Optimal siting and sizing of distributed generation system in radial distribution network using particle swarm optimization technique

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Abstract : Power losses and voltage profile maintenance are the biggest restrictions of existing power system. In this paper we are suggesting optimal siting of optimal sized distributed generation system in the existing radial distribution network at the bus having maximum power losses. These power losses will be calculated by load flow analysis and particle swarm optimization technique has been applied for optimal siting and sizing of distributed generation system in the existing radial distribution system. The testing of optimal siting and sizing of distributed generation system will be done at IEEE 69 bus radial distribution network by particle swarm optimization technique. This will minimize the power losses and enhance the voltage profile.

IndexTerms – **Distributed Generation (DG), Radial distribution network (RDN), Particle swarm optimization technique (PSO).**

I. Introduction

Centralized power generation plants utilize conventional methods for generation, transmission and distribution of power to the customer. Despite reducing the dependence on fossil fuels, boosted transmission as well as distribution expenses, deregulation fads, ecological worries and also technical advancements modify the existing generation situation [1]. Distributed generation (DG) is a sensible solution for most of these troubles. Distributed generation is the generation of electricity near the distribution system or load. Significant essential factor to consider of DG system linked with distribution network appertains siting and sizing. Random siting and sizing of DG system might affect the existing network, i.e. rise in power loss, reduction in voltage profile [2]. So, ideal allowance of DG systems in distribution network is an extremely significant problem. The distribution network has a large range of customers and shares major part of power losses. The load demand keeps on changing and this growth is a continual phenomenon which cause voltage drop and also even more losses. But also for distribution system the significant restraint is to maintain a voltage profile. To maintain the voltage profile or decreasing the power losses, numerous methods are performed. One method is expansion of the existing system while various others are to postpone the building and construction of brand new one by adding capacitors or inclusions of distributed generation (DG) [3]. DG might provide numerous benefits as voltage control, quality of power, power loss minimization and so on. DG can be effective in power loss minimization or voltage account enhancement if dimension and siting of placement are effectively chosen otherwise these DG causes unfavourable impacts. DG has the advantage of providing real and reactive power in the network. The majority of the authors have actually attained appealing lead to resolving DG allocation problem in RDSs, but there are particular constraints in regards to computational time, operating effectiveness of the system and the convergence rate of the remedy. So, in order to lower these issues a brand-new population based search strategy is needed [4]. There are various analytical techniques for optimal siting as well as sizing of DG like fabricated Bee swarm for DG siting as well as sizing, biogeography based optimization etc. Among these methods, PSO has actually come to be common because of its simplicity as well as maintaining equilibrium between neighbourhood minima and worldwide minima which helps to locate option of the problem in particular instructions. Neighbourhood minima of specific and also worldwide minima of a group make use of to produce new populace. It is observed that often PSO catches in neighbourhood minima and also merges very quickly in a make couple of models. To conquer this trouble, there is a need to raise diversity in the populace. Therefore, in this paper, a populace based approach for Distributed generation siting and sizing is also implemented which gives optimum solution in less computational time [5].

II. Problem Formulation

Load flow analysis is used to discover power loss and voltage representing each branch. The two bus distribution system is shown in the Fig. 1.

The voltage representing that bus k +1 is figured out by using KVL and it is offered by Eq. 1.

$$V_{k+1} = V_k - I_{k,\,k+1}(Z_{k,\,k+1}) \tag{1}$$

Where, $Z_{k,\,k+1} = R_{k,\,k+1} + j\,X_{k,\,k+1}$; is the impedance of the line between k and k+1, V_k is the voltage at bus k, The current injected at node k is established as well as it is given up Eq. 2.

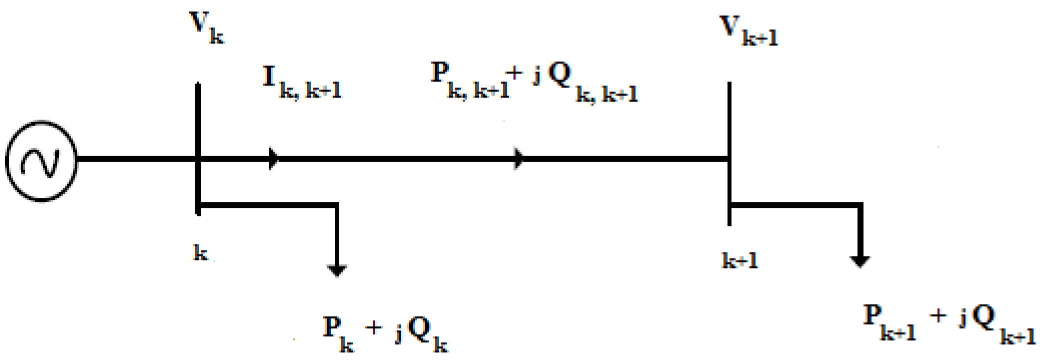

Figure 1. Two bus distribution system

$$I_k = \left(\frac{P_k + Q_k}{V_k}\right)^* \quad (2)$$

Where P_k and Q_k are the true and reactive power supplied at bus k [6].

Branch current is figured out at the buses k and k +1 by using KCL and it is offered by the Eq. 3

$$I_k = I_{k+1} + I_{k+2} \quad (3)$$

The true and reactive power loss representing the buses k and k +1 is established from Eq. 4 and Eq. 5.

$$P_{l(k,k+1)} = R_{k,k+1}\left(\frac{P_{k,k+1}^2 + Q_{k,k+1}^2}{|V_k^2|}\right) \quad (4)$$

$$Q_{l(k,k+1)} = X_{k,k+1}\left(\frac{P_{k,k+1}^2 + Q_{k,k+1}^2}{|V_k^2|}\right) \quad (5)$$

The complete power loss represents all buses is the summation of losses in all sections which is identified making use of Eq. 6 and Eq. 7.

$$P_{Tl} = \sum_{k=1}^{b} P_{l(k,\ k+1)} \quad (6)$$

$$Q_{Tl} = \sum_{k=1}^{b} Q_{l(k,\ k+1)} \quad (7)$$

Power Loss with Positioning of DG, Whenever DG devices are put at optimum area they will minimize power loss in a line, boosts the voltage profile, voltage security and peak demand saving [7]. The power loss after positioning of DG at equivalent buses k and k+1 can be calculated as.

$$P_{DG,l(k,k+1)} = R_{k,k+1}\left(\frac{P_{DG,k,k+1}^2 + Q_{DG,k,k+1}^2}{|V_k^2|}\right) \quad (8)$$

$$Q_{DG,l(k,k+1)} = X_{k,k+1}\left(\frac{P_{DG,k,k+1}^2 + Q_{DG,k,k+1}^2}{|V_k^2|}\right) \quad (9)$$

The total power loss with placement of DG can be calculated by the summation of the losses in all line sections of the system as adheres to.

$$P_{DG,Tl} = \sum_{k=1}^{b} P_{DG,l(k,\ k+1)} \quad (10)$$

True Power Loss minimization with DG Positioning is calculated by power loss index, which is the proportion of total power loss with placement of DG to the total amount power loss without positioning [8] of DG can be created as:

$$F_1 = \text{Power loss index} = \left(\frac{P_{DG,Tl}}{P_{Tl}}\right) \quad (11)$$

The overall quantity of power loss can be minimized with positioning of DG can be improved by minimizing power loss index.

Voltage Inconsistency Index, when the DG system are placed optimally in the distribution network, it enhances the voltage profile of this system. This is given by voltage inconsistency index principle.

$$F_2 = \text{Voltage inconsistency index} = \text{Max}\left(\frac{|V_1|-|V_k|}{|V_1|}\right) \text{ where } k = 1.2 \ldots n \quad (12)$$

Throughout positioning of DG in the distribution network which gives greater voltage inconsistencies from the real value, the suggested method reduces the voltage inconsistency index near to zero no and boosts the voltage security of the network [9].

III. PARTICLE SWARM OPTIMIZATION TECHNIQUE (PSO)

The PSO technique checks out the potential ideal areas within the practical brief amount of time. The PSO technique has the ability to discover international remedies of the issue. The algorithm of the recommended strategy is as defined as:

STEP I: At first a population of people is created. In PSO, individuals are called as a bit (B) and a group of the population is known as flock (F). Each bit i^{th} iteration has speed and placement within the search space. In this paper, each bit stands for the discrete sizes of DG system for nb branches.

STEP II: To locate the ideal size of DG system, health and fitness function is specified representing the unbiased function.

STEP III: After the estimation of physical fitness feature, the best fitness function for each and every bit and among swarm is found out. The ideal fitness feature of bit is called B_{best} and which of the flock is specified as F_{best}.

STEP IV: In The Beginning Version after computation of fitness, at iteration i= 1, F_{best} is taken into consideration equivalent to B_{best}. Contrast the physical fitness value of the particle B at i +1 with that of the previous ideal one.

STEP V: A value of probability variable (V) is chosen in order to use PSO for future generation. The value is established by the customer.

STEP VI: If value of V is less than the user specified value after that upgrade speed and placement vector of bit B utilizing F_{best} as well as B_{best} till V is not greater than user specified value.

STEP VII: To generate populace for following model i= i +1, an anomaly operator is used at the existing populace at i= 1. Three bits are picked randomly and also a mutant vector is generated.

STEP VIII: To increase diversity in the search area, test vectors are generated by applying crossover between an earlier generation at i^{th} version as well as mutant vector.

STEP IX: The selection is performed if the trial vectors will certainly become part of the brand-new populace or not. To choose this, health and fitness feature of trail vector is calculated and compared to B_{best} If it is better than earlier after that B_{best}, than the trial vector is taken into consideration as bit for brand-new generation and also store brand-new worth of B_{best}.

STEP X: Update B_{best} and F_{best} representing best trial vector.

STEP XI: The above steps from V to X are repeated till the search satisfies the termination problem. The discontinuation problem may be the optimal number of versions or the margin requirements set [10].

IV. RESULT S

The PSO technique for optimal siting and sizing of DG system is tested on 12.66 kV, 69 bus radial distribution network (RDN) as shown in Fig. 2. The total actual and reactive load is 3.72 MW as well as 2.3 MVAR. Line and bus data's for the 69 bus RDN are taken from [11]. The true power loss is 230.34 kW and minimum bus voltage is 0.9072 per unit (pu). the comparison of results with PSO technique, load (with DG) and base (without DG) are shown in table 1.

Table 1 Comparison of the results

IEEE 69 Bus RDS	Voltage Profile (per unit)	Power Loss (Kw)	Power loss Minimization (%)	DG Size (kVA)	DG placed at Bus No.
Base	0.9072	230.34	_	_	_
Load	0.9176	227.78	1.11	48	36
PSO	0.9492	199.10	13.56	40	31

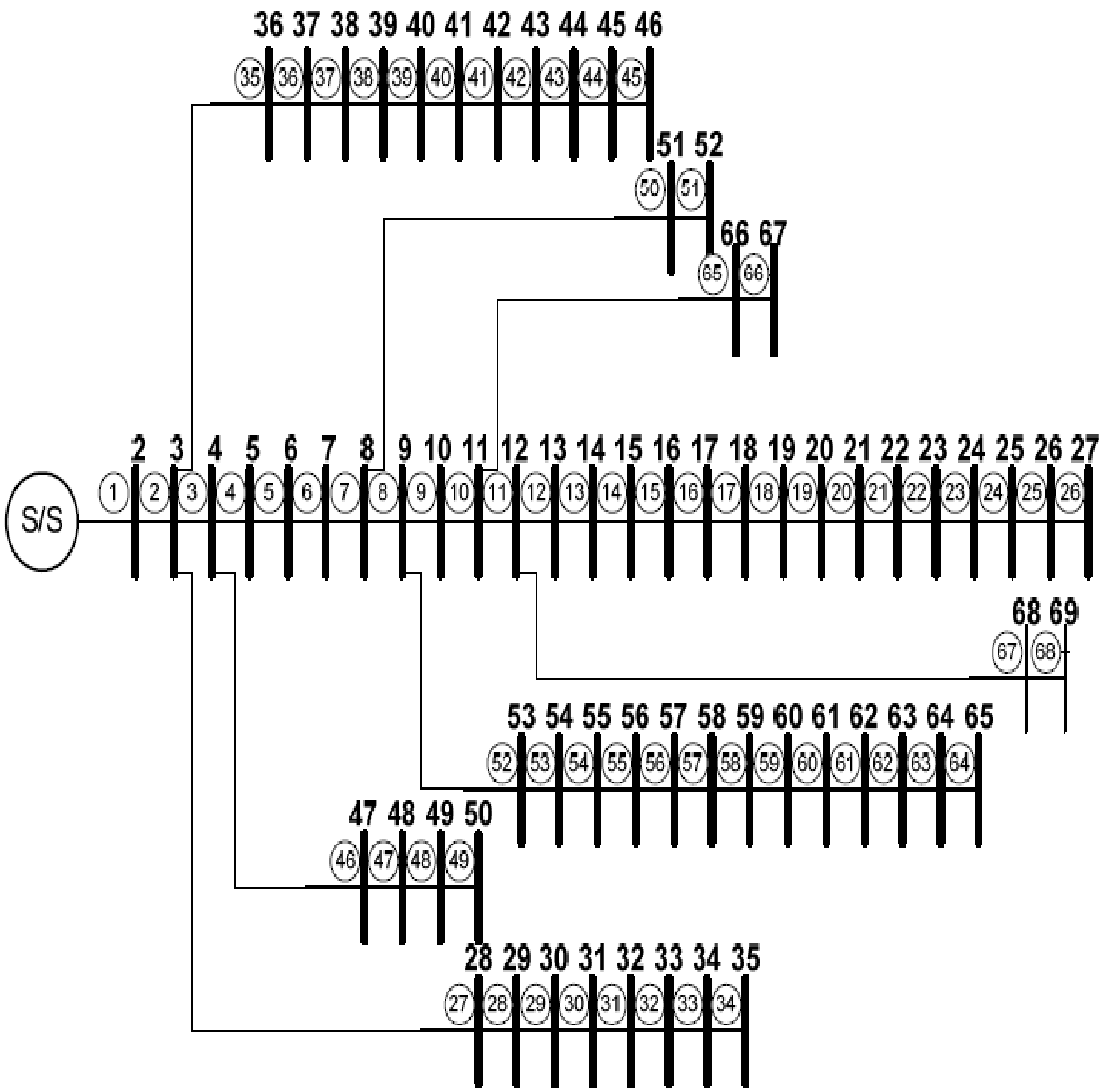

Figure 2. The IEEE 69 Bus Radial distribution system

By the PSO technique the optimal size of 40 kVA DG is connected to the optimal bus 31. PSO technique reduced the DG size by 8 kVA. The power loss obtained from the PSO technique is 199.10 kW, 227.78 kW with load model and the 230.34 kW from base model. Minimization of power loss by the PSO technique is by 13.56% as compared with 1.11% by load case. The voltage profile enhances from 0.9072 pu to 0.9492 pu from base model to the PSO technique.

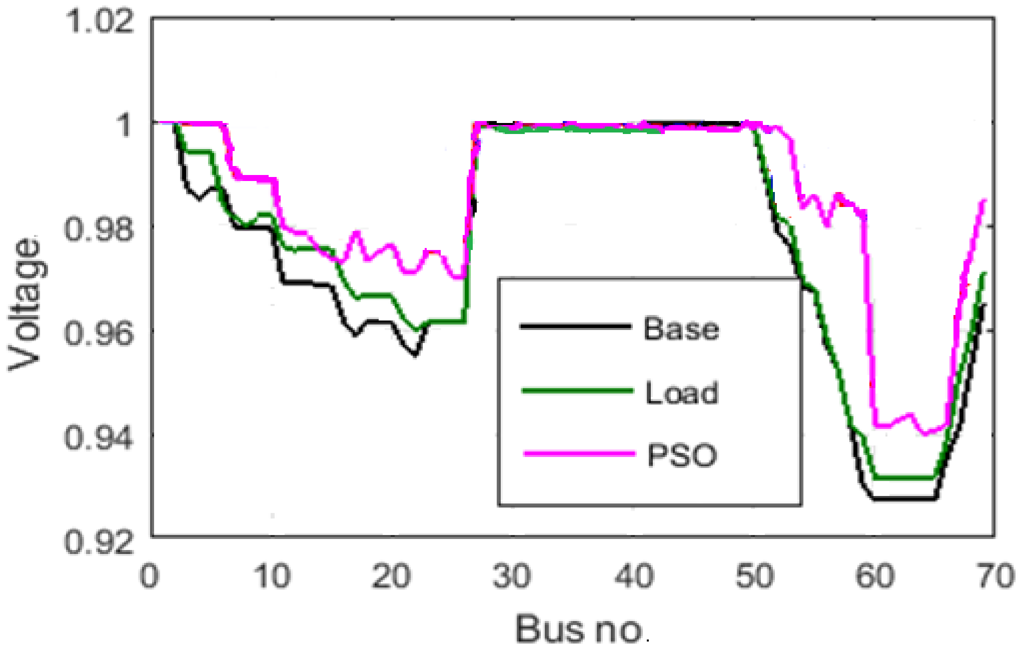

Figure 3. Voltage profile comparison

Fig. 3 shows the voltage profile comparison due to the optimal siting and sizing of DG system with PSO technique, load and base model. The computation rate of the PSO technique is near 85 iterations to reach the optimal results.

V. CONCLUSION

This paper applied a PSO technique for optimal siting and sizing of DG system in existing radial distribution system for power loss minimization and voltage profile improvement at the bus with maximum power losses. This PSO technique is successfully simulated using MATLAB software and tested into the IEEE 69 bus RDN. The optimal siting and sizing of DG system has been successfully done by PSO technique for power loss minimization and enhancing the voltage profile at the optimal bus.

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