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OPTIMAL PLACEMENT & SIZING OF DISTRIBUTED GENERATION FOR REAL POWER LOSS REDUCTION IN DISTRIBUTION NETWORK

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Abstract- The modern power system introduces a new Distributed Generation (DG) technology in restructured power system. It plays an important role in distribution system and participates in market to provide ancillary services. They are small power generation technologies are integrated in distribution system to compensate the load demand. Inappropriate DG integration can result into maximization of power loss. Therefore, optimal location and size of DG installation in distribution system should be found before its integration. In this paper, distribution system load flow is performed using repeated load flow (RLF) and particle swarm optimization (PSO) for IEEE 12-bus test system. These techniques are used to find out the optimal location and sizing of DG in distribution network which minimizes the power loss. The line loss reduction index (LRII) is also described which aids in lowering the power loss with the help of DG. With both techniques, the optimal location is bus-9 leads to reduction in power loss up to 43.36% with RLF and 43.44% with PSO. These results are obtained using MATLAB 13.0 and are found to be nurturing. The installation of DG unit in distribution system provides a better power quality in an electrical distribution system.

Index Terms- Distributed Generation (DG); Distribution System; Power Loss; Optimum Location

1. INTRODUCTION

Traditionally, the distribution scheme of electric power system was a radial system with unidirectional current flow. Recently, with restructured and deregulated power system, centralized energy is converting into decentralized energy system. The aim of restructuring of regulated power system is to separate the functions of power generation, transmission and distribution via Gencos, Transcos and Discos. While deregulation is changing the rules of regulated industry, the business of electric companies and consequently customer services are affected. So, the decentralized system has distribution system designed to operate with bidirectional power flow from source to the load or vice-versa. The benefit of this decentralized system is that customers have more choices and get better services of electricity at cheaper rates.

These distribution systems have DGs which are small scale power generation technologies ranging from a few kilowatts up to 50 MWs that provide a superior electric power at a place closer to consumers and provide multitude of services to utilities and customers, including peak shaving, base load generation, and more efficient power at power rates cheaper than the central generating stations [1]. DGs are quickly becoming an attractive alternative for more densely populated areas where difficulties are associated with transmission and distribution investments. Also, DGs have always been a choice for rural areas where transmission and distribution costs are high [2]. The technologies with lower DG capacity that are being adopted in distribution network consists of fuel cell, solar cells, hydro power plants, gas turbine, micro-turbine, wind plants etc., with renewable sources of energy such as geothermal, hydro, wind and sunlight [3]. These plants have excellent technical and economic aspects and have no adverse effects on the environmental and are more beneficial from customer point of view. It can provide quick response to the peak load and base load; it supplies electricity and reduces the electricity consumption of the network. DG can also reduce the overloading of line when the loading capacity of the long transmission line is increased [4]. Therefore, DG induces reliability, improves voltage quality, helps in exceeding voltage profile, increase the efficiency in power production and thus support the distribution network. Hence, the latest advancement in DG technologies has widened the range of its applications and lowered the total amount of cost while maximizing the benefits [5]. In spite of the maximized benefits to the power grid due to DG, there are several factors such as reliability, stability, power quality issues, power loss, and components of protection etc., that are taken into consideration. The mandatory factor is the selection of optimal locations and ratings before implantation of multiple DGs to the power grid in order to maximize the benefits of DGs and minimize the power losses [6].

A network reconfiguration technique was introduced by R. Srinivasa Rao et al. in [7] to reduce power loss in distributed system with the implementation of DG. Soo Hyoung Lee et al. in [6] proposed an analytical method for calculating optimal size of DG and an efficient methodology for identifying its optimum location in order to reduce the losses. W. S. Tan et al. in used an optimization technique named Cuckoo Search Algorithm for allocation and sizing of DG [8]. The multi-objective method proposed in this paper is the weight method to find optimal siting and sizing of DG implementation by minimizing the power losses, while improving the voltage profile in the system.

The remainder of this paper is systematized as: Section-II defines the power loss in transmission and distribution system, Section-III explains the DG impact on distribution system, Section-IV introduces the optimization techniques which are used to minimize real power loss, Section-V gives results obtained by using RLF & PSO, and Section-VI concludes this paper.

2. POWER LOSS

Electric line loss is a waste of electrical energy in the form of heat. It occurs in transmission and distribution system when the current flows. The magnitude of real power line loss depends on the square of amount current flows and resistance of transmission line. Electric line loss can be calculated by using the following equation for the case where there is no DG interconnection in the system.

$$P_{Loss} = 3 \times I_L^2 \times R \times L \qquad (2.1)$$

Where;

P_{LOSS} is the real power line loss without DG connected in KWs.
I_L is the transmission line current in Amperes.
R is the resistance of line in ohm.
L is the distance between load and substation in Km.

3. DG IMPACT ON DISTRIBUTION SYSTEM

With the inclusion of DG in the distributed network, there is decrease in the amount of line current flows which results in the reduction of line losses. DG causes a major impact in electric losses due to its closeness to the load centers. DG units should be allocated in areas where they offer a higher reduction in line current and thus a decrease in power loss. Hence, voltage stability margin can be enhanced in distribution system with appropriate location of DG. This particular site where line losses are minimized can be known as optimum location.

This procedure of DG placement is related to capacitor placement for power loss reduction. The only thing that differentiates both of them is that DG causes effect on both the real and reactive power, but capacitor banks only have control on the reactive power. Therefore, technical benefits of implementation of DG unit minimize network losses, improves voltage profile, voltage stability, enhance system reliability and increase overall efficiency of distributed electric power.

The renewable energy based DGs have environmental benefits including low level of noise and lower emission of toxic gases hence providing more green power. DG can save expenditure on transmission and distribution, reduce the whole sale power cost and hence, decrease the total amount of electricity cost. Also, it can provide better quality of power supply at lower cost due to the reduction of line losses.

3.1 LINE LOSS REDUCTION INDEX (LRII)

Line loss reduction helps to decrease the power loss with the help of DG unit. The Line Loss Reduction Index (LRII) is expressed as:

$$\text{LRII} = \frac{\text{LL}_{\text{W/DG}}}{\text{LL}_{\text{WO/DG}}} \quad (3.1)$$

Where;

$\text{LL}_{\text{W/DG}}$ is the line loss of distribution system with DG and $\text{LL}_{\text{WO/DG}}$ is the line loss of distribution system without inclusion of DG.

4. PROPOSED TECHNIQUES

4.1. REPEATED LOAD FLOW (RLF)

Repeated load flow is applied for each network bus. In this technique, load flow is run repeatedly until the results are obtained. Firstly, the ranges of DG sizes are defined and load flow is run for every bus. This provides the power loss for particular ranges of DG size for every bus. The bus location where power loss is least is the optimum location and the corresponding size for this location is the optimum size for DG [10].

4.2 PARTICLE SWARM OPTIMIZATION (PSO)

PSO is a population based optimization technique proposed by Kennedy and Eberhart. It provides a procedure to solve the non-linear and composite optimization problem by examining behaviour of group of fishes or birds. In this technique, population contains particles present in n-dimensional search space which change their places with respect to time. Each particle has a sufficient knowledge so it will move on the basis of its knowledge and will modify its direction towards the best position, said as pbest and overall best position said as gbest [11]. In terms of loss reduction in distribution system, the DG values are taken as particles and power loss is an objective function which has to be minimized.

4. RESULTS OF IEEE-12 BUS NETWORK

5.1 TEST SYSTEM

The study has been conducted on an IEEE-12 bus radial distribution network demonstrated in Figure 5.1.1. The base voltage is 12.66 KV & the base apparent power is 100 MVA. The total real and reactive power loads are 0.435 MW and 0.405 MVAR respectively. The bus with least voltage profile is 12 and the real power loss without implementation of DG unit is 0.0186 MW. The result of load flow for base case is given in table 5.1.1. Figure 5.1.2 shows the power loss curve for the base case.

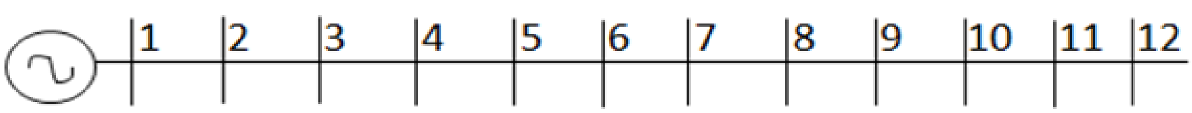

Figure 5.1 IEEE-12 Bus Radial Distribution System

Table 5.1 Base Case Load Flow

Min Voltage Profile (p.u.)	Min Voltage Profile Node	Real Power Loss (in KW)	Reactive Power Loss (in KVAR)
0.99268	12	18.564	7.2149

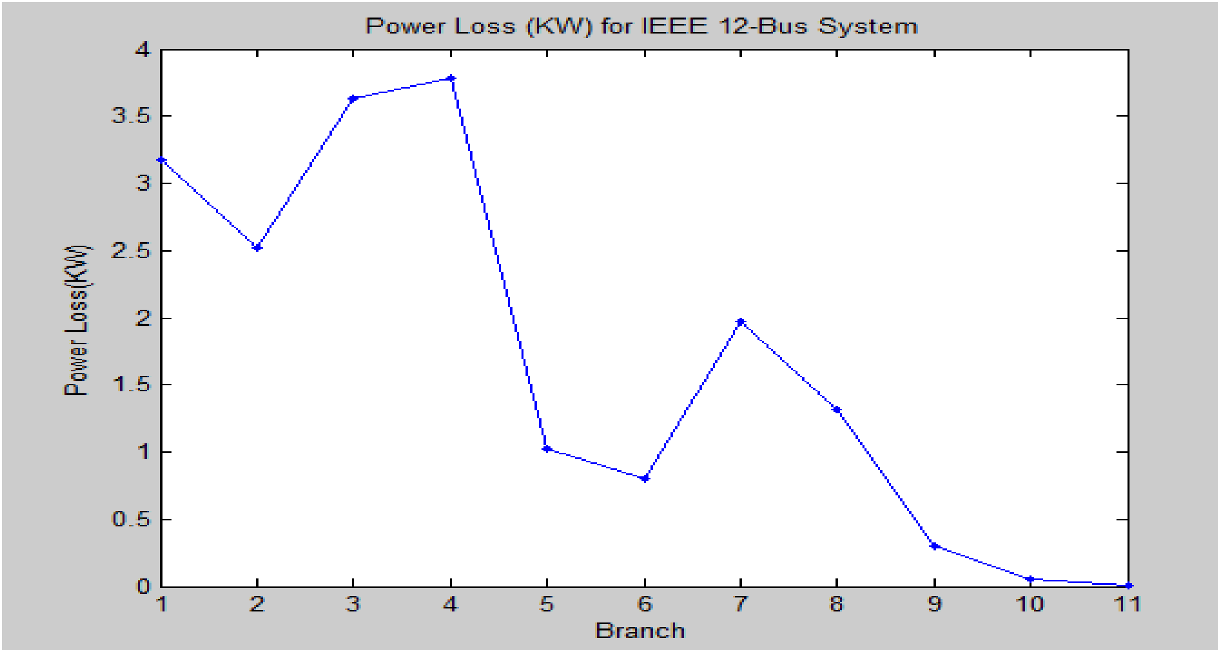

Figure 5.2 Power Loss Curve for Base Case

5.2 OPTIMAL SITING AND SIZING OF DG

In this study, two optimization methods have been analyzed to find out optimum location and rating of DG. The power loss curve and LLRI are obtained for both techniques. The results achieved by these approaches are compared in the following sections:

5.2.1 Power Loss Curve

The study has been conducted for unity power factor. Table 5.2.1 gives the comparisons of results obtained by techniques used in this load flow analysis. The ranges of DG sizes are taken from 1 MW to 5 MW for RLF technique. The optimum DG placement and rating are bus-9 and 3.2 MW respectively when RLF technique is applied. The power loss is reduced up to 43.36% which is 10.514 KW. On the other hand, for PSO the optimum DG placement and rating are bus-9 and 3.143 MW. The power loss is reduced up to 43.44% which is 10.5 KW. Therefore, it can be concluded that PSO gives better result than RLF. The power loss curve and voltage profile curve obtained are shown in figure 5.2.1 & figure 5.2.2 respectively.

Table 5.2 Comparisons of Results

Test System	Applied Techniques	Optimum Location	Optimal Sizes	Real Power Loss		% Reduction in Real Power Loss
				Without DG	With DG	
12-Bus Radial Distribution System	RLF	Bus-9	3.2 MW	18.564 KW	10.514 KW	43.36%
	PSO	Bus-9	3.143 MW	18.564 KW	10.5 KW	43.44%

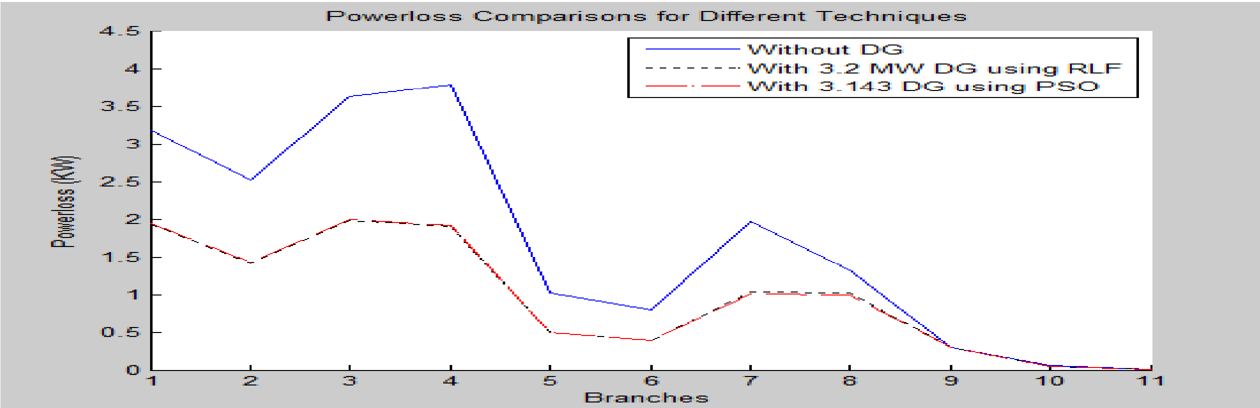

Figure 5.3 Power Loss Curve for Different Optimization Techniques

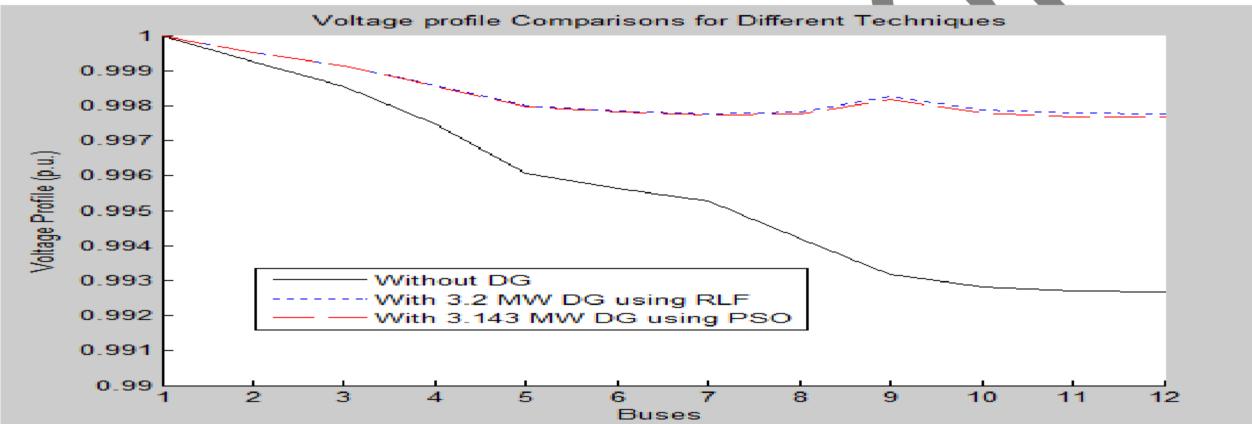

Figure 5.4 Voltage Profile Curve for Different Optimization Techniques

5.2.2 LINE LOSS REDUCTION INDEX (LRII)

LRII is a fraction of power loss with implementation of DG to the power loss without implementation of DG. It is calculated for both approaches and result obtained is shown in Figure 5.2.2.

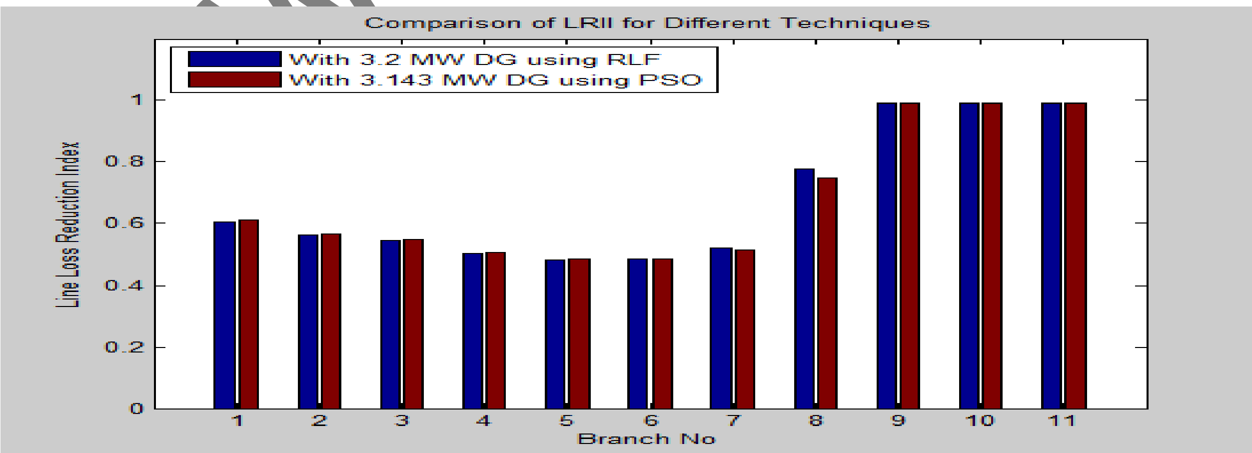

Figure 5.5 LRII for Different Optimization Techniques

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CONCLUSIONS

The implementation of DG in distribution network is beneficial from technical, economic, environmental and customer point of view. From technical aspects, power loss and voltage profile are the main factors in distribution network for power supply. In the current study, DG is introduced to reduce power loss so that supply power can become more reliable. A simple IEEE 12-bus radial distribution system is taken for test analysis. Here, RLF and PSO techniques have been implemented to obtain DG optimal location and size which provides reduced line loss. The DG optimum location is bus-9 and percentage reduction in power loss is 43.36% when RLF is used while 43.44% when PSO is used. It can be concluded that PSO shows better result than RLF.

APPENDIX

Table a. Line-data of IEEE-12 Bus Radial Distribution System

Branch No.	Sending End Node	Receiving End Node	Resistance R(ohm)	Reactance X(ohm)
1	1	2	1.093	1.455
2	2	3	3.184	0.494
3	3	4	2.095	0.873
4	4	5	3.188	1.329
5	5	6	2.093	0.455
6	6	7	2.002	0.417
7	7	8	4.403	1.215
8	8	9	5.642	1.597
9	9	10	2.89	0.818
10	10	11	1.514	0.428
11	11	12	2.238	0.351

Table b. Load-data of IEEE-12 Bus Radial Distribution System

Bus No.	Real Load (KW)	Reactive Load (KVAR)
1	0	0
2	60	60
3	40	30
4	55	55
5	30	30
6	20	15
7	55	55
8	45	45
9	40	40
10	35	30
11	40	30
12	15	15

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