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OPTIMAL PLACEMENT OF PSO BASED PHOTOVOLTAIC (PV) DISTRIBUTED GENERATION (DG) IN A DISTRIBUTION SYSTEM

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Abstract

The power demand is increasing due to the globalization of intelligent and smart technology. This imposes challenging situations to the power system engineering towards maintaining safer and efficient power. This paper uses meta-heuristic algorithm to optimally place with minimum rating of the Distributed generator. Photo-Voltaic Distributed Generator (PVDG) is modelled through Probability density function and included in distribution systems. The position of DG is tested for Standard IEEE 33 bus radial distribution system. Location of DG and its size is based on Power loss minimization and improvement in voltage profile. Particle Swarm Optimization (PSO) technique pertaining to basic power equation of PVDG is implemented. Problem is analysed considering without DG and with PVDG on the system under the consideration.This implementation of PVDG and PSO algorithm reduces power losses and decreased the size of PVDG. Also voltage profile is improved in the distribution system considered.

Key words - Distributed Generation (DG), PSO algorithm, Power loss reduction, Voltage stability improvement

1. INTRODUCTION

Worldwide, the demand for electricity, risk for fossil fuel depletion and environmental issues are increasing. Hence, the renewable based power generation (i.e. wind turbine, solar PV, biomass, micro-turbine etc.) are feasible options in the distribution system. Among the renewable based power generation, there is an increasing trend of power generation from solar based DGs. Because it is non-exhaustible and freely available in nature. It is also noticeable that distribution system is radial in nature, which possesses high resistance to reactance ratio and draws more power loss and decreases the voltage quality of the system.

In this case, optimal integration of solar DG advances many benefits, i.e. increase the power losses reduction, improve voltage profile and voltage stability index. It also reduces the greenhouse gas effects and defers the network upgradation. Many positive benefits can be claimed from DG integration. However, the integration of distributed generation in distribution system witnesses to change the operational and control behaviour of the distribution network. Such as non-optimal placement may worsen the situation than existing one. Hence, an efficient optimal placement method

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is required to overcome these complexities and improve the system performance. Therefore in this work use Optimal Placement of PSO based PhotoVoltaic (PV) Distributed Generation (DG) in a Distribution System. The manin objectvies of this work is discussed as follows.

i. To compute optimal capacity of single and multiple DG units that minimize total real power loss, enhance voltage profile and maximize voltage stability index using PSO algorithm.
ii. To investigate the impact of PSO based optimal placement of single and multiple DG units on total active power loss, voltage profile and voltage stability of Distributed Generation (DG) in a Distribution System.

2. LITERATURE SURVEY

The load centers are located far off from the generation sites. This necessitates the transmission systems to transfer the power from generation end to load end. Transmission systems are prone to losses and hence decrease the efficiency. These problems can be overcome if there is local generation nearby to the load centers. Henceforth Distribution Generation systems became prominent.

As Renewable energy sources are naturally available in nature, integration of these into distribution systems are becoming more common and efficient. Hence the study of procedure in allocating these resources also is of utmost importance. Amongst renewables, Photo-voltaic cells can be considered for supplying power to distribution systems. Now the question of allocation and size arises for these solar photo-voltaic cell integration into the system. Proper algorithm is necessary in allocating these resources into the distribution systems. Also the technical and economic impacts are known.[1]

Review of published literature on the subject under consideration is as follows:Exact loss formula is used to reduce power losses and improve voltage profile in distribution systems and also enhance the power transfer capacity[2]. Hybrid algorithms like genetic algorithms along with Particle swarm Optimization have greater impact on Distributed generators placement and sizing in IEEE Standard Distribution systems[3]. Tremendous result obtained through Rank Evolutionary Particle Swarm Optimization (REPSO) in determining the rating of DG in distribution systems to minimize power loss in Distribution Systems [4]. DG Bus available limits considered in placement of DG. Solar and Wind energy generator models with constant power factor and variable reactive power respectively are used[5]. Optimal location of DG and Capacitor considering incremental steps of their capacity and at variable power factors is analyzed. DG performance found better when both real power and reactive power is considered and can be extended to multiple DG also[6].

Simultaneous allocation of non-renewable DGs and DSTATCOM with different load power factors in radial distribution systems are studied[7]. Effect of multiple PV DGs and Wind DGs are studied on distribution systems with each DG impact on power losses and voltage profile. NEPLAN software is used for the analysis of different DGs and size of DG is compared[8-9]. Proposed algorithm indicated that the size of DG

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can have greater impact on reduction in power losses[10]. Renewable DGs are placed in sub transmission and Distribution networks to compare their effect on voltage profile and power losses[11]. Multi-state modelling through probability density functions incorporated for implementing the renewable DGs into distributed systems[12]. Application of photovoltaic technology in utilization of benefits in placing PVDG is studied for real local distribution network. The strategy considers the current magnitude and direction in lines and voltage profile in feeders, which are of utmost important[13]. Review of different methods and uncertainties involved in renewable DGs and effect of optimization methods on different DGs allocation and their comparison[14]. Biogeography based optimization algorithm is applied to allocate the PVDGs in Distribution system in reducing power losses and total harmonic distribution[15].Renewable energy sources are modelled as time varying voltage dependent load models. Impact of hourly variations in demand on distribution systems is studied. Optimal siting and sizing of wind DG is done using Salp swarm algorithm [22]. Wind and solar photovoltaic has uncertainties, which are modelled as weibull distribution and probability distribution function respectively [23] The two objectives of power loss minimization and improvement in voltage deviation limits is taken into account. Renewable DGs like Solar and Wind is chosen for studying IEEE 33 Bus distribution system. The non dominating sequencing genetic algorithm is used. Practical distribution system not considered for study. [24] Survival probability distribution function is used to for correlating the line congestion margin and security risk probability. Mixed Integer linear programming optimization model is developed for determining DG size to know the penetration level of Wind DG.[25]

Review of published literature points to the reduction of power losses and enhancement of voltage profile, but possibility of further reduction in losses and decrease in size of DG with integration of PVDG using PSO is not explored

3. OBJECTIVE FUNCTION

DG can reduce distribution network power losses (both real and reactive) due to their proximity to load centers, .Also voltage profile is improved through effective DG placement and sizing [17]. For the N-bus system, the active power losses can be reduced by using following objective function:

$$f_{p_{loss}} = \sum_{i=1}^{N-1} m_i \times R_i \left(\frac{P_i^2 + Q_i^2}{V_i^2} \right) \tag{1}$$

Where ‘m_i’ represents number of lines, R_i - branch resistance, V_i - voltage magnitude, P_i - active power and Q_i - reactive power at bus *i*.

The voltage stability index ($V_{stab,m}$) used for power flow solution is;

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$$V_{stab,m} = 4\left[\left(XP_j + RP_j\right)V_i^2 + \left(XP_j - RP_j\right)^2\right] \Big/ V_i^4 \tag{2}$$

Where 'm' represents number of lines, 'R_i' is branch resistance, 'X_i' is reactance, 'i'representssending end bus and 'j' represents receiving end bus. For stable system, the voltage magnitudes of all the branches need to be maintained within 1p.u. Hence, the voltage stability is analysed within the limits through voltage stability index ($V_{stab,m}$).

The maximum '$V_{stab,m}$' can be given as;

$$fV_{stab} = \max\left\{V_{stab,1}, V_{stab,2}, V_{stab,3}, \ldots, V_{stab,N}\right\} \tag{3}$$

Where, 'f' indicates the double objective function to minimize the losses and improve the voltage stability.

The optimization function of 'f' can be given by using the weight coefficient approach.

$$\min\ f = a \times w_1\left(\frac{f_{ploss}}{ploss_{init}}\right) + b \times w_2\left(\frac{f_{Vstab}}{V_{stab_{init}}}\right) \tag{4}$$

In above equation, initial power loss (real) and initial voltage stability index is represented as $Ploss_{init}$ and $Vstab_{init}$respectively. The variables 'a' and 'b'are respective penalty factors for the active power loss and voltage stability index. i.e.

$$a = \begin{cases} if\ \dfrac{f_{ploss}}{ploss_{init}} \geq 1, & a = N \\ else & a = 1 \end{cases} \tag{5}$$

$$b = \begin{cases} if\ \dfrac{f_{Vstab}}{V_{stab_{init}}} \geq 1, & b = N \\ else & b = 1 \end{cases} \tag{6}$$

The above equation suggests that the greater level of optimization in the real power losses than the initial value of no DG system, then a = large positive value enhances objective function 'f' value i.e., optimal solution else a=1. Similarly, the value of 'b' is updated.

The weighting factors w_1 and w_2 are accompanied with voltage stability index and active power loss respectively. Generally, the addition of these two factors $w_1 + w_2 = 1$.Also, if $w_1 = 1$, $w_2 = 0$ it refers to either real power loss or voltage stability index pertaining to single optimization.

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4. PERFORMANCE ANALYSIS

Initially the base system is considered for analysis. Later comparative analysis of the power system with and without PV based DG is considered. Figure.1 shows the architecture of design considerations. The study considers the IEEE 33 bus system for analysis of No DG and Solar PV DG. Both the load and line database is considered to get the initial value of active power (P), Reactive power (Q), resistance (R), and reactance (X). The base impedance (Z_b) is computed by considering the rated MVA and kV of the IEEE 33 bus system. Later, per unit value of the R, X, P, and Q is calculated using Z_b. The voltage of No DG and solar DG is calculated. The solar DG system is incorporated with a PSO algorithm for the best DG placement and size to lower the power loss. Finally, for power system with No DG and with solar DG, performance analysis is carried out to know the DG system placement's effectiveness and adequacy of sizing.

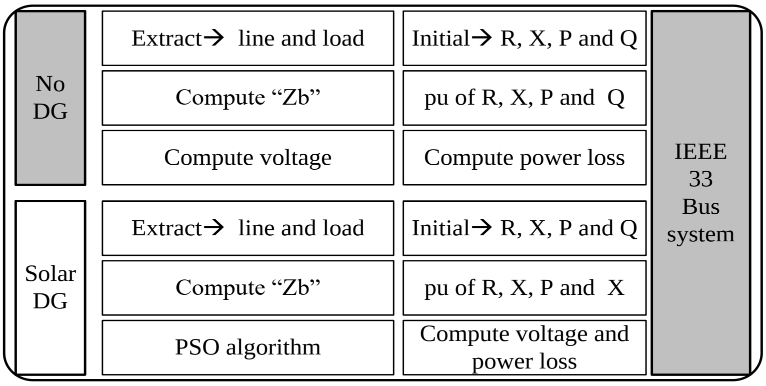

Figure1. Proposed DG system

DG is neither a voltage dependent nor power dependent, and it can be classified either as renewable or non-renewable DG. For instance, Solar PV DG is considered for study. An IEEE 33 bus system is given in Figure.2, where it is composed of 33 buses and 32 lines. The end nodes in the below shown IEEE bus system are 18, 22, 25, and 33. These buses exhibited the voltage levels of base values of 12.66 kV and 100 MVA with a steady-state power factor of 0.8.

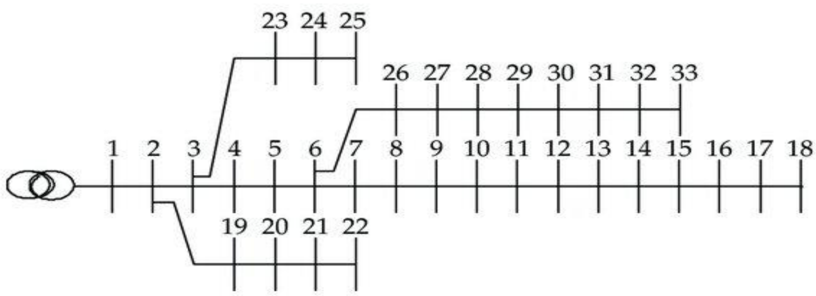

Figure 2. IEEE 33 Bus System

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3.1 No DG power system

The 33 kV bus system is analysed without DG at the beginning. The data for this system is adopted from the line and load database for IEEE 33 bus system. The model with the initial active Power (P_i) and Reactive Power (Q_i) with load is given in Figure.3, where it is observed that the initial condition active and reactive power is zero and is varying for bus number 2 to 33. The total active power load is 3715 kW, while the reactive load is 2300 kVAR. The maximum "P_i and Q_i" is 420kW and 200kVAR (observed at bus number 24 & 25) and 600kW and 200kVAR (observed at bus number 30), respectively. Also, the minimum P_i and Q_i are zero kW and zero kVAR(observed at bus number 1)

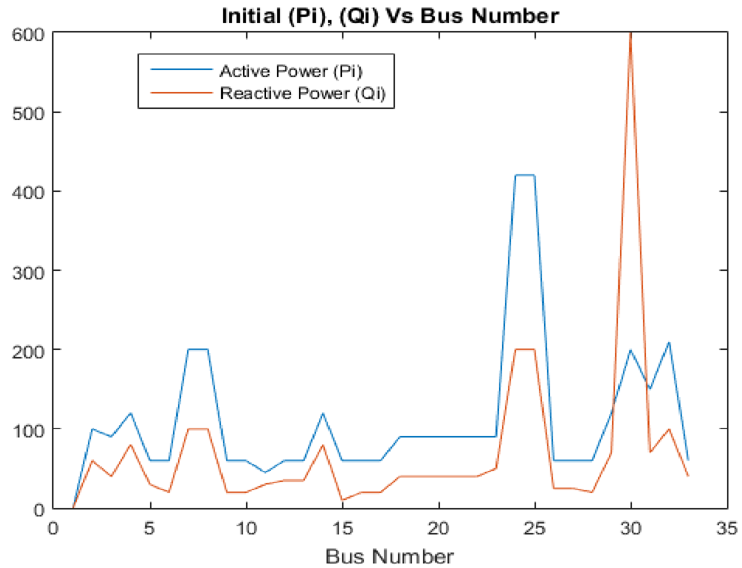

Figure 3. Plot of extracted load data (active and passive power) for 33 Bus System

Further, line data, i.e., resistance and reactance, is extracted from the line database for the IEEE 33 bus system [16] is plotted in Figure.4.

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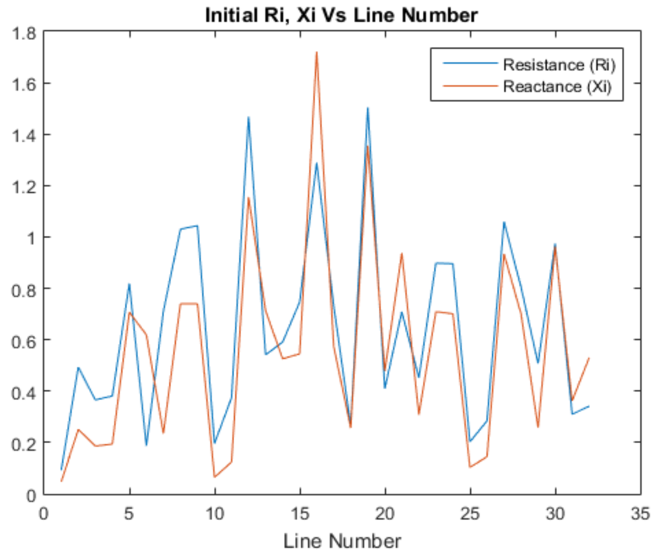

Figure 4 Plot of extracted load data (Resistance and reactance) for 33 Bus System

The computation of the base impedance (*Zb*) is performed by considering the kV and MVA of the 33 bus system;

$$Z_b = {KV^2}/{MVA} \tag{7}$$

Further, the per-unit value of Resistance "(R) p.u" and Reactance"(X) p.u" of each line is computed as below.

$$(R)_{pu} = {R_i}/{Z_b} \tag{8}$$

Where *"R_i"* indicates the initial value of resistance obtained from the line database.

$$(X)_{pu} = {X_i}/{Z_b} \tag{9}$$

Where *"X_i"* indicates the initial value of reactance obtained from the line database.

The obtained value of Resistance "(R)p.u." and Reactance "(X)p.u" are plotted against 32 lines as shown in Figure.5, where it is observed highest resistance of 0.938508419 **Ω** (at line 19) and highest reactance of 1.073775 **Ω** (at line 16)while the lowest resistance of 0.057525912 **Ω** (at line 1) and reactance of 0.029324 **Ω** (at line1).

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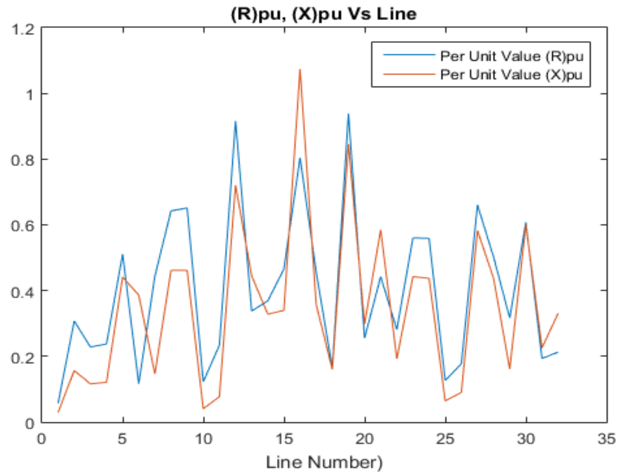

Figure 5 33 Bus System (Per unit value of R and X for each line)

The per-unit value of Active power "(P) p.u" and Reactive power "(Q) p.u" of each line is computed as below.

$$(P)_{pu} = {P_i}/{(1000 \times MVA)} \tag{10}$$

Where 'P_i'indicates the initial value of active power obtained from the line database.

$$(Q)_{pu} = {Q_i}/{(1000 \times MVA)} \tag{11}$$

Where 'Q_i 'indicates the initial value of reactive power obtained from the line database.

The obtained value of "(P) pu" and "(Q) pu" is plotted against 33 lines as shown in Figure.6, where it is observed highest "(P)pu"of $6x10^{-3}$ (at bus30) and highest "(Q)pu" of $4.2x10^{-3}$ (at bus 24 and 25) while the lowest "(P)p.u"and "(Q)p.u"is0 (at bus 0).

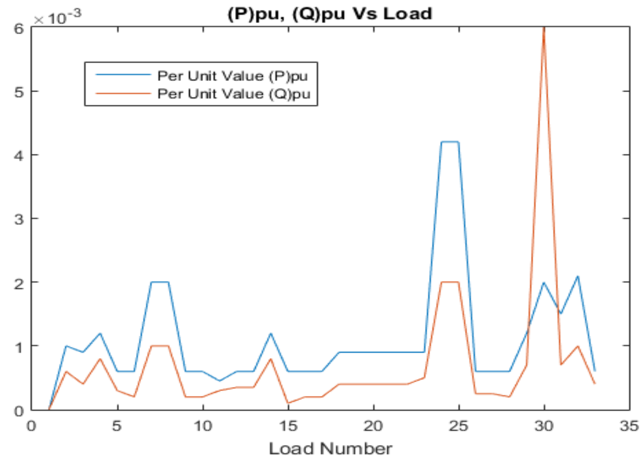

Figure.6 Plot of P (p.u) and Q (p.u) Vs load

Further, both active "(P) $_{loss}$"and reactive "(Q) $_{loss}$" power loss is computed as,

$$(P)_{loss} = \sum_{K=i}^{l} I^2 R \quad (12)$$

$$(Q)_{loss} = \sum_{K=i}^{l} I^2 X \quad (13)$$

Where l indicates the line number and K indicates iteration.

Pseudo code for No DG power system

Input: IEEE 33 bus load/line database

Output: Power loss

Start

1. Initialize→P_i, Q_i ∀ *l*
2. *Initialize* →∀ L: (N_i→N_j) R_i, X_i
3. *Initialize* →*MVA, KV*
4. *Compute* →*Zb*
   Zb=KV²/ (MVA)
5. for ∀L, compute→(R)p.u, (X)p.u
   (R)p.u←R_i/Zb
   (X)p.u←X_i/Zb
6. for ∀*l,* compute →(P)pu, (Q)pu
   (P) p.u←P_i/ (1000xMva)
   (Q) p.u←Q_i/ (1000xMva)
7. Compute for ∀*l,* compute →Voltage, (P)loss, (Q)loss

End

Pseudocode is an informal way of describing programming that does not necessitate any strict programming language syntax or underlying technology considerations. It is used to create a program outline or rough draft.Pseudo code represents the steps in the execution process in simulation software through the variables defined and looks similar to algorithm. Representation of variables more clear compared to algorithm. The pseudo code for No DG power system is initiated by extracting (P) and (Q) from the load database (Step-1) while resistance (R) and reactance (X) from the line database (Step-2) of 33 bus system where N_i indicates sending node and N_j represents receiving node. Also, rated MVA and kV (Step-3) is considered for the computation of base impedance (Zb)(Step-4) by using Equation (1) while the per-unit value of R, X, P, and Q is computed by using Equation (8), (9), (10) and (11) (Step-5 and 6). Finally, the power loss is computed by considering equations (12) and (13) (Step-7).

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3.2 Modelling of PV DG

The PV-DG has a constant voltage. In order to maintain a constant voltage, an appropriate power is inserted so that, δv= (V_i -V_j)→'0'. As the electric power generated from the PV-DG is in the form of DC, the equipment at the load side working on DC receives power output as DC. DC power from PV-DG is converted to AC through inverter. Therefore the load working on AC power receives AC power output from an inverter's output. Only care to be taken to see that the converter shall provide compatible AC output with the AC grid distribution system. The power capacity output (P_c) of the PV-DG[20]:

$$(P_c) \rightarrow f\,(Ap,\ Is,\ \mu) \tag{14}$$

WhereAp =Area of the solar panel, Is= solar irradiance, which is a function of time, and μ = efficiency of the solar panel in used in the PV-DG. The computation of the Pc at a time instance δt takes place using Equation indicated below:

$$Pc(\delta t) = Ap\ x\ \mu \text{ x } \mathrm{Is}(\delta t \tag{15}$$

Therefore, the energy generated from the PV-DG falls under the category of unstable energy source generation system. Another important aspect of the respective energy converters is the characteristic of real and reactive power, and in case of solar power converter it may provide either variable or constant power factor depending on converters used. If static electronic converter (SEC) is used then it is modeled as a power source with a constant power factor. Inthe generalized operating condition, the modeling of the PV-DG is done as non-varying or a constant power-factor model (CPFM). And the maximum power rating of the PV-DG (Prmax) is computed using Equation (16)

$$\text{Prmax} = \frac{1}{i \to j} \sum_{i=1}^{j=24} Pc(\delta t)_{ij} \tag{16}$$

The proper placement of DG and the sizing of DG helps inpower loss minimization and voltagestability enhancement. Thus, the proposed system places the PV based DG using PSO algorithm which has many advantages.PSO is a metaheuristic algorithm because it makes little or no assumptions about the problem to be solved and can search a huge number of candidate solutions. Metaheuristics like PSO, on the other hand, do not ensure that an optimal solution will ever be identified. PSO also doesn't employ the gradient of the issue being optimized, hence it doesn't require the optimization problem to be differentiable, as traditional optimization methods like gradient descent and quasi-newton methods do.

The PSO algorithm works based on a bird flocking mechanism where the birds can move towards food at a certain speed/position. This movement depends on the type of groups that exist, i.e., particle best (P_b) and global best (G_b). This system's velocity can be considered "DG size" and the position as "DG placement." The new velocity (S_p^{n+1}) and the position (T_p^{n+1}) is given as:

$$S_p^{n+1} = I_w \times S_p^n + w_{f1} \times rand_1 \times (P_{bp}^n - T_p^n) + w_{f2} \times rand_2 \times (G_{bp}^n - T_p^n) \tag{17}$$

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$$T_p^{n+1} = T_p^n + S_p^{n+1} \tag{18}$$

Where,

S_p^n And T_p^n is the particle (p) velocity and position in iteration 'n' respectively.

P_{bp}^n and G_{bp}^n indicates particle best and global best value in iteration 'n' respectively.

w_{f1} and w_{f2} is the weighting factor (generally about the value of 2)

$rand_1$ and $rand_2$ are the random (0 to 1) values.

The inertial weight (I_w) is given as,

$$I_w(n) = (I_w)_{\max} - \frac{(I_w)_{\max} - (I_w)_{\min}}{n_{\max}} \times n \tag{19}$$

Where,

$(I_w)_{\max}$ and $(I_w)_{\min}$ indicates the maximum and min value of (I_w)

$n_{\max}$ is the maximum number of iteration (n)

The particles can be updated with the consideration of switches (S) and DG size (Ds) as:

$$T_p = \{S_1, S_2, .. S_\beta \times D_{s1}, D_{s2}, ..., D_{s\alpha}\} \tag{20}$$

Where, α and β are the DG number and line number respectively.

In this PV-DG system, the implementation of the PSO is performed as below:

Pseudo code for PV-DG power system

Input: IEEE 33 bus load/line database

Output: Power loss

Start

1. Initialize→P_i, Q_i ∀ *l*
2. *Initialize* →∀ L: (N_i→N_j) R_i, X_i
3. *Initialize* →*MVA, kV*
4. *Compute* →Z_b

   $Z_b = KV^2 / (MVA)$
5. for ∀L, compute→(R)pu, (X)pu

   (R) p.u←R_i/Zb

   (X) p.u←X_i/Zb
6. for ∀*l*, compute →(P)pu, (Q)pu

   (P) p.u←P_i/ (1000xMva)

   (Q) p.u←Q_i/ (1000xMva)

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7. Set→ p, w_{f1}, w_{f2} for PSO
8. Determine→population (selecting switches (S), DG size (Ds)) using Equation.12
9. Compute for ∀*l*, compute →Voltage, (P)loss, (Q)loss

End

5. RESULTS AND DISCUSSIONS

The design, development, and analysis of the optimal approach for solar DG are performed in MATLAB and compared with the No DG system. The performance parameters for comparative analysis are “P Loss”, and voltage stability Index.

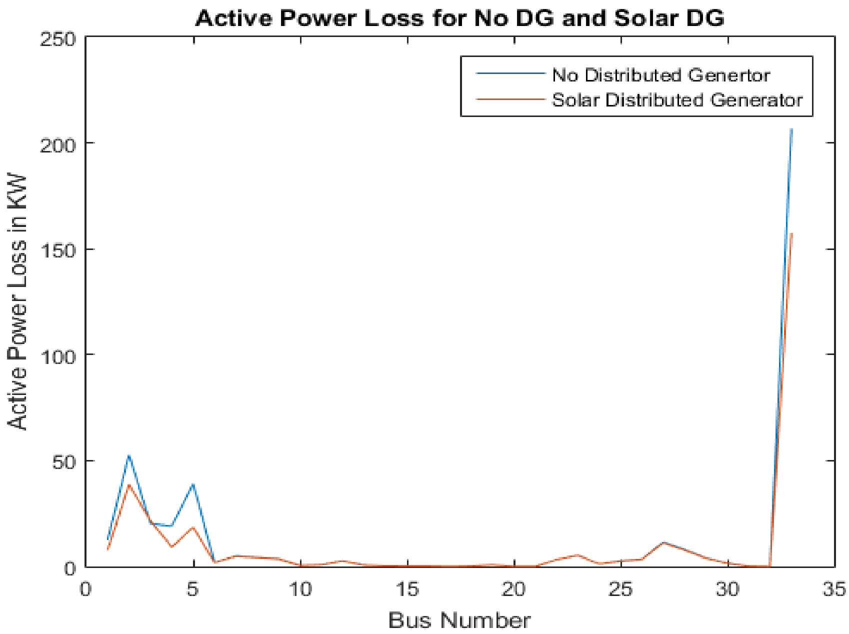

Figure 8. Active Power losses vs. Bus Number for both No DG and Solar DG

Figure 8 indicates the power loss analysis plot for both with no DG system and solar DG system. It is observed that bus number 33 has peak active power loss of 206.73kW with No DG and 157.45kW with solar DG, which indicates that the system with No DG exhibits more active power loss than the system having the best placement of PV-DG

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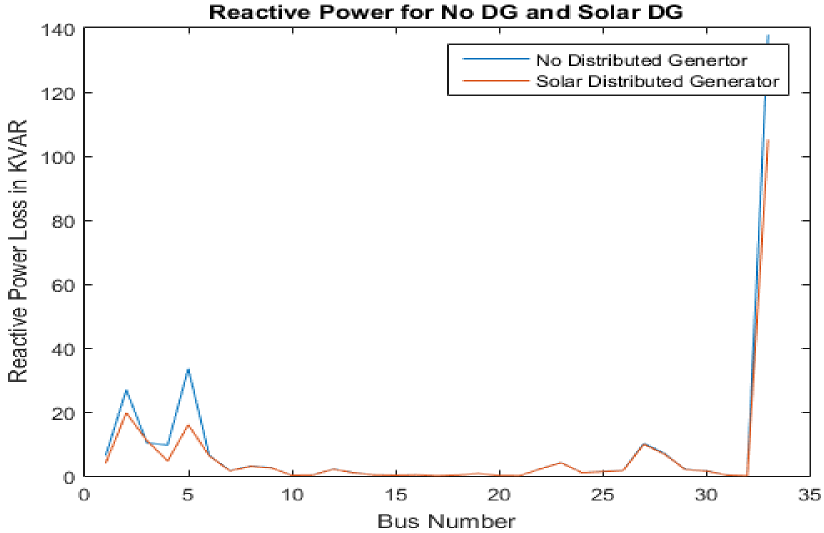

Figure 9. Reactive Power Losses vs. Bus Number for both No DG and Solar DG

Figure 9 shows the reactive power loss analysis for both No DG and solar PV DG and is found that the system with No DG has a reactive power loss of 137.91kVAR and system with solar PV DG exhibits a reactive power loss of 105.13kVAR. This suggests that No DG system has more reactive power loss than solar DG.

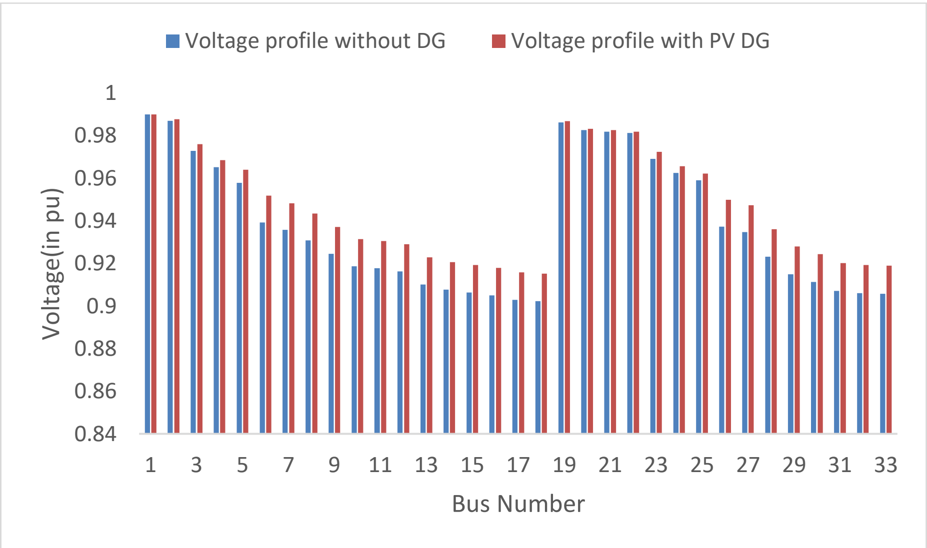

Figure 10: Voltage vs. Bus Number for both No DG and PV DG

The system bus voltage analysis without DG system and solar DG is illustrated in Figure.10. The 33bus system's voltage profile is is plotted and analyzed in which the lowest possible voltage of 0.902 p.uis seen at bus number 17 and is increased to 0.918 p.u with solar DG at bus 17

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From the above comparison, the PSO system based Solar DG offers reduced active power loss of about 49.28%, reactive power loss about 32.78%, and improved voltage stability 7% than No DG.

A comparative analysis of Solar DG is performed with Remha et al. [18] where firefly algorithm is used for active power loss minimization for considered over 33 bus system as shown in table below. Solar PV DG is located at 29th Bus of capacity 1.19MW and also compared with Genetic Algorithm [19], where the size of DG is 2.89MW with power loss reduction 46.65%.

Parameter/Author	**Method**	**Reduction in Active power loss**
Remha et al. [18]	Fire Fly Algorithm	47.39%
T Matlokosti [19]	Genetic Algorithm	46.65%
Proposed system	Particle Swarm Optimization	49.28%

Also the size of solar PV DG is more (2.89MW) compared to [21], whereas its 1.19MW in this present work

6. CONCLUSION

This paper introduces PSO technique for siting and sizing of PhotoVoltaic (PV) DG system also the power losses are compared over the No-DG system. Standard IEEE-33 bus system is considered for analysis. As PSO technique works on swarm intelligence with accurate candidate solution, it is opted for optimal placement of PV-DG. The outcomes indicate that the PSO system based Solar PV DG offers reduced "P" loss about 49.28%, "Q" loss about 32.78%, and improved voltage profile 7% than No DG. Also the size of Solar PV DG is reduced to 1.7%, which had an added economical advantage. Hence it can be said that PV-DG with PSO can be better option for reduction in power losses in distribution systems.

The proposed PV-DG can ease the dependency of the conventional power system during load demand. PV-DG can be deployed in the region where the high intensity of sunlight is available. Towards the future scope of the researchers with a renewable source-based DG system, this can be extended to develop wind DG and perform the comparative analysis involving both solar DG and Wind-DG.

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REFERENCES

[1] Medina, J. C. Hernández, and F. Jurado, "Optimal placement and sizing procedure for PV systems on radial distribution systems," 2006 Int. Conf. Power Syst. Technol. POWERCON2006, vol. 707, no. December 2014, 2006, doi: 10.1109/ICPST.2006.321954.

[2] Parizad, A. Khazali, and M. Kalantar, "Optimal placement of distributed generation with sensitivity factors considering voltage stability and losses indices," Proc. - 2010 18th Iran. Conf. Electr. Eng. ICEE 2010, pp. 848–855, 2010, doi: 10.1109/IRANIANCEE.2010.5506959.

[3] M. H. Moradi and M. Abedini, "A combination of genetic algorithm and particle swarm optimization for optimal distributed generation location and sizing in distribution systems with fuzzy optimal theory," Int. J. Green Energy, vol. 9, no. 7, pp. 641–660, 2012, doi: 10.1080/15435075.2011.625590.

[4] J. J. Jamian, M. W. Mustafa, H. Mokhlis, and M. N. Abdullah, "Comparative study on Distributed Generator sizing using three types of Particle Swarm Optimization," Proc. - 3rd Int. Conf. Intell. Syst. Model. Simulation, ISMS 2012, pp. 131–136, 2012, doi: 10.1109/ISMS.2012.71.

[5] C. Yammani, S. Maheswarapu, and S. Matam, "Optimal Placement of Multi DGs in Distribution System with Considering the DG Bus Available Limits," Energy and Power, vol. 2, no. 1, pp. 18–23, 2012, doi: 10.5923/j.ep.20120201.03.

[6] S. GopiyaNaik, D. K. Khatod, and M. P. Sharma, "Optimal allocation of combined DG and capacitor for real power loss minimization in distribution networks," Int. J. Electr. Power Energy Syst., vol. 53, pp. 967–973, 2013, doi: 10.1016/j.ijepes.2013.06.008.

[7] K. R. Devabalaji and K. Ravi, "Optimal size and siting of multiple DG and DSTATCOM in radial distribution system using Bacterial Foraging Optimization Algorithm," Ain Shams Eng. J., vol. 7, no. 3, pp. 959–971, 2016, doi: 10.1016/j.asej.2015.07.002.

[8] V. Vita, T. Alimardan, and L. Ekonomou, "The impact of distributed generation in the distribution networks' voltage profile and energy losses," Proc. - EMS 2015 UKSim-AMSS 9th IEEE Eur. Model. Symp. Comput. Model. Simul. pp. 260–265, 2016, doi: 10.1109/EMS.2015.46.

[9] S. Linda, "Optimal Sizing and Placement of Multiple Distributed Generation in Radial Distribution Networks considering Uncertainty in the Variation of Loads," vol. 1, no. 232, pp. 232–238, 2016.

[10] V. Vita, "Development of adecision-making algorithm for the optimum size and placement of distributed generation units in distribution networks," Energies, vol. 10, no. 9, 2017, doi: 10.3390/en10091433.

[11] S. Chowdhury and T. Matlokotsi, "Optimal placement and sizing of renewable distributed generation in electricity networks considering different load models," 2017 52nd Int. Univ. Power Eng. Conf. UPEC 2017, vol. 2017-Janua, pp. 1–6, 2017, doi: 10.1109/UPEC.2017.8232012.

[12] K. Mahesh, P. Nallagownden, and I. Elamvazuthi, "Optimal placement and sizing of renewable distributed generations and capacitor banks into radial distribution systems," Energies, vol. 10, no. 6, 2017, doi: 10.3390/en10060811.

[13] H. Sadeghian, M. H. Athari, and Z. Wang, "Optimized solar photovoltaic generation in a real local distribution network," arXiv, 2017.

[14] M. Pourbehzadi, T. Niknam, J. Aghaei, G. Mokryani, M. Shafie-khah, and J. P. S. Catalão, "Optimal operation of hybrid AC/DC microgrids under uncertainty of renewable energy resources: A comprehensive review," Int. J. Electr. Power Energy Syst., vol. 109, no. August 2018, pp. 139–159, 2019, doi: 10.1016/j.ijepes.2019.01.025.

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[15] M. Q. Duong, T. D. Pham, T. T. Nguyen, A. T. Doan, and H. Van Tran, “Determination of optimal location and sizing of solar photovoltaic distribution generation units in radial distribution systems,” Energies, vol. 12, no. 1, 2019, doi: 10.3390/en12010174.

[16] S. T. A, “Appendix A IEEE 33-Bus Network Model Data,” 2020.

[17] Guan, Wanlin, et al. "Optimal placement and sizing of wind/solar based DG sources in distribution system." IOP Conference Series: Materials Science and Engineering. Vol. 207. 2017.

[18] Remha, S., S. Chettih, and S. Arif. "Optimal DG location and sizing for minimum active power loss in radial distribution system using firefly algorithm." *International Journal of Energetica (IJECA), ISSN* (2017): 2543-371.

[19] T Matlokotsi and S. Chowdhury “Optimal Placement and Sizing of Renewable Distributed Generation in Electricity Networks Considering Different Load Models” IEEE Conference, 2017.

[20] Atwa, Y. M., et al. "Optimal renewable resources mix for distribution system energy loss minimization." IEEE Transactions on Power Systems 25.1 (2009): 360-370.

[21] T Matlokotsi and S. Chowdhury “Optimal Placement and Sizing of Renewable Distributed Generation in Electricity Networks Considering Different Load Models” IEEE Conference, 2017.

[22] A. Ahmed, M. F. N. Khan, I. Khan, H. Alquhayz, M. A. Khan, and A. T. Kiani, “A Novel Framework to Determine the Impact of Time Varying Load Models on Wind DG Planning,” IEEE Access, vol. 9, pp. 11342–11357, 2021, doi: 10.1109/ACCESS.2021.3050307.

[23] Q. Chen, W. Wang, H. Wang, J. Wu, and J. Wang, “An Improved Beetle Swarm Algorithm Based on Social Learning for a Game Model of Multiobjective Distribution Network Reconfiguration,” IEEE Access, vol. 8, pp. 200932–200952, 2020, doi: 10.1109/ACCESS.2020.3035791.

[24] T. Huiling, W. Jiekang, W. Fan, C. Lingmin, L. Zhijun, and Y. Haoran, “An optimization framework for collaborative control of power loss and voltage in distribution systems with DGs and EVs using stochastic fuzzy chance constrained programming,” IEEE Access, vol. 8, pp. 49013–49027, 2020, doi: 10.1109/ACCESS.2020.2976510.

[25] T. M. Masaud and E. F. El-Saadany, “Optimal Wind DG Integration for Security Risk-Based Line Overload Enhancement: A Two Stage Approach,” IEEE Access, vol. 8, pp. 11939–11947, 2020, doi: 10.1109/ACCESS.2020.2965157.