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Optimal Planning of Renewable-Based Distributed Resources for Power Distribution System Using Artificial Intelligent Based Genetic Algorithm

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Abstract: Renewable-based distributed generation has become an attractive alternative to meet the growing electric demand of the future. It has many advantages, including pollution fee generation and other technical parameters. Such DGs are typically deployed at the load end and highly influence network performance. However, improper DG planning and deployment may result in poor voltage regulation and higher line losses. The generation of such DGs is not constant but depends on environmental conditions. This paper presents an optimal strategy for deploying such renewable-based DGs, which provide variable generation on a real-time basis based on different environmental parameters. An artificial intelligence genetic algorithm has been used to get a realistic solution for deploying such DGs across the distribution network. The IEEE-33 bus network has been used for the analysis, and the NR-based load flow program has been used to compute the network performance parameters. The present strategy helps the distribution network operator to decide which type of Dgs are more suitable at a specific geographical location to reduce the payback period for a particular investment. It gives these DGs an appropriate location and size to ensure consistent generation, good power quality, and higher distribution efficiency. A multi-objective fitness function has been formulated to solve the constraint optimization problem. The present strategy has been proposed for optimal planning of a distribution grid operated with renewable-based micro DGs.

Keyword: *Artificial Intelligence, Optimization Algorithm, Genetic Algorithm, Distributed Generation*

1. Introduction:

Distribution networks must operate as efficiently as possible regarding resource use and equipment management, including transformer tap-ganging depending on loads, AVRs, and capacitors. The goal of the DG allocation optimization is to minimize the objective function while considering the technical issue constraint. Distribution networks could not integrate DG resources into the primary utility grid. However, current networks can easily link distributed generators (DGs) to the electric grid. Increased DG use inside the network might harm traditional distribution networks. The optimum DG usage problem formulation aims to minimize grid losses using an active power resources management pattern[3-4]. In recent years, several analytical approaches and optimization algorithms have been applied to address that issue[5-8].

In[9], the heuristic approach adopted by the author to address the problem considers loss minimization as an objective. The author in [10] executes the DG sizing problem considering a network with a multi-load level network. A new approach has been proposed to investigate integration points and the size of DG across microgrids operated in a grid-connected mode.

The author in [11] presents a novel approach which consists of several indices based on different DG models

These performance indices include voltage regulation, active power loss and reactive loss. The author in[12] applied two AI-based algorithms, i.e. Ant colony optimization and gradient search. In[13], the author presents a new methodology to reduce transmission congestion in the deregulated electricity market. Past research also includes various multi-objective optimization algorithms to improve the network's performance, considering different objectives[14-22].

However, past research includes an analysis of the constant power DG model. However, renewable-based DG provides the generation based on various environmental conditions. It cannot inject constant generation as per it's rated capacity consistently. The present paper addresses the optimal DG deployment problem considering variable DG generation based on different environmental parameters. Proposed methodology has been executed on IEEE-33 bus network. Figure(1) shows one line diagram of IEEE-33 bus network. Table 1 shows network parameters and their corresponding values.

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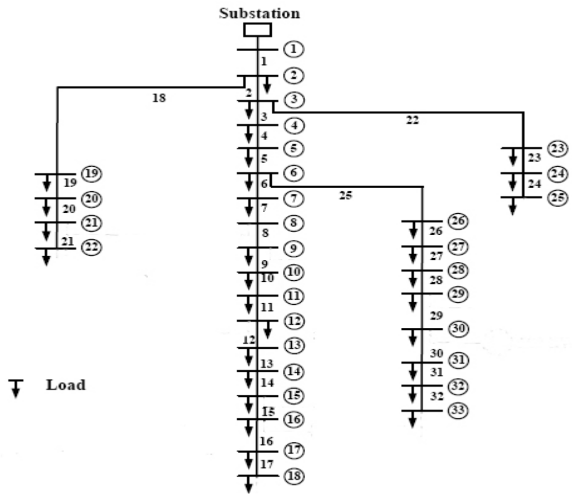

Fig. 1 IEEE-33 Bus network line diagram

Table 1 Network Parameters and their corresponding values

Network parameter	Value
Total Load(P)(Fixed)	3.72 MW
Total Load(Q)(Fixed)	2.30 KVAR
Active Loss	0.203 MW
Reactive Loss	0.14 MVAR
Minimum Voltage	0.917 P.U
Network Type	Radial Type

NR based load flow programme has been used in MATLAB environment for performing load flow solution to compute losses and bus-voltages.

2. Modelling of wind and solar type DGs:

Renewable based DGs are normally generate the power based on environmental condition. In this paper variation of wind speed and solar irradiation have been incorporate to compute the hourly generation of wind and solar type DG. Mathematical modelling for solar power generation is given by equation(1) and Equation(2) shows computation of wind power generation based on wind speed value at t^{th} hour.

$$E_s = n_{PV} * A_{pv} * G_t \text{ KW} \quad (1)$$

Where E_s total power generated from the pv unit, n_{pv} is the PV panel generation efficiency, G_t solar radiation available in kw per m^2 and A_{pv} generator area in m^2. Modelling of wind type DGs can be avail using following equations,

$$P_w = (bV^3 - a)P_{rat} \ (VC_i \leq V \leq V_r) \quad (2)$$

$$P_w = P_{rat} \ (V_r \leq V \leq VC_o) \quad (3)$$

$$P_{rat} = 0.5 * c_p * P_{ar} * n * v^3 \quad (4)$$

Where P_{rat} is the rated power produced by wind type DG, C_p is the power coefficient , n is the wind generator efficiency and v is the velocity of air.

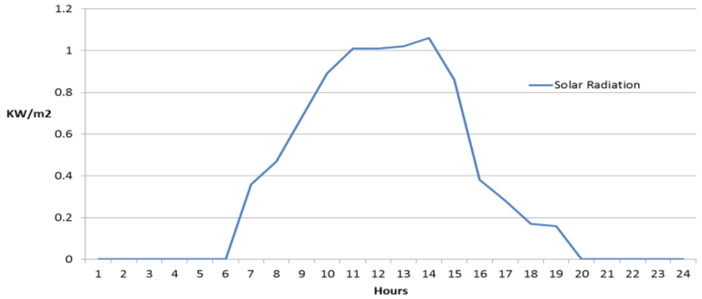

Fig. 2 Hourly variation of Solar irradiation

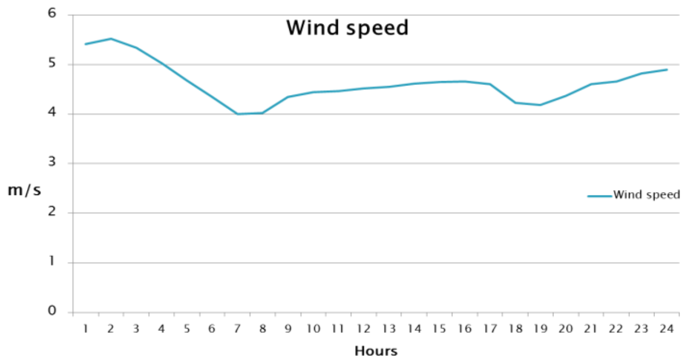

Fig. 3 Hourly variation of wind speed

Figure (2) shows hourly variation of solar irradiation and Figure(3) shows wind speed variation on hourly basis. Both these environmental parameters have been used to compute the generation of wind and solar type DG models.

3. Optimal Location for DG deployment:

One important factor in preserving the voltage between two nodes is the voltage drops in the line that connects them, a phenomenon commonly referred to as voltage regulation. There are decreases in voltage regulation because of reactance and resistance in a line, even though it should ideally be zero. In transmission lines, resistance is significantly less than reactance; but, in overhead distribution systems, reactance is much less than line resistance. On the other hand, the voltage drop in the line may be greatly reduced by meeting active and reactive power needs locally. This would reduce line current and power loss and enhance system efficiency. To fortify the distribution network against future load expansion, it is essential to identify the most crucial buses that cause the system to become unstable when the load above a certain threshold.

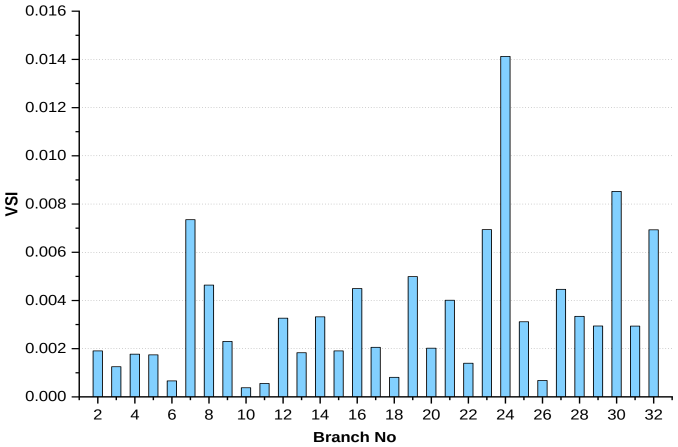

Fig. 4 VSI values of different sections of network

Bus Locations for DG placement	8	24	25	31

4. Proposed Mult objective fitness function:

Proposed Multi objective fitness function includes various performance indices i.e. investment cost, loss and voltage stability. Equation(5) shows proposed multi objective fitness function with weighted distributed normalized objective. However present analysis incorporates hourly variation of DG's generation , optimal value of MOF need to be computed using GA on hourly basis. Table 2 shows variable bounds and constraints for optimization problem solution.

$$Min\,F = K_1 * \frac{P_{Loss}}{P_{Loss\,B}} + K_2 * \frac{\sum Cost_{DG}}{Cost_{DG^{max}}} + K_3 * \frac{CVSI}{CVSI_B} \quad (5)$$

Where,

F= Minimization type multi-objective optimization function.

K_1,K_2,K_3 = Weighting factors .

P_{Loss} = Power loss of the network after deployment of DG and RPC.

$P_{Loss\,B}$ = Base case Power loss of the network without DG and RPC.

$\sum Cost_{DG}$ = Investment Cost of DG to be placed across the network.

$Cost_{DG^{max}}$ = Maximum investment cost of DG with it's full capacity.

CVSI= Cumulative Voltage Stability Index.

$CVSI_B$ = Base Case CVSI without DG and RPC deployment.

Table 2 Variable bounds and Constraints

1	Type of optimization problem	Minimization
2	Nos of Varibles	08
3	Type of variable	DG size[Continous type] RPC size[Continuous type]
4	No of constraints	02
5	Type of Constraints For DG	Power constraint for solar pv type DG 0<Pmax<0.7 P.U.[700kw] Nos of location-02
		Power constraint for wind type DG 0<Pmax<1 P.U.[1000kw] Nos of locations-02
		Voltage Constraint 0<V<1.0 PU
6	Type of Constraints For RPC	0< Q <0.5 P.U.[500 kvar]
	Base MVA	1 MVA

5. Optimal sizing of DG using GA

Artificial intelligent based genetic algorithm has been used to find optimal capacity of solar and wind type DG based on their generation and their influence on to the network performance. Figure(4) shows flow chart to minimized MOF using GA. Table 3 shows algorithm specific parameters which have been used to minimized the MOF.

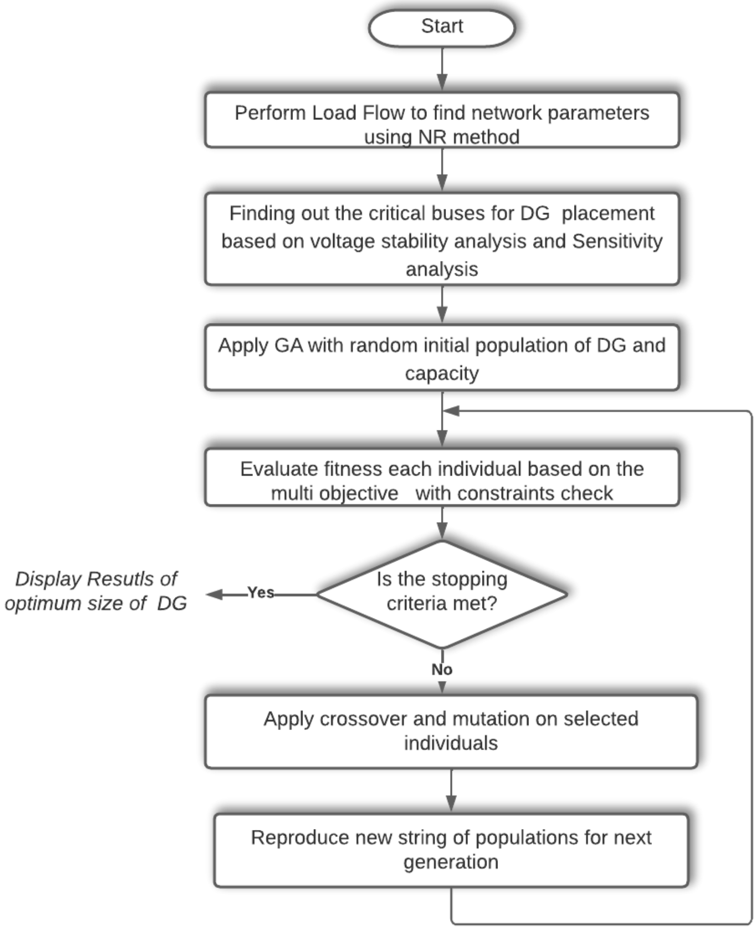

Fig. 5 Flow chart of GA to minimized MOF

Step 1: Use the NR approach to perform a load flow in order to determine the network characteristics, such as the voltage profile and losses.

Step 2: Using the results of the VSI indices, determine the possible locations of DG

Step 3: Use GA with a DG size random beginning population.

Step 4: Taking restrictions into account, assess each chromosome's fitness using the suggested MOF.

Step 5: Verify the requirements for termination circumstances.

Step 6: Apply crossover and mutation to the chosen person to see if there could be a better option elsewhere in the search space.

Step 7: Use the route wheel approach to replicate a fresh population, which is then taken into consideration for the next generation.

Table (4.5) lists the values of certain algorithm-specific parameters that GA utilized to improve MOF.

Table 3 GA-Parameters to minimized proposed MOF

Sr. No	Component of GA	Method/Value
1	Crossover Probability	0.95
2	Mutation Probability	0.2
3	No. of Populations	80
4	Max.No. Generations	100
5	Termination Criteria	Max. No. of Generations
6	Objective Function	Minimization Type
7	Selection Method	Roulette Wheel Selection

6. Result and Discussion:

The optimal size of all four DG models has been identified using an AI-based genetic algorithm. However, given the hourly variable - generation having been considered, GA needs to be applied on each hour, and optimal capacity needs to be computed. Figure(5) shows the convergence graph of the proposed MOF using GA. As with generation increment, the proposed MOF becomes minimized. Figure(6) shows the optimal capacity of solar-type PV model 1 and PV model 2 type DGs at each hour. Results show that PV1 type DG have a more positive impact on the network parameters, so the optimal size of DG for PV1 is quite more than PV2 type DG. Figure(7) shows the optimal size of Wind type DG 1 and DG2 models. Results show that W2 type DG has a more positive influence on the network parameters than W1. The algorithm uses more W1 generation than W2 based on the proposed MOF. Figure 8 shows the hourly variation of line losses based on the optimal value of MOF. Figure 9 shows the optimal value of the proposed MOF using GA at each hour slot.

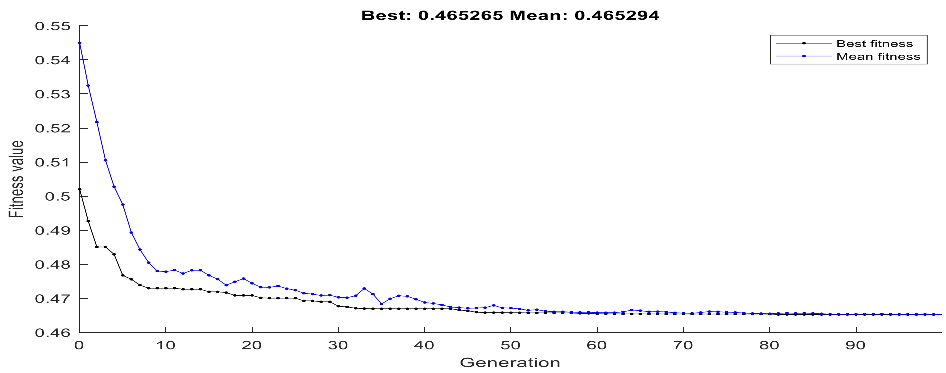

Fig. 6 Convergence Curve for minimization for MOF using GA

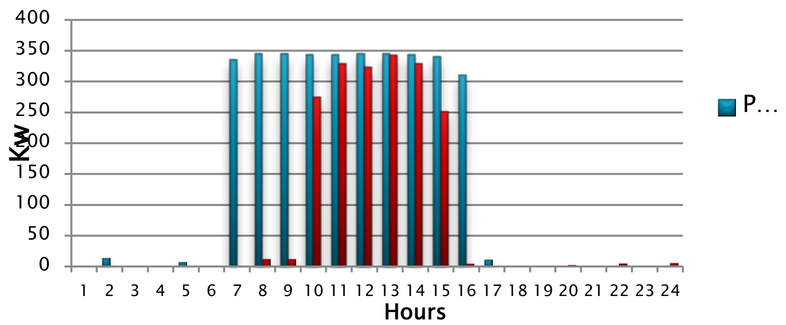

Fig. 7 Optimal size of Solar type DG model PV-1 and PV-2

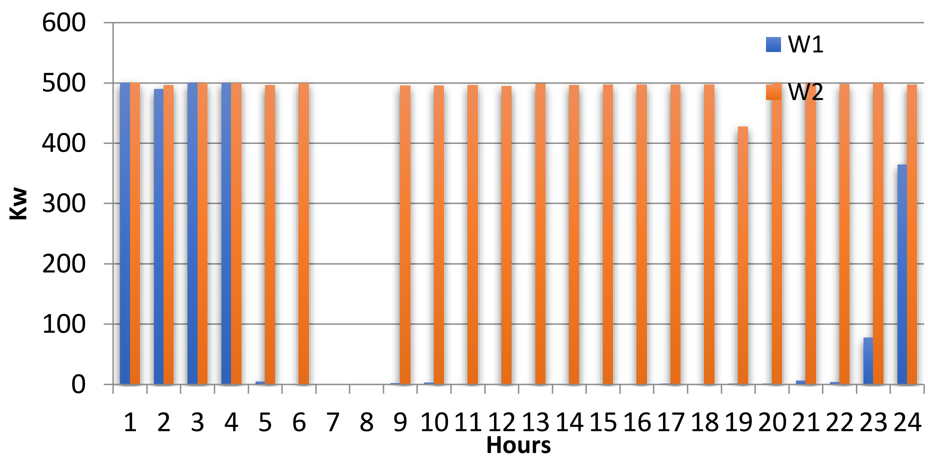

Fig. 8 Optimal Size Of Wind Type DG Model W-1 And W-2

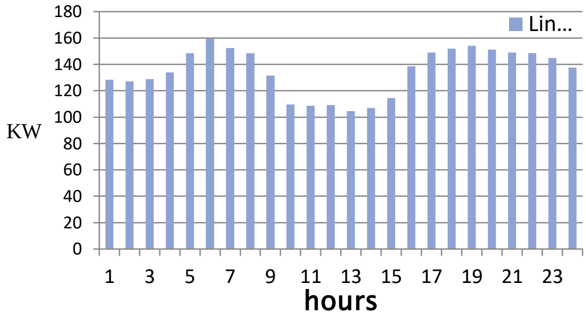

Fig. 9 Hourly Line loss

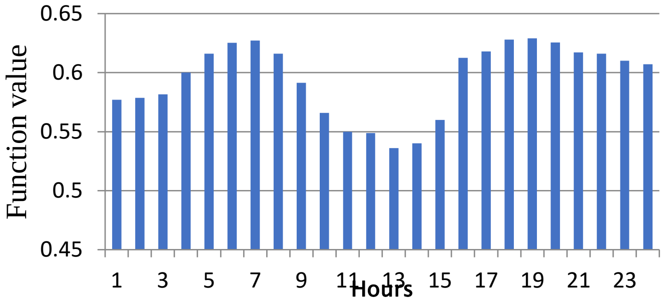

Fig. 10 Hourly minimum value of proposed MOF

7. Conclusion:

The optimal sizing of solar and wind-type distributed generators has been addressed in this paper. It has been considered that renewable-based DGs generate variable amounts of energy based on wind speed and solar irradiation. The proposed approach yields variable generation of these DG models based on environmental conditions. The result shows that GA incorporate more generation to minimize MOF based on the influence of each DG model on the network performance. The proposed strategy suggests a higher capacity of PV1 and W2 type DG models at their corresponding locations as they positively impact the network loss reduction and improvement in voltage profile. The present strategy can become helpful in any distribution operator to plan a network with renewable resources. It suggests which location is more suitable for the placement of DG and which type of DG(solar or wind) is more appropriate at a specific geographical location.

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