Voltage Stability Maximization by Optimal Wind Turbine Insertion Using Genetic Algorithm

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Abstract: The integration of clean or renewable sources such as wind turbines based distributed generation (WT_DG) into the power system has become one of the priorities of the grid operator. In this paper a study on the search for optimal locations and sizes of WT in the transmission network has been carried in order to maximize the lambda parameter and therefore the voltage stability, using Genetic Algorithms Technique (GAT). This method has been applied on the modified IEEE 30 bus network, with MATLAB code. The results demonstrated the effectiveness of wind turbine integration in improving the voltage stability of the studied network.

Keywords: Power system, Voltage stability, Wind turbine.

1. INTRODUCTION

The transmission of power through a power system is characterized by voltage drops between the points of production and load under normal operating conditions. These voltage drops are of the order of a few percent of the nominal voltage. Under specific conditions, however, within seconds or minutes of the occurrence of a disturbance, voltages can drop catastrophically, to the point where power can no longer be properly delivered to consumers and system integrity can be put under load [1]. The mechanism underlying this voltage collapse is voltage instability and the resulting catastrophe of voltage collapse. Voltage collapse by definition is the process by which voltage instability leads to a very low voltage in part or all of the network which causes a cascading collapse of the network. To avoid voltage collapse of the network several solutions have been proposed in the literature, such as maximizing the voltage stability indices by integrating FACTS systems, decentralized sources and etc. The integration of wind turbines into the power system is done in an optimal way, as an inadequate insertion can cause a negative impact on the operation of the network.

The clean energy sources (such as PV and wind) do not emit emission of greenhouse gases and are renewable sources. For these advantages several searches in the literature have been carried out on these topics [2-6]. The integration of decentralized generators (DG) into the power grid requires certain conditions to ensure the proper functioning of the system (grid/decentralized source). Some research has shown that the improper insertion of DGs can cause adverse effects on network parameters [5]. For this reason, it is necessary to know how and where to insert the DGs and how much power to inject. According to the literature, several studies have been carried out proposing solutions to avoid negative effects [8]. As an example, the paper [9] proposes a study on the optimal integration of DGs using the Monte Carlo method to minimize losses, improve the voltage profile and maximize the voltage stability of the network. The technique of Artificial Bee-Colony, was presented to determine the optimal location and size of DGs in the network, in order to evaluate a multi objective function (improving the voltage profile and reducing active losses) [10]. An analytical technique has been proposed in reference [11] to determine the optimal size and location of DGs. The objective functions considered in this study are the improvement of the voltage stability index and the minimization of active losses. Another research in [12] presents the application of the Cuckoo Search method to identify the best sites and sizes of DGs that maximize voltage stability and minimize active losses. Different methaheuristic techniques have been proposed in the literature to ensure optimal integration of DGs, based on Particle Swarm Optimization method, based on Evolutionary Algorithms method, Genetic Algorithm method [13-19].

In this paper a study of the problem of searching for optimal locations and sizes of wind turbines in the modified IEEE 30 bus power network using the genetic algorithm method. The objective function of this study is to maximize the voltage stability of the network. The simulations have been performed under MATLAB environment. The results have been compared with work in the literature.

2. MATHEMATICAL MODEL

The load can keep increasing until the occurrence collapse of voltage. This means the equilibrium of the system starts losing[20]. For maximizing the Load-Margin (LM), the determination of more than one WT_DG site becomes an optimization problem in the power system. Thus, it requires to define both the objective function and constraints[21].

To evaluate voltage stability, the LM parameter (λ) is a common index utilized in the power system[16, 22]. As in Fig. 1, it represents λ and point of collapse. The LM parameter (λ) indicates the space between the start current point and the critical point that results in the voltage collapse. The system becomes more stable as long as λ is increased.

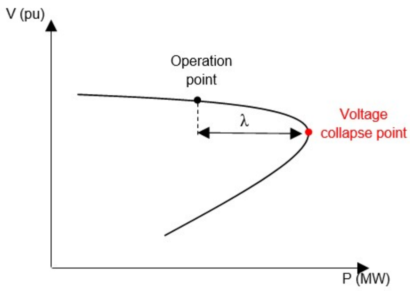


Fig. 1 Labda parameter and the collapse point.

The wind turbine size and site are formulated as an optimization problem for maximizing voltage stability under all technical constraints in the power network.

$$F = \max \lambda \quad (1)$$

There are two constraints. The first one is known as power balance equations in the power network. Eq. (2) presents this balance including the WT_DG units.

$$S_G + S_{DG} = S_D + S_L \quad (2)$$

where S_G, S_{DG}, S_D and S_L are apparent power of the centralized generator, apparent power of the decentralized generator, load apparent power and apparent power loss in the network respectively.

The second one is inequality constraints. It represents the line thermal limits (Eq.3), voltages limits (Eq.4), real power generation limits (Eq.5) and the WT_DG limits (Eq.6) respectively [23].

$$S_k \le S_{kmax} \quad \text{for } k = 1 \dots \dots . NB \quad (3)$$

$$0.95 \le V_i \le 1.05 \quad \text{for } i = 1 \dots \dots N \quad (4)$$

$$P_{Gimin} \le P_{Gi} \le P_{Gimax} \quad \text{for } i = 1..NG \quad (5)$$

$$0 \le \sum_{i=1}^{Nw} P_{DGi} \le 0.3 * \sum_{i=1}^{Nbus} P_{Di} \text{ for } i = 1 \dots NW \quad (6)$$

3. APPLIED METHOD

The most widely used metahistorical method in literature is the genetic algorithm technique, which was developed by J_Holond in 1975. The advantage of this method is its simplicity, effectiveness and ease of implementation in all domains. [24, 25]. It is capable to handle more than a single objective function for different scales of power networks. The GAT is built based on a set of chromosomes. Each chromosome shows a solution to the given problem and makes a group of different chromosomes generating the population.

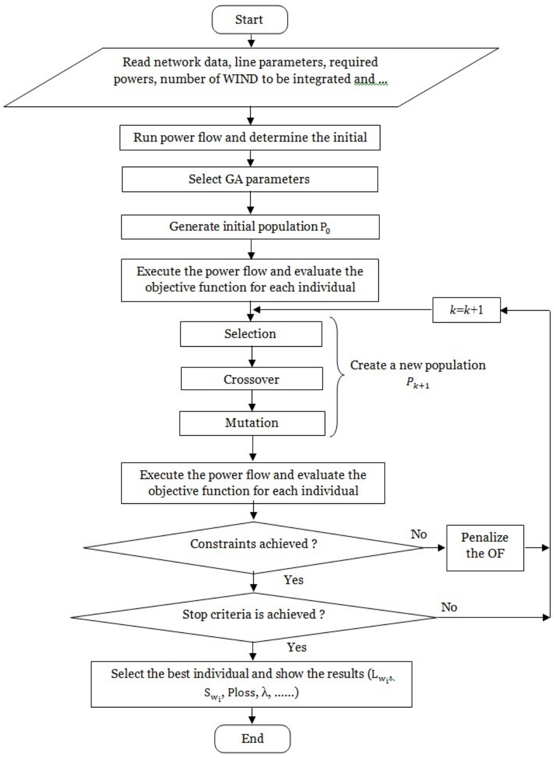


Fig. 2 Flow chart of the best size and site of wind.

In this population, every chromosome has an evaluation of fitness to the environment. By evolutionary operators, an offspring population is then generated. The selection operator choose the most proper combinations of individuals. By crossover and mutation operators, these should result in better solution in the coming population. Fig. 2 is the flowchart of GAT. It illustrates how it works.

In order to determine the suitable sites for WT_DG in the power network, this requires generating random sites by GAT. After evaluation, the best solution is chosen. To do this, the defining variables for both input and output in the problem are required.

In general, the input variables indicates to the control parameters which are the site (L_i) and size (S_i) of the WT_DG as in Eq. (7).

$$v^T = [S_{w_1}, S_{w_2} \dots S_{w_{Nw}}, L_{w_1}, L_{w_2} .. L_{w_{Nw}}] \quad (7)$$

On the other hand, the calculated parameters after load flow analysis are defined as the output variables. These variables are the active power of generation at bus(P_{G1}), the load voltage of the bus (V_L), the reactive power of the traditional generator(Q_G), the transited apparent powers(S_l) in transmission lines as in Eq. (8).

$$\chi^T = [P_{G1}, V_{L1} .. V_{LND}, Q_{G1} .. Q_{GNG}, S_{l1} \dots S_{lNL}] \quad (8)$$

4. RESULTS SECTION

The determining optimal sites of WT_DGs is conducted on the IEEE 30-bus modified transmission network. This network, consists of 41 lines, 4 on load tap changing transformers and 6 traditional generations. The total active power is 189.2MW while total reactive power is 107.2MVAr. For the voltage limits, the minimum and maximum values are ±5 %. In this study, four cases are taking in consideration as:Case 1: without injecting WT_DG.Case 2: inserting 01 WT_DG.Case 3: inserting 02 WT_DGs andCase 4: inserting 03 WT_DGs.For the controlling parameters of the GAT, the number of population is 100 and the maximum generation number is 500. Table I. represents the simulated results obtained using the proposed GAT. This is used for the aforementioned cases including the optimizing both sizes and sites of WT_DGs in the power network, total active lossesmin voltage, max Load-Margin. In addition, the simulated results are then compared with similar works as in[26, 27]. Based on the Table I, LM is more increased when the number of WT_DG is increased. Likewise, the increased of WT_DG number result in the better the voltage profile. This also results in a minimization of losses in the power network.

The validation of the proposed method is obtained by comparing the simulated result with the paper method published in[26, 27] as shown in Table I (case of the integration of 03 wind turbines). It proves the power network performs better during the proposed method. It proves that, the voltage stability is enhanced during the injection of WT_DGs. it is interesting to mention that the work in references [26, 27] is modeled as wind turbines as a source injecting apparent poverty with a power factor (PF) of the 0.9. However, in this study the each WT_DG is modelled as a randomly deliver power between 0 and 100 MW with PF = 0.8.In each case, the voltage profile is illustrated by Fig.3. Case 4 shows the best voltage profile at stifle of integration 3 wind turbines. For the transmitted apparent power, the power transited in the lines is influenced by the number of integrated wind turbines as in Fig.4. By comparing the case 4 to the case1, the transmission line1 (between two buses 1 and 2) has shown a noteworthy change in apparent or MVA power. For conventional generators, Fig.5, Fig.6 shows the active and reactive power respectively. Meanwhile, Fig.7, Fig.8 and Fig.9illustrate PV curve for the three cases (2, 3and 4) with comparison to the first case.According to the results shown in Table I, it is noted that the integration of wind turbines with PF of 0.8 is better than wind turbines with PF of 0.9 in terms of improving voltage stability.

Table 1. Optimal site and size of WT_DG and the system performance for modified IEEE 30 bus power system

Methods	Before integration wind			After integration wind						
	Real power loss (MW)	Min voltage (pu)	Max loading (pu)	Wind Number	Wind Size MW	Wind Size MVAr	Wind location	Real power loss (MW)	Min voltage (pu)	Max loading (pu)
Proposed method	2.44	0.96063	2.63	01 wind	25.16	18.87	8	1.65	0.9675	3.31
				02 wind	15.02	11.26	8	1.72	0.9660	3.33
					9.97	7.47	24			
				03 wind	8.44	6.33	8	1.79	0.9659	3.4
					9.75	7.31	24			
					6.82	5.12	28			
Work in [26]				01 wind	5	1.64	8	2.25	0.9632	2.77
				02 wind	5	1.64	8	2.14	0.9648	2.83
					5	1.64	28			
				03 wind	5	1.64	6	2.03	0.9661	2.88
					5	1.64	8			
					5	1.64	28			
Work in [27]				01 wind	25.25	8.31	8	1.755	0.9667	3.1
				02 wind	9.12	3	24	1.983	0.9654	3.15
					16.25	5.34	28			
				03 wind	4.59	1.51	8	1.75	0.9676	3.3
					15.21	5	9			
					5.41	1.77	28			

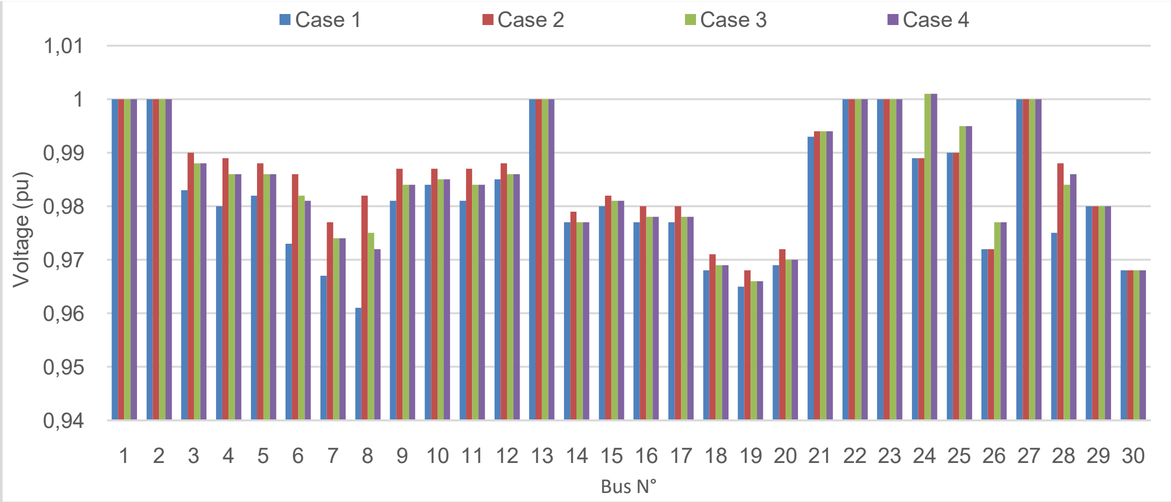


Fig. 3 Voltage profile without and with WT_DG

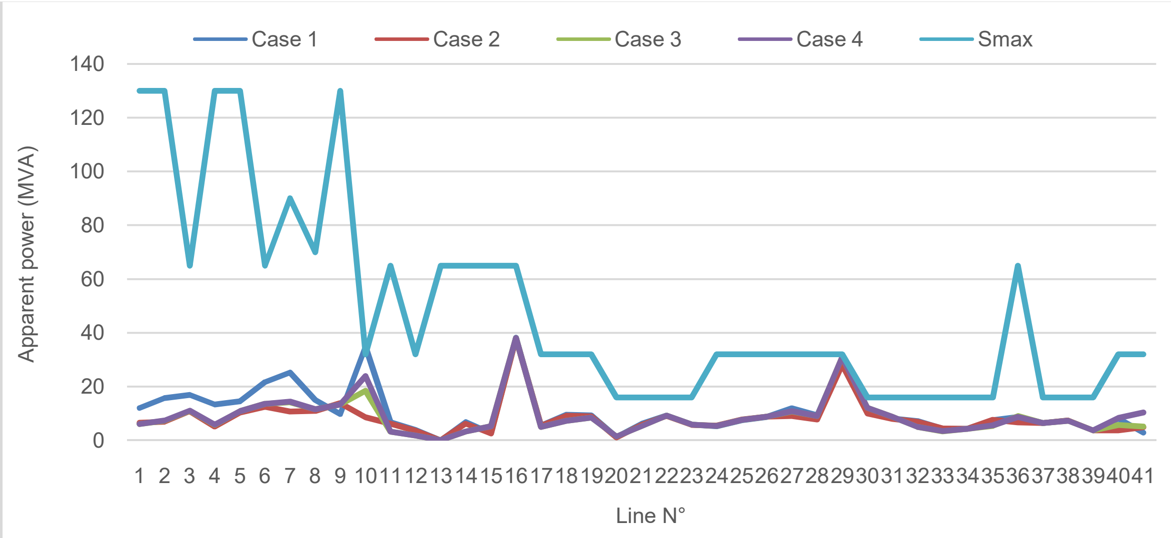


Fig. 4 Line apparent powers without and with WT_DG

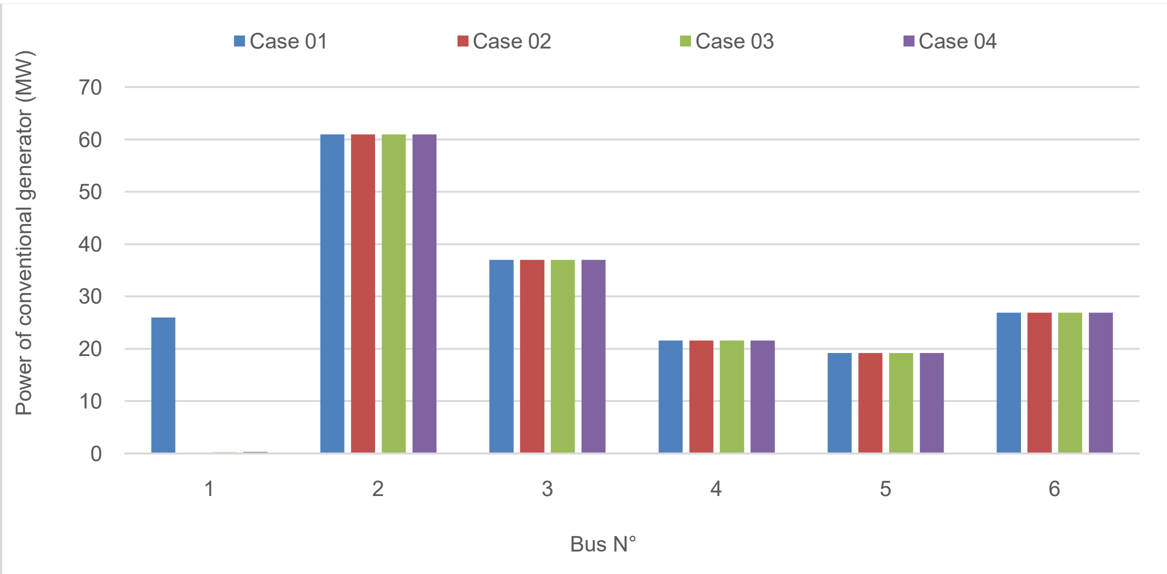


Fig. 5 Total active powers of the conventional generators

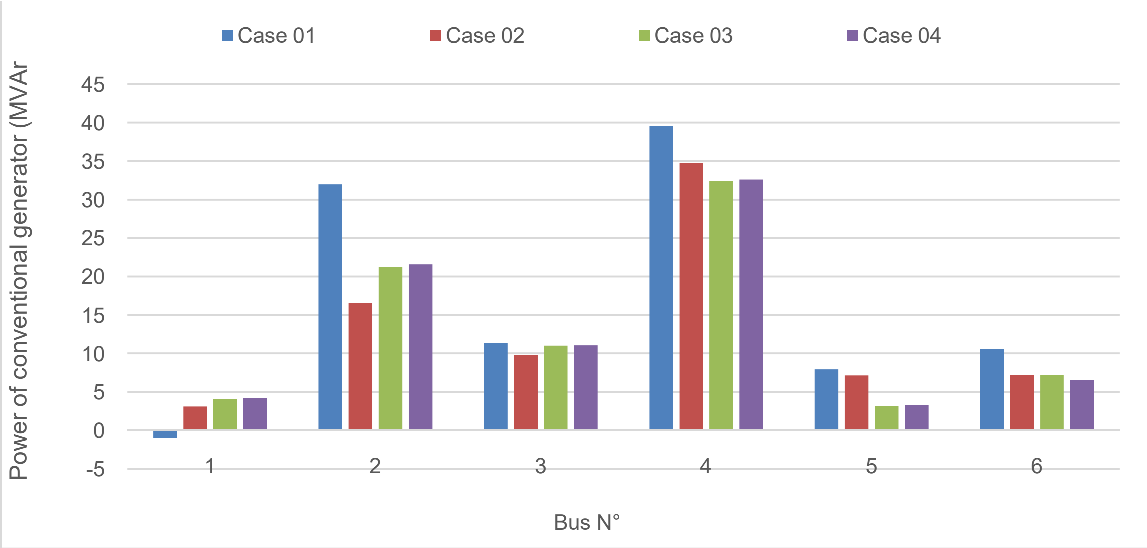
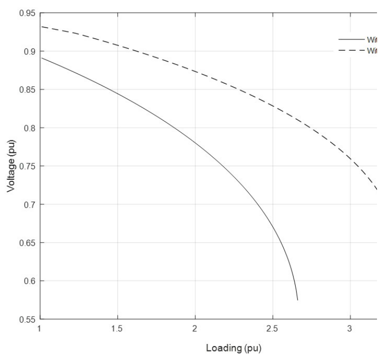
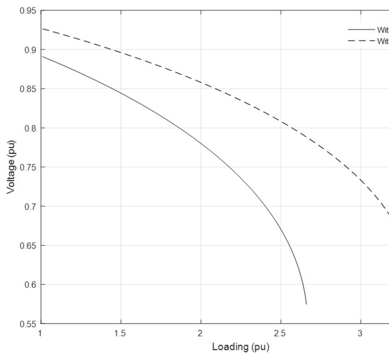


Fig. 6 Total reactive power of the traditional generators





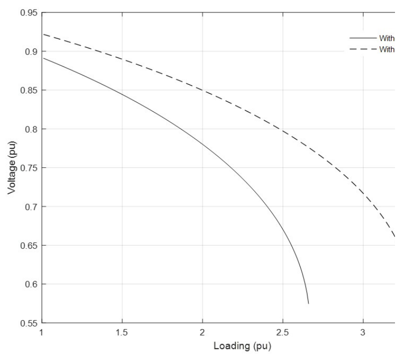


Fig 7. PV curves without and with 01 WT-DGs

Fig 8. PV curves without and with 02 WT-DGs

Fig 9. PV curves without and with 03 WT-DGs

5. CONCLUSION

This study is focused on the optimal integration of wind turbines into the modified IEEE 30 bus network to maximize voltage stability. Optimal integration provides a better location and adequate power injection. Genetic algorithms are used to optimize the insertion of these wind turbines taking into consideration all the constraints of the power grid, under MATLAB routing. The results obtained are compared with bedding work. And according to the comparisons it is found that,the integration of wind turbines with PF of 0.8 is better than wind turbines with PF of 0.9 in terms of improving voltage stability.

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