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OPTIMAL DISTRIBUTED GENERATORS LOCATION FOR POWER LOSSES IMPROVEMENT USING SENSITIVITY BASED METHOD

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ABSTRACT

The electrical energy generation companies try always to improve the system performance through reducing the active power losses and that lead the fuel cost is reduced also. One of the way is by incorporate is Distributed Generation (DGs). DGs are becoming more prominent in transmission systems due to increased demand for the electrical energy. The location of DGs sources will have an impact on system losses of the network. This article discusses the application of Sensitivity Analysis (SA) to improve power losses when Distributed Generators (DGs) are used. And by substituting these loss sensitivities, the optimal generation location for minimizing the system loss can be directly obtained. The simulation results on IEEE 30 bus test system indicate that bus 13 is the optimal location of DG based on its negative of partial derivative value.

Key words: DG• Sensetivity method• Powe losses•

INTRODUCTION

Active power losses in the transmission are about 4–8% of the total active power generated as example for that in Brazil the cost of the loss is half a billion U.S. dollars a year [1].

Recently, Distributed Generations (DGs) have received great attention in power systems as a solution to environmental and economical challenges caused by conventional power plants. DGs are defined as electric power generations directly connected to near the loads or in the distribution networks, also the DGs range from a few kWs to a few MWs and DGs have many types like (wind turbines, photovoltaic, full-cells, biomass, micro turbines, etc.) [2].

According to CIGRE report, the contribution of DGs in Denmark and the Netherlands has reached 37% and 40%, respectively, as a result of liberalization of power market in Europe [3].

In general because of the fundamental importance of these sources (renewable energy) the international demand for energy has been growing progressively. This demand, which is expected to increase by about 30% for 2040 as compared to 2010, has been driven by the demographic and economic growth, mainly related to emerging economies, especially in Asia [4].

In [5], by considering the flow of current and voltage along the lines the researchers developed a mathematical model for determining power losses over typical transmission lines, as the resultant effect of ohmic and corona power losses. Application of the classical optimization technique aided the formulation of an optimal strategy for minimization of power losses on transmission lines.

Insertion of DGs plants into the distribution system may benefit utilities, customers, and the environment. It may also cause operation and safety problems. One of the most important technical problems concerning the installation of DGs in distribution systems is the power loss. Characteristics such as the size, location, and operation mode of the distributed generators are decisive in determining the impacts of DGs on power losses of distribution systems. Due to the complexity of the networks, to identify which generator can reduce the power losses, may be a difficult task. In such case, successive power flow studies must be carried out, especially in multi-DG systems.

Using sensitivity based method, this paper presents DGs allocation for power losses improvement. SA has the cababilty to directly calculate the change in all network variables [6].

REAL POWER LOSS SENSITIVITY DETERMINATION

Power systems designed with several generators interconnected with one another by long transmission lines are suffer from high losses. These losses depend on the current and resistances in transmission lines. The losses usually referred as thermal losses. While the resistance is usually a fixed value, the current is a variable which is a compound function of the system (grid) arrangement, generator locations and loads.

This work is concerned with the real power as it is directly related to transmission losses. The system power losses (P_{Loss}) can be expressed as follows:

$$P_{Loss} = \sum_{i=1}^{N} P_{Gi} - \sum_{i=1}^{N} P_{Li} \qquad (1)$$

Where

P_{Gi} : real power generated at bus (i).P_{Li} : real power load at bus (i).

The losses sensitivities from the power injections in each bus system are calcualated here.

Mathematically the total active power losses of a line lumped model are calculated from:

$$P_{LOSS} = \sum_{i=1}^{nL}\left[g_{km}\left(V_k^2+V_m^2-2V_K V_m\cos\theta_{km}\right)\right] \qquad (2)$$

where nL is the number of lines of the network; V_k and V_m are the nodal voltages of bus k and bus m respectively; g_{km}

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is the conductance of the line *km*; and the θ_{km} is the phase angle difference between the busses *k* and *m*.

The total power losses can be expressed as function of the active power injection (P) and reactive power injection (Q), which in turn depend on the network state (V, θ).

Active Loss Sensitivity

Using partial derivatives [7], the total active losses can be expressed as follows:

$$\frac{\partial P_{LOSS}}{\partial \theta} = \frac{\partial P_{LOSS}}{\partial P}\left(\frac{\partial P}{\partial \theta}\right) + \frac{\partial P_{LOSS}}{\partial Q}\left(\frac{\partial Q}{\partial \theta}\right) \qquad (3)$$

$$\frac{\partial P_{LOSS}}{\partial V} = \frac{\partial P_{LOSS}}{\partial P}\left(\frac{\partial P}{\partial V}\right) + \frac{\partial P_{LOSS}}{\partial Q}\left(\frac{\partial Q}{\partial V}\right)$$

Manipulating (3), it can be rewritten as:

$$\begin{bmatrix} \left(\dfrac{\partial P_{LOSS}}{\partial \theta}\right)^T \\ \left(\dfrac{\partial P_{LOSS}}{\partial V}\right)^T \end{bmatrix} = \begin{bmatrix} \left(\dfrac{\partial P}{\partial \theta}\right)^T & \left(\dfrac{\partial Q}{\partial \theta}\right)^T \\ \left(\dfrac{\partial P}{\partial V}\right)^T & \left(\dfrac{\partial Q}{\partial V}\right)^T \end{bmatrix} \begin{bmatrix} \left(\dfrac{\partial P_{LOSS}}{\partial P}\right)^T \\ \left(\dfrac{\partial P_{LOSS}}{\partial Q}\right)^T \end{bmatrix} \qquad (4)$$

Finally, the active loss sensitivities with respect to the power injection in each bus system is expressed by:

$$\begin{bmatrix} J_{A-P} \\ J_{A-Q} \end{bmatrix} = \begin{bmatrix} \dfrac{\partial P_{LOSS}}{\partial P} \\ \dfrac{\partial P_{LOSS}}{\partial Q} \end{bmatrix} = \left[J^T\right]^{-1} \begin{bmatrix} \dfrac{\partial P_{LOSS}}{\partial \theta} \\ \dfrac{\partial P_{LOSS}}{\partial V} \end{bmatrix} \qquad (5)$$

where J_{A-P} is the active loss sensitivity related to the active power injection, the J is the active loss sensitivity related to the reactive power injection J_{A-Q}, and represents the Jacobian matrix of power flow. The superscript T indicates the transpose of matrix.

Next figure illustrate the meshed test system used in this paper. IEEE 30 bus test system consists of 30 bus, 42 lines, 5 generators and 24 bus load.

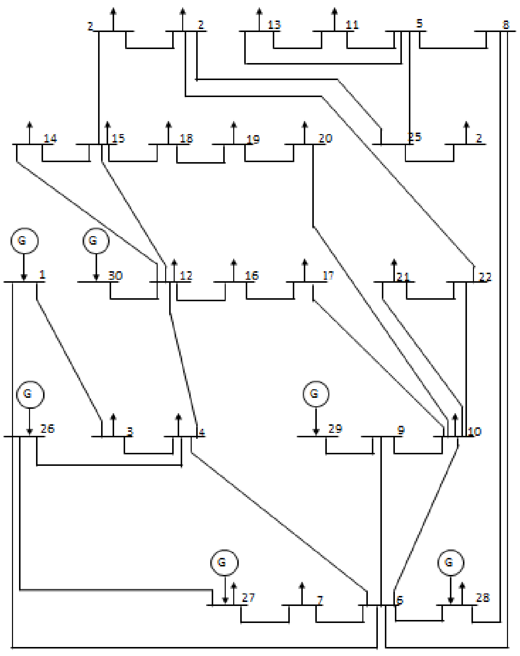

Figure 1: IEEE 30 buses test system

RESULTS

The proposed method was tested on the IEEE 30-bus test system shown in figure 1, in case of maximum load which can be considered as a meshed transmission/subtransmission system [8].Table 1 represents the bus loads in a descending order for the partial derivative values.

Table1: Loads connected to buses in a descending order for the partial derivative values

Bus No.	Partial derivatives	Bus No.	Partial derivatives
13	-0.2041	15	-0.1147
2	-0.1734	7	-0.1142
11	-0.1634	8	-0.1089
24	-0.1383	14	-0.1062
19	-0.1365	17	-0.106
25	-0.1338	10	-0.1004
18	-0.1326	16	-0.0992
23	-0.1306	9	-0.0988
20	-0.1281	6	-0.0983
21	-0.1187	4	-0.0836
22	-0.1172	12	-0.0811
5	-0.1166	3	-0.0654

From Tables 1, bus 13 with the biggest negative derivative, and bus 3 with the least negative derivative were selected to be the only two locations for real power injection in a gradual way. Then the variation in the loss was recorded with the real power added and the value of the sensitivity for each of these bus.

Figures 2 and 3 show the relationship between the loss and the real added power at buses 13 and 3 respectively for the case of maximum load.

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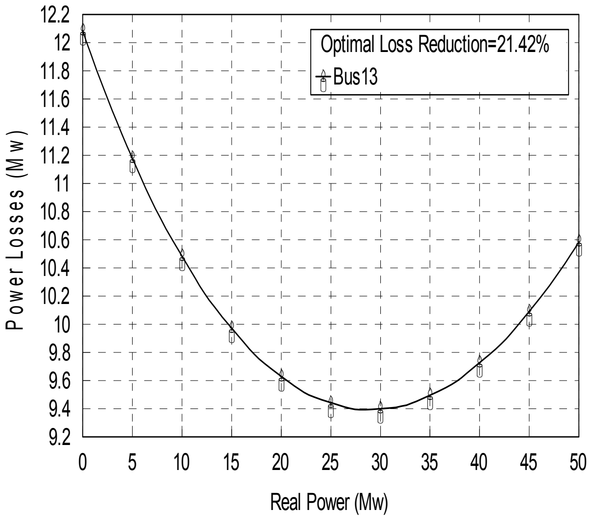

Figure 2: Real power sensitivity and power losses at bus 13 for maximum load case

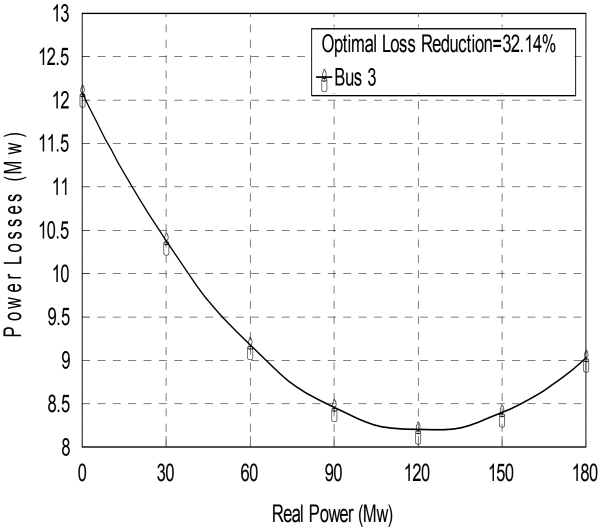

Figure 3: Real power sensitivity and power losses at bus 3 for minimum load case

As it can be seen that the percentage decrease in the loss for bus 13 was 21.42% while for bus 3 it was 32.14%. By comparing the results of bus 13 for both maximum loads in Table 1 it can be seen that the value of the partial derivatives was -0.2041 for the maximum load while it is -0.0654 on bus 3. Also, the amount of the real power required to reach the point where the loss start to increase was around 30 MW for bus 30, while it was around 120 MW for the bus 3 load.

Figures 4 and 5 illustrate the relationship between the loss with the value of the sensitivity for buses 13 and 3 respectively for the case of maximum load.

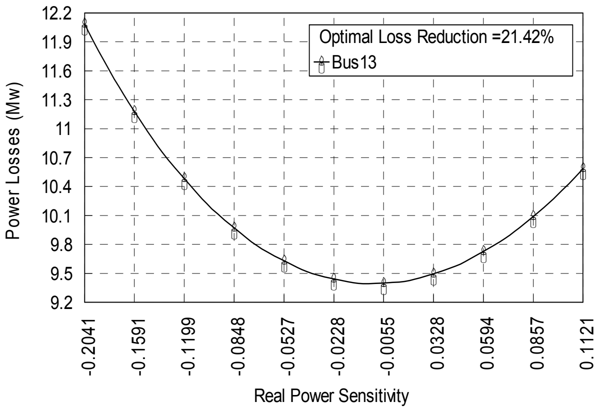

Figure 4: Real power sensitivity and power losses at bus 13

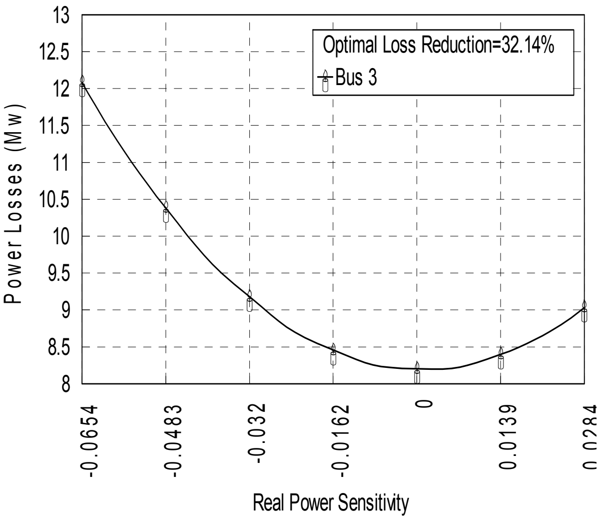

Figure 5: Real power sensitivity and power losses at bus 3

It can concluded that, increasing the load results i.e. increase in the value of the partial derivative $(\partial P_{loss}/\partial P_i)$ will cause an increase in the value of the real injected power. Therefore, we can consider the derivative as a guide for the system to have the optimum distribution of the real power as well as being a guide for the ability to decrease the loss.

The reason for the increase in the real power loss when adding generator units at any additional point can be attributed to the fact that the power system of the electrical power is composed of a number of interconnected lines, and the total real loss depends on the resultant current of the network and on the values of the resistance. Therefore, adding generator units will decrease the currents of the interconnected lines with the added load which alters all the network currents. In the beginning the loss will decrease, but continuous increase in injected power will cause the loss to increase again as the overall current of the network will reach a state where it will start to increase as the value of the loss depends on the values of the line constants.

CONCLUSION

This paper has proposed Sensitivity Analysis approaches to determine the most suitable DG location

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towards inimizing power losses. The sensitivity of real power losses with respect to the size and operating point of DG has been studied and disscussed.The developed methods have been tested on the IEEE-30 BUS system. The results show that the integration of DG is highly effective in reducing power losses in the sytem. The studies also reveal that maximum benefits from DG can be obtained only if proper DG planning is performed. Artificial intelligence Optimization techquniques such as genatic algorithm (GA) and partical swarm optimization (PSO)can be used for more accurate ans high speed results.

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