Congestion Alleviation by Optimal Placing of Renewable Energy Generator in Power System Network using Stochastic Optimization Techniques

R.Ramaporselvi, G.Geetha, Mrunal Deshpande, J.Shri Saranyaa

Abstract— This paper peculiarly narrates about the optimal location of the renewable electrical generator along with minimizing the cost of generation. The aim of optimal congestion management is achieved by the suitable placement of the renewable electrical generator through PSO and VEPSO optimization technique. The renewable energy source boasts to be a vital and cost-free source for generating energy in the deregulated electricity network. Renewable energy generator (REG) location is identified on the minimum losses of the system thereby reducing the cost of generation. The approach is simulated and the results demonstrate the optimal location of REG and cost of generation in the 6 bus test system, IEEE- 14-bus and IEEE- 30 bus system.

Index Terms—Particle swarm optimization (PSO), Vector Evaluated Particle Swarm Optimization (VEPSO)

I. INTRODUCTION

In the deregulated electricity network, security and reliability play a paramount role. The outage in generation, failure of equipments, tripping of the transmission lines, sudden increment in demand, etc. scenarios affects the power system security and reliability. The transmission system is the heart of the electricity network that it has been operated at the near to peak capacity. The network's power transfer capability may exceed beyond the scheduled transfer limit due to the sudden increasing power demand of the system. That's the major reason for congestion occurring in the transmission sector. These congestion issues are mitigated by congestion management such as rescheduling the generation, curtailment of load, using FACTS devices, usage of renewable energy sources, etc. The sensitivity of the system loading factor based real and reactive power index scheme to determine the optimal location of FACTS device proposed [2]. Gravitational search algorithm for the optimal placement of IPFC for congestion management is proposed in [3]. In the developing countries, the global demand has seen a steady increase due to rising population, thereby making it necessary to meet the future demand by using new generator location in optimal places based on the minimum fuel cost, total emission and system loss [4].

Congestion management enacts to relieve the system congestion by non-cost free methods like re-dispatch of generation, load curtailment and built a new transmission line and cost-free methods are transformer taps, phase shifters, FACTS devices and renewable energy generation (REGs). Renewable energy generators pave a better solution for an economic electrical generation in electricity networks concerning the future power demand. Conventional energy sources are not adequate enough for generating the required energy and may lead to exploitation. It's also environmentally harmful. A bio-inspired PSO algorithm is proposed to enhance the voltage profile and minimize the system power losses for placing multi-generator in the optimal location of distribution network [5]. Nguyen Tung presented artificial bee's colony algorithm for placement of DG and size considering reliability and energy loss [6]. REG is one of the less cost-free methods because the operating cost is not included in the cost of generation. Locating the REG's is based on the system's minimum power loss.

II. PROPOSED METHODOLOGY

The global optimal location of REGs is resolved using stochastic optimization technique. The optimal location of REGs based on real power loss. The optimum location of REG gives the following benefits such as relieving congestion of system, minimizing the generation cost. The minimum objective generation cost is given by

Min G.C= $F(P_{gm}) + C(P_{REG})$ (1)

Subjected to

i) Equality constraints

Power balance equation

$$P_{gT} = P_L + P_D \quad (2)$$

where,

$$P_{gT} = \sum_{m=1}^{N} P_{gm} + P_{REG}$$

ii) Inequality constraints

Constraints (line flow, generating power of the unit, bus voltage, Complex power etc.) are operated within the operating limit.

$$P_{Lfk} \leq P_{Lfk\,(Max)} \quad (3)$$

$$P_{gm(Min)} \leq P_{gm} \leq P_{gm(Max)} \quad (4)$$

$$V_{bp(Min)} \leq V_{bp} \leq V_{bp(Max)} \quad (5)$$

Where p=1,2…..N

Fuel cost of existing system

Revised Manuscript Received on December 30, 2019.
* Correspondence Author
R.Ramaporselvi*, Innovate Educational Institute, Tambaram, Chennai. cholanrama@gmail.com,
Dr. G.Geetha, Jerusalem College of Engineering, Pallikaranai, Chennai. togeethamohan@gmail.com,
Dr. Mrunal Deshpande, SSN College of Engineering, Chennai. mrunald@ssn.edu.in
J.Shri Saranyaa, Research Assistant) SSN College of Engineering, Chennai. shrisaranyaa@gmail.com

$$F(P_{gm}) = \sum_{m=1}^{M} a_m P_{gm}^2 + b_m P_{gm} + c_m \quad (6)$$

Generation cost of Renewable energy generation system.

$$C(P_{REG}) = 0.0001 P_{REG}^2 + 0.4 P_{REG} \quad (7)$$

Line loss of the system

$$P_{L_k} = G_k\left(V_{b_p}^2 + V_{b_q}^2 - 2V_{b_p}V_{b_q}\cos(\delta_p - \delta_q)\right)$$

Where k=1, 2….. L (8)

P_{gm} is generating power of the existing system, P_{REG} is the generating power of renewable energy system, a_m, b_m and c_m are coefficients of fuel cost of the existing system, P_D is the demand power of system, P_{L_k} is system loss of k[th] line , P_{gT} is total generating power, P_{L_k} is power flow of k[th] line, V_{bp} is voltage magnitude of p[th] bus, G_k is conductance of k[th] line between p and q[th] bus, V_{b_p} and V_{b_q} are voltage magnitude of p[th] and q[th] bus, δ_p and δ_q are voltage angle of p[th] and q[th] bus, M is a number of existing generator, L is a number of lines and p is a number of buses.

In the solution suggested, the REG's are connected at every bus to find the fuel cost and power losses of the system with assumption of constant power demand using the popular optimization algorithms PSO and VEPSO. The vital task of the PSO and VEPSO is to search the optimal value of generating cost and minimum real power losses of the system when REG is to be located on each bus through the various processes of iterations. The above process is then reiterated for all buses of the system until an optimal result is obtained. The lowest system losses give the optimal location for placing REGs. Thus by roping in the renewable sources at that particular location of bus helps in reducing all sorts of congestion challenges. Figure (1) shows the flowchart of the above proposed methodology.

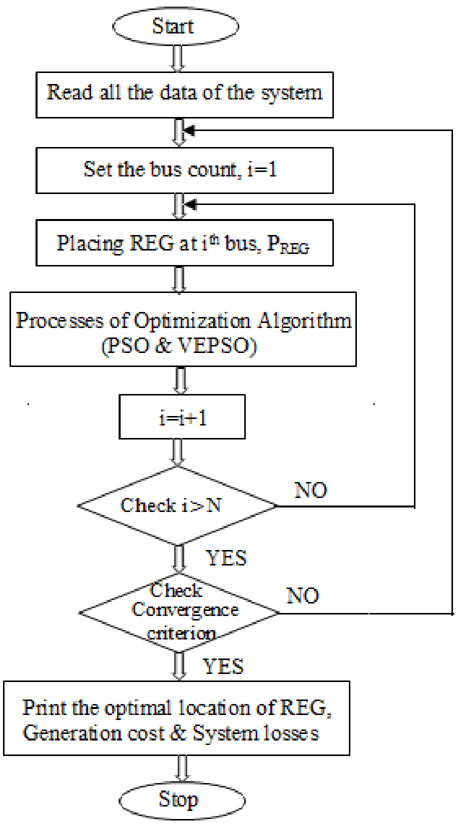


Fig.1 Flow chart of proposed system

III. CASE STUDIES AND RESULTS

The proposed framework is tested in a 6 bus system, IEEE-14 bus system and IEEE-30 bus system using the stated optimization techniques to solve the congestion management and determine the suitable location of REG based on the system losses and minimum generation cost.

Six bus system

It has 11 lines, one slack bus considered as 1[st] bus and 2-generator bus and 3-load bus. The minimum system losses occur in the given system when the REG placed on 5-bus. Table (1) shows the system losses, minimum generating cost and generating power for PSO and VEPSO technique.

Table 1: REG on different bus for six bus system

Bus No	PSO			VEPSO		
	Total Gen. (MW)	Total Gen. Cost ($/ hr)	Total Loss (MW)	Total Gen. (MW)	Total Gen. Cost ($/hr)	Total Loss (MW)
Bus 1	211.815	3312.25	6.8148	211.895	3312.92	6.8954
Bus 2	211.621	3309.75	6.6211	211.732	3310.04	6.7323
Bus 3	211.587	3309.35	6.5871	211.613	3309.99	6.6136
Bus 4	211.508	3308.55	6.5081	211.578	3308.69	6.5789
Bus 5	211.442	3307.45	6.4423	211.448	3307.64	6.4483
Bus 6	211.467	3307.55	6.4671	211.5	3307.8	6.5007

Table 2: Result of six bus system with and without REG

Status	PSO			VEPSO		
	Total Gen. (MW)	Total Gen. Cost ($/hr)	Total Loss (MW)	Total Gen. (MW)	Total Gen. Cost ($/hr)	Total Loss (MW)
with REG on Bus 5	211.442	3307.45	6.4423	211.448	3307.64	6.4483
With out REG	216.815	3375.9	6.8148	216.82	3376	6.8197

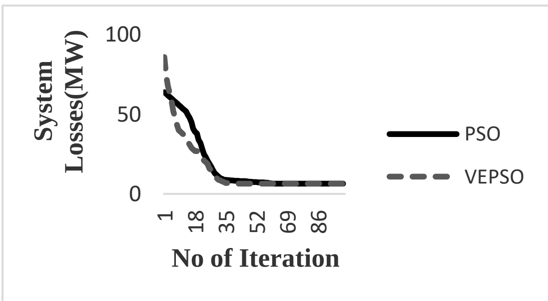
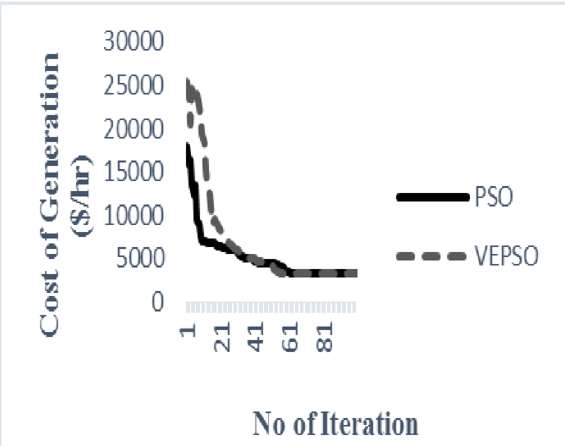


Fig.2 System losses of six bus system

Table 3: REG on different bus of IEEE-14 bus system for PSO and VEPSO

Bus No	Total Generation (MW)		Total Power Loss (MW)		Generation Cost ($/hr)	
	PSO	VEPSO	PSO	VEPSO	PSO	VEPSO
With out REG	272.653	273.121	13.654	14.1217	12551	12563.9
1	267.653	267.97	13.654	13.9707	12344	12352.7
2	267.389	267.826	13.3899	13.8266	12333	12345
3	**266.973**	**266.979**	**12.9737**	**12.9798**	**12316**	**12316.2**
4	267.101	267.231	13.1011	13.2316	12321	12324.6
5	267.19	267.059	13.1903	13.0597	12325	12321.4
6	267.184	267.569	13.1846	13.5696	12325	12335.6
7	267.101	267.289	13.1014	13.2896	12321	12326.2
8	267.101	267.962	13.1016	13.9626	12321	12344.7
9	267.101	267.364	13.1016	13.3646	12321	12328.2
10	267.088	267.163	13.0889	13.1636	12321	12323.1
11	267.125	267.968	13.1255	13.9686	12322	12345.2
12	267.117	267.002	13.1173	13.0026	12322	12318.9
13	267.074	267.562	13.0747	13.5626	12320	12333.4
14	266.983	267.361	12.9838	13.3616	12316	12326.4



I Fig.3 Cost of generation of six bus system

IEEE 14-bus system

The minimum system losses occur in the given system when the REG placed on 3-bus. Table (3) shows the system losses, minimum generating cost and generating power for PSO and VEPSO technique. Fig (4) & Fig (5) illustrate the minimum cost of generation and system losses with respect to iteration respectively. Table (4) gives the information of line losses of each line.

IEEE 30- bus System

It has 41 lines, one slack bus considered as 1st bus and four generator bus. The minimum system losses occur in the given system when **the** REG placed on 5-bus. Table (5) shows the system losses, minimum generating cost and generating power for PSO and VEPSO technique.

Table 4: Line losses of IEEE-14 bus system with and without REG

Line Number	Without REG	With REG		
		On 3rd Bus	On 14th Bus	On 13th Bus
1 –Line(1-2)	4.2532	4.0264	4.0565	4.0631
2 –Line(1-5)	2.8059	2.7035	2.6603	2.6581
3 – Line(2-3)	2.3874	2.2006	2.339	2.3436
4 –Line(2-4)	1.6872	1.6435	1.6002	1.6075
5 –Line(2-5)	0.9203	0.9052	0.8646	0.8614
6 –Line(3-4)	0.4214	0.3433	0.4392	0.4386
7 –Line(4-5)	0.4917	0.4659	0.4786	0.4911
8 –Line(4-7)	0	0	0	0
9 –Line(4-9)	0	0	0	0
10 –Line(5-6)	0	0	0	0
11 –Line(6-11)	0.1091	0.1084	0.1047	0.1152
12 –Line(6-12)	0.0805	0.0804	0.0734	0.0675
13 –Line(6-13)	0.2488	0.2482	0.2126	0.1837
14 -Line(7-8)	0	0	0	0
15 –Line(7-9)	0	0	0	0
16 –Line(9-10)	0.0063	0.0064	0.0068	0.0046
17 –Line(9-14)	0.0944	0.0952	0.0406	0.0718
18 –Line(10-11)	0.0422	0.0419	0.0398	0.0446
19 –Line(12-13)	0.0102	0.0102	0.0077	0.006
20 –Line(13-14)	0.0954	0.0947	0.0597	0.1181
Total	**13.654**	**12.9737**	**12.9838**	**13.0747**

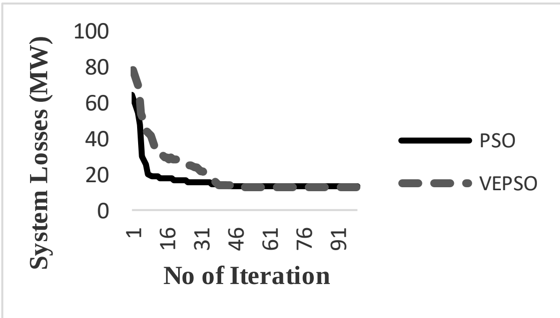


Fig.4 System losses of IEEE-14 bus system

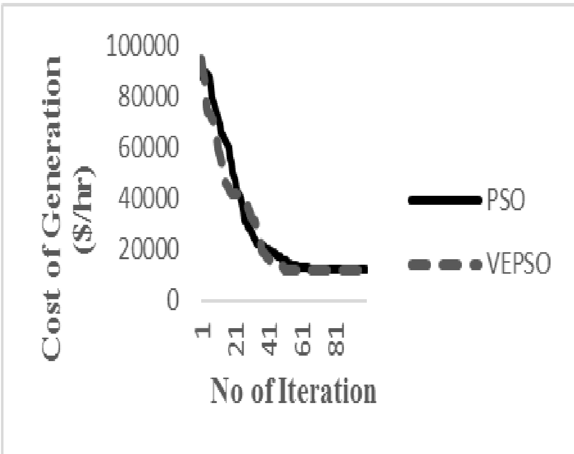


Fig.5 Cost of generation of IEEE-14 bus system

Fig (6) & Fig (7) illustrate the minimum cost of generation and system losses with respect to iteration. Table (6) gives the information of line losses of each line.

Table 5: REG on different bus of IEEE-30 bus system for PSO and VEPSO

Bus No	Total Gen. (MW)		System Loss (MW)		Generation Cost ($/hr)	
	PSO	VEPSO	PSO	VEPSO	PSO	VEPSO
Without REG	301.067	301.763	17.6714	18.3672	15234	15260.057
1	296.067	296.669	17.6714	18.2733	15010	15032.444
2	295.766	296.001	17.3699	17.605	15132	15140.764
3	295.659	295.782	17.2625	17.3859	15128	15132.6
4	295.536	295.814	17.1399	17.4174	15122	15132.345
5	**295.29**	**295.298**	**16.9027**	**16.9111**	**15111**	**15111.31**
6	295.442	295.967	17.0465	17.5721	15118	15137.598
7	295.35	296.119	16.9538	17.7232	15114	15142.694
8	295.41	295.654	17.0138	17.2578	15116	15125.096
9	295.44	295.444	17.044	17.0483	15118	15118.16
10	295.439	295.836	17.0435	17.4407	15118	15132.808
11	295.44	296.173	17.0441	17.7772	15118	15145.339
12	295.531	295.314	17.1358	16.9187	15122	15113.91
13	295.531	296.171	17.1358	17.7758	15122	15145.865
14	295.462	295.837	17.0656	17.441	15119	15132.995
15	295.417	295.624	17.0211	17.2279	15117	15124.709
16	295.469	295.653	17.0725	17.2567	15119	15125.866
17	295.428	295.4	17.032	17.0044	15117	15115.971
18	295.36	295.783	16.9641	17.3878	15114	15129.797
19	295.34	295.372	16.9444	16.9762	15113	15114.185
20	295.363	295.789	16.9673	17.3931	15114	15129.875
21	295.372	295.463	16.9765	17.0675	15115	15118.392
22	295.412	295.982	17.016	17.5863	15117	15138.265
23	295.371	295.418	16.9756	17.0229	15115	15116.763
24	295.347	296.102	16.9519	17.7066	15114	15142.145
25	295.384	295.821	16.9882	17.4252	15115	15131.293
26	295.354	295.3	16.9582	16.9037	15114	15111.969
27	295.43	295.843	17.0335	17.4465	15117	15132.398
28	295.411	295.298	17.0154	16.9025	15116	15111.793
29	295.319	296.002	16.9233	17.6063	15112	15137.47
30	295.324	295.562	16.9278	17.1662	15110	15118.89

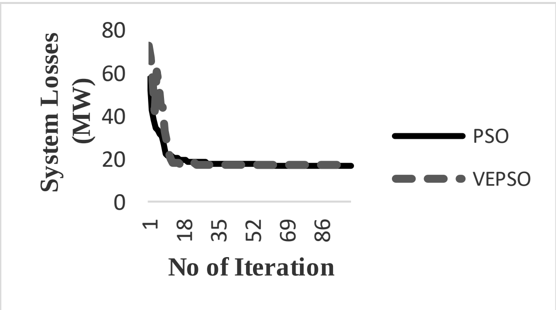


Fig.6 System losses of IEEE-30 bus system

Table 6: Line losses with and without REG

Line Number	Without REG	With REG		
		On 30^{th} Bus	On 5^{th} Bus	On 29^{th} Bus
1 –Line(1-2)	5.1169	4.8961	4.8665	4.8996
2 –Line(1-3)	3.161	3.0161	3.0581	3.0184
3 – Line(2-4)	1.0243	0.9721	1.0107	0.973
4 –Line(3-4)	0.8715	0.8306	0.8425	0.8313
5 –Line(2-5)	3.0035	2.9478	2.7836	2.9488
6 –Line(2-6)	1.9823	1.875	1.9395	1.8767
7 –Line(4-6)	0.645	0.6056	0.6174	0.606
8 –Line(5-7)	0.1641	0.1741	0.1275	0.1741
9 –Line(6-7)	0.3889	0.4036	0.345	0.4033
10 –Line(6-8)	0.1044	0.0989	0.1043	0.099
11 –Line(6-9)	0	0	0	0
12 –Line(6-10)	0	0	0	0
13 –Line(9-11)	0	0	0	0
14 -Line(9-10)	0	0	0	0
15 –Line(4-12)	0	0	0	0
16 –Line(12-13)	0	0	0	0
17 –Line(12-14)	0.0745	0.0728	0.0743	0.0729
18 –Line(12-15)	0.2147	0.2062	0.2136	0.2065
19 –Line(12-16)	0.0587	0.056	0.0581	0.0561
20 –Line(14-15)	0.0056	0.0051	0.0055	0.0051
21 –Line(16-17)	0.0138	0.0125	0.0135	0.0126
22 –Line(15-18)	0.0435	0.0426	0.0433	0.0427
23–Line(18-19)	0.0062	0.0059	0.0061	0.0059
24 –Line(19-20)	0.016	0.0162	0.016	0.0162
25 –Line(10-20)	0.0777	0.0787	0.078	0.0786
26 –Line(10-17)	0.0136	0.0141	0.0137	0.0141
27 –Line(10-21)	0.1542	0.1488	0.1545	0.1491
28 –Line(10-22)	0.0294	0.0239	0.0293	0.0242
29 –Line(21-23)	0.0001	0	0.0001	0
30 –Line15-23()	0.025	0.0219	0.0247	0.0221
31 –Line(22-24)	0.0464	0.0378	0.0464	0.0382
32 –Line(23-24)	0.0062	0.0034	0.0061	0.0036
33 –Line(24-25)	0.0081	0.0231	0.0082	0.023
34 –Line(25-26)	0.0453	0.045	0.0453	0.0451
35 –Line(25-27)	0.024	0.0442	0.0242	0.0436
36 –Line(28-27)	0	0	0	0
37 –Line(27-29)	0.0876	0.0397	0.0875	0.0189
38 –Line(27-30)	0.1647	0.0567	0.1646	0.1057
39 –Line(39-30)	0.0341	0.007	0.0341	0.0629
40 –Line(8-28)	0.0003	0.0015	0.0003	0.0015
41–Line(6-28)	0.06	0.0446	0.06	0.0447

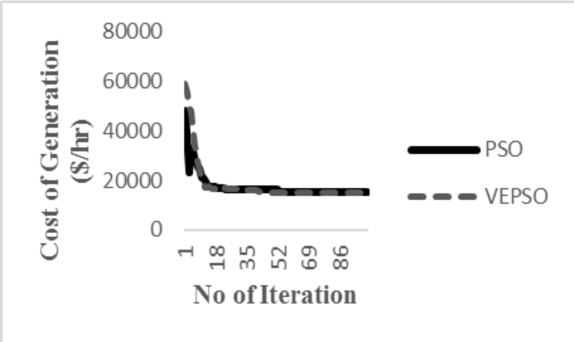


Fig.7 Cost of Generation of IEEE-30 bus system

IV. CONCLUSION

The techniques implemented in this paper exhibit that the congestion management can be rectified using PSO and VEPSO optimization techniques to determine the optimal placing of REG based on the system losses. The work is demonstrated with the 6-bus system, IEEE-14 bus and IEEE-30 bus system to prove its effectiveness. It shows that power can be generated with minimum generating cost with the help of renewable energy generator, also by minimizing the system losses and alleviates the impact of congestion.

REFERENCES

1. A.Keane, M.O.Malley, "Optimal allocation of embedded generation on distribution network" ,IEEE Trans. PWRD 1989.
2. Rakhmad Syafutra Labis, Sasongko Pramono Hadi and Tumiran, "Selection of suitable Location of FACTS devices for optimal power flow", International Journal of Electrical and computer sciences (IJECS - IJENS). Vol.12, No.03, pp. 38-49, June 2012.
3. Akanksha Mishra, G.Venkata Nagesh Kumar, "Congestion management of Deregulated power system by optimal setting of interline power flow controller using Gravitational search algorithm", Journal of Electrical system and Information Technology (4) 2017, pp. 198-212.
4. M.Y.Hassan, M.N.Suharto, M.p. Abdullath, M.S.Majid and F.Hussin, "Application of particle swarm optimation for solving optimal generation plant location problem", International journal of Electrical and Electronics system research, Vol.5, pp.47-56, June 2012.
5. Mounika Lakshmi Prasanna.K, Amit Jain and james ranjith Kumar, " Particle swarm Optimation application for optimal location of multiple Distributed Generators in power distribution network", Journal of Electrical and Electronics system 2017,6:4, volume 6. Issue 4.1000244.
6. Nguyen Tung Lish and Dam Xuan Dong, "Optimal location and size of distributed generation in Distributed System by Artificial Bees colony algorithm", International Journal of Information and Electronics Engg.,Vol-3,No:1, pp. 63-67,January.2013
7. J.kennedy and R.Eberhart, particle swarm Optimization, Proc. IEEE International Conference Neural Network (1995), vol. 4, pp. 1942-1948.

AUTHORS PROFILE

R.Ramaporselvi obtained her B.E (Electrical and Electronics Engineering) from Dr.Sivanthi Aditanar college of Engg, Manonmaniam Sundranar University, Thirunelveli and her M.E (Power Systems Engineering) from College of Engg., Anna University, Chennai.She had been in teaching field for the past 17 years. Her areas of interests are FACTS devices, Renewable energy and Deregulated Power Systems. Currently she is working as Research Coordinator in Innovative Educational Institute Chennai, Tamil Nadu, and India.

Dr.GeethaMohan obtained her B.E (Computer Science and Engineering) from IRTT,BharathiarUniversity, Erode and her M.E (Computer Science and Engineering) Sathyabama university, Chennai and Ph.D from Anna University, Chennai. She had been in teaching field for 18 years. She has published many papers in International Journals and International Conferences. Her areas of interest include Network security, Automation Algorithms, Data Science and Theory of Computation. Currently, she is working as women scientist trainee, Chennai, Tamil Nadu, and India.

Dr Mrunal Deshpande obtained her B.E (Electrical and Electronics Engineering) from Nagpur University and her M.E (Applied Electronics) and Ph.D from Anna University, Chennai. She has been in teaching field for more than 23 years. She has published many papers in International Journals and International Conferences. Her areas of interest include Non linear control systems, Electrical Machines and drives and Power Electronics. Currently, she is working as Associate Professor in Department of EEE, SSN College of Engineering Chennai, Tamil Nadu, India

J. Shri Saranyaa obtained her B.E (Electrical and Electronics Engineering) from Anna University, Chennai and her M.E (Power Systems Engineering) from Anna University of Technology, Coimbatore. She is in teaching field for the past 7 years. Her areas of interests are Microgrids, Smart grids and Deregulated Power Systems. Currently she is working as Research Assistant in Department of EEE, SSN College of Engineering Chennai, Tamil Nadu, India