Educational Administration: Theory and Practice
2023, 29(4), 5371-5384
ISSN: 2148-2403
https://kuey.net/

Research Article

A Hybrid Approach of GA- TS based Multi-Tasking Optimisation for Optimal Location and Sizing of Distributed Generation in Distribution Networks

Deependra Kumar Mishra[1*], Bindeshwar Singh[2]

[1*]Indian Institute of Technology (Indian School of Mines), Dhanbad, Jharkhand, India. Email: deependra2010@gmail.com
[2]Kamla Nehru Institute of Technology (KNIT), Sultanpur, Uttar Pradesh, India. Email: bindeshwar.singh2025@gmail.com

Citation: Deependra Kumar Mishra, et al (2023) A Hybrid Approach of GA- TS based Multi-Tasking Optimisation for Optimal Location and Sizing of Distributed Generation in Distribution Networks. *Educational Administration: Theory and Practice*, *29*(4), 5371-5384
Doi: 10.53555/kuey.v29i4.10202

ARTICLE INFO | **ABSTRACT**

Using hybrid approach of genetic algorithm and tabu search algorithm based multi-tasking optimisation in distribution networks with static load models, this article has attempted to improve system performance indices for the best placement and sizing of various types of distributed generation from the perspective of minimising the overall real power loss of the distribution networks. Indicators of system performance such real power loss, reactive power loss, voltage deviation, line capacity, and voltage regulation are taken into account when developing distributed generating systems with static load models. For the 16-bus, 37-bus, and 69-bus test systems, the suggested practise has been illustrated. The suggested approach should to produce improved outcomes with high accuracy for the ideal positioning and sizing of distributed generations with static load models in the distribution networks. The distribution networks' loadability, frequency stability, and voltage stability can be improved by placing distributed generation equipment in the best possible locations and sizing it for static load models.

Keywords: Distributed Generations, Distribution Networks, Genetic Algorithm, Static Load Models, System Performance Indices, Tabu Search Algorithm.

Nomenclature

Abbreviations			
CMS	Commercial StaticLoad Model	IDS	Industrial Static Load Model
CNS	Constant StaticLoad Model	ld, lg	Leading, and lagging, respectively
DGs	Distributed Generations	Pf	Power factor
DGT-1	DG type 1	RES	Residential Static Load Model
DGT-2	DG type 2	RFS	Reference Static Load Model
DGT-3	DG type 3	TS	Tabu Search
DGT-4	DG type 4	WDG	With DG
SLM	Static Load Models	WODG	Without DG
GA	Genetic Algorithm		

Symbols			
α	Real power exponent	*IVR*	Voltage regulation indices
β	Reactive power exponent	P_{i_bus}	Real power of static load model ($p.u.$)
F	Supply frequency (50 Hz)	P_{loss}	Real power loss of the system ($p.u.$)
ILC	Line capacity indices	Q_{i_bus}	Reactive power of static load model ($p.u.$)
ILP	Real power loss indices	S_{DG}	DG intake
ILQ	Reactive power loss indices	S_{int}	Apparent power intake of the system ($p.u.$)
IVD	Voltage deviation indices	S_{sys}	Apparent power of main substation ($p.u.$)

1. Introduction

According to IEEE, "DGs provided electricity is smaller in comparison with the central generation and linked at nearly any point in the distribution networks" [1]. According to Ackermann, "DGs is an electric power source connected directly to the distribution networks or on the customer side of the meter" [2]. The DGs impact in the distribution networks is either positively or negatively to the flow of power and voltage situations in the distribution networks. The DGs can be categorized based on real and reactive power provided/consumed as follows in Table 1.

Table 1: Classification of DGs

Types of DGs	Real and reactive power provided/consumed	Power factor	Examples
DGT-1	Real power provided to the distribution networks	Unity pf	Fuel cell, Photo-voltaic system
DGT-2	Real and reactive both powerprovided to the distribution networks	0.80-0.99 ld pf	Synchronous generators
DGT-3	Reactive power provided to the distribution networks	Zero pf	Synchronous condenser, Phase modifier circuit
DGT-4	Real power provided and consumes reactive power from the distribution networks	0.80-0.99 lg pf	Doubly-fed induction generator

Pepermans *et al.* [1], presented the definition, benefits, and key issues of DGs. Ackermann *et al.* [2], outlined the ideas of classification, purpose, location, rating, power conveyance zone, specialized issue, ecological effects, method of activity, possessions, and infiltration of DGs. Singh *et al.* [3], discussed the definition, benefits, key issues, technical and economic aspects of the DGs. Rugthaicharoencheep*et al.* [4], addressed the technical and economic impacts of DGs. IEEE task force [5], presented the dynamic performance analysis for system load models is reviewed. Singh *et al.* [6], proposed a novel method for the location of DGs in distribution networks. A GA based methodology for sizing and location of DGs keeping because of system power loss minimization in different loading conditions. Singh *et al.* [7], suggested the hybrid manner of evaluation approach in DGs planning in distribution networks from minimization of real power loss of the system. Payasi *et al.* [8], introduced the examination of DGs may help for a suitable choice of the kind of DG and its planning in the distribution networks for the various loads situation. Mishra *et al.* [9], suggested the approaches of DGs planning in the distribution networks for reducing the losses. Singh *et al.* [10], introduced the multi-objective optimization of DGs planning, impact of voltage step constraint and load models in optimum position and size of DGs.

Parihar *et al.* [11], proposed the sizing of biomass based distributed hybrid power generation systems in India. Akbar *et al.* [12], presented the hybrid algorithm was chosen because of its ability to reduce trip distance. The outcome of this investigation demonstrates that the algorithm not only decreased the existing route well, but it also forecasted the ideal number of homogeneous fleet. Umam *et al.* [13], presented a novel partial opposed-based population initialization technique, this paper merges the tabu search procedure with a genetic algorithm to decrease makespan. Alharbi *et al.* [14], suggested the optimisation model for increasing DGs allocation also includes network reconfiguration and the capacity curve defining the active and reactive power limits of DGs. Jiang *et al.* [15], discussed the fault location in distribution nrtworks with DGs. Abou *et al.* [16], discussed the logical methods for the optimum position of DGs in the distribution networks for minimizing the power loss of the system. Gustavo *et al.* [17], suggested the economic analysis of DGs for residential sectors. Attia *et al.* [18], suggested the suitable position and magnitude of DGs in the distribution networks and gives the ideas of system performance indices in the distribution networks. Ali *et al.* [19], presented the optimal site and size of DGs allocation in radial distribution networks using multi-objective optimization to minimize real power losses and voltage deviation, and to maximize the voltage stability index. Nsaif *et al.* [20], discussed the challenges and suggestions of fault detection and protection schemes for DGs integrated to distribution networks. Leon *et al.* [21], presented the review of the literature dedicated to mitigate these overvoltage problems, proposing the classification and definition of regulation devices and control schemes used. Stecanella *et al.* [22], presented the method with indicators that quantify the technical impacts that photo voltaic DGs growth causes to an actual utility that contains hundreds of feeders with different topologies, load types, and densities. Amin *et al.* [23], discussed a novel hybrid approach of anti-islanding protection scheme for virtual synchronous machine inverters for integration of DG sources into the grid. Saad *et al.* [24], introduced the historical review of optimal placement of electrical devices in power systems and critical analysis of renewable DGs efforts.

The above literature survey gives the ideas of DGs location and sizing in the distribution networks with load models for enhancement of system performances. In this paper, the hybrid approach of GA-TS method can be solved the problem of DGs location and sizing in the distribution networks with SLM. The optimum placed and sized of DG reduces the total real power loss of the system and also enhances the system performance indices. The main contribution of this paper can be outlined are as follows:

a) Minimize the total real power loss of the system.

b) Improve the voltage deviation and voltage regulation of the system.
c) Increases the short circuit current capacity of the system.
d) Increases the apparent power of the system which means enhances the loadability of the system.

The association of the paper is as follows: *Section 2* converses the problem formulation. *Section 3* converses the GA-TS implementation. *Section 4* converses the simulation results and discussions. *Section 5* presents the conclusion of this paper and also the scope of future work.

2. ProblemFormulations

SLMs such as *CNS, IDS, RES, CMS*, and *RFS*, the result of different types of DG (*i.e.* DGT-1, DGT-2, DGT-3, DGT-4) a 16-bus, 37-bus, and 69-bus test systems are taken for simulation. DGs arrange to decrease the real power loss in the distribution networks. With some other system performance indices like decrease reactive power loss, improvement of the voltage profile, increase short circuit current capacity, better voltage regulation, and MVA intake in the distributed networks. The load modeling, and DGs modeling are explained in *sub-sections* 2.1-2.2, respectively.

2.1 Load modeling

The SLM [5] that characterizes the power relationship to voltage as an exponential equation and characterized in the following in eqs. (1) - (2)

$$P_{i\_bus} = P_{0i\_bus}\left(\frac{|V_{i\_bus}|}{|V_{0i\_bus}|}\right)^{\alpha} \tag{1}$$

$$Q_{i\_bus} = Q_{0i\_bus}\left(\frac{|V_{i\_bus}|}{|V_{0i\_bus}|}\right)^{\beta} \tag{2}$$

where, P_{i_bus}, Q_{i_bus}, P_{oi_bus}, Q_{oi_bus}, V_{i_bus}, and V_{oi_bus} are all in per unit. Eqs.(1), and (2) neglect the frequency dependence of distribution networks load, because it is a pan-system phenomenon that can't be controlled locally and continue the same for the whole of the distribution networks.

The test system is assumed to be supplying power to mix of industrial, residential, commercial, and reference load without neglecting bus voltage and line capacity limits. The following test cases are developed for optimal size and location of DGs for SLM from total the real power loss (P_{Loss}) minimization viewpoint. The types of DGs are as follows: DGT-1; DGT-2; DGT-3; and DGT-4. The parameters considered for the study are MVA intake such as DG intake (S_{DG}), apparent power intake (S_{int}), and apparent system power requirement (S_{sys}) and power system performance indices (*ILP, ILQ, IVC, ILC,* and *IVR*).

2.2 DGs modeling

The formulation of DGs planning is proposed based on objective function such as the total real power loss of the system viewpoint [6-10].
The apparent power of the main substation without DG (S_{WODG}) in MVA is given in eq. (3).

$$S_{WODG} = \sqrt{P_G^{\,2} + Q_G^{\,2}} \tag{3}$$

where, P_G = Active power generating in MW, and Q_G = Reactive power generating in MVAR at generating station.
The apparent power of the main substation with DGT-1 (S_{WDGT-1}) in MVA is given in eq. (4).

$$S_{WDGT-1} = \sqrt{(P_G + P_{DGT-1})^2 + Q_G^{\,2}} \tag{4}$$

where, P_{DGT-1} = real power delivered by DG-T1 in MW.
The apparent power of the main substation with DGT-2 (S_{WDGT-2}) in MVA is given in eq. (5)

$$S_{WDGT-2} = \sqrt{(P_G + P_{DGT-2})^2 + (Q_G - Q_{DGT-2})^2} \tag{5}$$

where, P_{DGT-2} is the real power delivered by DGT-2 in MW, and Q_{DG-T2} is the reactive power delivered by DGT-2 in MVAr.
The apparent power of the main substation with DGT-3 (S_{WDGT-3}) in MVA is given in eq. (6)

$$S_{WDGT-3} = \sqrt{P_G + (Q_G - Q_{DGT-3})^2} \tag{6}$$

where, Q_{DGT-3} is the reactive power delivered by DGT-3 in MVAr.
The apparent power of the main substation with DGT-4 (S_{WDGT-4}) in MVA is given in eq. (7)

$$S_{WDGT-4} = \sqrt{(P_G + P_{DGT-4})^2 + (Q_G \pm Q_{DGT-4})^2} \quad (7)$$

where, P_{DGT-4} is the real power delivered by DGT-4 in MW, and Q_{DG-T4} is the reactive power delivered/consumed by DGT-4 in MVAR.
The objective function is the total real power loss (P_{Loss}) of the system. The P_{Loss} in the system is represented by eq. (8).

$$P_{Loss} = \sum_{i\_bus, j\_bus \in NL} \frac{P_{i\_bus,j\_bus}^2 + Q_{i\_bus,j\_bus}^2}{|V_{i\_bus}|^2} \times r_{i\_bus,\, j\_bus} \quad (8)$$

where, $P_{i\_bus,\, j\_bus}$ and $Q_{i\_bus,\, j\_bus}$ is real and reactive power flow in bus *i-j*, V_{i_bus} is the voltage at *i*th bus, $r_{i\_bus,\, j\_bus}$ is the line resistance of bus *i-j* and *NL* is the number of lines. The total losses mainly depend on the voltage profile.

3. GA-TSImplementation

a) Enter the 16-bus or 37-bus or 69-bus test system data, SLMs data (*i.e.CNS-IDS-RES-CMS-RFS,* respectively) and DGs data (*i.e.* DG-1, DG-2, DG-3 & DG-4) and calculate load flow from the initial case (primary fitness result) and estimate the voltage for the initial case with keeping the initial case (primary fitness result) features.
b) Coding of the 16-bus, 37-bus, and 69-bus system data, SLMs data (take one load model into consideration at a time), and DGs data to achieve an aim.
c) To get a unique response from GA-TS, create the main population and fitness function value. Reproduction, crossover, mutation, and TS phases all yield excellent results when using the GA-TS.
d) If the desired result is achieved, the value of the load flow conversation, distribution line capacity, and voltage deviation limitations. These are then used to form a new group for a fresh set of findings. If the result is not satisfactory, repeat step 3 and perform additional calculations.
e) The novel fitness outcome should be calculated along with power flow. Establish a connection between innovative fitness results and the primary fitness result's case characteristics.
f) The goal function is accomplished if the outcomes are fulfilled. After that, halt the programme and review the outcome. If the result is not satisfactory, repeat step 3 and make another calculation.

The flowchart of GA-TSoptimization of DGs in the distribution networks with SLM for minimizing the total real power loss perspective is shown in Fig. 1.

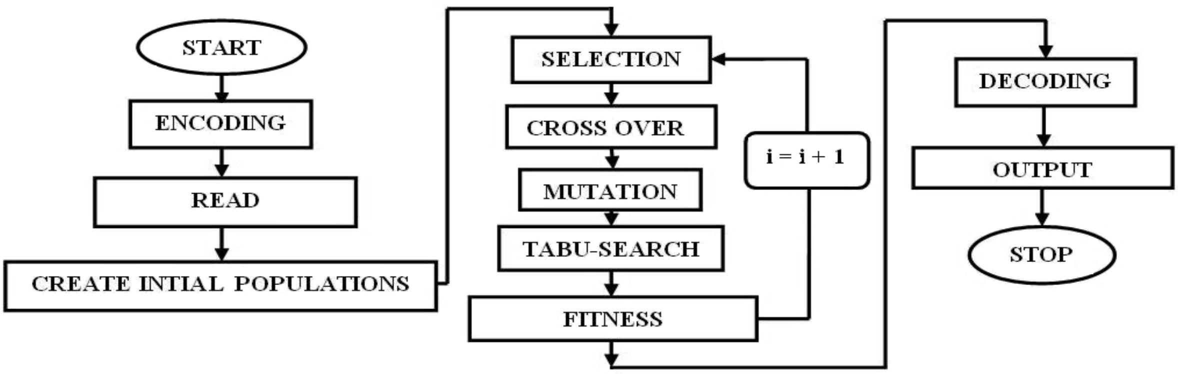

Fig. 1. Flowchart of the hybrid methodology of GA-TS optimization of DGs in the distribution network with SLM

3.1 System performances indices

(i) Real power loss indices (*ILP*): The lower the values of this index indicate better real power loss reduction. The % *ILP* is given in eq. (9).

$$\% ILP = \frac{P_{LWDG}}{P_{LWODG}} \times 100 \quad (9)$$

where, P_{LWDG} is the total real power loss with DGs, and P_{LWODG} is the total real power loss without DGs in the distribution networks.
(ii) Reactive power loss indices (*ILQ*): The lower the values of this indices indicate better reactive power loss reduction. The % *ILQ* is given in eq. (10).

$$\% ILQ = \frac{Q_{LWDG}}{Q_{LWODG}} \times 100 \quad (10)$$

where, Q_{LWDG} is the total reactive power loss with DGs, and Q_{LWODG} is the total reactive power loss without DGs in the distribution networks.
(iii) Voltage profile indices (*IVD*): This index is related to the maximum voltage drop between the root node and each node. The lower the values of this index indicate better voltage profile of the distribution networks. The % *IVD* is given in eq. (11).

$$\% IVD = \max_{i=2}^{n} \frac{|V_1| - |V_i|}{|V_i|} \times 100 \tag{11}$$

where, $V1$ is the root voltage and Vi is the voltage at bus *i*.
(iv) Line capacity indices (*ILC*): The power flows may diminish in some sections of the distribution networks and reduced more capacity with the power supplied near to the load. This index provided important information about the level of power flows/currents through the distribution networks regarding the maximum capacity of distribution lines. The lower value of this index indicates more capacity available. The % *ILC* is given in eq. (12).

$$\% ILC = \max_{i=1}^{n} \frac{|S_{ij}|}{|CS_{ij}|} \times 100 \tag{12}$$

where, *Sij* is MVA flows/currents in the line *i-j* and *CSij* is MVA capacity of the line *i-j*.
(v) Voltage regulation indices (*IVR*): This index related to the difference between nodal voltage during maximum and minimum demand. The indices value close to zero means better voltage regulation. The % *IVR* is given in eq. (13).

$$\% IVR = \max_{i=2}^{n} \frac{|V_{i,\min}| - |V_{i,\max}|}{|V_{i,\max}|} \times 100 \tag{13}$$

where, *Vi,*min is the minimum voltage magnitude of bus *i* when the bus is loaded minimum demand and *Vi,*max is the maximum voltage magnitude of bus *i* when the bus is loaded maximum demand.

3.2 Multi-objective formulations basedfunction

DGs planning with SLM, the multi-indices for performance assessment of distribution networks takes into account all previously described indices via strategic weight. It could be done by standardizing all effect performance indices (values varying from 0 to 1). This form of the problem is focusing on multi-objective output indices function (MOF) based on hybrid GA-TS methods is described in eqs. (14)- (15).

$$MOF = \eta_1 (ILP) + \eta_2 (ILQ) + \eta_3 (IVD) + \eta_4 (ILC) + \eta_5 (IVR) \tag{14}$$

where, $\sum_{r=1}^{5} \eta_r = 1 \wedge \eta_r \in (0 \quad 1)$ (15)

The values η_r were dependent on their significance in the performance indices distribution networks. The value of specific η_r is higher if the performance indices imports become of the highest significance relative to others. In this research work, the above objective function is designed via hybrid GA-TS methods.

The values used in this research paper for weights are similar to [8,15], despite the standard operation analysis. Therefore, that value can vary, depending on the concern of the engineer. During these researches, the *ILP* and *ILQ* obtained important first and second weights 0.40 and 0.30, simultaneously. The *IVD* operation got the third significant weight of 0.10 due to its effect on the performance of the power. The *ILC* obtained the fourth considerable weight of 0.10, as it provides valuable details regarding the amount of currents in distribution networks across the network on the total thermal efficiency for the conductors. The fifth important weight 0.08 was provided by *IVR*.

4 Simulation Results and Discussions

The 37-bus test system (16-bus, and 69-bus are the subset of 37-bus test system) and its data are given in Table 2 and Fig. 2, respectively. The real and reactive power exponential indices for SLM [6] are tabulated in Table 3. The comparison of simulation results of DGT-1, DGT-2, DGT-3, and DGT-4 operating at 1.00, 0.82 ld, 0.00, and 0.82 lgpf, respectively. Tables 4-6 shows that the simulation results for DGT-1, DGT-2, DGT-3, and DGT-4 planning with SLMs. The system performance indices such as % *ILP, % ILQ, % IVD, % ILC* and % *IVR* are shown in Figs. 3-5.

Table 2: Load data and line parameters for 37 bus test system [6]

		Line impedance(p. u.)		L	S_L	Load on the bus(p. u.)	
From	To	*R*	*X*		(p.u.)	*P*	*Q*
1	2	0.000574	0.000293	1	4.6	0.1	0.06
2	3	0.00307	0.001564	6	4.1	0.09	0.04
3	4	0.002279	0.001161	11	2.9	0.12	0.08

4	5	0.002373	0.001209	12	2.9	0.06	0.03
5	6	0.0051	0.004402	13	2.9	0.06	0.02
6	7	0.001166	0.003853	22	1.5	0.2	0.1
7	8	0.00443	0.001464	23	1.05	0.2	0.1
8	9	0.006413	0.004608	25	1.05	0.06	0.02
9	10	0.006501	0.004608	27	1.05	0.06	0.02
10	11	0.001224	0.000405	28	1.05	0.045	0.03
11	12	0.002331	0.000771	29	1.05	0.06	0.035
12	13	0.009141	0.007192	31	0.5	0.06	0.035
13	14	0.003372	0.004439	32	0.45	0.12	0.08
14	15	0.00368	0.003275	33	0.3	0.06	0.01
15	16	0.004647	0.003394	34	0.25	0.06	0.02
16	17	0.008026	0.010716	35	0.25	0.06	0.02
17	18	0.004558	0.003574	36	0.1	0.09	0.04
2	19	0.001021	0.000974	2	0.5	0.09	0.04
19	20	0.009366	0.00844	3	0.5	0.09	0.04
20	21	0.00255	0.002979	4	0.21	0.09	0.04
21	22	0.004414	0.005836	5	0.11	0.09	0.04
3	23	0.002809	0.00192	7	1.05	0.09	0.04
23	24	0.005592	0.004415	8	1.05	0.42	0.2
24	25	0.005579	0.004366	9	0.5	0.42	0.2
6	26	0.001264	0.000644	14	1.5	0.06	0.025
26	27	0.00177	0.000901	15	1.5	0.06	0.025
27	28	0.006594	0.005814	16	1.5	0.06	0.02
28	29	0.005007	0.004362	17	1.5	0.12	0.07
29	30	0.00316	0.00161	18	1.5	0.2	0.6
30	31	0.006067	0.005996	19	0.5	0.15	0.07
31	32	0.001933	0.002253	20	0.5	0.21	0.1
32	33	0.002123	0.003301	21	0.1	0.06	0.04
8	34	0.012453	0.012453	24	0.5	0	0
9	35	0.012453	0.012453	26	0.5	0	0
12	36	0.012453	0.012453	30	0.5	0	0
18	37	0.003113	0.003113	37	0.5	0	0
25	38	0.00313	0.003113	10	0.1	0	0

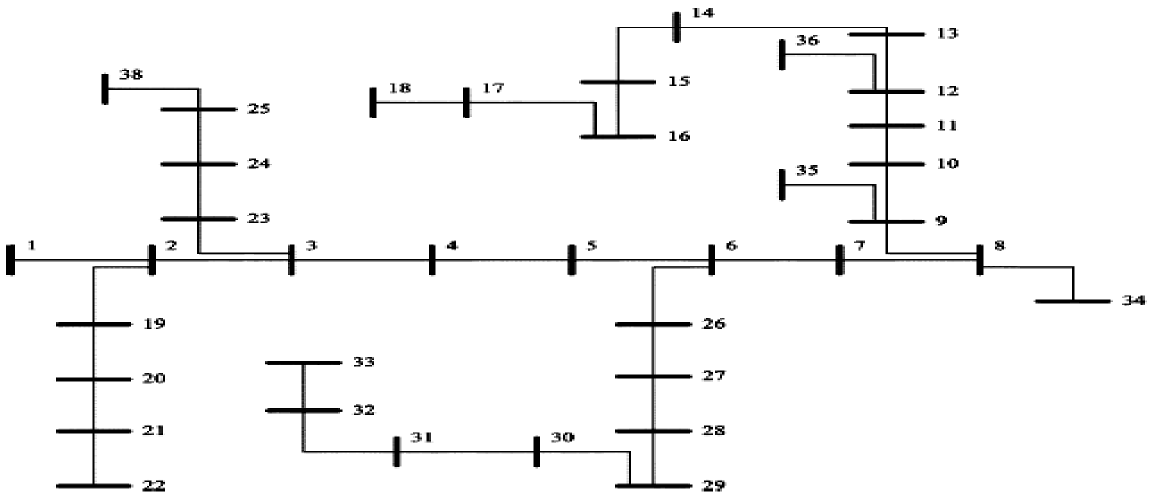

Fig. 2. 37-bus test system [6]

Table 3: Real and reactive power exponential indexes of SLM

SLM	α	β
CNS	0	0
IDS	0.18	6.0
RES	0.92	4.04
CMS	1.51	3.40
RFS	0.91	1.0

Table 4: Simulation results for DGT-1, DGT-2, DGT-3, and DGT-4 (operating at 1.00, 0.82 ld, 0.00, and 0.82 lgpf, respectively) planning with SLMs for 16-bus test System

SLM	WODG/ WDG	DG Type	DG Pf	DG Loc	S_{DG} (p.u.)	S_{int} (p.u.)	S_{sys} (p.u.)	% *ILP*	% *ILQ*	% *IVD*	% *ILC*	% *IVR*
CNS	WODG	-	-	-	-	1.6242	1.6242	100	100	2.22	92.17	2.11
		DGT-1	1.00	7	0.7014	1.3500	1.6219	45.84	44.48	1.84	92.26	1.75
	WDG	DGT-2	0.82 ld	7	0.7838	0.9833	1.6248	39.42	38.23	0.98	92.27	0.91
		DGT-3	0.00	8	0.2418	1.5290	1.6196	50.89	49.21	2.12	92.17	2.03
		DGT-4	0.82 lg	7	0.3090	1.4293	1.6212	48.83	47.07	1.96	92.20	1.88
IDS	WODG	-	-	-	-	4.3845	4.3845	100	100	8.12	94.89	8.10
		DGT-1	1.00	7	1.8936	3.6443	4.4055	48.19	46.92	6.77	95.21	6.68
	WDG	DGT-2	0.82 ld	7	2.1159	2.6548	4.4217	41.51	40.12	4.12	95.43	4.06
		DGT-3	0.00	8	0.6396	4.1275	4.3853	74.43	72.34	7.91	94.90	7.82
		DGT-4	0.82 lg	10	0.8720	3.8587	4.3871	52.13	50.61	7.24	94.95	7.16
RES	WODG	-	-	-	-	1.6660	1.6660	100	100	2.22	94.66	2.11
		DGT-1	1.00	7	0.6098	1.3042	1.6753	22.69	20.87	1.65	94.79	1.59
	WDG	DGT-2	0.82 ld	7	0.7643	1.0724	1.6813	18.40	17.67	0.85	94.90	0.79
		DGT-3	0.00	8	0.2794	1.5674	1.6673	29.84	28.42	1.83	94.68	1.78
		DGT-4	0.82 lg	6	0.5342	1.4948	1.6699	24.60	24.05	1.80	94.74	1.71
CMS	WODG	-	-	-	-	1.6700	1.6700	100	100	2.22	95.40	2.11
		DGT-1	1.00	8	0.6788	1.4126	1.6758	44.84	42.66	1.79	95.55	1.66
	WDG	DGT-2	0.82 ld	7	0.7185	1.1065	1.6870	38.09	37.04	0.96	95.67	0.90
		DGT-3	0.00	8	0.3105	1.4926	1.6732	49.95	47.51	2.11	95.50	2.02
		DGT-4	0.82 lg	7	0.5021	1.4335	1.6742	47.18	46.68	1.93	95.53	1.78
RFS	WODG	-	-	-	-	1.6734	1.6734	100	100	2.22	95.21	2.11
		DGT-1	1.00	7	0.7721	1.3710	1.6837	42.32	41.88	1.69	95.35	1.61
	WDG	DGT-2	0.82 ld	7	0.8290	1.0749	1.6919	37.63	36.14	0.94	95.45	0.87
		DGT-3	0.00	7	0.3235	1.4999	1.6765	49.10	47.23	2.09	95.31	2.00
		DGT-4	0.82 lg	7	0.5202	1.4409	1.6794	47.53	45.23	1.87	95.30	1.78

Table 5: Simulation results for DGT-1, DGT-2, DGT-3, and DGT-4 (operating at 1.00, 0.82 ld, 0.00, and 0.82 lg pf, respectively) planning with SLM for 37-bus test System

SLM	WODG/ WDG	DG Type	DG Pf	DG Loc	S_{DG} (p.u.)	S_{int} (p.u.)	S_{sys} (p.u.)	% *ILP*	% *ILQ*	% *IVD*	% *ILC*	% *IVR*
CNS	WODG	-	-	-	-	4.3845	4.3845	100	100	8.12	94.89	8.10
		DGT-1	1.00	31	1.8936	3.6443	4.4055	48.19	46.92	6.77	95.21	6.68
	WDG	DGT-2	0.82 ld	31	2.1159	2.6548	4.4217	41.51	40.12	4.12	95.43	4.06
		DGT-3	0.00	29	0.6396	4.1275	4.3853	74.43	72.34	7.91	94.90	7.82
		DGT-4	0.82 lg	30	0.8720	3.8587	4.3871	52.13	50.61	7.24	94.95	7.16
IDS	WODG	-	-	-	-	4.5160	4.5160	100	100	8.12	97.45	8.10
		DGT-1	1.00	30	2.0123	3.9835	4.5376	24.08	23.91	6.12	97.81	6.03
	WDG	DGT-2	0.82 ld	30	2.2223	2.8622	4.5543	21.75	20.83	3.43	97.95	3.35
		DGT-3	0.00	31	0.6778	4.2585	4.5169	62.47	60.45	7.23	97.50	7.14
		DGT-4	0.82 lg	30	0.9244	4.0504	4.5187	30.18	28.18	6.83	97.59	6.79
RES	WODG	-	-	-	-	4.5385	4.5385	100	100	8.12	97.23	8.10
		DGT-1	1.00	31	1.9601	3.5531	4.5602	23.58	22.24	6.10	97.49	6.01
	WDG	DGT-2	0.82 ld	31	2.1902	2.9141	4.5770	20.61	18.88	3.18	97.56	3.12
		DGT-3	0.00	30	0.6757	4.2902	4.5394	61.73	59.69	7.18	97.25	7.09
		DGT-4	0.82 lg	30	0.8636	4.0369	4.5412	27.09	25.65	6.80	97.30	6.71
CMS	WODG	-	-	-	-	4.5475	4.5475	100	100	8.12	97.82	8.10
		DGT-1	1.00	30	1.9640	3.6434	4.5693	47.08	45.22	6.41	97.95	6.33
	WDG	DGT-2	0.82 ld	30	2.1946	2.8289	4.5861	40.31	38.72	4.09	98.32	4.01
		DGT-3	0.00	31	0.6771	4.2860	4.5484	71.72	70.84	7.72	97.85	7.63
		DGT-4	0.82 lg	30	0.8653	4.0108	4.5502	50.17	48.65	7.01	97.90	6.94
RFS	WODG	-	-	-	-	4.5501	4.5501	100	100	8.12	97.66	8.10
		DGT-1	1.00	30	1.9651	3.6864	4.5719	44.17	42.51	6.25	97.89	6.17
	WDG	DGT-2	0.82 ld	30	2.1958	2.8669	4.5887	39.42	37.46	3.88	98.02	3.80
		DGT-3	0.00	30	0.6775	4.2625	4.5510	70.89	70.06	7.58	97.70	7.49
		DGT-4	0.82 lg	30	0.8658	4.0614	4.5528	49.73	48.01	6.98	97.73	6.91

Table 6: Simulation results for DGT-1, DGT-2, DGT-3, and DGT-4 (operating at 1.00, 0.82 ld, 0.00, and 0.82 lg pf, respectively) planning with SLM for 69-bus test System

SLM	WODG/	DG	DG	DG	S_{DG}	S_{int}	S_{sys}	%	%	%	%	%

	WDG	Type	Pf	Loc	(p.u.)	(p.u.)	(p.u.)	*ILP*	*ILQ*	*IVD*	*ILC*	*IVR*
CNS	WODG	-	-	-	-	10.7821	10.7821	100	100	8.96	95.34	8.95
		DGT-1	1.00	54	4.6567	8.9620	10.8338	49.44	48.03	7.89	95.81	7.81
	WDG	DGT-2	0.82 ld	54	5.2034	6.5285	10.8737	44.37	42.30	4.77	96.23	4.68
		DGT-3	0.00	53	1.6054	10.1513	10.7842	76.77	75.38	8.65	95.37	8.53
		DGT-4	0.82 lg	54	2.0518	9.4893	10.7885	53.97	52.41	8.29	95.40	8.17
IDS	WODG	-	-	-	-	11.1055	11.1055	100	100	8.96	97.78	8.95
		DGT-1	1.00	54	4.7920	9.9238	11.1588	27.17	25.15	6.79	97.85	6.71
	WDG	DGT-2	0.82 ld	54	5.3595	7.0386	11.1998	22.44	21.31	3.62	97.93	3.58
		DGT-3	0.00	51	1.6536	10.4724	11.1077	65.18	63.14	7.72	97.80	7.59
		DGT-4	0.82 lg	53	2.1133	9.9605	11.1121	33.81	32.31	7.39	97.82	7.23
RES	WODG	-	-	-	-	11.1721	11.1721	100	100	8.96	97.61	8.95
		DGT-1	1.00	52	4.8252	8.7466	11.2257	26.31	24.51	6.73	97.75	6.68
	WDG	DGT-2	0.82 ld	53	5.3916	7.1925	11.2670	21.02	19.79	3.51	97.89	3.44
		DGT-3	0.00	53	1.6635	10.5040	11.1743	63.17	61.41	7.70	97.65	7.53
		DGT-4	0.82 lg	54	2.1260	9.8571	11.1788	32.69	30.45	7.21	97.67	7.13
CMS	WODG	-	-	-	-	11.2391	11.2391	100	100	8.96	98.23	8.95
		DGT-1	1.00	52	4.8541	9.2295	11.2930	47.51	46.78	7.23	98.41	7.12
	WDG	DGT-2	0.82 ld	53	5.4239	7.0266	11.3346	42.53	40.25	4.28	98.65	4.19
		DGT-3	0.00	54	1.6735	10.4748	11.2413	75.65	73.89	8.18	98.27	8.10
		DGT-4	0.82 lg	53	2.1388	9.9679	11.2458	51.24	50.67	8.11	98.30	8.01
RFS	WODG	-	-	-	-	11.3031	11.3031	100	100	8.96	97.88	8.95
		DGT-1	1.00	54	4.8818	9.2221	11.3573	44.45	43.13	7.01	98.13	6.92
	WDG	DGT-2	0.82 ld	54	5.4548	7.1237	11.3991	40.41	39.08	4.11	98.46	4.03
		DGT-3	0.00	51	1.6830	10.6136	11.3053	73.49	72.12	7.81	97.90	7.72
		DGT-4	0.82 lg	54	2.1509	10.0473	11.3098	50.11	49.81	7.98	97.93	7.91

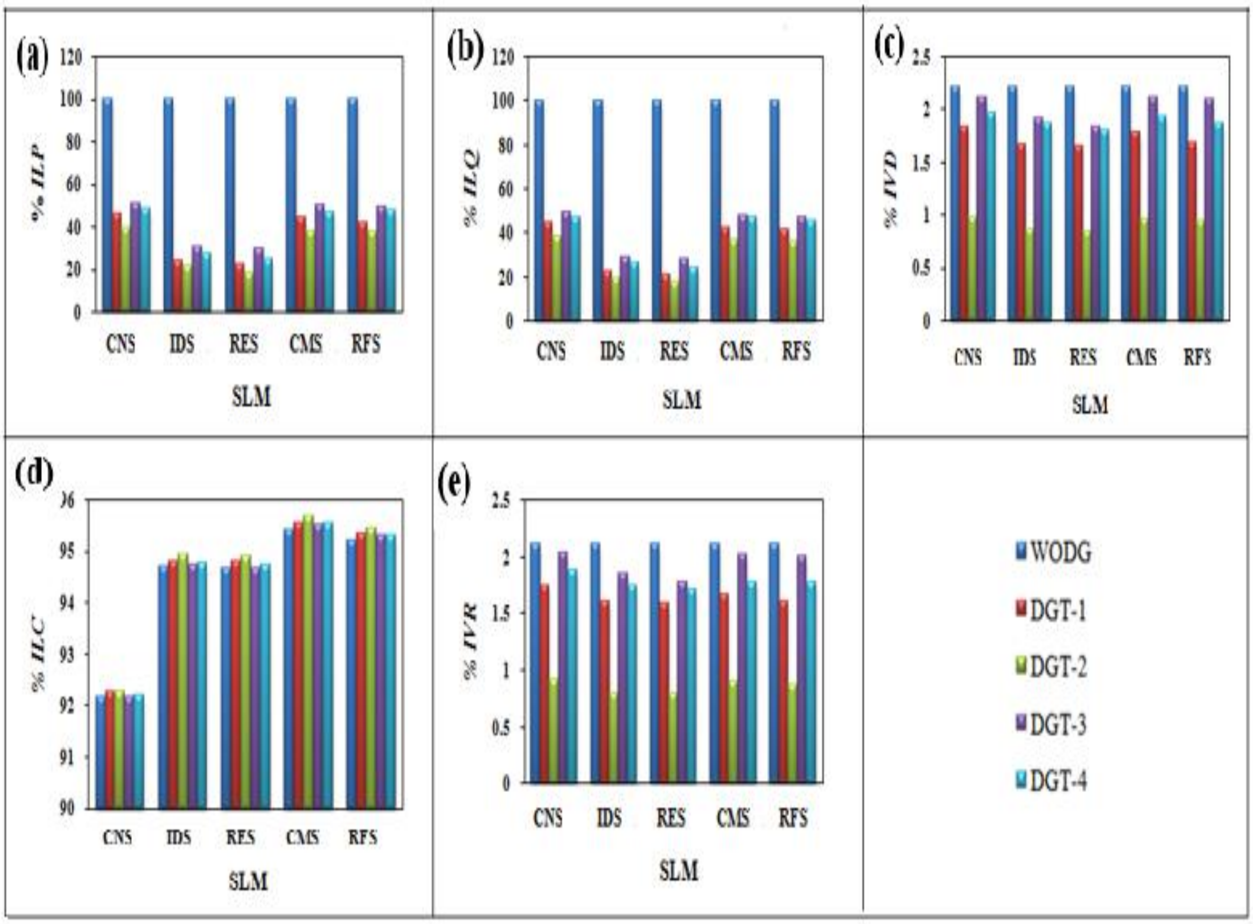

Fig. 3. Comparison of system performance indices profile WODG and WDG *vs* SLMs for 16-bus system

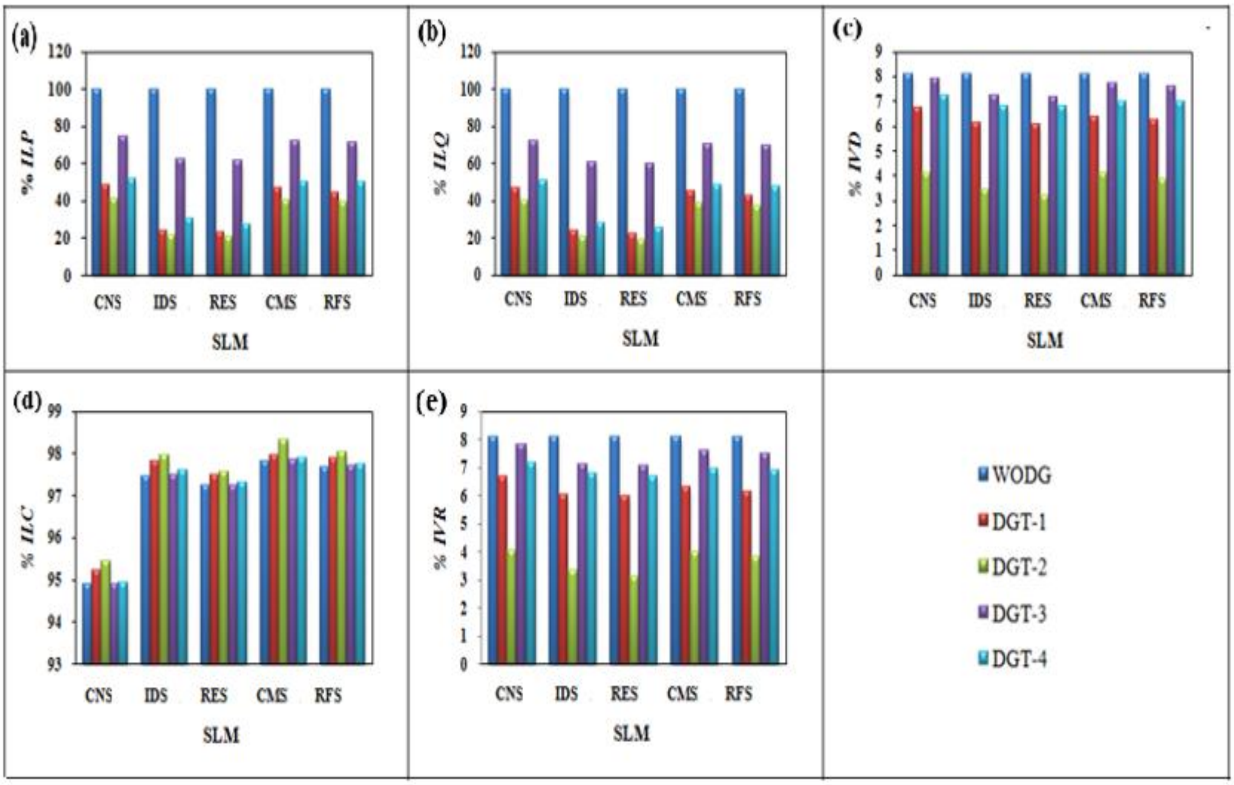

Fig. 4. Comparison of system performance indices profile WODG and WDG *vs* SLMs for 37-bus system

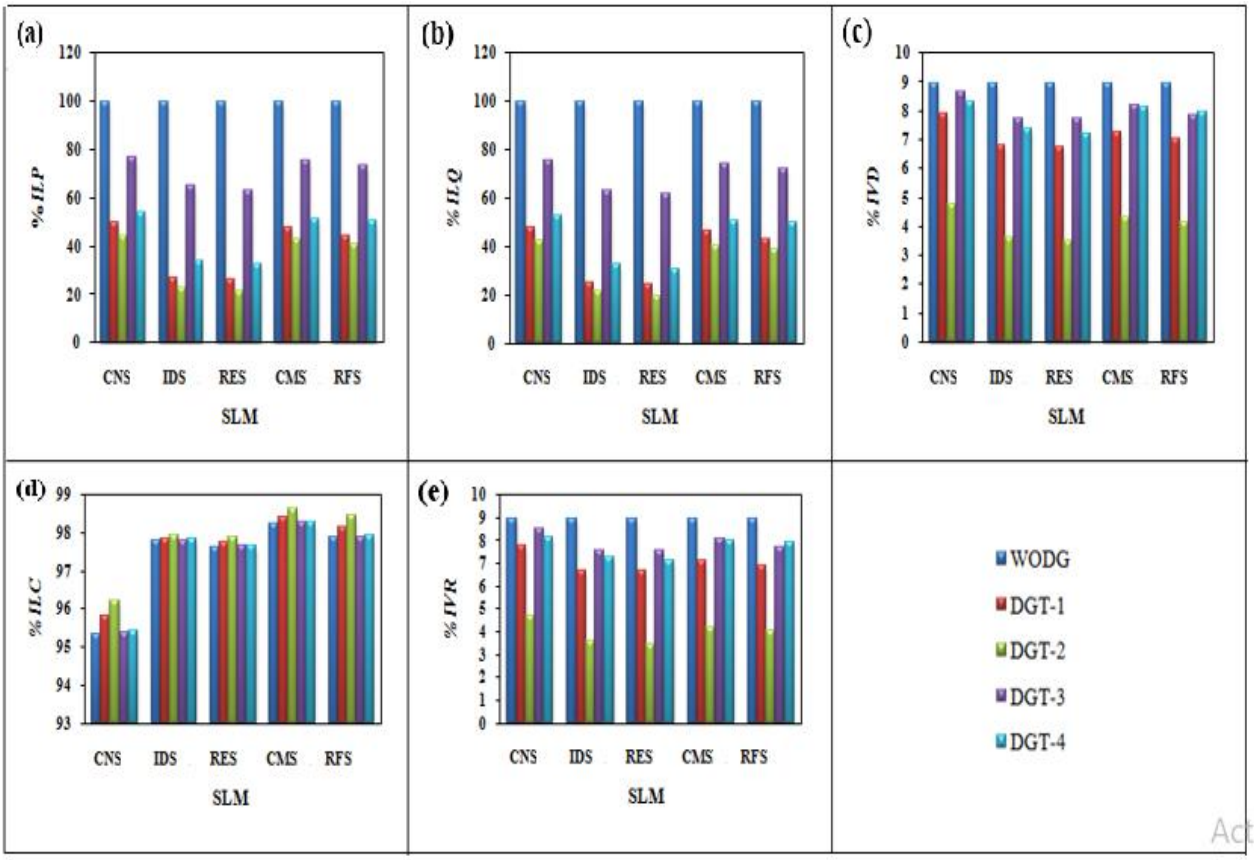

Fig. 5. Comparison of system performance indices profile WODG and WDG *vs* SLMs for 69-bus system

CNS: The assessment of *% ILP* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(100, 45.48, 39.42, 50.89 & 48.83), (100, 48.19, 41.51, 74.43, & 52.13), and (100, 49.44, 44.37, 76.77, & 53.97)} shown in Fig. 3(a), Fig. 4(a), and Fig. 5(a), respectively. So that *% ILP* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% ILQ* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(100, 44.48, 38.23, 49.21 & 47.07), (100, 46.92, 40.12, 72.34, & 50.61), and (100, 48.03, 42.30, 75.38, & 52.41)} shown in Fig. 3(b), Fig. 4(b), and Fig. 5(b), respectively. So that *% ILQ* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% IVD* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(2.22, 1.84, 0.98, 2.12 & 1.96), (8.12, 6.77, 4.12, 7.19, & 7.24), and (8.96, 7.89, 4.77, 8.65, & 8.29)} shown in Fig. 3(c), Fig. 4(c), and Fig. 5(c), respectively. So that *% IVD* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% ILC* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(92.17, 92.26, 92.27, 92.17, & 92.20), (94.89, 95.21, 95.43, 94.90, & 94.95), and (95.34, 95.81.96.23, 95.37, & 95.40)} shown in Fig. 3(d), Fig. 4(d), and Fig. 5(d), respectively. So that *% ILC* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a higher value whereas DGT-3 gives a lower value. The assessment of *% IVR* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(2.11, 1.75, 0.91, 2.03 & 1.88), (8.10, 6.68, 4.06, 7.82, & 7.16), and (8.95, 7.81, 4.68, 8.53, & 8.17)} shown in Fig. 3(e), Fig. 4(e), and Fig. 5(e), respectively. So that *% IVR* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value.

The location of DGT-1, DGT-2, and DGT-4 are at bus 7, whereas DGT-3 is at bus 8 in the 16-bus test system, the location of DGT-1, and DGT-2 are at bus 31, DGT-3 at bus 31, whereas DGT-4 at bus 30 in the 37-bus test system, and the location of DGT-1, DGT-2, and DGT-4 are at bus 54 whereas DGT-3 at bus 53 in the 69-bus test system.

IDS: The assessment of *% ILP* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(100, 24.23, 21.60, 30.93, & 27.13), (100, 24.08, 21.75, 62.47, & 30.18), and (100, 27.17, 22.44, 65.18, & 33.81)} shown in Fig. 3(a), Fig. 4(a), and Fig. 5(a), respectively. So that *% ILP* outline orders of DGT-3< DGT-4< DGT-1< DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% ILQ* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test system are {(100, 22.24, 19.49, 29.24, & 26.51), (100, 23.91, 20.83, 60.45, & 28.18), and (100, 25.15, 21.31, 63.14, & 32.31)} shown in Fig. 3(b), Fig. 4(b), and Fig. 5(b), respectively. So that *% ILQ* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% IVD* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(2.22, 1.67, 0.87, 1.91 & 1.86), (8.12, 6.12, 3.43, 7.23, & 6.83), and (8.96, 6.79, 3.62, 7.72, & 7.39)} shown in Fig. 3(c), Fig. 4(c), and Fig. 5(c), respectively. So that *% IVD* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% ILC* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(94.71, 94.80, 94.95, 94.75 & 94.78), (97.45, 97.81, 97.95, 97.50, & 97.59), and (97.78, 97.85, 97.93, 97.80, & 97.82)} shown in Fig. 3(d), Fig. 4(d), and Fig. 5(d), respectively. So that *% ILC* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a higher value whereas DGT-3 gives a lower value. The assessment of *% IVR* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(2.11, 1.60, 0.80, 1.85 & 1.74), (8.10, 6.03, 3.35, 7.14, & 6.79), and (8.95, 6.71, 3.58, 7.59, & 7.23)} shown in Fig. 3(e), Fig. 4(e), and Fig. 5(e), respectively. So that *% IVR* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value.

The location of DGT-1 and DGT-2 are at bus 7, DGT-3 is at bus 8, and DGT-4 is at bus 10 in the 16-bus test system, the location of DGT-1, DGT-2, and DGT-4 are at bus30, whereas DGT-3 is at bus 31 in the 37-bus test system, and the location of DGT-1, and DGT-2 are at bus 54, DGT-3 is at bus 51, whereas DGT-4 is at bus 53 in the 69-bus test system.

RES: The assessment of *% ILP* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(100, 22.69, 18.40, 29.84, & 24.60), (100, 23.58, 20.61, 61.73, & 27.09), and (100, 26.31, 21.02, 63.17, & 32.69)} shown in Fig. 3(a), Fig. 4(a), and Fig. 5(a), respectively. So that *% ILP* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DG-T2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% ILQ* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(100, 20.87, 17.67, 28.42, & 24.05), (100, 22.24, 18.88, 59.69, & 25.65), and (100, 24.51, 19.79, 61.41, & 30.45)} shown in Fig. 3(b), Fig. 4(b), and Fig. 5(b), respectively. So that *% ILQ* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% IVD* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(2.22, 1.65, 0.85, 1.83, & 1.80), (8.12, 6.10, 3.18, 7.18, & 6.80), and (8.96, 6.73, 3.51, 7.70, & 7.21)} shown in Fig. 3(c), Fig. 4(c), and Fig. 5(c), respectively. So that *% IVD* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% ILC* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(94.66, 94.79, 94.90, 94.68 & 94.74), (97.23, 97.49, 97.56, 97.25, & 97.30), and (97.61, 97.75, 97.89, 97.65, & 97.67)} shown in Fig. 3(d), Fig. 4(d), and Fig. 5(d), respectively. So that *% ILC* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a higher value whereas DGT-3 gives a lower value. The assessment of *% IVR* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus test systems are {(2.11, 1.59, 0.79, 1.78 & 1.71), (8.10, 6.01, 3.12, 7.09, & 6.71), and (8.95, 6.68, 3.44, 7.53, & 7.13)} shown in Fig. 3(e), Fig. 4(e), and Fig. 5(e), respectively. So that *% IVR* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value.

The location of DGT-1 and DGT-2 are at bus 7, DGT-3 is at bus 8, whereas DGT-4 is at bus 6 in the 16-bus test system, The location of DGT-1, and DGT-2 are at bus 31, whereas DGT-3, DGT-4 are at bus 30 in the 37-bus test system, and the location of DGT-1 is at bus 52, DGT-2, and DGT-3 are at bus 53, and DGT-4 is at bus 54 in the 69-bus test system.

CMS: The assessment of *% ILP* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus systems are {(100, 44.84, 38.09, 49.95, & 47.18), (100, 47.08, 40.31, 71.72, & 50.17), and (100, 47.51, 42.53, 75.65, & 51.24)} shown in Fig. 3(a), Fig. 4(a), and Fig. 5(a), respectively. So that *% ILP* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% ILQ* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus systems are {(100, 42.66, 37.04, 47.51, & 46.68), (100, 45.22, 38.72, 70.84, & 48.65), and (100, 46.78, 40.25, 73.89, & 50.67)} shown in Fig. 3(b), Fig. 4(b), and Fig. 5(b), respectively. So that *% ILQ* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% IVD* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus systems are {(2.22, 1.79, 0.96, 2.11, & 1.93), (8.12, 6.41, 4.09, 7.72, & 7.01), and (8.96, 7.23, 4.28, 8.18, & 8.11)} shown in Fig. 3(c), Fig. 4(c), and Fig. 5(c), respectively. So that *% IVD* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% ILC* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus systems are {(95.40, 95.55, 95.67, 95.50, & 95.53), (97.82, 97.95, 98.32, 97.85, & 97.90), and (98.23, 98.41, 98.65, 98.27, & 98.30)} shown in Fig. 3(d), Fig. 4(d), and Fig. 5(d), respectively. So that *% ILC* outline orders of DGT-3 <DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a higher value whereas DGT-3 gives a lower value. The assessment of *% IVR* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus systems are {(2.11, 1.66, 0.90, 2.02, & 1.78), (8.10, 6.33, 4.01, 7.63, & 6.94), and (8.95, 7.12, 4.19, 8.10, & 8.01)} shown in Fig. 3(e), Fig. 4(e), and Fig. 5(e), respectively. So that *% IVR* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value.

The location of DGT-1 and DGT-3 are at bus 8, DGT-2, and DGT-4 are at bus 7 in the 16-bus test system, the location of DGT-1, DGT-2, and DGT-4 are at bus 30, whereas DGT-3 at bus 31 in the 37-bus test system, and the location of DGT-1 is at bus 52, DGT-2, and DGT-4 are at bus 53, whereas DGT-3 at bus 54 in the 69-bus test system.

RFS: The assessment of *% ILP* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus systems are {(100, 42.32, 37.63, 49.10, & 47.53), (100, 44.17, 39.42, 70.89, & 49.73), and (100, 44.45, 40.41, 73.49, & 50.11)} shown in Fig. 3(a), Fig. 4(a), and Fig. 5(a), respectively. So that *% ILP* outline orders DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% ILQ* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus systems are {(100, 41.88, 36.14, 47.23, & 45.23), (100, 42.51, 37.46, 70.06, & 48.01), and (100, 43.13, 39.08, 72.12, & 49.81)} shown in Fig. 3(b), Fig. 4(b), and Fig. 5(b), respectively. So that *% ILQ* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% IVD* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus systems are {(2.22, 1.69, 0.94, 2.09, & 1.87), (8.12, 6.25, 3.88, 7.58, & 6.98), and (8.96, 7.01, 4.11, 7.81, & 7.98)} shown in Fig. 3(c), Fig. 4(c), and Fig. 5(c), respectively. So that *% IVD* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value. The assessment of *% ILC* outline variation without and with DGs for 16-bus system, 37-bus system, and 69-bus systems are {(95.21, 95.35, 95.45, 95.31, & 95.30), (97.66, 97.89, 98.02, 97.70, & 97.73), and (97.88, 98.13, 98.46, 97.90, & 97.93)} shown in Fig. 3(d), Fig. 4(d), and Fig. 5(d), respectively. So that *% ILC* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a higher value whereas DGT-3 gives a lower value. The assessment of *% IVR* outline variation without and with DGs for 16-bus, 37-bus, and 69-bus systems are {(2.11, 1.61, 0.87, 2.00, & 1.78), (8.10, 6.17, 3.80, 7.49, & 6.91), and (8.95, 6.92, 4.03, 7.72, & 7.91)} shown in Fig. 3(e), Fig. 4(e), and Fig. 5(e), respectively. So that *% IVR* outline orders of DGT-3 < DGT-4 < DGT-1 < DGT-2. Lastly, it is shown that DGT-2 gives a lower value whereas DGT-3 gives a higher value.

The location of DGT-1, DGT-2, DGT-3, and DGT-4 are at bus 7 in the 16- bus test system, the location of DGT-1, DGT-2, DGT-3, and DGT-4 are at bus 30 in the 37- bus test system, and the location of DGT-1, DGT-2, and DGT-4 are at bus 54, whereas DGT-3 at bus 51 in the 69- bus test system.

5 Conclusions and Future Scope of Research Work

The conclusions and future scope of research work are discussed in *sub-sections 5.1-5.2*, subsequently.

5.1 Conclusions

In this work, SLMs such as *CNS, IDS, RES, CMS*, and *RFS* at each bus for different types of DG are (DGT-1, DGT-2, DGT-3, and DGT-4) considered. The DGs arrangement contributes to the proper result. Optimum location and sizing of DGs can minimize the real power losses and reactive power losses of the distribution networks, improve the voltage profile of the distribution networks, increase the short circuit current capacity of the distribution networks and improve the voltage regulation of the distribution networks. The following conclusions are made as follows:

a) DGT-1 is more helpful for real power suppliers at unity pf. That is useful for frequency drop compensation in power grids.
b) DGT-2 is more helpful for real power and reactive suppliers at 0.80-0.99 ld pf. That is useful for frequency compensation as well as a voltage drop in power grids.
c) DGT-3 is more helpful for reactive power suppliers at zero pf. That is useful for a voltage drop in power grids.
d) DGT-4 is more helpful for real power and $\pm$ reactive suppliers at 0.80-0.99 lg pf. That is useful for frequency compensation as well as a voltage drop in power grids.
e) DGT-2 gives better performance whereas DGT-3 gives poor performance.

5.2 Scopes of future research work

The future scope of research work for DGs planning with SLMs in the distribution networks are as follows:
a) A combination of DGs (hybrid manner) is giving the best result for enhancing the power system performances.
b) In the future, the type of DGs such as DGT-1, DGT-2, DGT-3, and DGT-4 can be used for reactive power supporters in the distribution networks for the development of voltage profile.
c) The recent optimization technique such as grasshopper optimization technique (GOT), whale optimization technique (WOT), spider monkey optimization (SMO), and ant lion optimization (ALO), *etc.* can be used in the upcoming for the optimum location of DGs in distribution networks for better improvement of power system performances.
d) A combination of artificial intelligence techniques can be used for the optimum location of DGs in the distribution networks for the improvement of power system performances.
e) The different types of DGs arrangement with realistic load models also implementations in the future.
f) Reducing the real power losses and reactive power losses, the cost of electricity per unit is also minimized.
g) Real-world applications of these things are useful for society.

References

[1] G. Pepermans, J. Driesen, D. Haeseldonckx, W. D. Haeseleer, and R. Belmans, “Distributed generation: definition, benefits, and issues” *Ener. Tran. and Envir., University of Leuven Energy Institute*, pp. 1-22, 2003.

[2] T. Ackermann, G. R. Andersson, and L. S. der, “Distributed generation: a definition,” *Elect. Pow. Sys. Res.*, vol. 57, pp. 195-204, 2001, doi.org/10.1016/S0378-7796(01)00101-8.

[3] B. Singh, and D. K. Mishra, “A Survey on Enhancement of Power System Performances by Optimally Placed DG in Distribution Networks” *Else. Ener. Reps.*, vol.4, pp. 129-158, 2018, doi.org/10.1016/j.egyr.2018.01.004.

[4] N. Rugthaicharoencheep, and S. Auchariyamet, “Technical and economic impacts of distributed generation on the distribution system” *Int. J. of Elect., Comp, Ener., Electr., and Comm. Engg.*, vol. 6, no. 4, pp. 385-389, 2012, doi.org/10.5281/zenodo.1327636.

[5] IEEE Task Force on Load Representation for Dynamic Performance, “Load representation for dynamic performance analysis,” *IEEE Trans. Pow. Sys.*, vol. 8, no. 2, pp. 472-482, 1993, doi: 10.1109/59.260837.

[6] D. Singh, D. Singh, and K. S. Verma, “GA based optimal sizing &placement of distributed generation for loss minimization” *Int. J. of Elect., Comp, Ener., Electr., and Comm. Engg.*, vol. 1, no. 11, pp. 1604-1610, 2007, doi.org/10.5281/zenodo.1084516.

[7] B. Singh, V. Mukherjee, P. Tiwari, “GA-based multi-objective optimization for distributed generation planning with DLMs in distribution power systems” *J. Electr. Syst. Inf. Technol.* vol. 4, pp. 62-94, 2017, doi.org/10.1016/j.jesit.2016.10.012.

[8] R. P. Payasi, A. K. Singh, and D. Singh, “ Planning of different types of distributed generation with seasonal mixed load models,” *Int. J of Engg., Sci. and Techn.*, vol. 4, no. 1, pp. 112-124, 2012.

[9] D. K. Mishra, and B. Singh, ”Enhancement of Power System Performance by Optimal Placement of Distributed Generation using Genetic Algorithms.” *Int. Res. J. of Engg. and Tech.,* vol. 4, no. 9, pp. 370-377, 2017.

[10] D. Singh, D. Singh, and K. S. Verma, "Multiobjective Optimization for DG Planning With Load Models," *IEEE Trans. On Pow. Sys*, vol. 24, no. 1, pp. 427-436, Feb. 2009, doi: 10.1109/TPWRS.2008.2009483.

[11] A. K. S. Parihar, V. Sethi, and R. Banerjee, “Sizing of biomass based distributed hybrid power generation systems in India”*Renew Energy,* vol. 134, pp. 1400-1422, 2019, doi.org/10.1016/j.renene.2018.09.002.

[12] M. D. Akbar, and R. Aurachman, “Hybrid genetic - tabu search algorithm to optimize the route for capacitated vehicle routing problem with time window.” in *International Journal of Industrial Optimization*, vol. 1, no. 1, pp. 15-28, Feb 2020, doi: 10.12928/ijio.v1i1.1421.

[13] M. S. Umam, M. Mustafid, and S. Suryono, “A hybrid genetic algorithm and tabu search for minimizing makespan in flow shop scheduling problem.” in *Journal of King Saud University – Computers and Information Sciences*, Vol. 34, no. 9, pp. 7459-7467, Oct 2022, https://doi.org/10.1016/j.jksuci.2021.08.025.

[14] S. T. Alharbi, “A Hybrid Genetic Algorithm with Tabu Search for Optimization of the Traveling Thief Problem.” *International Journal of Advanced Computer Science and Applications*, Vol. 9, no. 11, pp. 276-287, 2018, doi: 10.14569/IJACSA.2018.091138.

[15] Y. Jiang, “Data-Driven Fault Location of Electric Power Distribution Systems With Distributed Generation,”*IEEE Trans. on Sm. Gr.*,, vol. 11, no. 1, pp. 129-137, Jan. 2020, doi: 10.1109/TSG.2019.2918195.

[16] A. A. A. El-Ela, R. A. El-Sehiemy, and A. S. Abbas, "Optimal Placement and Sizing of Distributed Generation and Capacitor Banks in Distribution Systems Using Water Cycle Algorithm," *IEEE Syst. J.*, vol. 12, no. 4, pp. 3629-3636, Dec. 2018, doi: 10.1109/JSYST.2018.2796847

[17] C. Gustavo, F. Penizzotto, and R. Pringles, “Economic analysis of photovoltaic projects: The Argentinean renewable generation policy for residential Sectors”*Renew.Energy*, vol.133, pp. 1167-1177,2019, doi: 10.1016/j.renene.2018.08.098.

[18] H. A. Attia, Z. H. Osman, M. El-Shibini, and A. A. Moftah, “An assessment of distributed generation impacts on distribution networks using global performance index,” *Nat. and Sci.*, vol. 8, no. 9, pp. 150-158, 2010.

[19] Ali, M. U. Keerio, and J. A. Laghari, "Optimal Site and Size of Distributed Generation Allocation in Radial Distribution Network Using Multi-objective Optimization," in *J. of Modern Pow.Syst. and Clean Energy*, vol. 9, no. 2, pp. 404-415, March 2021, doi: 10.35833/MPCE.2019.000055.

[20] Y. M. Nsaif, M. S. H. Lipu, A. Ayob, Y. Yusof, and A. Hussain, "Fault Detection and Protection Schemes for Distributed Generation Integrated to Distribution Network: Challenges and Suggestions," *IEEE Acc.*, vol. 9, pp. 142693-142717, 2021, doi: 10.1109/ACCESS.2021.3121087.

[21] L. F. León, M. Martinez, L. J. Ontiveros, and P. E. Mercado, "Devices and control strategies for voltage regulation under influence of photovoltaic distributed generation. A review," *IEEE Latin America Trans.*, vol. 20, no. 5, pp. 731-745, May 2022, doi: 10.1109/TLA.2022.9693557.

[22] P. A. J. Stecanella, D. Vieira, M. V. L. Vasconcelos, and A. D. L. Ferreira Filho, "Statistical Analysis of Photovoltaic Distributed Generation Penetration Impacts on a Utility Containing Hundreds of Feeders," *IEEE Acc.*, vol. 8, pp. 175009-175019, 2020, doi: 10.1109/ACCESS.2020.3024115.

[23] M. Amin, Q. C. Zhong, and Z. Lyu, "An Anti-Islanding Protection for VSM Inverters in Distributed Generation," *IEEE Open J. of Pow. Electr.*, vol. 1, pp. 372-382, 2020, doi: 10.1109/OJPEL.2020.3021288.
[24] O. Saad and C. Abdeljebbar, "Historical Literature Review of Optimal Placement of Electrical Devices in Power Systems: Critical Analysis of Renewable Distributed Generation Efforts," in *IEEE Syst. J.*, vol. 15, no. 3, pp. 3820-3831, Sept. 2021, doi: 10.1109/JSYST.2020.3023076.

Authors Bibliography

Deependra Kumar Mishra received the B.Tech. degree in electrical and electronics engineering from BBS College of Engineering and Technolgy, Allahabad, Uttar Pradesh, in 2010 from Dr. A.P.J. Abdul Kalam Technical University, Lucknow, India, M.Tech. degree in power system (electrical engineering) from Kamla Nehru Institute of Technology, Sultanpur, Uttar Pradesh, in 2017 from Dr. A.P.J. Abdul Kalam Technical University, Lucknow, India and currently pursuing Ph.D. degree in electrical engineering from the Indian Institute of Technology (Indian School of Mines), Dhanbad, Jharkhand, India. Presently, he is a lecturer in the department of electrical engineering, Government Polytechnic Bargarh, Chitrakoot-210208, Uttar Pradesh, India. His research interests are distributed generation planning and distribution networks analysis. He will be available at deependra2010@gmail.com.

Bindeshwar Singh received the B.E. degree in electrical engineering from Madan Mohan Malviya Engineering College, Gorakhpur, U.P., India, in 1999, and M. Tech. in electrical engineering (power systems) from the Indian Institute of Technology, Roorkee, Uttaranchal, India, in 2001. He received the Ph. D. degree in electrical engineering (power system) from Indian Institute of Technology (Indian School of Mines), Dhanbad, Jharkhand, India, in 2017. Presently, he is an associate professor in the department of electrical engineering, Kamla Nehru Institute of Technology, Sultanpur-228118, U.P India, where he has been since August 2009. His areas of research interest are optimal placement, sizing, and properly coordinated control of DG and FACTS controllers in power systems. He will be available at bindeshwar.singh2025@gmail.com.