units can greatly enhance voltage stability of the whole network and power transfer capability under contingencies. Reference [5] proposes a distributed generator (DG) placement methodology based on newly defined term reactive power loadability. The effectiveness of the proposed planning is carried out over a distribution test system representative of the Kumamoto area in Japan.

Firstly, this paper provides simulation results showing the sensitivity of the location of renewable energy based DG on voltage profile and stability of the system. Then, a suitable location is identified for two principal types DG, i.e., wind and solar, separately to enhance the stability margin of system. The analysis shows that the proposed approach can reduce the power loss of the system, which in turn, reduces the size of compensating devices. In [6] an optimal way of real and reactive power management in radial distribution systems with distributed generations (DG) to improve voltage profile is presented in this paper.

Distributed generations effectively reduce the real power loss in radial distribution system compared to other methods of loss reduction and simultaneously improve the reliability of the system. In this paper, a solution methodology based on the voltage stability index has been proposed for optimal siting of distributed generations. The optimal sizing of the sources has also been carried out using genetic algorithm for better voltage regulation, voltage stability index and reduced network power loss in the radial distribution system.

An emphasis is laid in this paper on the application of Wind Turbine Generator System (WTGS) because of the distinct behavior of the induction generators present in them. A detailed performance analysis is carried out on Indian 25-bus system, 33-bus and 69-bus systems to demonstrate effectiveness of the proposed methodology.

This paper proposes first to optimal allocate of DG units (suppose of unity power factor) by GA aspect of active power to decrease of power losses and improve of voltage profile with DG then proposes to compare of various technology of DG units instance of synchronizes generation by 0.8 lag power factor and wind turbines by 0.98 lead power factor. Same of expected if wind turbine units connected to grid this units consumer of reactive power of grid so occasion of increase of power losses and decrease of voltage stability of grid while these units connected to the grid.

In this paper second propose to while the wind turbine units connected to the grid allocate of VAR compensator units by GA aspect of reactive power to decreases of power losses and improve of voltage stability. In this paper, case study is a 34-bus IEEE distribution system finally indicate of results and compare of results. The paper organize as follows. Formulated as a multi-objective optimization problem and power flow problem by forward and backward procedure use in this paper in section II.

Then, two level scenario of GA indicate to background of GA use the paper in section III. In section IV, the framework and procedure of the two-level optimizer are discussed. The proposed optimizer is applied to 34-bus IEEE distribution system (section V).

II. PROBLEM FORMULATION

Calculating load flow is a critical calculating to appointment of behavior from distribution power system. Extension of power system and connected DG units to power system conventional methods of OPF instance of Newton- Raphson, Z_{bus}, fast decoupled could not support to OPF carefully because when the DG unit connected to grid cause to two vector power supply of grid thus in this paper for OPF as forward and backward method to solve this problem [7]. Restrictions and equations of this problem:

1- Restriction of VAR supplier installation:

$$0 \le Q_{ci} \le Q_{ci}^{\max} \tag{1}$$

2- Restriction of active and reactive power from DG units:

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max} \tag{2}$$

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max} \tag{3}$$

3- Power factor fix at load buses.

4- Power flow equations:

$$P_{gi} - P_{li} = \sum V_i V_j \left[G_{ij} \cos(\delta_{ij}) + B_{ij} \sin(\delta_{ij}) \right] \tag{4}$$

$$Q_{gi} - Q_{li} + Q_{ci} = \sum V_i V_j \left[G_{ij} \cos(\delta_{ij}) - B_{ij} \sin(\delta_{ij}) \right] \tag{5}$$

5- Voltage limitation at load buses:

$$V_i^{\min} \le V_i \le V_i^{\max} \tag{6}$$

A. Calculation of Voltage Stability Index

More indexes exist for analyze of improvement voltage stability at power system such as, analyze of Q-V curves, analyze of P-V curves and L-index. In this paper as L-index use to analyze of voltage stability. Thus, by suppose of n-bus system shared to two group of generation buses and load buses, 1 to g buses is generation buses and g+1 to n is odd buses. Consideration of admittance matrix:

$$\begin{pmatrix} I_g \\ I_l \end{pmatrix} = \begin{pmatrix} Y_{gg} & Y_{gl} \\ Y_{\lg} & Y_{ll} \end{pmatrix} \begin{pmatrix} V_g \\ V_l \end{pmatrix} \tag{7}$$

With the reorganization of the above equations, we get the following equations:

$$\begin{pmatrix} V_l \\ I_g \end{pmatrix} = \begin{pmatrix} Z_{ll} & F_{\lg} \\ K_{gl} & Y_{gg} \end{pmatrix} \begin{pmatrix} I_l \\ V_g \end{pmatrix} \tag{8}$$

L-index for load buses is obtained from the following equation:

$$L_j = \left| 1 - \sum_{i=1}^{g} F_{ig} \left(\frac{V_i}{V_j} \right) \right| \tag{9}$$

$F_{\lg}$ admittance matrix can be given by following equation:

$$F_{\lg} = -[Y_{ll}]^{-1} [Y_{\lg}] \tag{10}$$

The L-index is a number between zero and one, whatever that number is closer to one indicates instability and voltage collapse, and whatever that number is closer to zero can be indication-increased stability.

B. Calculation of Voltage Regulation

In order to calculate the voltage regulation, voltage profile flattening we use the following equation:

$$V_R = \frac{1}{n} \sum_{i=1}^{n} \left| V_i^{\max} - V_i^{\min} \right| \times 100 \tag{11}$$

where, n is number of buses, $V_i^{\max}$ is peak point voltage of bus i, $V_i^{\min}$ is minimum point of voltage from bus i.

III. TWO LEVEL SCENARIO OF GA INDICATE TO BACKGROUND OF GA USE THE PAPER

Algorithms to locate and identify problem in first part of DG capacity. In this section, placement of distributed generation sources in network, genetic algorithm is used. For placement of distributed generation sources in the network, it is considered as negative load, and the active power supply network we can reduce losses and improve the voltage profile and power factor units to locate and determine the optimal capacity.

The distribution networks because these networks are very sensitive for power load flow we use in channel vacuum backward and forward method was explained [7]. Solving flowchart is shown in Figure 1. DG units used in this paper are supposed three sources of distributed generation capacity of 1.5 MW, which are selected according to network capacity. The objective function that we minimize it to the tray is as Equation (12).

$$f_1(x) = AS_l^{total} + B \sum_{j=1}^{n} 1 - |V_j|^2 \tag{12}$$

First, we assume a constant power factor of DG then place them in the same capacity and type synchronous generator with power factor 0.8 lag assumed and in the latter scenario, the resources of wind turbines with a power factor of 0.98 lead assume that the results of these studies comes to in the next chapter.

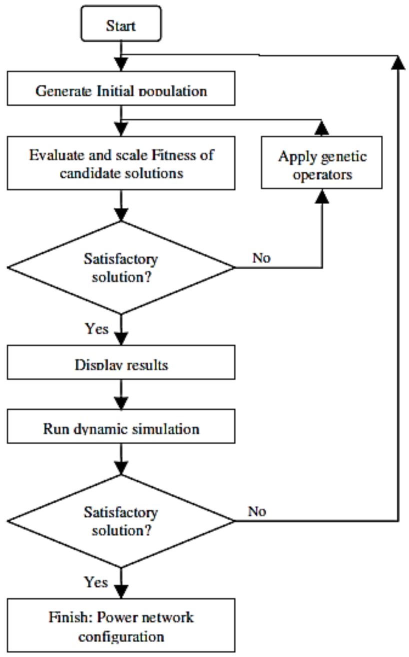


Figure 1. Flowchart of GA for optimal allocate of DG units

The second part of the algorithm solving the problem of allocating resources to the compensator network when use wind turbine. When the network of distributed generation sources of implemented renewable sources such as wind turbines and photovoltaic cells use because these sources are connected to the network by inverter In this case, the reactive power are consumption of these resources. Types of wind turbines connected to the grid are shown in Figure 2.

In this case, we use two scenarios of the genetic algorithm aspect of reactive power to improve voltage stability grid L-index and minimize the losses in the network, proposed flowchart is shown in Figure 3. In the first scenario, we assume that each of the three-power compensator with a maximum capacity of 1 MVAR is used to optimize the objective function.

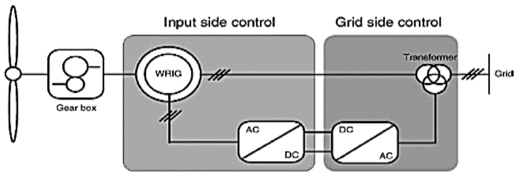
Table 1. Results of load flow before DG connected to network

P_{loss}	0.241 MW
$Q_{loadability}$	0.71 MVAR

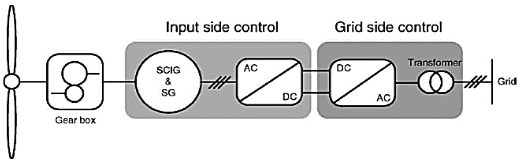
In the second scenario, we assume a maximum of three compensator sources, each with a capacity of 500 kVAR is used to optimize the objective function. The results of this study are presented in the next section. Optimization objective function for optimal allocation of resources pertaining to the following form.

$$f_{1(x)} = C\left[\frac{\text{real}(SLT_{(i)})}{\text{real}(SLT_{(i)})+\text{real}(SLT_{(Base)})}\right]+ \\ +D\left[\frac{\text{img}(SLT_{(i)})}{\text{img}(SLT_{(i)})+\text{img}(SLT_{(Base)})}\right]+L_j E \quad (13)$$

where, $SLT(I)$ is the total losses of the system at each step of the iteration, $SLT_{(Base)}$ is total loss before compensation system, L_j is voltage stability index, C, D, and E are weighting coefficients and matrices.



(a)



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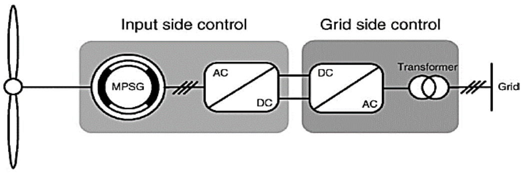

(c)

Figure 2. Types of methodology when wind turbine connected to grid

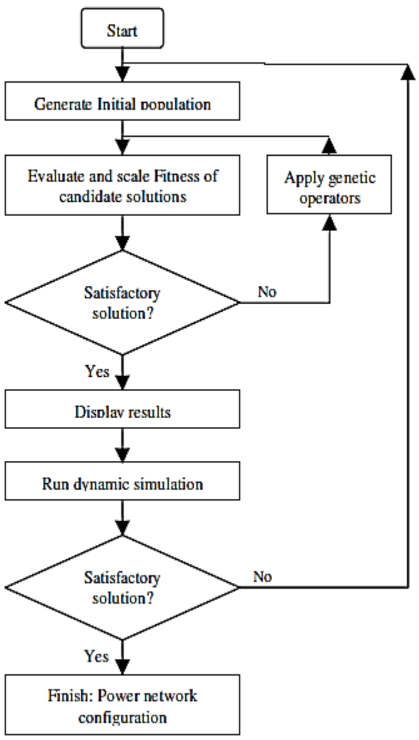

Figure 3. Flowchart of GA for optimal allocate of compensator resources

IV. CASE STUDY

Case study at this paper is a radial network standard IEEE 34-bus as shown in Figure 3. This network is a standard distribution network that additional information is provided in IEEE.

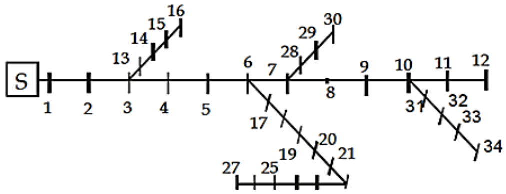

Figure 4. Case study IEEE 34-bus distribution system

V. SIMULATION RESULTS

Intelligent genetic algorithms has been discussed in various articles about intelligent genetic algorithm is an algorithm for optimization problems generations of evolutionary uses algorithm to achieve the optimal solution and the probability of falling in local minimum solution is very low. Distributed generation units are assumed with a capacity of 1.5 MW. Three units used in this paper, at first this units aspect of active power analyze to improve the voltage profile and reduce network losses locate and determine the optimal capacity.

In the second step, DG units used to this paper assumed type of synchronize generation by 0.8 lag power finally this units assumed type of wind turbine by 0.98 lead power factor then comparison between different approaches to DG. Before DG units connected to the grid, the results from load flow are shown in Table 1. Also in Figure 4, the voltage profiles are shown in standard mode network.

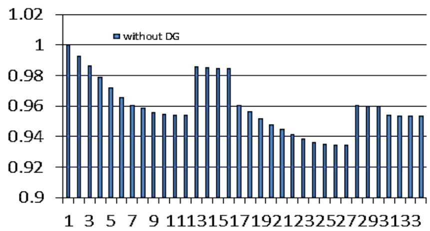

Figure 4. Voltage profile without DG from standard mode of network

After implementing first stage of allocating resources for MATLAB distributed generation by GA assuming unit power factor results are presented in Table 2.

Table 2. The results of the placement and allocation of DG units

Bus number	*P* generation (MW)
8	1.26
25	1.32
28	1.24

Power losses when DG units by unit power factor according to results of GA programming are shown at Table 3.

Table 3. Power losses by DG

P_{loss}	0.079 MW
$Q_{loadability}$	0.022 MVAR

If we assume that DG units uses kind of synchronous generator with power factor 0.8 lag in this case DG units are produced reactive power from network thus network losses are indicated in Table 4.

Table 4. Power losses by DG kind of synchronous generator

P_{loss}	0.028 MW
$Q_{loadability}$	0.006 MVAR

Then if we assume that DG units uses kind of wind turbine with 0.98 lead power factor in this case DG unit are consumption reactive power of network thus network losses are indicated at Table 5.

Table 5. Power losses by DG kind of wind turbine

P_{loss}	0.125 MW
$Q_{loadability}$	0.035 MVAR

Voltage profiles when DG units discussed in this paper connected to network are shown in Figure 5. As is clear when we use wind turbine power losses is increased and voltage profile is worse than when we use synchronous generator.

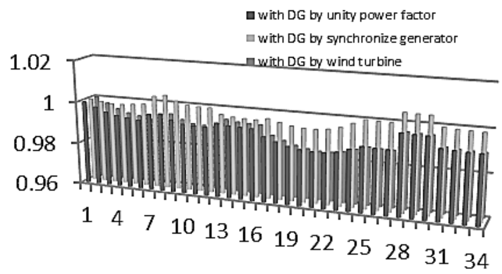

Figure 5. Voltage profiles discussed in this case

Comparison between the L-index to measure voltage stability discussed in this case is shown in Figure 6. The results are obtained when we use wind turbine unit L-index is increased that cause of voltage instability compared with other case discussed.

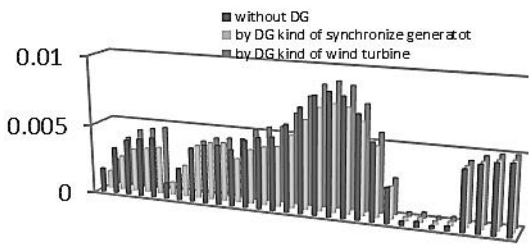

Figure 6. L-index for different mode of DG

Now we enter the second step problem solving. At this stage, the resource allocation compensator when we use wind turbine according to pervious results. At this stage we implemented GA by MATLAB for allocation of compensator resources with aim of decrease of power losses and increasing the voltage stability. For GA at this stage we define two scenario. In the first scenario, we assume a maximum capacity of three compensator is implemented 1 MVAR.

In addition, second scenario, we assume a maximum capacity of three compensator is implemented 500 kVAR. By performance of first scenario program Compensated resource allocation results is indicated in Table 6.

Table 6. The results of allocation compensator resources by implemented of first scenario of GA

Bus No.	Q injection
4	0.7969
23	0.2074
21	0.5638

According to the results of Table 6, the power losses are indicated in Table 7. According to the results of Table 8, the power losses are indicated in Table 9. Then by performance of second scenario program Compensated resource allocation results is indicated in Table 8.

Table 7. Power losses by wind turbines and compensator resources under first scenario

P_{loss}	0.023 MW
$Q_{loadability}$	0.004 MVAR

Table 8. The results of allocation compensator resources by implemented of second scenario of GA

Bus No.	Q injection
34	0.2009
22	0.316
30	0.4926

Table 9. Power losses by wind turbines and compensator resources under second scenario

P_{loss}	0.029 MW
$Q_{l0adability}$	0.006 MVAR

The performances of these programs, we conclude the optimal allocation of compensator resources sufficient to reduce power losses significantly. Power losses at first scenario is less than power losses at second scenario. In addition, power losses at first scenario is less than power losses system by assume synchronize generator connected to network. Figure 7 is the result of when we use optimal allocation of compensator resources when wind turbine unit connected to network voltage profile is smooth significantly.

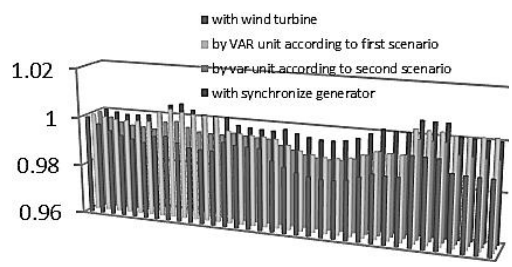

Figure 7. Voltage profile of system at all of scenario

L-index in various scenarios examined in this paper is shown in Figure 8. Figure 7 is the result of when we use optimal allocation of compensator resources when wind turbine unit connected to network voltage stability is increasing significantly.

The results of the first scenario, the second stage are more favorable than the results of the second scenario.

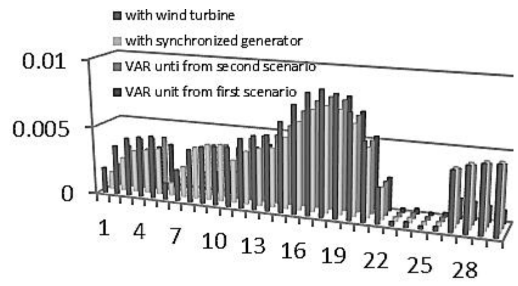

Figure 8. L-index of system at all of scenario

VI. CONCLUSIONS

In this paper, for reduce power losses and increasing of voltage stability aspect of reactive power when we use wind turbine unit at network by optimal compensator resources by GA to achieve this goal accurately. As is clear when we use wind turbine units in network this units consumed reactive power that leads to increasing power losses and voltage instability for compensate this manner by GA in MATLAB to optimal allocation of VAR units can be improve this manner.

NOMENCLATURES

$SLT_{(i)}$: The total losses of the system at each step of the iteration
$SLT_{(Base)}$: Total loss before compensation system
L_j: Voltage stability index
C, D, E: Weighting coefficients and matrices

ACKNOWLEDGEMENTS

The authors appreciate from Science and Research Branch, Islamic Azad University, Karaj, Iran for all supports.

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