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Optimal Allocation and Sizing of Sustainable Energy Resources in a Radial Distribution System using Particle Swarm Optimization

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Abstract
Depletion of fossil fuel, urbanization and industrial growth are the major factors for increase in demand of electrical energy.A practical way to distress such issue is to use SERs. It comprises of low capacity generating units installed near load centers. The penetration of SER units at distribution side is continuously increasing. Renewable energy-basedSERs such as Photo Voltaic, wind turbine, fuel cell etc.arewidely used to meet out the increased demand but it also increases the system complexity. SERs may also be used for reactive power support but it greatly varies with the type of SER units. SER placement in distribution system is achallenging issue. In this paper Particle Swarm Optimization (PSO) base Type-1 DG/SER allocation and sizing methodology has been discussed. The IEEE 33 RDS has been tested for the proposed approachand found to be effective in term of overall power loss minimization.

Keyword: *DG, Power Losses, RDS, Particle Swarm Optimization (PSO).*

1. Introduction

The main objective behind the modern power system network is to encounter the load side power requirement. Earlier the power system networks mainly use traditional sources of generation like fossil fuel and nuclear. Previously generation station were installed near the resource to reduce the transportation cost. Continuous use of conventional sources weakens the centralized power generation system due to depletion inavailability. Whereas DG is used for small scale generation to overcome the challenges that arises due to depletion of conventional sources.

Several authors also used terms ‘Embedded Generation’ or ‘Disperse Generation’ in place of DGs/SERs. According to CIGRE “DG as the generating plant with the maximum capacity of less than 100 MW, which is usually connected to the distribution networks and that are neither centrally planned nor dispatched”[1]. Few technologies given in[2] comes in the category of DGs which are currently in use.

There must be an optimization technique that canproperlyregulate power industry, which allows the foremostassortment of location of DG. Researchers in [3] shows the optimal allocation of DG. There is various type of DGs available categorized in[4] and shown below in table 1.

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Table I: Various type of DGs

Sr no	Types of DG	P (Real Power)	Q (Reactive Power)	Examples
1.	Type 1	+	0	Photovoltaic arrays, fuel cells
2.	Type 2	0	+	Synchronous condensers, capacitors
3.	Type 3	+	+	DFIG
4.	Type 4	+	-	DFIG at fixed speed

+ source - sink

This paper discusses PSO based optimal siting& sizingestimation of Type-I DG. Sorting of this paper is as follows: Part 2 discusses the problem formulation and related constraints. Part 3 explains adopted methodology using flow charts. Part 4 gives test system. Part 5 shows simulation results on the test system and ultimatelyPart 6 summarizes the article.

2. Problem Formulation

In the RDS optimal placement & sizing DG reflects minimum power loss[5].The active power loss representation that serves as objective function for the said problem is given by:

$$P_{LOSS} = \sum_{a=1}^{n}\sum_{b=1}^{n}\left(\alpha_{ab}\left(P_aP_b + Q_aQ_b\right) + \beta_{ab}\left(Q_aP_b - P_aQ_b\right)\right)$$
(1)

Where

$$\alpha_{ab} = \frac{r_{ab}}{V_aV_b}\cos\left(\delta_a - \delta_b\right) \text{(2)}$$

$$\beta_{ab} = \frac{r_{ab}}{V_aV_b}\sin\left(\delta_a - \delta_b\right) \text{(3)}$$

And

$$Z_{ab} = r_{ab} + jx_{ab} \text{(4)}$$

Where

r_{ab} , Z_{ab} and x_{ab} : line resistance, impedance and reactance respectively.

V_a, V_b : voltages

δ_a, δ_b: voltage angles

Q_a , P_b :reactive and active power injections respectively.

Subjected to the fallowing constraints:

1) System equations

$$P_{Ga} - P_{Da} = \sum_{b=1}^{N} V_a V_a \left[G_{ab}\cos\left(\delta_a - \delta_b\right) + B_{ab}\sin\left(\delta_a - \delta_b\right) \right]$$
(5)

$$Q_{Ga} - Q_{Db} = \sum_{b=1}^{N} V_a V_a \left[G_{ab}\sin\left(\delta_a - \delta_b\right) + B_{ab}\cos\left(\delta_a - \delta_b\right) \right]$$
(6)

2) Voltage constraints.

$V_{\min} \le V_a \le V_{\max}$ (7)

3) Current constraint

$I_a \le I_a^{Rated}$ (8)

4) The right-of-way buses may be omitted.

3. Mathematicalstrategy

In this paper PSO algorithm have been utilized to identify the optimal site & capacity of Type-I SER.Due to X/R<<1 in RDS we can't apply load flows method like Gauss-Seidel, Newton Raphson, Fast decoupled, etc.To achieve the desired goal backward/forward sweep load flows methodshas been used to evaluate the bus parameter like P, Q, V&δ[7]. PSOapproach for the problem is discussed below:

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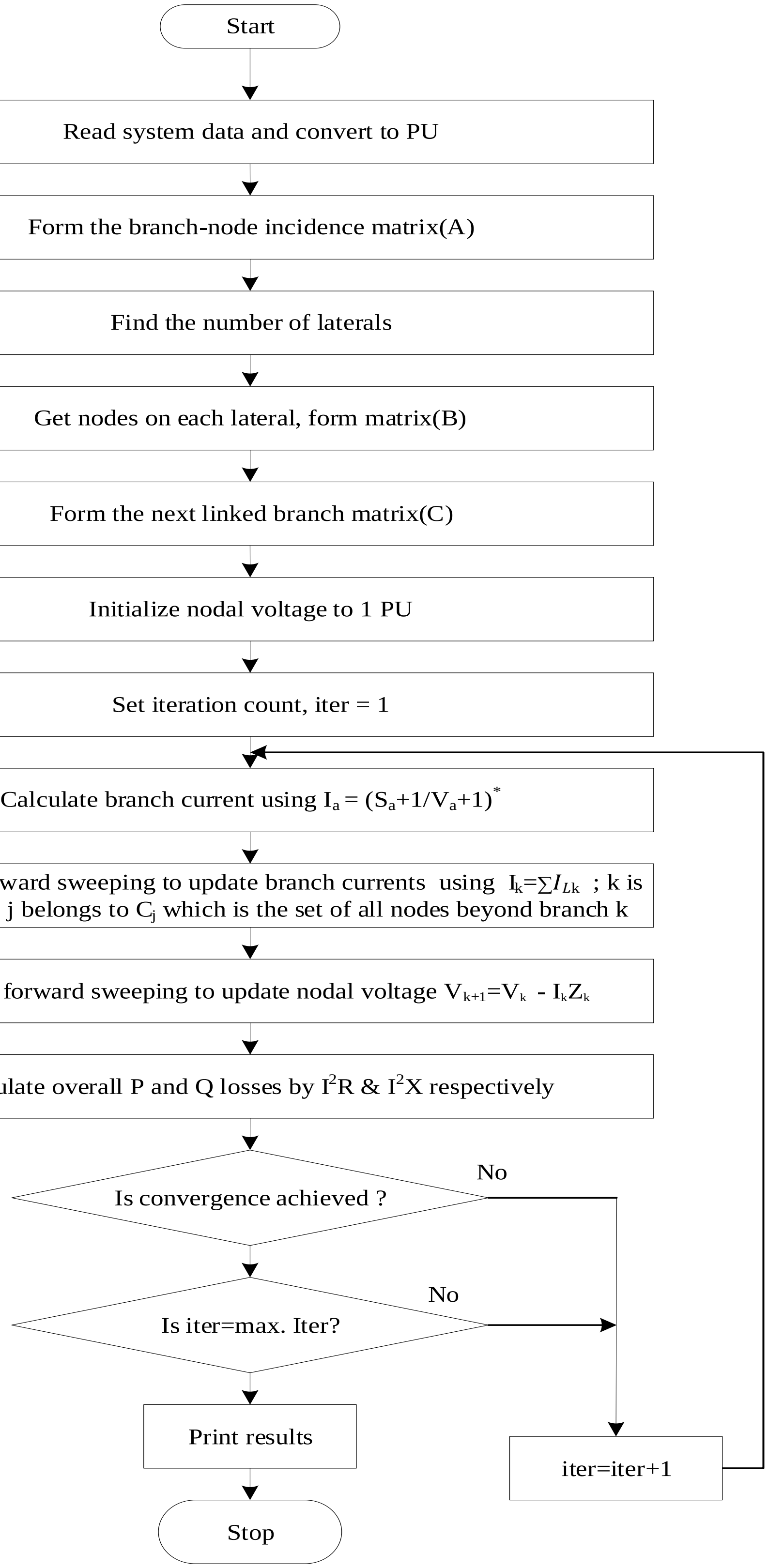

Fig.1 flowchart of backward/forward sweep load flow algorithm.

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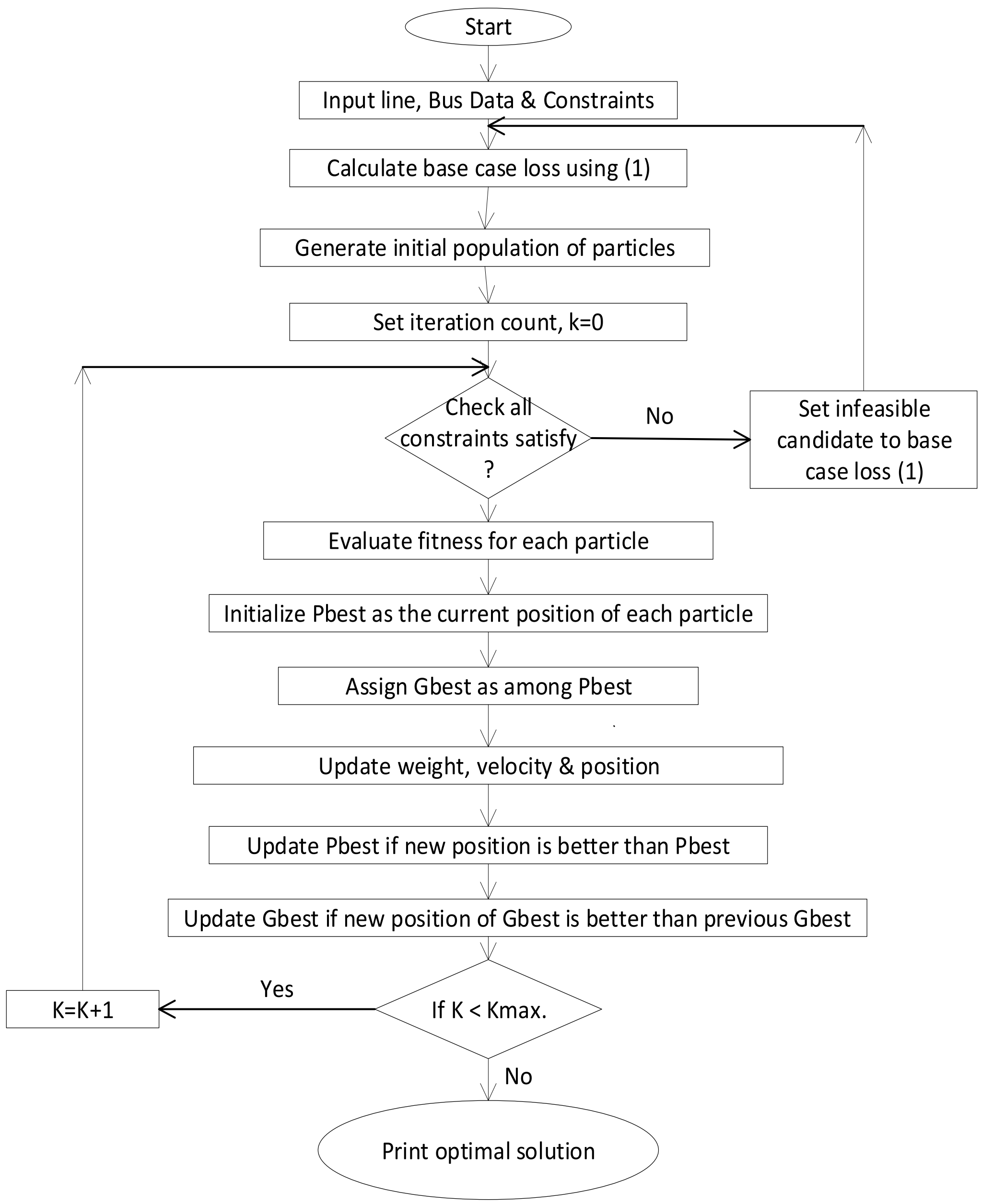

Fig.2 flowchart for computational procedure with the help of PSO

3.1 Particle Swarm Optimization (PSO)

PSO is nature (i.e. ants, termites, bees, and wasps) inspired herdbased optimization technique, which provides population based search technique. Each particle in the herd changes its position in the N-dimensional search space according to its own experience and that of a neighboring particle [8]. Mathematically the position and velocity of the m-particles in n-dimensional space is given as

$$POS_m = \left(pos_{m,1}, pos_{m,2}, pos_{m,3}, pos_{m,4}, ...pos_{m,n} \right) \quad (9)$$

$$Vel_m = \left(vel_{m,1}, vel_{m,2}, vel_{m,3}, vel_{m,4}, ...vel_{m,n} \right) \quad (10)$$

The current position and velocity of each particle is modified according to the fallowing equations

$$POS_{ad}^{k+1} = POS_{ad}^{k} + POS_{ad}^{k+1} \quad (11)$$

$$vel_{ad}^{k+1} = \omega_a vel_{ad}^{k} + c_1 rand \times \left(pbest_{ad} - x_{ad}^{k} \right) + c_2 rand \times \left(gbest_{ad} - POS_{ad}^{k} \right) \quad (12)$$

where

$a = 1, 2, ..., n$

$d = 1, 2, ..., m$

The weight function is given as

$$\omega_a = \omega_{\max} - \frac{\omega_{\max} - \omega_{\min}}{k_{\max}}.k \quad (13)$$

The values of $c_1, c_2, \omega_{\max}$ and $\omega_{\min}$ have been selected with the help of hit and trial method.

4. Test system

In this paper optimum allocation and sizing of Type-I DG is tested on IEEE 33 bus RDS with help of PSO algorithm.

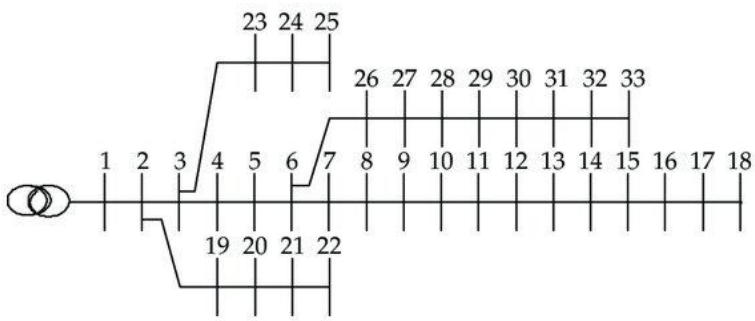

Fig.3 IEEE 33 BusRDS

5. Results & Discussion:

Fig.3 shows optimal active power loss corresponding to Type-1 DG at each bus in 33 bus RDS. Parameter values for PSO: C_1 = 0.5, C_2= 0.5, $\omega_{\min}$ = 0.4, $\omega_{\max}$ = 0.9.The minimum power loss is found corresponding to 6th bus is 103.9681 KW. Corresponding to minimum power loss optimal size of DG at each bus in in 33 bus RDS is shown in fig (4). The voltage profile of 33 bus RDS with and without SERs is shown in the fig (5). It is clearly shown in fig (5) that optimal allocation and estimation of size of DG improves the overall voltage profile of the system.

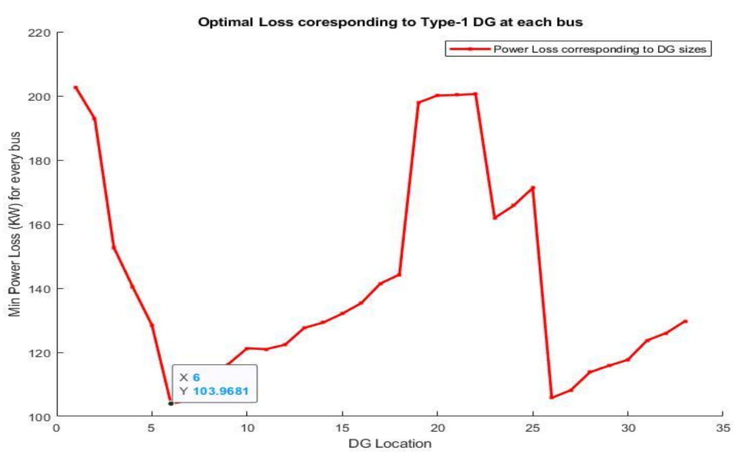

Fig (4) optimal loss corresponding to Type-1 DG at each bus in 33 bus RDS.

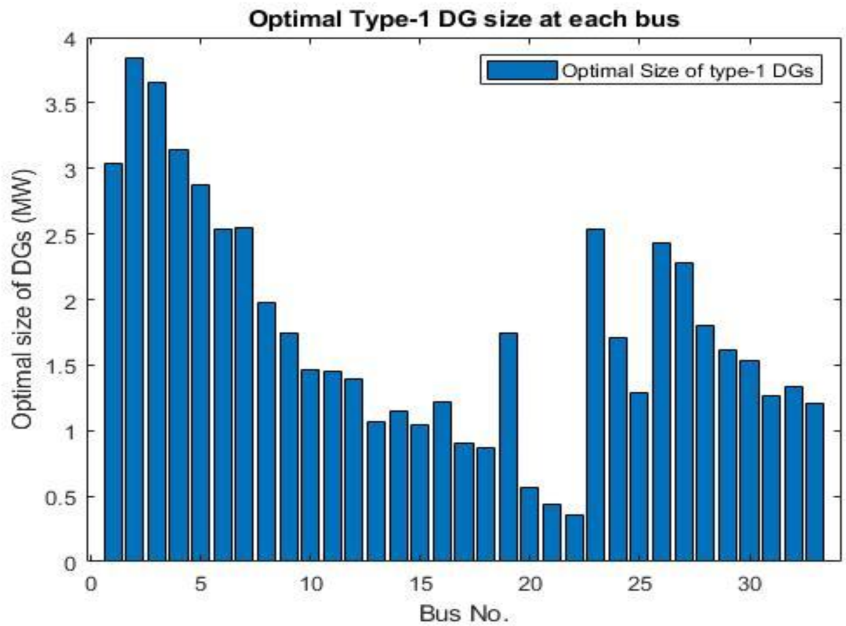

Fig (5) optimal size of DG at each bus in in 33 bus RDS.

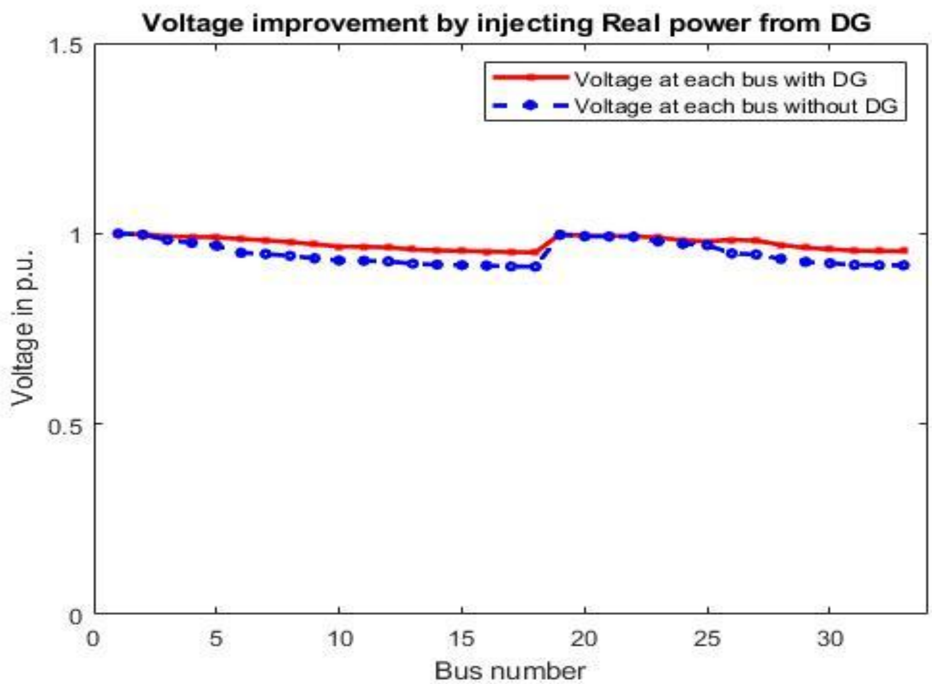

Fig (6) voltage profile of 33 bus RDS, with and without SER.

6. Conclusion

In this paper assignment of Type-I DG has been carried with the help of PSO algorithm to diminish the active power losses in the standard IEEE-33 RDS Bus system. The applied methodology indicates to inject a 2.5338MW at 6^{th} Bus and corresponding real power losses 103.9681KW. In the era of integration of the power system grid, the assignment of location& size of Type-I DG gives guidance for optimum operation of the modern power system networks.

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