Voltage Regulation and Power Loss Reduction in DN with DG When Load Changes Using MOSMA

Simarla Vijender Reddy(✉) and M. Manjula

Department of Electrical Engineering, UCE Osmania University, Hyderabad 500007, India
`simarlavijender@gmail.com`

Abstract. The objective of this paper is to explain the effect of connecting Distributed Generation (DG) on power loss and voltage regulation in the Distribution Network (DN). The optimum location and size of DG are chosen using the Multi-Objective Slime Mould Algorithm (MOSMA). DG placement and size determination has recently piqued the interest of many to achieve a variety of goals such as reducing power loss, improving voltage profile, enhancing power quality, and improving distribution system efficiency. When DG units are connected at fixed locations with fixed sizes, the voltages and power losses change abnormally when the load changes. This happens mostly during light load conditions when the voltages on the buses tend to rise above the boundary limit.

Keywords: Distributed Generation(DG) · Distribution Network(DN) · Multi-Objective Slime Mould Algorithm(MOSMA) · Slime Mould Algorithm(SMA) · Voltage Regulation · Power losses

1 Introduction

The world is facing numerous problems related to electricity supply to meet consumer demand. One of the most efficient ways to meet load demand is through Distributed Generation (DG). The DG is a tiny power generator that is directly connected to or near the load. Real design sketch problems require the use of optimization algorithms to find qualitatively feasible solutions Some heuristic algorithms have given correct results when solving load flows in DN by connecting DG units. The Genetic Algorithm(GA) was developed based on biologically inspired operators. Some of the applications of the GA are the optimal place and power size of the DG in the distribution network [5, 8, 9]. The invention of Particle Swarm Optimization(PSO) was inspired by the behaviour of animals such as flocks of birds, schools of fish, and shoals of fish. The applications of DG employing PSO are discussed in [4, 6]. The Ant Colony Search Algorithm(ACSA) was created by observing how ants forage for food in the wild [3]. To solve the various optimization problems, a new heuristic bionic algorithm, known as the Slime Mould Algorithm (SMA), with a robust and unique potential for course optimization, has emerged in recent years [2]. MOSMA is used to solve multi-objective problems [1]. This paper explains the

B. Raj et al. (Eds.): ICETE 2023, AER 223, pp. 579–587, 2023.
https://doi.org/10.2991/978-94-6463-252-1_60

MOSMA utility for the greatest allocation of DG units. The DGs unsegregated into the distribution system have a giant high-quality impact on system performance due to their preparedness to minimize distribution line loss, ameliorate voltage stability, shoot-up reliability, and scale down pollutant emissions primarily based on DG technology types.

2 85-Bus Distribution Network

The IEEE 85 bus radial DN is shown in Fig. 1. The DN line and load data are referred to as [11]. DN has a full load of 3640 kVA and operates with a power factor of 0.8. Various load flow techniques are available for calculating the voltages and power losses [7, 10, 12]. The topological method for the load flow is applied in this work.

Equation (1) has given the voltage for sending end "M" and receiving end "N" at any bus.

$$\mathrm{V_N} = \mathrm{V_{N-1}} - \left(\frac{\mathrm{P_{Neff}} \times \mathrm{R_{M,N}} + \mathrm{Q_{Neff}} \times \mathrm{X_{M,N}}}{\mathrm{V_{N-1}}}\right) + \mathrm{j}\left(\frac{\mathrm{Q_{Neff}} \times \mathrm{R_{M,N}} - \mathrm{P_{Neff}} \times \mathrm{X_{M,N}}}{\mathrm{V_{N-1}}}\right) \tag{1}$$

The active and reactive powers at nodes "N" are denoted as $\mathrm{P_{Neff}}$ and $\mathrm{Q_{Neff}}$ respectively.

The Eq. (2) is given the power loss of "N" buses.

$$\mathrm{P_{loss}} = \sum_{k=2}^{N} \left(\frac{\mathrm{S_k}}{\mathrm{V_k}}\right)^2 \times \mathrm{R}_{k-1,k} \tag{2}$$

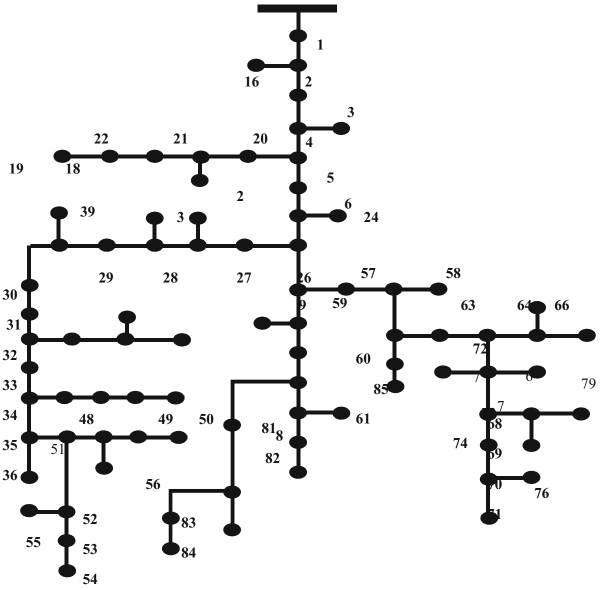

Fig. 1. IEEE-85 bus Distribution Network

3 Multi-objective Slime Mould Algorithm

The primary inspiration for Slime Mould Algorithm (SMA) comes from slime mould's search for food. In the process of foraging food, slime mould seeks organic matter, surrounds it, and secretes enzymes to digest it in order to exist. The steps for seeking food are food grab, food wrap, and food approach [2]. The mathematical equation is given as (3).

$$X = \begin{cases} \mathrm{rand} \cdot (\mathrm{ub} - \mathrm{lb}) + \mathrm{lb}, & \mathrm{rand} < \mathrm{z} \\ \mathrm{X_b(t)} + \mathrm{vb} \cdot (\mathrm{W} \cdot \mathrm{X_A(t)} - \mathrm{X_B(t)}), & \mathrm{r}lt; p \\ \mathrm{vc} \cdot \mathrm{X(t)}, & \mathrm{r} \geq \mathrm{p} \end{cases} \tag{3}$$

The MOSMA has developed by inserting extra features of the non-dominated solution and crowding distance into the SMA [1]. The objective functions of MOSMA are the minimization of losses and voltage deviations. The power losses are calculated from Eq. (2). Equation (4) gives the sum of the voltage magnitude deviations across all buses.

$$V_{mag} = \sum_{i=2}^{N} \| V_{REF} - V_i \| \tag{4}$$

where $\mathrm{V_{REF}}$ is the reference voltage. The reference voltage is 1.0 P.U. 'Vi 'represents the voltage at the 'i' bus.

3.1 Flow Chart of MOSMA

The flow chart of MOSMA is described in Fig. 2.

The tuning parameters of MOSMA are given as follows:

The number of variables = 10.
DG location lower bound limit (lb) = 2.
DG location upper bound limit (ub) = 85.
Maximum number of iterations = 100.
Initial slime mould numbers = 40.

4 Results of the Distribution Network

For the optimum placement and sizing of DGs, the MOSMA has been implemented on the IEEE 85 bus DN. In this work, ten DG units are connected at an optimum placement in the DN. The results of MOSMA are compared with GA, PSO, ACSA, and SMA. The locations of 10 DG units, as well as their power sizes, are shown in Table I. The comparison of power losses is shown in Fig. 3. The comparison of voltages for different optimization techniques is shown in Fig. 4. MOSMA has a higher average per unit voltage and is close to unity when compared to other approaches. The SMA has less power loss than the others. Although MOSMA has slightly higher power losses than SMA, it improves voltage levels for a more reliable power supply.

Once DGs are connected in DN, their positions should not be changed because it is extremely difficult to relocate solar and wind power generators. The optimal placements

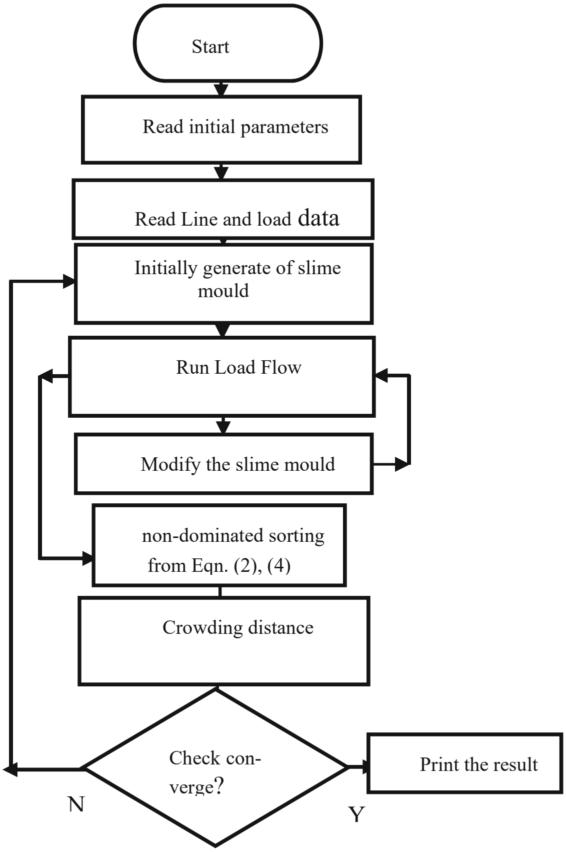

Fig. 2. MOSMA flow chart

of DG units are identified using MOSMA, which is given in Table 1. But, when the loads change with a fixed DG size of power, the voltages of the buses change. Since the voltages change abnormally, it damages the loads.

When loads change, the voltages and power losses are calculated in this paper. Figure 5 shows the voltages at 85 buses for various loads. The minimum voltages at 125%, 100%, 75% and 50% loads are 0.956, 0.98, 0.994, and 1.002 respectively. The maximum voltages at 125%, 100%, 75%, and 50% loads are 1.00, 1.012, 0.994 and 1.002 respectively. The maximum voltage of DN at 50% full load is 1.054 P. U, which is beyond the boundary limit (1.05 P. U).

From the above results, it is found that the voltages of DN have deviated more from their nominal voltages. The maximum voltage change is calculated as a percentage deviation. The percentage deviation is computed from the bus voltage and nominal voltage (unity voltage). Table 2 shows the minimum and maximum voltages among 85 buses and the percentage deviation of the minimum and maximum voltages from the nominal voltage. As per the standards, the voltages should not fluctuate by more than 5%

Table 1. Optimal placement and power size of DG units using GA, PSO, ACSA, SMA & MOSMA

DG Number	GA		PSO		ACSA		SMA		MOSMA	
	Bus Number	DG Size (kVA)	Bus No.	DG Size (kVA)	Bus Number	DG Size (kVA)	Bus Number	DG Size (kVA)	Bus Number.	DG Size (kVA)
1	61	251.771	63	195.984	51	270.041	83	280.254	83	291.237
2	40	127.557	44	250.801	22	202.909	31	292.588	53	297.733
3	80	181.341	62	206.366	71	223.661	71	302.637	51	284.483
4	11	200.933	35	269.347	42	303.853	18	83.817	29	274.201
5	28	275.631	17	225.723	83	234.336	74	296.457	85	221.702
6	45	82.683	70	204.826	72	153.517	48	283.221	63	298.447
7	48	224.167	56	263.776	54	241.913	84	69.019	82	289.089
8	47	234.065	64	75.709	49	129.438	39	273.159	29	286.471
9	81	300.493	72	204.269	83	107.614	57	282.045	69	197.508
10	40	167.607	27	230.617	68	229.812	53	279.575	82	275.431

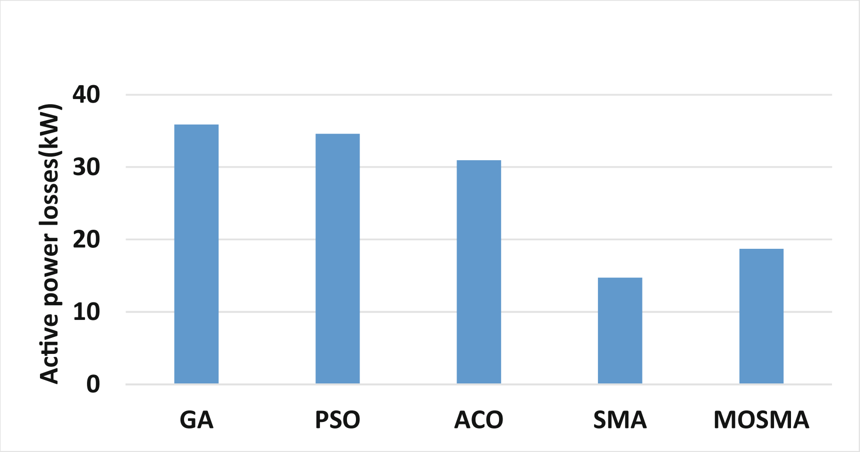

Fig. 3. Comparison of power losses for GA, PSO, ACSA, SMA and MOSMA

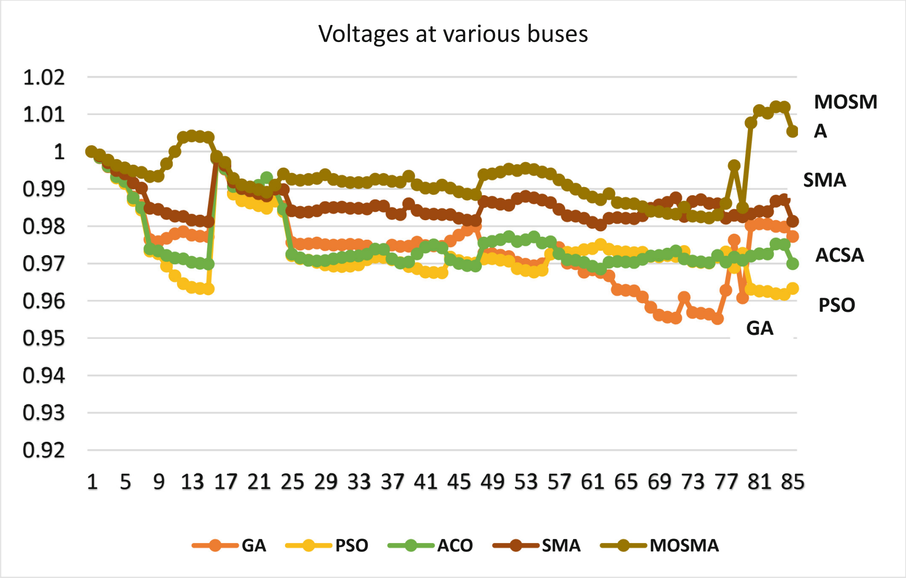

Fig. 4. Voltages at different buses using GA, PSO, ACSA, SMA and MOSMA

of the nominal voltage during load changes, but at 50% of the full load, the maximum voltage has exceeded the maximum limit.

If DGs are connected at a fixed place and with a fixed power size, the power losses are very high when the load changes. Table 3 shows the power losses that occur when the load changes. The maximum power loss is at 50% of load.

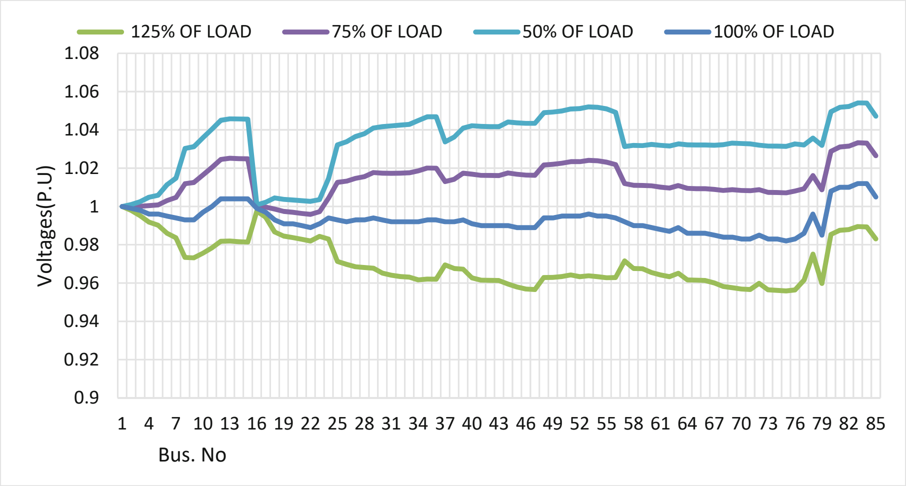

Fig. 5. voltages (p.u) at 85-buses with change of loads in DN

Table 2. The change of voltages with the change of loads

Load	Min voltage (P.U)	Max voltage (P.U)	The average voltage of 85 buses (P.U)	%Deviation of min. Voltage	%Deviation of max. Voltage
125%	0.956	1	0.970	4.4 (drop)	0
100%	0.982	1.012	0.993	1.8 (drop)	1.2(rise)
75%	0.995	1.033	1.013	0.5 (drop)	3.3(rise)
50%	1	1.054	1.033	0	5.4 (rise)

Table 3. Power losses at a fixed site and variable power of DGs with the change of loads

Loads	Power loss (kW)
125%	47.327
100%	14.724
75%	22.004
50%	52.241

5 Conclusion

In this paper, various techniques like GA, PSO, ACSA, SMA, and MOSMA are used for the optimal placement and size of DG. When comparing the slime mould algorithm to other approaches, the distribution network's power losses are low. For the single objective of loss minimization, the slime mould algorithm is superior to other approaches. The voltages are improved more for MOSMA compared to other methods, and power losses are lower than for GA, PSO, and ACSA. For the two objectives of improving voltage and reducing loss, MOSMA is preferred over SMA. The voltages and power losses are determined by the change in loads after the DGs are connected in the best locations with fixed sizes. The voltages are varied randomly and deviated from boundary limits at 50% of the full load.

References

1. M. Premkumar, P. Jangir, R. Sowmya, et al., "MOSMA: Multi-Objective Slime Mould Algorithm Based on Elitist Non-Domain Sorting", in IEEE Access, vol. 9, pp. 3229–3248, 2021.
2. M. A Elaziz, R. A. Ibrahim, D. Yousri, et al., "Fractional Calculus-Based Slime Mould Algorithm for Feature Selection Using Rough Set", in IEEE Access, vol. 9, pp. 131625–131636, 2021.
3. Yanhui Li, A Li, M Liu, et al., "A Slime Mould-Ant Colony Fusion Algorithm for Solving Traveling Salesman Problem", in IEEE Access, vol. 8, pp. 202508–202521, 2020.
4. Hassan M.H.Farh, Abdullah M. Al-Shaalan, Ali Mohamed Eltamaly, et al.: "A novel crow search algorithm Auto-Drive PSO for optimal Allocation and sizing of renewable Distribution Generation", IEEE Access, vol. 8, pp. 27807–27820, 2020.
5. Mikaeel Ahmadi, Mohammed Elsayed Lotfy, Ryuto Shigenobu, et al., "Optimal sizing and placement of rooftop solar photovoltaic at Kabul city real distribution network", IET Generation, Transmission & Distribution, vol. 12, Issue 2, pp. 303–309, 2018.
6. Sriparna Roy Ghatak, Surajit Sannigrahi, Parimal Acharjee "Comparative Performance Anaatedlysis of DG and DSTATCOM Using improved PSO based on the success rate for the deregulated environment", IEEE System Journal, vol. 12, Issue:3, pp. 2791–2802, 2018.
7. P. Rossoni, W. M. da Rosa, E. A. Belati, "Linearized AC Load Flow Applied to Analysis in Electric Power Systems", IEEE Latin America Transactions, vol. 14, Issue 9, pp. 4048–4053, 2016.
8. Mohammadreza Vatani, Davood Solati, et al.:" Multiple distributed generation Units allocation in the distribution network for loss reduction based on a combination of analytical and genetic algorithm methods", IET Generation, Transmission & Distribution, vol. 10, Issue 1, pp. 66–72, 2016.
9. Yuanyuan Zhao, Yiran an, Qian Ai, "Research on size and location of distributed generation with vulnerable node identification in the active distribution network", IET Proceedings-Generation, Transmission, and Distribution. vol. 8, Issue 11, pp. 1801–1809, 2014.
10. Sachin Singh, T. Ghose, "Improved radial load flow method" International Journal of Electrical Power & Energy Systems, vol. 44, Issue 1, pp. 721–727, 2013.
11. D. Das, D.P. Kothari, A Kalam, "Simple and efficient method for load flow solution of radial distribution networks", Journal of Electrical Power and Energy Systems, vol. 17, No. 5, pp. 335–346, 1995.
12. Julio A. D. Massignan, Benvindo R. Pereira, João B. A. London," Load Flow Calculation with Voltage Regulators Bidirectional Mode and Distributed Generation", IEEE Transactions On Power Systems, vol. 32, No. 2, pp. 1576–1577, March 2017.