Research Paper

APPLICATION OF SELF ADAPTIVE DIFFERENTIAL EVOLUTION ALGORITHM FOR OPTIMAL PLACEMENT AND SIZING OF RENEWABLE DG SOURCES IN DISTRIBUTION NETWORK INCLUDING DIFFERENT LOAD MODELS

M. Arumuga Babu[1], R.Mahalakshmi[2], S.Kannan[3], M.Karuppasamypandiyan[4] and A. Bhuvanesh[5]

Address for Correspondence

[1]Assistant Professor & Head, Dept. of EEE, Tejaa Shakthi Institute of Technology for Woman, Coimbatore
[2]Professor, Dept. of EEE, Kumaraguru College of Technology, Coimbatore
[3]Professor & Head, Dept. of EEE, Ramco Institute of Technology, Rajapalayam
[4] Assistant Professor, Dept. of EEE, Kalasalingam University, Krishnankovil
[5] Research Scholar, Dept. of EEE, Mepco Schlenk Engineering College, Sivakasi, India.

ABSTRACT-
In recent years, the renewable energy Distributed Generation (DG) sources like Photovoltaic, Wind farms gain more importance in the distribution network due to its fuel free, emission less operation and their system loss reduction capability, when they are placed in an optimal place/location with an optimal size. This paper presents the application of Self-Adaptive Differential Evolution Algorithm (SaDE) for finding an optimal placement and size of renewable DG sources for real power loss minimization. Photovoltaic cell and Wind type DGs are used in this work for real power loss minimization. Photovoltaic cell is modeled as a real power generating unit while Wind plant is modeled as a real power generating and reactive power consuming unit. When high solar energy and/or wind energy are present, the excessive power generated is stored in storage units. During unavailability of solar and wind, the demand is satisfied by utilizing power from the storage units. The optimal DG Placement and its size are calculated for constant and voltage dependent loads. The performance of SaDE for finding optimal placement and size of DGs in the distribution network is illustrated with two distribution networks namely 33-bus and 69-bus system.

KEYWORDS- Distributed Generation, Photovoltaic, Self-adaptive Differential Evolution, Wind farms.

I. INTRODUCTION

The negative environmental impact of exhaustible non-renewable fuels (coal, oil and nuclear etc.) has made the dependence on the renewable sources such as Biomass, Wind and Solar in recent days for the production of electricity. Distributed Generation (DG) is defined as the generating plant with a capacity without exceeding 100 MW, which is connected to the distribution networks that may be centrally planned nor dispatched [1]. The integration of renewable DG units in distribution network provides voltage stability and voltage profile enhancement, loss reduction, postponement of generation, transmission or distribution system expansion and reliability improvement.

At Present, only a very few DGs like Reciprocating Engines, Micro Turbines, Combustion Gas Turbines, Fuel Cells, Photovoltaic and Wind Turbines are available and others are in the research and development stage. All these technologies have its own advantages and disadvantages [2]. In this work, photovoltaic and wind turbines are considered as DG sources, since improved technologies are available in the market.

In distribution networks, the placement of DG and its sizing is a challenging issue. Placing DG with higher capacity, majorly leads to higher power loss and lower voltage profile. So the optimal placement and size of DG should be calculated for effective active power loss reduction. Various methods have been proposed in the literature for optimal location and sizing of DG sources. In [3] an analytical technique to determine the optimal size and placing of DGs in a distribution system for active power loss reduction and voltage profile improvement is presented. In this work, the DG unit sizing and placement are calculated by a sensitivity index that include the exact loss formula and voltage sensitivity coefficients. Investigation is done on the IEEE 13 bus test feeder to validate the effectiveness of the proposed method. A hybrid algorithm PSO and HBMO for optimal placement and sizing of DG in radial distribution system to reduce the total power loss and improve the voltage profile is presented in [4]. This work is employed on a standard 13 bus radial distribution system. An overview of art models and procedures applied to the optimal DG placement problem, analyzing and classifying current and future research trends is stated in [5]. In [6] an analytical approach for DG allocation in primary distribution network in which DG is placed using sensitivity approach in order to reduce the real power loss is stated. A fast analytical approach to find the optimal size of DG, at optimal power factor has been proposed in [7]. Recently, most of the authors use optimization algorithm such as Genetic Algorithm (GA) in [8, 9], Particle Swarm Optimization (PSO) in [10], Modified Bacterial Foraging Optimization algorithm in [11] for finding optimal placement and size of DG sources for real power loss minimization. A synchronizing GA and PSO in [12], are employed for optimal DG location and sizing of distribution systems to minimize network power losses. Both GA and PSO suffer from computational burden and memory. In addition, the premature convergences degrade their performance and reduce its search capability.

Many authors have considered demand as a constant. However, active and reactive power demands of the distribution system are dependent on bus voltage. So the outcome of DG in various voltage dependent loads such as Residential, Commercial, Industrial and combination of all should be analyzed.

In [13], a report as a practical guide to the available energy storage solutions and their applications in the context of islands communities have developed. The report also includes various best practice cases and different scenarios and strategies.

In this paper, the impact of different loads on DG placement is analyzed. Photovoltaic cell and Wind type DGs are used in this work for real power loss minimization. Photovoltaic cell is designed as a real power generating unit while Wind plant is modeled as a real power generating and reactive power consuming unit. When high solar and/or wind energy are present, the excessive power generated is stored in storage units. During unavailability of solar and wind, the demand is met by utilizing power from the storage units. The proposed approach is tested on 33-bus and 69-bus distribution system. The results are compared with previously published paper results on the basis of optimal size, optimal location and loss minimization.

The implementation of this paper is as follows: Section 2, represents problem formulation. Section 3, presents modeling of renewable DGs and the voltage dependent load model. Section 4, gives SaDE computational procedure for finding optimal location and size of Renewable DGs for loss minimization. Simulation results on two different distribution test system are illustrated in section 5 and finally conclusion is presented in section 6.

II. PROBLEM FORMULATION

The objective function of optimal placement and size of renewable DGs in distribution network is minimization of real power loss subject to equality and inequality constraints. This is mathematically stated as

Minimize $P_{loss} = \sum_{k=1}^{N_l} Loss_k$ (1)

Where,

$$Loss_k = \sum_{i=1}^{N}\sum_{j=1}^{N} A_{i,j}(P_iP_j + Q_iQ_j) + B_{i,j}(Q_iP_j - P_iQ_j) \quad (2)$$

$$A_{i,j} = \frac{R_{i,j}\cos(\delta_i - \delta_j)}{V_iV_J}$$

$$B_{i,j} = \frac{R_{i,j}\sin(\delta_i - \delta_j)}{V_iV_J}$$

where N_l is the number of transmission lines, P_i and P_j are real power injection at bus *i* and *j* ly, Q_i and Q_j are reactive power injection at bus *i* and *j* respectively, $R_{i,j}$ is the line resistance between bus *i* and *j*, V_i and δ_i are voltage and angle at bus *i* respectively, subject to following equality and inequality constraints.

2.1 Equality Constraints

Real power balance equation and reactive power balance equations are

$$P_i - V_i\sum_{j=1}^{N_B} V_j\left[G_{ij}\cos\theta_{ij} - B_{ij}\sin\theta_{ij}\right] = 0 \quad i = 1,2,......N_{B-1} \quad (3)$$

$$Q_i - V_i\sum_{j=1}^{N_B} V_j\left[G_{ij}\sin\theta_{ij} - B_{ij}\cos\theta_{ij}\right] = 0 \quad i = 1,2,......N_{PQ} \quad (4)$$

2.2 Inequality Constraints

DG's Unit constraints

$$P_s^{\min} \le P_s \le P_s^{\max} \quad (5)$$

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max} \quad (6)$$

Bus voltage limit

$$V_{\min} \le V \le V_{\max} \quad (7)$$

Line current limit

$$I_i \le I^{Rated} \quad (8)$$

where

G_{ij}, B_{ij} Conductance and Susceptance of transmission line connected between i^{th} and j^{th} bus

P_i, Q_i Real and Reactive power injection of i^{th} bus

P_s Real power generation of slack bus

Q_{gi} Reactive power generation at bus *i*

N_{PV} Number of voltage buses

N_B Total number of buses

N_{PQ} Number of load buses

N_{B-1} Total number of buses excluding slack bus

V_{min} Minimum voltage limit in all the buses

V_{max} Maximum voltage limit in all the buses

I Line Current

I^{Rated} Rated current (Maximum allowable current)

III. MODELING OF RENEWABLE DGS SOURCE

In this paper, Photovoltaic and Windmill are considered as DG's for real power loss minimization problem.

A. Modeling of Photovoltaic Type DGs

Photovoltaic type DGs are modeled as a real power injecting device. To find the optimal size of photovoltaic at bus *i*, the following formula is used.

$$P_{DGi} = P_{Di} - \frac{1}{A_{i,i}}\sum_{\substack{j=1\\ j\neq i}}^{N}(A_{i,j}Q_j + B_{i,j}P_j) \quad (9)$$

B. Modeling of Wind Mill Type DGs

Wind mill type DGs are capable of supplying real power and in turn will absorb reactive power. Hence, in this paper Wind mill type DGs are modeled as real power injecting as well as reactive power consuming device. The amount of reactive power consumed by Windmill [14] is given by:

$$Q_{DGi} = -(0.5 + P_{DGi}^2) \quad (10)$$

where P_{DGi} is the real power injected by Wind mill type DGs at bus *i*.

C. Voltage Dependent Load Model

Most of the researchers consider real and reactive power loads as voltage independent loads in distribution system. However, in actual distribution system the voltage dependent loads such as commercial, industrial and residential loads are present. These loads have considerable effect on system load flow and system power loss. So, the effect of voltage dependent loads on distribution system should be analyzed.

The voltage dependent load model can be mathematically expressed as follows:

$$P_L = P_{L0}\left(\frac{V}{V_0}\right)^{\alpha} \quad (11)$$

$$Q_L = Q_{L0}\left(\frac{V}{V_0}\right)^{\beta} \quad (12)$$

Where α and β are active and reactive power exponents respectively. P_L and Q_L are the values of real and reactive powers, while P_{L0} and Q_{L0} are the values of active and reactive powers at nominal voltages, respectively. V represents the voltage magnitude at each bus and V_0 is nominal voltage at each bus.

For practical application, the evaluation of coefficients α and β requires field measurement and parameter estimation techniques [14].

The values of the real and reactive power exponents used in the present work for Industrial, Residential, and Commercial loads are given in Table I [15].

TABLE I. LOADS EXPONENT VALUES

Load Model	α	β
Constant	0	0
Industrial	0.18	6
Residential	0.92	4.04
Commercial	1.51	3.04

IV. DETAILS OF SELF ADAPTIVE DIFFERENTIAL EVOLUTION (SaDE) ALGORITHM IMPLEMENTATION

DE is an evolutionary algorithm that uses rather great selection and less stochastic approach to solve optimization problems, than any other evolutionary algorithms stated [16, 17]. DE uses the difference of randomly sampled pairs of object vectors to guide the mutation process, which makes it relatively new, when compared to other algorithms. The main features of Differential Evolution Algorithm (DE) are its simple structure, convergence property, quality of solution and robustness. It is used for solving complex constrained non-linear optimization problem. SaDE algorithm for solving numerical problem is given in [18].

When applying SaDE for real power loss minimization problem, two main issues need to be addressed.

- Representation of the decision variables
- Formation of the Fitness function

A. Variable Representation

Each individual in the genetic population represents a candidate solution. For selecting optimal size and optimal place of Renewable DGs for real power loss minimization problem, the bus location and DGs size are taken as decision variable. The lower and upper bound for bus location is set at 1 to N_B (Number of buses). The lower and upper bound for DGs size is taken as 0 to 5000 kW.

B. Fitness Function

Evaluation of the individuals in the population is accomplished by calculating the objective function value for the problem using parameter set. The result of the objective function calculation is used to calculate the fitness value of the individual. Fitter chromosomes have higher probabilities of being selected for the next iteration. The fitness function is calculated based on the formula given in equation (1).

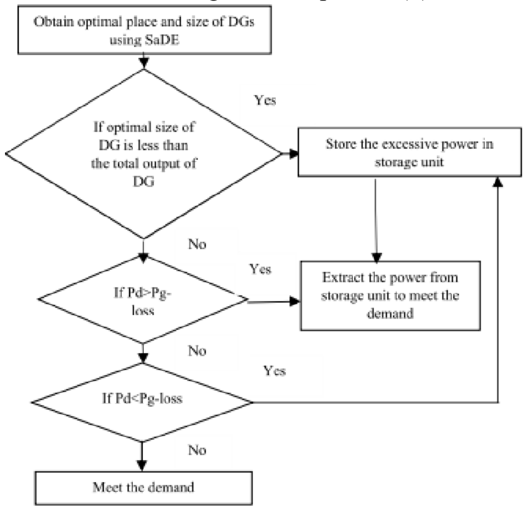

Fig.1 Flowchart for proposed approach

C. SaDE Procedure for Real Power Loss Minimization Problem

The SaDE approaches for solving the Real power loss minimization for distribution system are as follows: Fig.2 shows flowchart of SaDE for Real Power Loss Minimization.

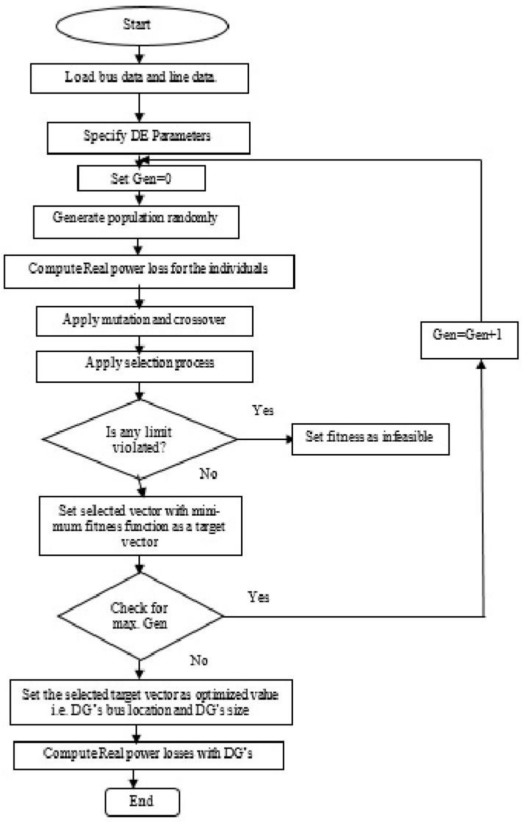

Fig 2. Flow Chart of SaDE for Real Power Loss Minimization

i. Read bus data, line data
ii. Run distribution system load flow for base case without DG and to find the loss using Eqn.(1)
iii. Read data for SaDE operations i.e. maximum iteration limit, number of population, the decision variable, lower and upper limit of decision variable, scaling factor F,
iv. Set generation/Iteration, Gen=0.
v. Generate population randomly, where decision variable is within its feasible bound.
vi. Compute Real power loss using Eq. (1) for each population of parent vector
vii. Set the parent population with the minimum value P_{loss} is the target vector i
viii. Perform mutation and crossover to get trial vector.
ix. Select among the target and trial vector for the survival
x. Using selected best vector value run distribution system load flow and compute P_{loss}
xi. Check for any operating limit violation. If any limit is violated, set the corresponding fitness as infeasible.

xii. Best vector selected will be the next parent vector for the next Population.

xiii. Increase the generation gen = gen+1

xiv. Check the maximum generation limit, if yes go to next step, otherwise go to step iv.

xv. Print the corresponding selected best vector as the optimum location and optimum size of DGs

xvi. Compute P_{loss} using Eq. (1).

V. RESULTS AND DISCUSSIONS

In order to test the effectiveness of proposed algorithm, two different distribution test system such as 33-bus [19], 69-bus [20] are considered. The optimum location and size of DGs for different test systems are calculated using SaDE and they are compared. Simulation studies were carried out by developing program on MATLAB version R2013a, on a Compaq laptop with Intel Core i3 processor having 3.10 GHz speed and 2 GB RAM.

The following parameters were chosen through trial and error.

TABLE II. PARAMETERS OF SaDE

S. No	Parameter	SaDE
1	Number of Iteration	100
2	Population size	50
3	Mutation Rule or Probability	Adaptive
4	Scaling Factor	0.5
5	Crossover Probability	Adaptive

A. Test System 1: 33-Bus Radial Distribution System

This system consists of 33-bus and 32 branches with a total load of 3715 kW and 2300 kVAr. The base case total system real power loss is 211.23 kW.

a) Case 1: Placement and sizing of Photovoltaic Type DGs

TABLE III OPTIMAL PLACEMENT AND SIZING OF PHOTOVOLTAIC DG IN 33-BUS SYSTEM WITH CONSTANT LOAD

Real power loss without DG (kW)	Optimal Placement of DG (Bus Location)		Optimal Size of DG (MW)		Real Power Loss with DG (kW)	
	SaDE	PSO	SaDE	PSO	SaDE (Loss Reduction %)	PSO (Loss Reduction %)
211.23	6	6	2.62	3.15	108.76 (48.51)	115.29 (45.36)

TABLE IV OPTIMAL PLACEMENT AND SIZING OF PHOTOVOLTAIC DG IN 33-BUS SYSTEM WITH DIFFERENT LOAD MODEL

Load Model Type	Real Power Loss without DG (kW)	Optimal Placement of DG (Bus Location)	Optimal Size of DG (MW)	Real Power Loss with DG (kW) (Loss Reduction %)
Commercial Load	157.34	6	2.30	75.59 (64.21)
Residential Load	161.25	6	2.39	72.64 (65.61)
Industrial Load	165.44	6	2.52	67.59 (68.00)
Commercial (40%) + Residential (40%) + Industrial (20%)	158.57	6	2.42	68.52 (67.56)

In this case Photovoltaic type DG is used. The optimal place and size of Photovoltaic type DG for real power loss minimization problem is given in Table 3. Here load is considered as a constant. The results obtained using SaDE are compared with PSO [6]. The percentage of real power loss minimization is also presented in Table III. According to Table III, the system power losses decrease from 211.23 kW to 108.76 kW in the presence of a photovoltaic type DG unit installation. The optimal DG unit location for a DG unit is bus 6.

As mentioned in section 3, the distribution system loads are mainly categorized into Residential, Industrial, and Commercial loads. These types of loads are voltage dependent. The voltage exponents of different load model are shown in Table I.

Table IV shows optimal place and size of photovoltaic DG for different load models obtained using SaDE. Table 4 also shows the percentage of real power loss reduction in the presence of DG.

If the optimal size of DG is less than the actual output of DG, the excessive power is stored in storage unit. During the unavailability of solar power, the stored energy is used to meet the demand.

b) Case 2: Placement and sizing of Wind mill Type DG's

In this case, Wind mill is used as a DG. The optimal placement and sizing of DG obtained using SaDE is given in Table V. The Windmill type DG has less loss reduction capability compared to photovoltaic type DG, this is because Windmill consumes some amount of reactive power.

TABLE V OPTIMAL PLACEMENT AND SIZING OF WIND MILL TYPE DG IN 33 BUS SYSTEM WITH CONSTANT LOAD

Real power loss without DG (kW)	Optimal placement (Bus Location)	Optimal Size (MW)	Real Power Loss (Loss Reduction %)
211.23	6	2.51	112.18(46.89)

Table VI shows optimal place and size of Photovoltaic DG for different load model obtained by SaDE. Table VI also shows the real power loss reduction percentage in the presence of DG.

TABLE VI OPTIMAL PLACEMENT AND SIZING OF WINDMILL TYPE DG IN 33-BUS SYSTEM WITH DIFFERENT LOAD MODEL

Load Model Type	Real Power Loss without DG (kW)	Optimal Placement of DG (Bus Location)	Optimal Size of DG (MW)	Real Power Loss with DG (kW) (Loss Reduction %)
Commercial Load	157.34	6	2.24	77.71 (50.61)
Residential Load	161.25	6	2.34	74.78 (53.62)
Industrial Load	165.44	6	2.46	69.64 (57.91)
Commercial (40%) + Residential (40%) + Industrial (20%)	158.57	6	2.36	70.56 (55.50)

If optimal size of Wind type DG is less than the actual output of DG, the excessive power is stored in storage unit. During the unavailability of wind, the stored energy is used to meet the demand.

Fig. 3, shows voltage magnitude in different buses with and without DG. From this figure it is inferred that the voltage profile has improved in the presence of DG. Compared to Windmill type DG the Photovoltaic type DG improves the voltage to little extend. This is because Windmill consumes reactive power.

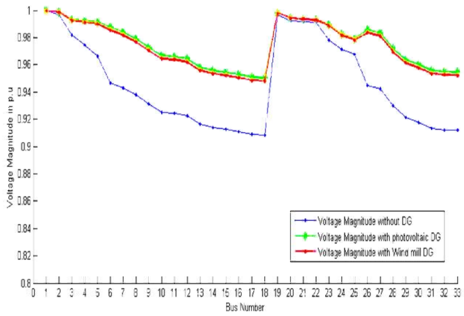

Fig 3. Voltage magnitude of 33 bus system with and without DG

Fig. 4, shows loss reduction percentage for different loads with different DGs for 33 bus distribution system. From Fig.4, it is evident that the photovoltaic type DG has high loss reduction capability compared with Windmill type DG and the Photovoltaic DG has higher impact on Industrial load in real power loss reduction.

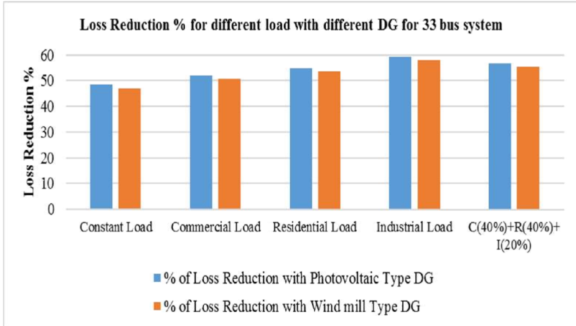

Fig 4. Loss Reduction percentage for different load with different DG for 33 bus system

B. Test System 2: 69-Bus Distribution System

This system consists of 69-buses with a total load of 3.80 MW and 2.69 MVAr. The base case total system real power loss is 224.60 kW.

a) Case 1: Placement and sizing of Photovoltaic Type DG's

In case 1, photovoltaic type DG is used. The optimal place and size of Photovoltaic type DG for real power loss minimization problem for 69 bus system is given in Table VII. Here load is considered as constant. The results obtained using SaDE is compared with PSO [6].

TABLE VII OPTIMAL LOCATION AND SIZE OF PHOTOVOLTAIC TYPE DG FOR 69 BUS SYSTEM

Real power loss without DG (kW)	Optimal Placement of DG (Bus Location)		Optimal Size of DG (MW)		Real Power Loss with DG (kW)	
	SaDE	PSO	SaDE	PSO	SaDE (Loss Reduction %)	PSO (Loss Reduction %)
224.60	61	61	1.89	1.81	81.54 (63.69)	83.37 (62.93)

Table VII shows, optimal place and size of Photovoltaic DG for different load model obtained using SaDE for 69-bus system. Table VII also shows real power loss reduction percentage in the presence of DG.

TABLE VIII OPTIMAL PLACEMENT AND SIZING OF PHOTOVOLTAIC DG IN 69-BUS SYSTEM WITH DIFFERENT LOAD MODEL.

Load Model Type	Real Power Loss without DG (kW)	Optimal Placement of DG (Bus Location)	Optimal Size of DG (MW)	Real Power Loss with DG (kW) (Loss Reduction %)
Commercial Load	160.13	61	1.65	54.85 (65.75)
Residential Load	165.43	61	1.72	49.66 (69.98)
Industrial Load	171.81	61	1.82	41.54 (75.82)
Commercial (40%) + Residential (40%) + Industrial (20%)	171.16	61	1.81	41.78 (75.60)

b) Case 2: Placement and sizing of Wind mill Type DG's

In this case, Wind mill is used as a DG. The optimal placement and sizing of DG obtained using SaDE is given in Table IX.

Table X shows Optimal Placement and Sizing of Wind type DG in 69-bus system with different load model for real power loss minimization

TABLE IX OPTIMAL PLACEMENT AND SIZING OF WIND MILL TYPE DG IN 69 BUS SYSTEM WITH CONSTANT LOAD

Real power loss without DG (kW)	Optimal placement	Optimal Size (MW)	Real Power Loss (Loss Reduction %)
224.60	61	1.84	84.79 (62.23)

TABLE X OPTIMAL PLACEMENT AND SIZING OF WIND TYPE DG IN 69 BUS SYSTEM WITH DIFFERENT LOAD MODEL

Load Model Type	Real Power Loss without DG (kW)	Optimal Place-ment of DG (Bus Location)	Optimal Size of DG (MW)	Real Power Loss with DG (kW) (Loss Reduction %)
Commercial Load	160.13	61	1.61	56.76 (64.55)
Residential Load	165.43	61	1.69	51.58 (68.82)
Industrial Load	171.81	61	1.79	43.38 (74.75)
Commercial (40%) + Residential (40%) + Industrial (20%)	171.16	61	1.79	43.62 (74.52)

Figures 5 and 6 show voltage magnitude of 69-bus system with and without different types of DG and loss reduction percentage of different load models in presence of Photovoltaic type DG and Wind type DG.

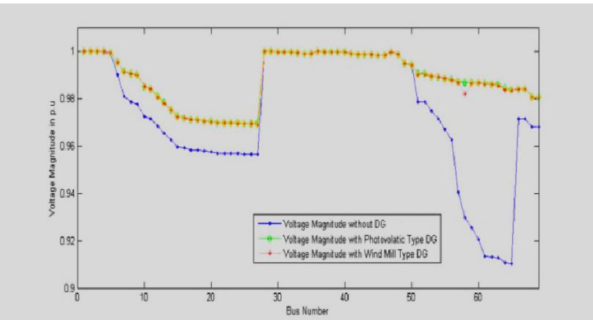

Fig 5. Voltage magnitude of 69 bus system with and without DG

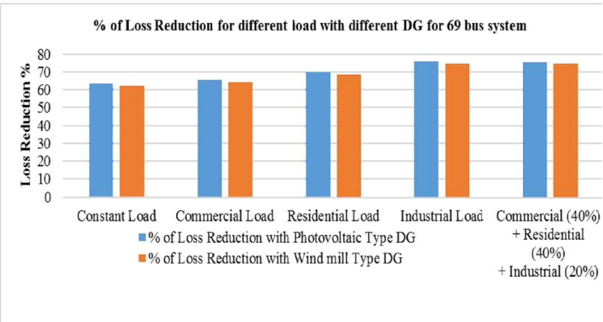

Fig 6. Percentage of Loss Reduction for different load with different DG for 69 bus system

VI. CONCLUSION

This paper presents the application of Self Adaptive Differential evolution (SaDE) algorithm for optimal size and placement of renewable DG sources in distribution network. Simulation study carried out on two different test system yields the following conclusion:

- Compared to PSO, the proposed SaDE has higher real loss power reduction capability in the distribution system loss reduction.
- The photovoltaic type DG has higher real power loss reduction capability in comparison with wind type DG.
- Among all load models, the DG placement in industrial load model has great impact in terms of real power loss minimization.
- The voltage magnitude of the distribution system is improved in the presence of DG.
- The voltage magnitude is slightly more when placing photovoltaic type DG in comparison with wind generation type DG.

REFERENCES

1. CIGRE, Impact of increasing contribution of dispersed generation on the power system, 1999.
2. Khattam W, Salama MMA, "Distributed system planning using distributed Generation", *In Proceeding of IEEE Canadian conference on electrical and computer engineering*, 1, pp. 579–82, 2003.
3. Mohamed Shaaban, J. O. Petinrin, "Sizing and siting of distributed generation in distribution systems for voltage improvement and loss reduction", *International Journal of Smart Grid and Clean Energy*, pp. 350-356, 2013.
4. Afzalan M, M.A.Taghikhani, "Placement and Sizing of DG Using PSO&HBMO Algorithms in Radial Distribution Networks", *I.J. Intelligent Systems and Applications*, 10, pp. 43-49, 2012.
5. Pavlos S. Georgilakis, Nikos D. Hatziargyriou, "Optimal Distributed Generation Placement in Power Distribution Networks: Models, Methods, and Future Research", *IEEE Transactions on Power Systems*, 28(8), pp. 3420-3428, 2012.
6. Naresh Acharya, PukarMahat, Mithulananthan N, "An analytical approach for DG allocation in Primary distribution network", *Electrical Power and Energy Systems*, 28, pp. 669–678, 2012.
7. Hung DQ, Mithulananthan N, Bansal RC, "Analytical expressions for DG allocation in primary distribution networks", *IEEE Transactions on Energy Conversion*, 25(3), pp. 814–820, 2010.
8. Biswas, Soma, Kumar Goswami, Swapan, Chatterjee, Amitava, "Optimum distributed generation placement with voltage sag effect minimization", *Energy Conversion and Management*, 53, pp. 163–174, 2012.
9. Kim KH, Lee YJ, Rhee SB, Lee SK, "Dispersed generator placement using fussy-GA in distribution systems", *Proceeding of IEEE power engineering society summer meeting, USA*, 2, pp. 1148–53, 2012.
10. Satish Kansal, Vishal Kumar, Barjeev Tyagi, "Optimal placement of different type of DG sources in distribution networks", *Electrical Power and Energy Systems*, 53, pp. 752–760, 2013.
11. Devi S., Geethanjali M, "Application of Modified Bacterial Foraging Optimization algorithm for optimal placement and sizing of Distributed Generation", *Expert Systems with Applications,* 41, pp. 2772–81, 2012.

12. Moradi, M. H., & Abedini, M, “A combination of genetic algorithm and particle swarm optimization for optimal DG location and sizing in distribution systems”, *Electrical Power and Energy Systems*, 34, pp. 66–74, 2012.
13. Paul Komor, John Glassmire, “Electricity Storage and Renewables for Island Power- A Guide for Decision Makers”, *International Renewable Energy Agency*, 2012.
14. Hossein Nasiraghdam, Morteza Nasiraghdam, “Load Model Effect Assessment on Optimal Distributed Generation Sizing and Allocation Using Improved Harmony Search Algorithm”, *Journal of Artificial Intelligence in Electrical Engineering*, 1 (1), pp. 1-17, 2012.
15. Singh, D., Singh, D. and Verma, K.S, “Multiobjective optimization for DG planning with load models”, *IEEE Transaction on Power Systems*, 24(1), pp. 427-36, 2009.
16. Storn R., and Price K., “Differential Evolution – a Simple and Efficient Heuristic for Global Optimization over Continuous Spaces”, *Journal of Global Optimization*, 11, pp. 341–359, 2012.
17. Kenneth V. Price, Rainer M. Storn and Jouni A.Lampinen, “Differential Evolution, a practical approach to global optimization”, *Springer*, 1998.
18. Qin, A.K. and Suganthan P.N, “Self-adaptive differential evolution algorithm for numerical optimization”, *IEEE Evolutionary Computation*, 2, pp. 1785 – 1791, 2005.
19. Kashem M. A., Ganapathy V., Jasmon G. B., and Buhari M. I, “A novel method for loss minimization in distribution networks”, *Proceeding of International Conference of Electrical Utilization, Deregulation Restructuring Power Technology*, pp. 251–256, 2000.
20. Baran M. E. and Wu F. F., “Optimum sizing of capacitor placed on radial distribution systems”, *IEEE Transaction on Power Delivery*, 4(1), pp. 735–743, 1989.