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Simulation and Analysis of DG Set Placing and Sizing in Grid Network

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Abstract – This paper presents the application of heuristic optimization techniques for determining optimal placement and sizing of photovoltaic-based distributed generation (PVDG) in a distribution system. Nowadays in all over world constant increasing request of electrical power is increasing. Mostly power demand is delivered by the standard power generating sources, but they because air pollution, global warming, degradation in fossil fuels and their increasing cost have made men to look towards renewable energy sources. The demand for more power along with interest in clean technique has driven one to develop distributed power generation systems using renewable energy sources. We should look for new power generation technologies. One answer which is recently in attention is micro grid system. Micro grid contains some natural energy sources. They may have solar cells, wind turbines, micro turbines, fuel cells and storage battery systems like fly-wheel, battery back-up. This paper proposed the improved gravitational search algorithm (IGSA) and its performances are compared with two other algorithms such as the gravitational search algorithm (GSA) and particle swarm optimization (PSO). A comparison of the performances is also made using optimization techniques when PVDGs are fixed at critical buses.

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INTRODUCTION

Micro grid contains some natural energy sources. They may have solar cells, wind turbines, micro turbines, fuel cells and storage battery systems like fly-wheel, battery back-up. The definition of micro grid can be defined according to Department of Energy at U.S.A.: "A group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid connect and disconnect from the grid to enable it to operate in both grid connected or island mode." Here are reasons that why micro grids are so useful. Because they have some provision of alternative, and mostly renewable sources give more efficiency and less environmental problems than those conventional power generations. Further, they can reduce losses of transmitting power which makes micro grids more efficient than our standard power plants. It is possible to form a micro grid to match the necessities of the area it will be examining. Thus it can provide electricity for lighting as needed by some isolated areas. Then again, it can provide high quality; continue electricity needed by industries which use highly sensitive equipment and also for hospitals purpose.

Various technologies are used for generation of power and storage units within or outside of a Micro grid, which are listed as below:-

- *DG -Distributed Generation: - generators are at both within and outside of a Micro grid*
- *RES-Renewable Energy Sources: - these are DG units which are renewable and mostly discontinuous*
- *CHP -Combined Heat and Power: - generation technology which are having heat driven type device.*
- *DER -Distributed Energy Resources: - generator, some controllable loads and storage units are defined as DER*
- *MS -Micro-sources: - generators within a Micro grid only*

Here micro grid contains loads, storage device, PV system, micro turbine, fuel cells. Micro grid is connected to utility grid via circuit breaker .Here micro grid supports the main grid when load demand is greater. Hence more load demand can be full filled by various sources within micro grid. And on other hand when climate changes, energy storage devices supply the power to maintain continuity.

DISTRIBUTED GENERATION (DG)

Energy is very important and necessary to whole world for providing quality in our lives and other elements for society's requirements. Conventional electrical energy sources are degradable and hence renewable energy sources are taking place by considering economic and environmental factors nowadays. It is to be said that the consumption of electrical power should be in limit, but the truth is there is always collective demand for this energy. Hence, the demand is to be fulfilled, by growing electricity generation capacity. Almost all the power generation takes place which uses coal, oil, natural gas, water or nuclear material as the main source of fuel. The problems facing by the further development of generation methods are based on any of this fuel. Water power generation is restricted sometimes due to areas, and funds of coal. The possible hazards of nuclear power have been involving military usage of nuclear waste things. Also, in order to maintain electrical power supply in many neighborhoods fusion reactors will be tolerated. To achieve the above mentioned goal, it is advisable to enhance in our management system that includes present fossil fuel resources, and use those with non-conventional resources like solar photovoltaic cells, wind energy systems etc. Because of good availability and efficiency that better than these sources, natural sources are also good substitutes for their working. Besides, they are lesser in costs. These sources also give power supply solutions for remote areas, which is outskirts of grid power supply. Hybrid models are so effective options for production of power in whole world. Many studies have been done on it and permanent houses more facilities in the systems. This thesis refers the possible concert valuation in the wind energy, solar photovoltaic panel, fuel cell stack and other hybrid energy system. Also in this solar, wind, Fc systems backup storage battery are designed, integrated and elevated to foresee the behaviour of the generation system.

SOLAR PHOTOVOLTAIC PLANT

Operating Principle

Photovoltaic plants directly convert the instantaneous solar energy to electrical energy without using any fuel. The PV system generates electrical energy when exposed to sunlight by electromotive force which is generated by the absorption of ionizing radiation defined as photovoltaic effect. Such many advantages support solar photovoltaic plant as a future source of energy. But the only disadvantage is high initial cost for the development of such plants. Moreover, the solar energy source is also variable in nature and availability is at daytime only. However, the yearly electrical power output of Photovoltaic plant depends on different factors such as:

- Availability of solar irradiation at the installed plant site.
- Inclination and orientation of PV panels according to the sun light direction.
- Environmental condition surrounding the solar plant for e.g. presence of shading due to clouds.
- Technical performance of plant components.

A photovoltaic plant consists of PV panels, supporting structure to mount the panels on ground or building, power conditioning unit, possible storage system and other electrical switchboards and switch gears assembly with protection equipment and connection cables.

Different topologies of photovoltaic plants

The Solar Plants are largely installed in two different ways

(1) Standalone plants

(2) Grid connected plants

Standalone Plants

Solar plants which are not connected to the grid and consist of storage system which allows the plant to supply power even when the sunlight is not available in proper amount or in dark. In such a plant the generated power is directly stored in batteries as DC supply and if AC supply is required then an inverter is needed. Such type installation is more beneficial where the grid network is not available as it can easily replace the generator for generation.

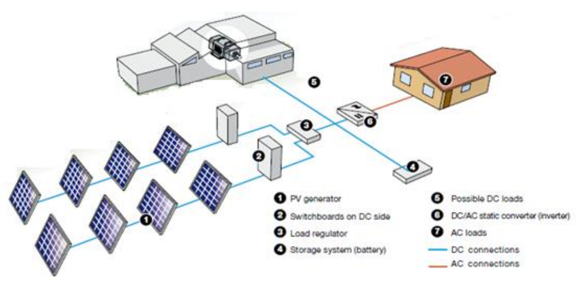

Figure 3. 1: Standalone PV Plant (Bratton and Kennedy, 2007)

Grid-connected Plants

Grid connected Plants are permanently connected to grid and takes power during insufficient solar power generation to satisfy the requirement of consumer. And at the time of low consumer load the excess of power generated by the solar power plant is given to the grid. The energy generated near the load have higher value the conventional power from grid which is transmitted from longer distance. Also, the power generated during peak hours by the solar plant reduce the need of grid during insolation hour that is when demand is higher.

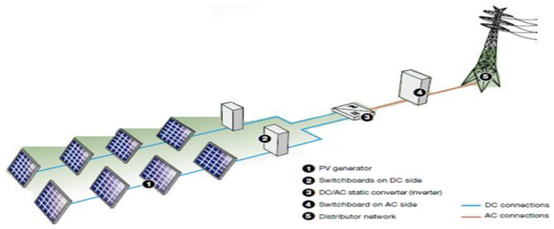

Figure 3. 2: Grid-connected plants (Bratton and Kennedy, 2007)

Mathematical model of PV Module

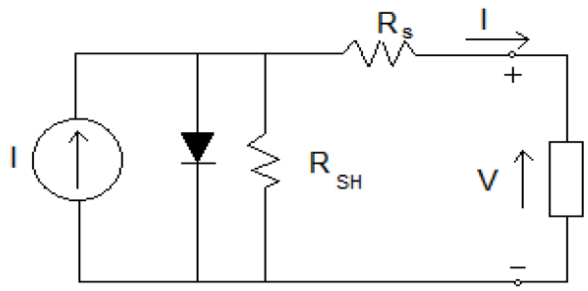

Figure 3. 3: Single diode equivalent circuit

The PV array is build-up of solar cell as shown in Fig.3.3. The characteristic of a solar array is given by following equation. The main equation of output module.

$$I = I_{ph} - I_s \left[e^{\left(q\frac{V+IR_S}{kT_c} \right)} - 1 \right] - \frac{V+IR_S}{R_{sh}} \qquad (1)$$

Where,

$$I_{ph}(\text{Photo current}) = [\, I_{sc} + k_i\,(T_c - T_{ref})\,]\,\lambda \qquad (2)$$

$$I_s(\text{Reverse saturation current}) = I_{rs}\left(\frac{Tc}{Tref}\right)^3 e^{\left[q\frac{Eg\left(\frac{1}{Tref} - \frac{1}{Tc}\right)}{ka} \right]} \qquad (3)$$

V = voltage across solar panel terminal.

I = current across solar panel terminal.

k = the Boltzmann constant.

a = ideality factor

T = cell working temperature

ki = shore circuit current temperature coefficient

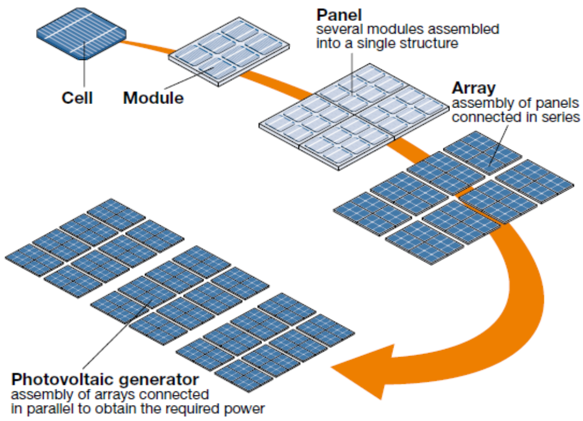

Figure 3.4: PV Array Formation (Bratton and Kennedy, 2007)

PLACING AND SIZING OF DG WITHOUT IMPLEMENTING OPTIMIZATION TECHNIQUES

In order find the optimum location for placing DG units a number of methods are developed. In this thesis, a technique based voltage stability index (VSI) has been developed for optimal placing of DG units. A node with minimum value of VSI is considered as the optimum location for placement of DG.

In order to obtain optimal DG size, below steps should be followed:

1) A node with minimum VSI should be found first and then he DG is placed at that node.

2) Assuming Distributed generation power factor as constant, size should be varied in constant steps from a minimum value to a maximum value (feeder loading capacity) till minimum losses are obtained

3) The size of DG which produces minimum loss is considered as optimal size.

The system considered here is an IEEE-33 bus system. It has an voltage of 12.66 kV and total real power demand of 3.715 MW and reactive power demand 2.3 MVAr. In the first case load flow without DG is analysed and bus voltages magnitudes and total power loss of the network in RDS are computed. VSI at various buses is also calculated. From the analysis, we found that the bus 18 is having lowest VSI value of 0.66721. Hence, bus 18 is optimal location for placing DG.

For analysis, the following two cases are considered:

Case 1: DG operating at 0.9 power factor lagging

Case 2: DG operating at unity power factor

For finding the optimal size of DG in both the cases, the DG size is varied from 0.5 MVA to 4.0 MVA in step of 0.5 MVA. From the test result we observe that power losses are non-linearly varying with capacity of generator. First the power losses are decreased up to some minimum values and then start increasing with DG capacity increment. Hence from the test results, it is observed that in the base case without DG, total respective real and reactive power losses are 210.99 kW and 143.03 kVAr. Whereas the losses after placing a DG with 1 MVA at a lagging power factor of 0.9 produces more loss reduction when compared with the DG size of 0.85 MVA at unity power factor. Hence, optimal placing and sizing of DG reflects the power loss reduction in radial distribution system. We can also note that substation capacity release is more for case 1 compared to case 2. As DG injects real and reactive power to the load centers locally, it helps in improving the bus voltages and also reduce the losses at the load side. Comparison of the voltage variation for different cases viz. base case (without DG), Case 1 and Case 2 proves that improvement in voltage for case 1 is more compared to case 2. Similarly analysis is done for IEEE-69 bus network. It has a voltage of 12.66 kV and total real power demand of 3.802 MW and reactive power demand 2.694 MVAr. From the analysis, we found that the bus 65 is having lowest VSI value of 0.68345. Hence, bus 65 is the optimal location for placing DG.

PARTICLE SWARM OPTIMIZATION

Optimization technique is used to find the best solution for any given circumstances. For example, in a company if it is required to improve its rating, technological and managerial plans have to be taken many times. Here, the goal of the plans is to either maximize the profits or to minimize the spending effort. Optimization is referred as both minimizing and maximizing the tasks. Since the minimization of any function is same as maximizing its additive inverse, the terminology minimization and optimization can be used interchangeably. Because of this reason, optimization became very important in many fields. Basically, in order to solve the optimization problems, PSO algorithm is inspired by the animal's activity. In PSO, swarm means population; particle represents each member of the population. Each particle searches through the entire space by randomly moving in different directions and remembers the previous best solutions of that particle and also positions of its neighbor particles. Particles of a swarm adjust their position and velocity dynamically by communicating best positions of all the particles with each other. In this way, finally all particles in the swarm try to move towards better positions until the swarm reaches an optimal solution Thus, due to its easy implementation and its ability to obtain fast convergence, PSO technique is becoming very popular. Moreover PSO uses only basic mathematics and it does not involve any derivative or gradient information.

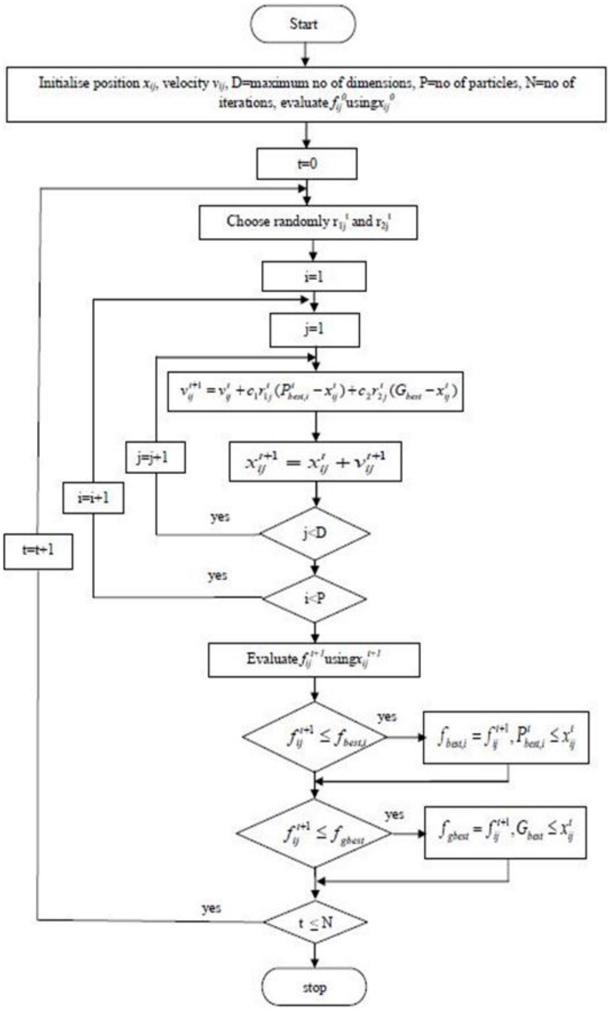

Figure5.1: Flowchart for Global best PSO

Hybrid of Solar-Wind Using V_L-V_P Control Method

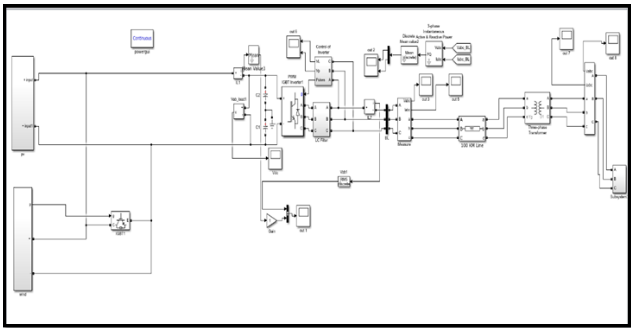

Fig 5-2 Hybrid of Proposed Solar PV and Wind with Line and Phase voltage control method

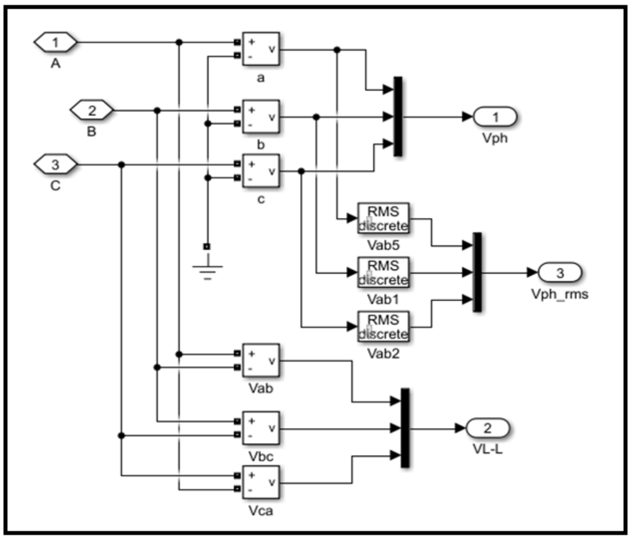

Fig 5-3 Line and Phase voltage control subsystem

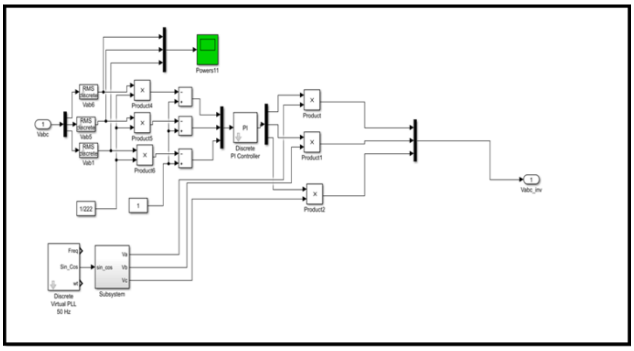

Fig 5-4 PI Controller Subsystem

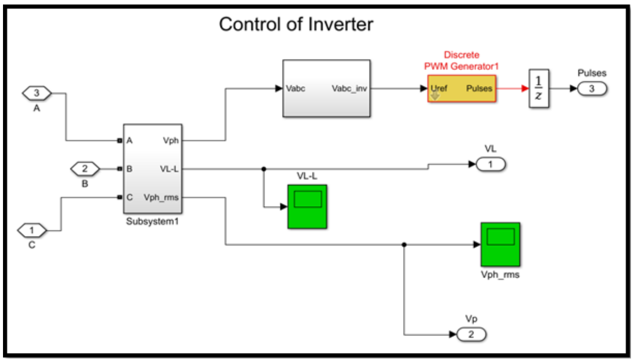

Fig 5-5 Inverter Control Subsystem

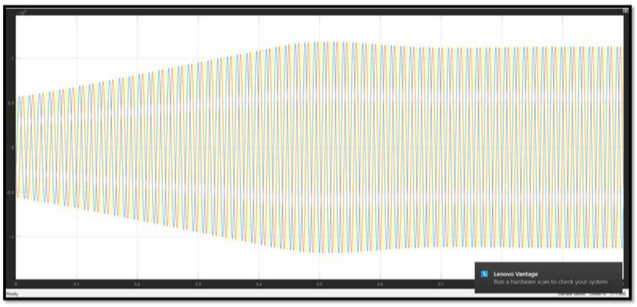

Fig 5-6 Grid Side Synchronized Output Voltage

Fig 5-7 Grid Side Synchronized output current

PERFORMANCE OF 33 BUS SYSTEM WITH OUT INSTALLATION OF DG:

Total Real Power Loading: 3715 kW

Total Reactive Power Loading: 2300 kVAr

LOSSES IN THE NETWORK

Total Real Power Loss: 210.99 kW

Total Reactive Power Loss: 143.03kVAr

Minimum Bus Voltage: 0.9038 p.u.

Corresponding Bus No. : 18

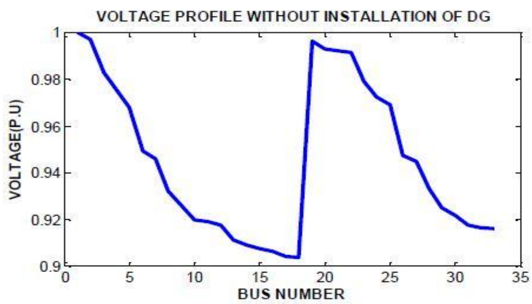

Figure 6.1: IEEE 33 bus voltage profile without installation of DG

Table 6.1: IEEE 33 Bus voltage profile without installation of DG

BUS NO.	VOLTAGE(p.u.)	BUS NO.	VOLTAGE(p.u.)
1	1.00000	18	0.90380
2	0.99703	19	0.99650
3	0.98289	20	0.99292
4	0.97538	21	0.99221
5	0.96796	22	0.99158
6	0.94948	23	0.97931
7	0.94596	24	0.97264
8	0.93231	25	0.96931
9	0.92598	26	0.94756
10	0.92011	27	0.94499
11	0.91925	28	0.93355
12	0.91774	29	0.92534
13	0.91158	30	0.92179
14	0.90931	31	0.91763
15	0.90790	32	0.91672
16	0.90655	33	0.91645
17	0.90454		

BUS NO.	VOLTAGE STABILITY INDEX	BUS NO.	VOLTAGE STABILITY INDEX
2	0.98814	18	0.66721
3	0.93292	19	0.98606
4	0.90500	20	0.97195
5	0.87776	21	0.96922
6	0.81211	22	0.96673
7	0.80069	23	0.91974
8	0.75516	24	0.89487
9	0.73511	25	0.88276
10	0.71666	26	0.80614
11	0.71403	27	0.79745
12	0.70936	28	0.75931
13	0.69042	29	0.73304
14	0.68360	30	0.72193
15	0.67937	31	0.70899
16	0.67531	32	0.70621
17	0.66931	33	0.70537

Table 6.2: IEEE 33 Bus Voltage Stability Index without DG

PERFORMANCE OF33 BUS SYSTEM WITH INSTALLATION OF DG BY USING PSO

CASE-1: Here DG will inject only real power

LOSSES IN THE NETWORK

Total Real Power Loss: 145.89 kW

Total Reactive Power Loss: 100.31kVAr

Total Loss after DG placement: 246.20 kVA

Size of DG is: 0.8061 MVA

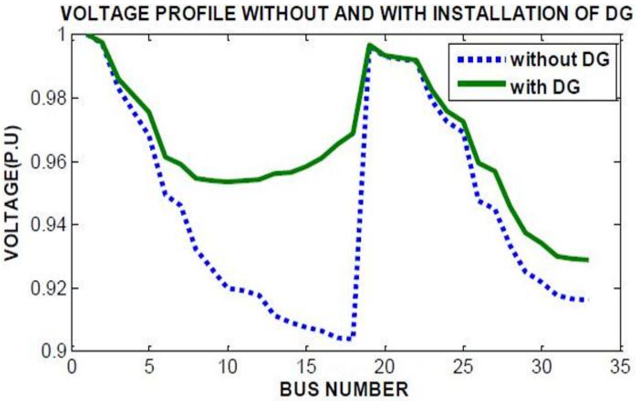

Figure 6.3: Voltage profile without and with installation of DG (injecting only real power) for IEEE 33 bus system

CASE-2: Here DG will inject both real and reactive power

LOSSES IN THE NETWORK

Total Real Power Loss: 123.72 kW

Total Reactive Power Loss: 87.027kVAr

Total kVA Loss after DG placement: 210.99 kVA

Size of DG is: 0.8489+j0.4914 MVA

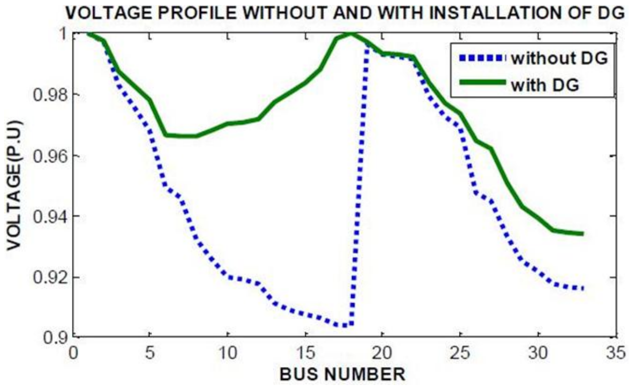

Figure6.4: Voltage profile without and with installation of D (injecting both real and reactive power) for IEEE 33 bus system

CONCLUSION

A comparative study has been carried out to evaluate the performance of IGSA, GSA and PSO in determining the optimal placement and sizing of PVDG in a distribution system. IGSA is an improved heuristic optimization technique that has several advantages such as adaptive learning rate, better execution and fast convergence in finding the optimal solution. The objective function of the optimization considers total real power loss, average voltage deviation, average. All of the cases plotted the improvement values of the fitness function as the number of iteration increases. This paper also shows that it is better to search for an optimum locations and sizes of PVDG in the system, instead of fixing the locations based on a certain issue such as the voltage collapse point of view.

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