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CONGESTION MITIGATION IN DISTRIBUTION NETWORK BY INTEGRATED DISTRIBUTED GENERATIONS FOR IMPROVING VOLTAGE PROFILES AND MINIMIZING THE LOSSES

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Abstract: In electrical power systems, unexpected outage of transmission systems, sudden increase of loads, the exit of generators from service, and equipment failure, leads to a contingency occurring on one or several transmission lines. The loads must be within the specified state and the transmission lines should not exceed the thermal limits. One of the important methods used to alleviate the contingency and reduce the congestion lines by injected a Distributed Generation (DG) within an optimal siting and optimal sizing in the distribution network that achieves improvement of the voltage profile as well as leads to reduce the losses. First, to achieve the best goals in this paper that is determined contingency lines, an index has been used called (Active Power Flow Performance Index) (PI_{RPF}) and an equation called (Line Flow Sensitivity Index) (LFSI) is used for finding the optimum site for Distributed Generation. Second, to determine the optimum size for distributed generators, the Genetic Algorithm (GA) is used. Also, this research was distinguished by choosing new sites and sizes according to the GA to obtain the best desired results. Finally, these methodologies were applied to the IEEE-30 bus ring network using the MATPOWER Version 6.0, 16-Dec-2016 program within MATLAP R2018a environment.

Keywords: *Distributed Generation, Line Flow Sensitivity Index, Performance Index.*

1. Introduction

For the electric power system to be safe and reliable, it must have a continuous supply of electrical power without losses. When the operating parameters of the system are exceeded, that means the system at a contingency state.

The evaluation of safety system operations occurs by calculating the determinants of work before the emergency and after the emergency, and studying the extent of the impact of adding equipment to the network such as (DG) in terms of reducing emergency lines, improving voltages, and reducing losses.

The emergency analysis takes a long time since the calculation of the AC load flow calculations includes all possible outage events such as interruptions occurring in different generators and transmission lines. This creates a very long list of emergency accounts.

In this research, the approach of contingency screening is adopted that distinguishes and arrange only those outages that cause the voltage and power flow parameters in the lines to be exceeded. The contingencies are screened according to a guide called (Performance Index) (PI) and the highest value of these indices indicates the seriousness of this line or a critical condition and requires treatment.

To alleviate this trouble, the research is characterized by following the methodology of connecting a number of DGs for the purpose of mitigating or eliminating emergency lines that

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cause a state of instability in the network and its and this has been applied and obtaining the

Required results and accurate details of the status of each line.

This research is characterized by being flexible in the possibility of linking more than one DG with the appropriate sizes and locations for the purpose of obtaining the best results. The electric power system is a complex network that aims to secure demand loads according to demand economic and environmental limits [1].

Some states in the contingency set may result in overloading of the transmission line or violations of bus voltage limits during operations. Such contingencies must be identified rapidly for more detailed assessment. This critical emergency identification process is pointed to as the emergency selection that uses the full AC load flow program taking into account the interruption of each generator or line. [2]

The AC power flow method application in interruption cases has been discussed by using a fast approximate method. Is achieved through decoupling of real and reactive power equations, sparse matrix methods, an experimentally determined iteration scheme and the use of the matrix to simulate the effect of line outages [3].

In [4] and [5] describes how to line flow is affected by generators and lines interruption using a set distribution factors of reactive power flow based on decoupled load flow.

The analytical procedure is approaching to specify the optimum siting of DGs in a meshed network to obtain benefits like reduce the power loss of the system. The positioning of DG is evaluated and the theoretical optimum location (bus) for the addition of DG is obtained for various Load Forms and DG Sources. Then, a technique is provided to find the best bus to place DG in a networked based on information of generation and load delivery of the device on the bus admittance matrix. [6]

Units of DGs in distribution networks lead to some effects such as enhancement voltage level, energy quality, and reducing losses.

Nowadays, the enormous size of research papers is obtainable for optimal sizing and optimization from the DG unit. [7]

The genetic algorithm-based approach (GA) introduced optimum siting and sizing for multiple DGs with independent objective function to achieve two aims to reduce losses and improve voltage profiles in distribution networks [8].

The target is used on the optimal DG site without giving the size of the DG. The current based injective sensitivity losses factor used to minimize total power losses to optimum positioning and size volumes for (DG) unit [9]. A new approach is suggested to optimize the siting and sizing of (DG) unit in a large ring connected network. Provides a visual optimization technique in which the developer plays a significant role in deciding the optimum position and scale of the DG by choosing the necessary weight factors for the parameters specified in the machine deficiency optimization technique. In the algorithm, losses, voltage level and short circuit level are used to evaluate the optimal sizing and location of DG [10].

It has been proven that controlling load demands are more effective than rescheduling generators

Emergency freeing. The congestion alleviate with DG connection and GA can get good results [11].

A based method for (PSO) particle swarm optimization is suggested for finding the optimum generation of rescheduling to reduce branch congestion depending on real power flow performance index (PI) to determine the severe contingency cases [12].

A cost analysis was used with optimum siting and appropriate size of distributed Generation for management of the congestion when we testing the system's reliability [13].

An approach that counts on sensitivity to mitigate the congestion was suggested by injection the DG units immediately.

The optimum rating of the DG unit is optimized by using of Genetic Algorithm (GA) to minimize losses and improvement of voltage profiles system on the looking at the real value Power flow performance index for the most serious emergency cases [14].

Mitigation congestion of transmission lines by adding DG to an appropriate location and optimal size based on PSO and employs a Line Flow Sensitivity Factor (LFSF) [15].

Optimal allocation and sizing for DG based on Ant Colony Algorithms and Genetic Algorithms is applied and computation of the active power losses as a function of power supplied from the generators when penetration various levels of generation from DG [16].

In research [17] used an approach that depends on finding a value of a factor depending on the ratio of power flow changes in line between two buses to determine congestion lines and manage them through distributed generations.

In the current work, It was suggested that location or sitting of DGs will be according to the mitigation of congestion in overload lines which are being under sever contingency i.e violate thermal limits and voltage levels at system buses. Also, according to minimizing losses and enhancement of voltage profile.

That is achieved in this paper, on ring network IEEE 30 bus bar that consists of 6 generators,41 branches, 24 load bus (PQ), by running Load Flow (Newton-Raphson) at the base case and (N-1) contingency method, then calculating active power flow performance index (PI_{RPF}). After that, (LFSI) is calculated to specify optimum placement for Distributed Generation. Finally, an algorithm GA is used to find an optimum size of DGs.

Thus, we will get reducing of overload lines in the base case and contingency state, decreasing power losses and improving voltage profile.

2. Theoretical Background

An appropriate site that identified the allocation of the Distributed Generation to mitigate congestion, can present improved performance in almost all conditions. Using the N-1 contingency mitigation is sure to give us some of the necessary solutions against the threat of system security. Results of contingency arrangements are implemented using limits for voltage and performance index.

2.1 Contingency Screening

Maintaining the security of the system against threats is an important part of necessities in the electric grid system. Part of the most common threats in violation of the limits of transmission lines. To follow up and monitor this problem by the system operator, an index has been collected to calculate the hazardousness of each line if it exceeds the thermal limiter. Assessment of the process the effect of the violation of the thermal limits called (contingency screening).This index is called (real power flow performance index)(PI_{RPF}) and its general formula are given by equation (1)[14]

$$(PI_{\text{RPF}})^{i} = \sum_{\substack{all\\ branches}} \left(\frac{\mathrm{w}_{l}}{2\mathrm{n}}\right)\left(\frac{\mathrm{P}_{\mathrm{flow}\,l}^{(\mathrm{i})}}{\mathrm{P}_{l}^{(\max)}}\right)^{(2\mathrm{n})} + \sum_{\mathrm{j=1}}^{\mathrm{N}} \left(\frac{\mathrm{w_j}}{2\mathrm{n}}\right)\left(\frac{\Delta \mathrm{V}_{\mathrm{j}}^{(\mathrm{i})}}{\Delta \mathrm{V}_{\mathrm{j}}^{(\mathrm{limit})}}\right)^{(2\mathrm{n})} \tag{1}$$

$$\Delta V_j^{(i)} = V_j^{(i)} - V_j^{(limit)} \tag{2}$$

$$V_j^{(limit)} = V_j^{(max)} , \quad \forall V_j^{(i)} \geq 1.0 \tag{3}$$

$$V_j^{(limit)} = V_j^{(min)} , \quad \forall V_j^{(i)} < 1.0 \tag{4}$$

$$V_j^{(i)} = V_j^{(max)} , \quad \forall V_j^{(i)} > V_{max} \tag{5}$$

$$V_j^{(i)} = V_j^{(min)} , \quad \forall V_j^{(i)} < V_{min} \tag{6}$$

$$\Delta V_j^{(limit)} = \frac{V_j^{(max)} - V_j^{(min)}}{2} \tag{7}$$

Where $i = 1 \ldots \mathrm{N}_{\mathrm{line}}$, [$(PI_{\text{RPF}})^{i}$] denotes on the active power performance index of the ith outage, [w_{l}] & [$\mathrm{w_j}$] denotes on weight factors of line l and bus j respectively that chosen by the operator after taking into consideration the systems condition work, [$\mathrm{P}_{\mathrm{flow}\,l}^{(i)}$] denotes on the line flow of the l th line with (i)th outage,[$\mathrm{P}_{l}^{(\max)}$] denotes on the maximum rating of the l th line, N denotes on the total number of buses in the system, and the term (2n) denotes the order of active power performance index, which considered as 2.

It is clear that (1) includes two terms, and each term represents an electric quantity. The first term symbolizes the real power flow, and the second symbolizes to the voltages. Thus, the two most important electrical elements that cause their violation of truth problems on system security.

The results are ranking in descending order. The line has the highest number acts the most dangerous line compared to the rest of the lines, and this is for the rest of the lines.

2.2 Finding the optimum siting for DGs

Load flow sensitivity on the congestion line will be different regarding generators and load buses in the system in interest. Management of contingency might not always be adequate for the generators rescheduling at all time sbecause of, the variation of daily loads and loads increasing. Therefore, the performance should be on the demand side to decrease the system's congestion [14].

A line flow sensitivity index (LFSI) with active power and reactive power injection is using to mitigate overloading from the congestion line. It can be achieved by calculating the change of power flow in a transmission line (l) which is connected between buses i & j regarding injection at a specific node. Change the power flow in a transmission line is achieved by connecting DG to the specific node. The index's formula and the procedural steps can be written as proposed in [14]

$$\Delta S_{ij}=\frac{\partial S_{ij}}{\partial P_l}\Delta P_l+\frac{\partial S_{ij}}{\partial Q_l}\Delta Q_l \qquad (8)$$

Where ΔS_{ij} is denoting on the changing of line flow through nodes i &j, ΔP_l is denoting on the changing of injection active power at the l Th line, ΔQ_l is denoting on the change of injection reactive power at the l th node.

The variance of ΔS_{ij} related to reactive power Q_l is extremely small if compared with the active power P_l that leads to delete the reactive power from Equ. (8). Therefore Equ. (8) Rewritten as

$$\Delta S_{ij}=\frac{\partial S_{ij}}{\partial P_l}\Delta P_l \qquad (9)$$

When PV coupling is neglected, Eq.(9) will written as following ,

$$(LFSI)_N^L=\frac{\partial|S_{ij}|}{\partial\delta_i}\cdot\frac{\partial\delta_i}{\partial P_l}+\frac{\partial|S_{ij}|}{\partial\delta_j}\cdot\frac{\partial\delta_j}{\partial P_l} \qquad (10)$$

Where δ_i & δ_j are represented voltage angle for buses i & j respectively, l denotes on transmission line (l) that connected between buses i & j

$$|S_{ij}|=(V_i^4Y_{ij}^2+V_i^2V_j^2Y_{ij}^2-2V_i^3V_jY_{ij}^2\cos\delta_{ij}+2V_i^3V_jY_{ij}B_{sh}\sin(\theta_{ij}+\delta_{ij})$$

$$-2V_i^4Y_{ij}B_{sh}\sin\theta_{ij}+V_i^4B_{sh}^2)^{0.5} \qquad (11)$$

$$|S_{ij}|=(T_{ij})^{0.5} \qquad (12)$$

Where

$$T_{ij}=V_i^4Y_{ij}^2+V_i^2V_j^2Y_{ij}^2-2V_i^3V_jY_{ij}^2\cos\delta_{ij}+2V_i^3V_jY_{ij}B_{sh}\sin(\theta_{ij}+\delta_{ij})-2V_i^4Y_{ij}B_{sh}\sin\theta_{ij}+V_i^4B_{sh}^2 \qquad (13)$$

$$\frac{\partial|S_{ij}|}{\partial\delta_i}=(T_{ij})^{0.5}\ (V_i^3V_jY_{ij}B_{sh}\sin\delta_{ij}+V_i^3V_jY_{ij}B_{sh}\cos(\theta_{ij}+\delta_{ij}) \qquad (14)$$

$$\frac{\partial|S_{ij}|}{\partial\delta_j}=-(T_{ij})^{0.5}\ (V_i^3V_jY_{ij}B_{sh}\sin\delta_{ij}+V_i^3V_jY_{ij}B_{sh}\cos(\theta_{ij}+\delta_{ij}) \qquad (15)$$

Jacobian matrix in Newton Raphson load flow expressed as,

$$[\Delta P]=[J][\Delta\delta] \qquad (16)$$

$$\begin{bmatrix}\Delta P_1\\ \Delta P_2\\ \vdots\\ \Delta P_i\\ \Delta P_j\\ \vdots\\ \Delta P_l\\ \vdots\\ \Delta P_n\end{bmatrix}=\begin{bmatrix}\frac{\partial P_1}{\partial\delta_1}&\frac{\partial P_1}{\partial\delta_2}&\cdots&\frac{\partial P_1}{\partial\delta_i}&\frac{\partial P_1}{\partial\delta_j}&\cdots&\frac{\partial P_1}{\partial\delta_l}&\cdots&\frac{\partial P_1}{\partial\delta_n}\\ \frac{\partial P_2}{\partial\delta_1}&\frac{\partial P_2}{\partial\delta_2}&\cdots&\frac{\partial P_2}{\partial\delta_i}&\frac{\partial P_2}{\partial\delta_j}&\cdots&\frac{\partial P_2}{\partial\delta_l}&\cdots&\frac{\partial P_2}{\partial\delta_n}\\ \vdots&\vdots&\vdots&\vdots&\vdots&\vdots&\vdots&\vdots&\vdots\\ \frac{\partial P_i}{\partial\delta_1}&\frac{\partial P_i}{\partial\delta_2}&\cdots&\frac{\partial P_i}{\partial\delta_i}&\frac{\partial P_i}{\partial\delta_j}&\cdots&\frac{\partial P_i}{\partial\delta_l}&\cdots&\frac{\partial P_i}{\partial\delta_n}\\ \frac{\partial P_j}{\partial\delta_1}&\frac{\partial P_j}{\partial\delta_2}&\cdots&\frac{\partial P_j}{\partial\delta_i}&\frac{\partial P_j}{\partial\delta_j}&\cdots&\frac{\partial P_j}{\partial\delta_l}&\cdots&\frac{\partial P_j}{\partial\delta_n}\\ \vdots&\vdots&\vdots&\vdots&\vdots&\vdots&\vdots&\vdots&\vdots\\ \frac{\partial P_l}{\partial\delta_1}&\frac{\partial P_l}{\partial\delta_2}&\cdots&\frac{\partial P_l}{\partial\delta_i}&\frac{\partial P_l}{\partial\delta_j}&\cdots&\frac{\partial P_l}{\partial\delta_l}&\cdots&\frac{\partial P_l}{\partial\delta_n}\\ \vdots&\vdots&\vdots&\vdots&\vdots&\vdots&\vdots&\vdots&\vdots\\ \frac{\partial P_n}{\partial\delta_1}&\frac{\partial P_n}{\partial\delta_2}&\cdots&\frac{\partial P_n}{\partial\delta_i}&\frac{\partial P_n}{\partial\delta_j}&\cdots&\frac{\partial P_n}{\partial\delta_l}&\cdots&\frac{\partial P_n}{\partial\delta_n}\end{bmatrix}\begin{bmatrix}\Delta\delta_1\\ \Delta\delta_2\\ \vdots\\ \Delta\delta_i\\ \Delta\delta_j\\ \vdots\\ \Delta\delta_l\\ \vdots\\ \Delta\delta_n\end{bmatrix} \qquad (17)$$

The inverse of $\frac{\partial P_l}{\partial\delta_i}$ and $\frac{\partial P_l}{\partial\delta_j}$ are used in (10) to account $LFSI$ values.

The calculation of LFSI's values is implemented for (PQ) bus (load bus) through employing the equations (8) to (17) then these values are ranked in a downward order. The (PQ) bus that has a larger negative value of (LFSI) is chosen for DG siting on the basis that it is the weakest bus bar and so on for the rest buses.

2.3 Finding Line Losses

In the electrical power system, the losses vary with many factors. The distribution system losses depend on the impedance and current passing through lines (losses= $I^2 * Z$).
The load flow S_{ij} passing through bus i to j can be represented as,

$$S_{ij} = V_i \, I_{ij}^* \qquad (18)$$

$$S_{ji} = V_j \, I_{ji}^* \qquad (19)$$

Where, V_i and V_j are the voltages at bus i & j respectively, I_{ij} the line current at bus i in the direction from i to j and I_{ji}at bus j in the direction from j to$i$. Thus, power loss in any line between buses i and j can be written as the sum of power flows from (18) & (19) [18]

$$S_{Lij} = S_{ij} + S_{ji} \qquad (20)$$

After each iteration ends, power loss in any line can be calculated using Eq.(20). The summation of all line losses lead to the total losses of the network can be calculated using Eq. (21)

$$\text{Losses} = \sum_{K=1}^{N} S_L(K) \qquad (21)$$

Where S_L is a loss of one branch, N denotes on the lines' numbers, K acts specified line.

2.4 Genetic Algorithm for finding DG units optimum sizing

The optimum size of the DG is determined by the GA. The goals (objectives) used in GA-based optimization technology are to assign the optimum size for DG units by reducing voltage deviation, active power loss, and active energy performance index. The objective function is specified as follows, [11]

$$Minf = W_1 \sum_{i=1}^{N} (1 - V_i)^2 + W_2 \sum_{j=1}^{nl} P_{Lj} + W_3 \sum_{\substack{all\ congested \\ branches}} PI_{RPF} \qquad (22)$$

where V_i mean voltage at ith bus, P_{Lj} mean the active power losses at j th line, N means total busses' number, nl mean total lines' number, and W_1, W_2, and W_3 are mean weights of the objectives for voltage deviation, active power losses, and active power performance index respectively.
This function is to enforce equality constraint:

$$\sum_{i=1}^{ng} P_g - \sum_{i=1}^{nl} P_d - P_{losses} = 0 \qquad (23)$$

where P_g means the power generation in (MW), P_d means the power demand in (MW), P_{losses} means active losses, ng means the number of generators, and nl mean the lines' number.
At each bus, the voltage with angle is subject to the specified conditions maximum and minimum value and flow limits of transmission lines are given as:

$$V_i^{(min)} \le V_i \le V_i^{(max)} \qquad (24)$$

$$\delta_i^{(min)} \le \delta_i \le \delta_i^{(max)} \qquad (25)$$

$$|S_{ij}| \le | S_{ij}^{(max)}| \qquad (26)$$

Where, $V_i$means the voltage of i th bus; $V_i^{(min)}$ and $V_i^{(max)}$ mean the minimum and maximum voltage limit of ith bus, respectively; δ_i mean the actual voltage angle of i th bus; $\delta_i^{(min)}$ and $\delta_i^{(max)}$ mean the minimum and maximum voltage angle limits of i th bus, respectively, S_{ij} mean the power flow passes through the line, that is connected between buses i &j, $S_{ij}^{(max)}$ mean the maximum thermal limit of the same line[11].

3. The results and discussion

Emulation tests were performed on the IEEE -30 bus network [11] to check the performance of the proposed methodology. Single line network of the test system as shown in Fig. 1, that consists of 24 load buses,41 branches, 6 generators, 4 taps changing, and 2 charging.

At first, implement and analyze a Newton Raphson load flow to determine if a limit has been violated or not.

The congestion is occurring, if the limit is exceeded. The ending results of the load flow analysis clarify that there was no congestion in the test system.

Subsequently, the analysis methodology of N–1 emergency is performed to find the critical outages cases as shown in Table 1 for 10 cases as extremely dangerous cases to detect the serious contingency in the tested network. From the analysis it was found that the outage of lines like 1-2, 28-27,2-5,1-3, 3-4, 10-20, 4-6, and generator interruptions 2, 8, 5 show that they have violated the limits(i.e overloading other lines and generators). In this study, all the results mentioned earlier for lines and the generators outages cases were taken into account. Ten simulation test cases are considered.

The most dangerous interruption with a certain level the loading order is based on its (*PI* RPF) values in descending order which is calculated using (1) and is determined in Table 2. It's clear from them that line outage 1-2 occupies the highest position and is defined as the most dangerous emergency with its outage and another case.

When the line 1-2 is an outage,as shown in Fig. 2, the most congested lines are 1-3,3-4 and 4-6 with overload 48.13%,39.1% and22.74% respectively. As a result, it is reasonable to mitigate these transmission lines .To achieve that, the DGs are located at the proper siting of the PQ bus as a reformative procedure for mitigation contingency. To hold a suitable location of DGs, LFSI values (10) are estimated for each line is overloaded to known the most critical case contingency. The top five favorite places for each overloaded line are given in Table 3. Among these values, the bus has the most negative value of the LFSF was determined as the ideal DG positioning. The bus that has the highest negative value represents the most sensibility and responsiveness to the connected of DG]15].

The main objective of this research is to eliminate or minimize the congestion by finding for DG unit the optimum size and site, after obtaining the optimal site, our effort is focused on finding the optimal size of the DG unit by GA. The best DGs size is evaluated 40.7752MW and 18.6073MW located at buses 22 and 23 respectively. Table 4and Table 5 showing how contingency and line flow has been reduced on lines after connected 2DGs.

In this research as shown in Table 6, firstly, we take two most sensitive buses as a location to integrate two DGs only (i.e. buses 22 and 23).

Then

Connected 2DG at buses 5 and 30 with size 49.278MW and 16.229MW respectively as another optimal size and locations selected by the GA,which lead to reduce the congestion line from 17 lines to one line in losses reduction from 39.89% to 55.09% while Table 7 represent acomprision the results of this work with another research. Fig.3 ,epresented the flowchart of stepes work implementation.

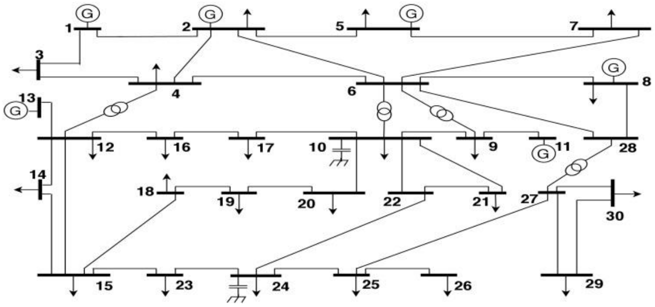


Figure 1. A diagram for a single line network of the IEEE 30 bus

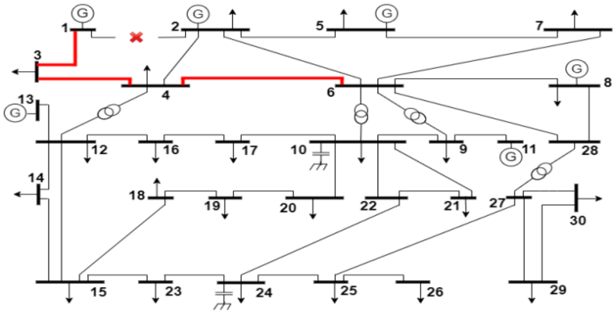


Figure 2. Diagram showing critical lines when line 1–2 is an outage

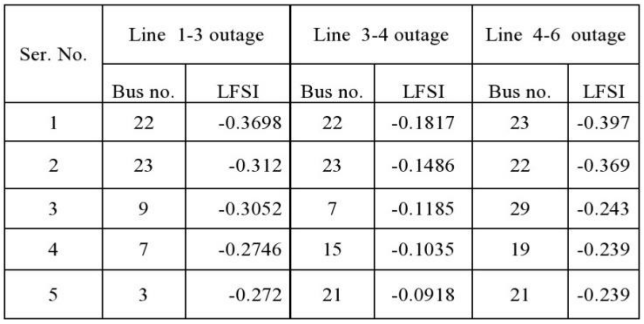
Table .1. Contingency result without DG placement

Ser. No.	Outage Line/ Unit	Cong. line	Max. Line Limit MVA	Line Flow MVA	% over load
1	1-2	1–3	130	192.567	48.13
		3–4	130	180.824	39.1
		4–6	90	110.470	22.74
2	1-3	1–2	130	183.180	40.91
		2–6	65	66.310	2.02
3	3-4	1–2	130	180.386	38.76
		2–6	65	65.388	0.6
4	2-5	2–6	65	75.125	15.58
		5–7	70	83.833	19.76
5	4-6	1–2	130	132.080	1.6
		2–6	65	69.107	6.32
6	10-20	15–18	16	16.320	2
7	28-27	22–24	16	19.63	22.65
		24–25	16	19.48	21.72
8	2	1–2	130	158.386	21.84
9	5	1–2	130	133.664	2.82
10	8	1–2	130	131.938	1.49

Table 2. Results of contingency ranking based on PI power, PI voltage, and PI $_{RPF}$

branch or unit	From bus No.	To Bus No.	PI power	PI voltage	PI $_{RPF}$ total	Sum Cong. Line
1	1	2	8.88	1.95	10.83	3
36	28	27	6.46	2.05	8.51	2
5	2	5	5.30	1.71	7.01	2
2	1	3	5.01	1.94	6.94	2
4	3	4	4.74	1.76	6.50	2
25	10	20	2.78	1.93	4.71	1
7	4	6	3.01	1.61	4.62	2
2	2	2	2.59	1.53	4.12	1
8	8	8	2.68	1.30	3.98	1
5	5	5	1.95	1.47	3.42	1

Table 3. Results of five locations for DGs calculated LFSI [15]



Ser. No.	Line 1-3 outage		Line 3-4 outage		Line 4-6 outage	
	Bus no.	LFSI	Bus no.	LFSI	Bus no.	LFSI
1	22	-0.3698	22	-0.1817	23	-0.397
2	23	-0.312	23	-0.1486	22	-0.369
3	9	-0.3052	7	-0.1185	29	-0.243
4	7	-0.2746	15	-0.1035	19	-0.239
5	3	-0.272	21	-0.0918	21	-0.239

Table 4. Results of congestion after connected two DGs

branch or unit	From bus No.	To Bus No.	PI power	PI voltage	PIrp total	Sum Cong. Line
36	28	27	4.0665	0.7768	4.84333	2
5	2	5	3.1516	1.2425	4.3941	1
25	10	20	2.4023	1.7014	4.1037	1

Table 5. Results of Line Flow with and without DG placement at buses 22 and 23 after congestion

Outage Line/ Unit	Congest. line	Max. Line Limit MVA	Line Flow (MVA) without DG	Line Flow (MVA) with 2DG	% of line loading
1--2	1–2	130	192.57	119.86	92.2
	3–4	130	180.82	111.68	85.908
	4–6	90	110.47	70	77.778
1--3	1–2	130	183.18	115.22	88.631
	2–6	65	66.31	40.47	62.262
3--4	1–2	130	180.39	112.63	86.638
	2–6	65	65.39	39.58	60.892
2--5	2–6	65	75.13	53.72	82.646
	5–7	70	83.83	73.24	104.63
4--6	1–2	130	132.08	85.92	66.092
	2–6	65	69.11	43.82	67.415
10--20	15–18	16	16.32	15.27	95.438
28-27	22–24	16	19.63	11.35	70.94
	24–25	16	19.48	15.26	95.38
2	1–2	130	158.39	116.82	89.862
5	1–2	130	133.66	92.59	71.223
8	1–2	130	131.94	91.19	70.146

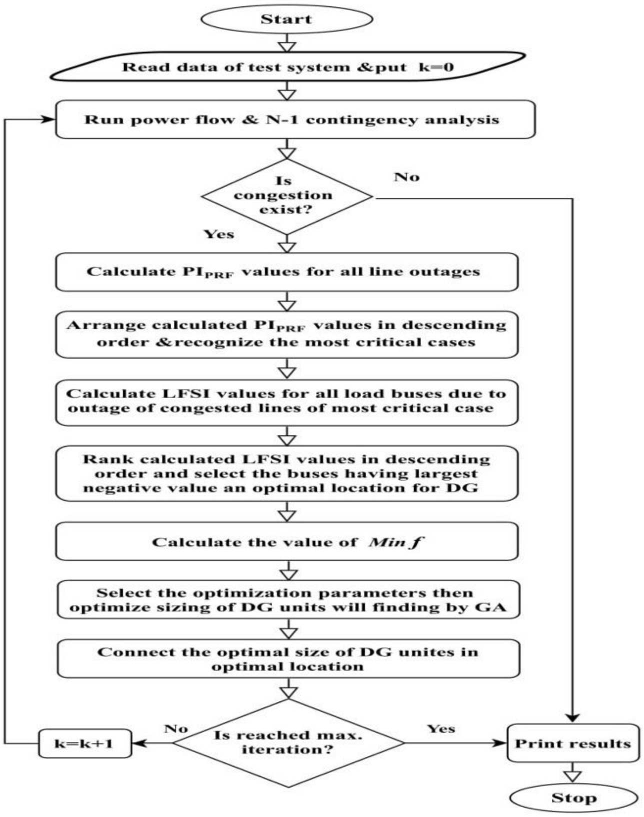


Figure 3. Steps of work implementation.

Table .6. Result with 2DG in difference sitting

Cases	P Losses MW	Congeston Lines	DG location on bus	DG size MW	Reduction MW	% Reduction
Without DG	9.511	17	/	/	/	/
Add 2DG	5.71699	4	22	40.7752	3.79401	39.890758
			23	18.6073		
Add 2DG	4.27106	1	5	49.2788	5.2353	55.093471
			30	16.229		

Table 7. Result with 2DG in difference sitting and comparing with another research

Cases	DG location on bus	P Losses MW		Reduction MW		% Reduction	
Without DG	/	9.482[11]	9.511	/		/	
Add 2DG	22	5.875[11]	5.71699	3.607[11]	3.79401	38.04[11]	39.8907
	23						
Add 2DG	5	4.27106		5.2353		55.09347072	
	30						

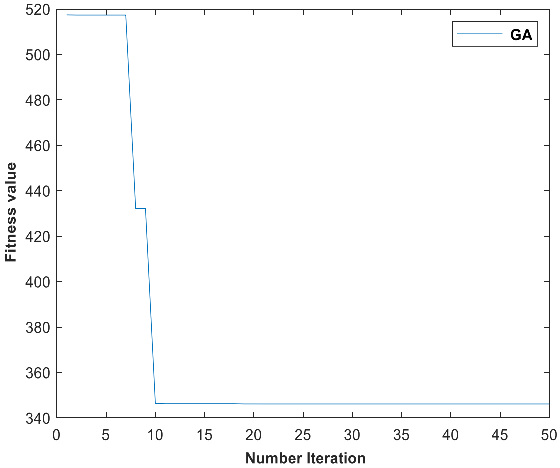


Figure 4. Fitness vs the number of iteration

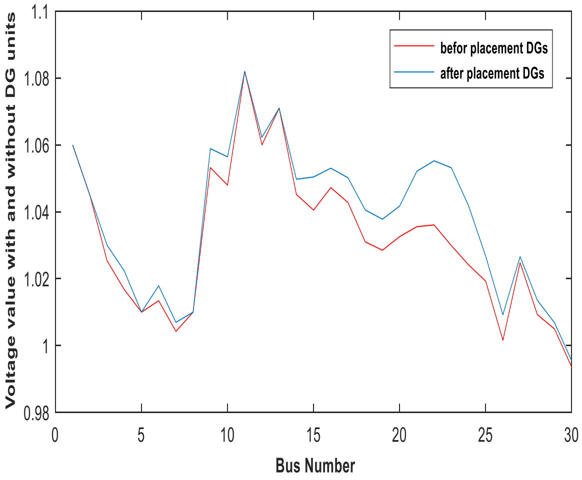


Figure 5. Voltage profile before and after DG placement.

Fig. 4, shown the relation between fitness function convergences against the number of iteration. Also, as shown the Fig. 5, illustrate the improvement of voltage profile before and after connect DG.

4. Conclusions

In this paper, congestion mitigation is implemented with the optimum position and sizing of the DG unit. It's clear the improper position and improper size of the DG units lead to more energy losses and dangerous effort problems. Therefore, this search uses LFSI to determine the suitable DGs locations and using GA to choose the best DG unit size. Also, this research was distinguished by choosing new sites and sizes according to the GA to obtain the best desired results.

This inquiry aims to reduce active power losses, voltage violations, and active power performance index. The proposed approach has been tested for this predicted method in modified IEEE -30 buses as a system for test. The results of the N-1 emergency analysis after DG unit are established the efficiency of this proposal methodology, where the total number of congestion lines decreases from 17 to 4 lines as shown in Table 4 with a reduction percentage level violent is 76.47% while as in Table 6, is 94.12% as result of decreases from 17lines to one line when choosing another buses 5 and 30. Also, as shown in Table 5 the mitigation the value of load flow that pass through the lines when connected DGs which lead to lines loadability.

The mitigation of congestion is implemented with the optimum position and size of DG units. It's clear the improper size and improper position of the DG units lead to more energy losses and dangerous effort problems. Therefore, this search uses LFSI to specify the most proper DG's location and using GA to choose the best size for the DG unit.

The reduction of active power losses, voltage violations, and active power performance index was achieved. The active power losses (P_{losses}) were reduced (Table 6) from 9.511 (MW) to (5.7169MW) by a reduction of 39.89% at buses 22and 23.While (P_{losses}) became 4.27106MW by a reduction of 94.117% at buses 5and 30. Also, the total summation of ($\mathrm{PI_{RP}}$) was reduced from 60.6611 to 13.3045 and 10.6021(as a result to mitigate congested lines as mentioned earlier) and voltage deviation from 0.00492063 to 0.00151591 and 0.001263 respectively. In comparison with other research, it was found that choosing the DG sites at buses 5 and 30 achieved the best results in this research as in Table 7.

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Conflict of interest

The authors of this article acknowledge that the publication of this article causes no conflict of interest to anybody or institution.

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