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REVIEW

Effect of Wind Farm and Thyristor Switched Series Capacitors on a Faulty Network

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ARTICLE INFO

Article history
Received: 30 March 2019
Accepted: 16 April 2019
Published Online: 30 April 2019

Keywords:
Wind farm
TSSC
IEEE 14-bus network
Faulty network

ABSTRACT

Controlling voltage and active or reactive losses are one of the most important issues in each power grid. In this paper, the influence of wind farm and thyristors switched capacitors on the network are considered. TSSC and Wind turbines are one of the significant components of each network. These instruments are also one of the resources of producing active and reactive power. In this study, wind farm and TSSC are already located optimally by Genetic algorithm. This network studied when a fault considered in one of buses. So that, in first step none of wind farm and TSSC are in the power grid. In the second step, both wind farm and TSSC are connected while a short circuit accrues in one of the busses or lines of the network. At the end, it will be observed that using thyristor switched capacitors and wind farm influence the network. So that, the capacity of producing the reactive and active power will be increased and totally the loss of the system will be decreased. Furthermore, the voltage profile will be in a suitable range.

1. Introduction

Power networks, as expensive systems, are dealing with different kind of events. The most important of these events is a different type of short circuits in the power network [1,2]. These events may lead to an outage of power lines in the power circuit. These phenomena result in two main issues: occurring overload on the lines which don't have any fault, and collapsing of the voltage symmetry. So far, lots of methods exist to control this kind of problems like the integration of TSSC as one type of FACTS devices into the network [3-6]. The system can improve the transient stability, reduce the under synchronous oscillations, damp dynamic oscillations, prevent voltage collapse, and also increase the reliability of the system with considering series capacitor on power lines. Certainly, using TSSC for each of the aforementioned objectives would require optimum placement. The stability of the system can be controlled by TSSC. The voltage profile can be controlled with the impedance of the power line when the system is designing [2,7]. When a fault occurs in the system, one or more than one lines are affected. it is very important to control the stability of the system in the face of decreasing the system voltage or increasing of the losses. Several authors have presented a couple of methods for the optimum placement of TSSC. Therefore, the issue which can be interesting is designing TSSC rate under fault state.

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DOI: https://doi.org/10.30564/ese.v1i1.977

In the first instance, it is required to identify the optimum points for installing and using TSSC on the power system so that the study of their function is not affected by the displacement [2,8].

Wind energy is characterized by a high rate of development in the world. Issues concerned with energy have crucial importance on the environmental state of the earth. According to the experts, continuous utilization of wind power process requires dauntless research and development as well as the governmental support to backing this technology [2]. The new era for the wind energy began in the late '70s and the first wind-power station started to work in California on '80s. According to Charles Mc Guvin, technical director of wind energy in "Research Institute of Electricity Power", this industry is of an annual growth rate from 20-30% in the world [6,8]. The wind energy is typically generated by the very huge three-blade turbines which are placed on the very high towers. These turbines generate power electricity by wind power. Turbines in industrial-scale are produced to give public service which may generate electrical power from 750 kW to 1.5 MW. Three-blade wind turbines are placed windward and the blades are against the wind. Another widely used wind turbine is a two-blade type. Thanks to research and development, wind turbines have been impressively evolved during the past twenty years. According to Trescher, the length of diameter was 20 meters in 1984-85, but now it has risen to 100 meters. The width of modern wind turbines is even more than that of a 747 airliner's wings. There are a series of wind turbines connected for power generating and transmitting it into the main power network in wind farms and or in windswept fields. This power is accessible for the users by transmission and distribution power lines [6-8].

With increasing the using wind farm in the network, changing the voltage profile is one of the most important issues that a designer is dealing with. This problem is due to changes in output power according to the wind and weather conditions. Then, the system needs some reactive devices to control these changes. As a result, minimizing reactive power and voltage in buses are especially important. It is a big problem to control these factors in the presence of wind farms [9, 10].

2. Study System

This system is consisting of IEEE 14-bus network. This system has been shown in Figure 1. In the first stage, the wind farm has already to be allocated on an appropriate bus with a load of 400 MW in a peak. A normal weather condition with an average wind speed of 15 m/s is considered. According to Figure 2 total power in this wind farm is 20 MW. Each wind turbine can produce 1.5 MW. Then, 14 turbines are necessary to have 20 MW. Besides, the TSSC are already placed on the network. For better studies two steps are studied:

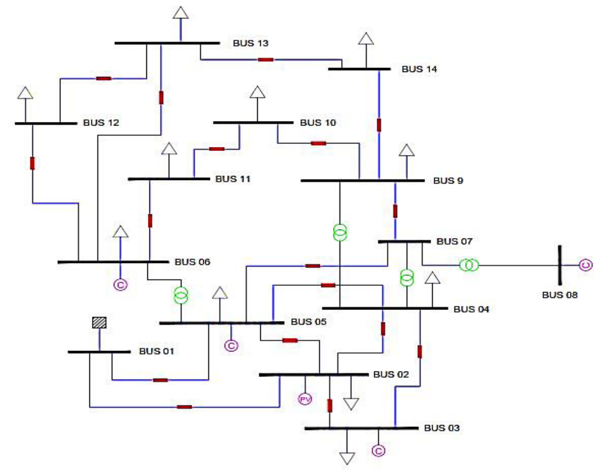

Figure 1. Standard IEEE 14-bus system

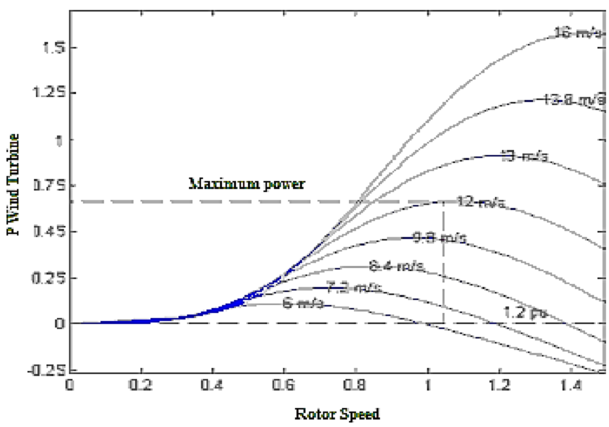

Figure 2. Mechanical Power of Wind Turbine against various wind speeds [1]

Step 1: System study without the presence of wind farm and TSSC.

Step 2: System study in the presence of wind farms and TSSC.

It is mentioned that a fault will be accrued in the network and the steps will be considered with a faulty condition.

2. Methodology

Load flow is a significant calculation to considering the behavior from the power network. Extending the power system and connected distributed generation (DG) units to power system have been done by conventional methods, including Newton- Raphson, Z_{bus}, fast decoupled which could not consider OPF carefully. Because when DG units are connected to the power grid, they result in two-vector power supply in grid. Thus, for OPF, we use forward and

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backward method [11-13]. Related constraints and equations of the problem are:

(a) VAR supply installation limit [11]:

$$0 \le Q_{ci} \le Q_{ci}^{\max} \quad (1)$$

(b) Active and reactive power generated by DG units [11]:

$$P_{gi}^{\min} \le P_{gi} \le P_{pi}^{\max} \quad (2)$$

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max} \quad (3)$$

$$Q_{gi} \le Q_{gi}^{\max} \quad (4)$$

(c) Power factor fix at load buses

(d) Power flow equations [11]:

$$P_{gi} - P_{li} = \sum V_i.V_j\left[G_{ij}\cos(\delta_{ij}) + B_{ij}\cos(\delta_{ij})\right] \quad (5)$$

$$Q_{gi} - Q_{li} + Q_{Ci} = \sum V_i.V_j\left[G_{ij}\cos(\delta_{ij}) - B_{ij}\cos(\delta_{ij})\right] \quad (6)$$

(e) Voltage limitation at load buses [11]:

$$V_i^{\min} \le V_i \le V_i^{\max} \quad (7)$$

Calculation of voltage stability index:

There exist more indexes to analyze voltage stability improvement at power system, such as considering of Q-V curves, analyze of P-V curves, and L- index. Then, L-index is used to analyze voltage stability. Thus, an n busbar system is considered in which the buses are shared between two groups of Generation buses and load buses. Bus numbers from 1 to g are taken as generation buses, while g+1 to n buses are assumed as load buses. From admittance matrix [12]:

$$\begin{bmatrix} I_g \\ I_l \end{bmatrix} = \begin{bmatrix} Y_g & Y_{gl} \\ Y_{lg} & Y_l \end{bmatrix} \begin{bmatrix} V_g \\ V_l \end{bmatrix} \quad (8)$$

To reorganize above equation, the following equation is received [12]:

$$\begin{bmatrix} V_l \\ I_g \end{bmatrix} = \begin{bmatrix} Z_l & F_{lg} \\ K_{gl} & Y_g \end{bmatrix} \begin{bmatrix} I_l \\ V_g \end{bmatrix} \quad (9)$$

L index for load buses is calculated in the following [12]:

$$L_j = \left|1 - \sum_{i=1}^{i=h} F_{ji}(V_i/V_J)\right| \quad (10)$$

F_{ig} admittance matrix can be given as to follow [12]:

$$F_{lg} = -\left[Y_{ll}\right]^{-1}\left[Y_{lg}\right] \quad (11)$$

L index is a number between zero and one. The more this number is closer to one, the more likely are instability and voltage collapse. On the other hand, if the number is get closer to zero, the stability will be increased. Calculation of voltage regulation:

In order to calculate the voltage regulation, the following equation is used [13]:

$$VR = \frac{1}{n}\sum_{i=1}^{n}\left|V_i^{\max} - V_i^{\min}\right| * 100 \quad (12)$$

In the above equation, $V_i^{\max}$ is Peak voltage of bus I, $V_i^{\min}$ is minimum voltage of bus I. In this case, the reactive power is absorbed form these resources. The topology of wind turbines which are connected to the power system are shown in Figure 3 [15-19].

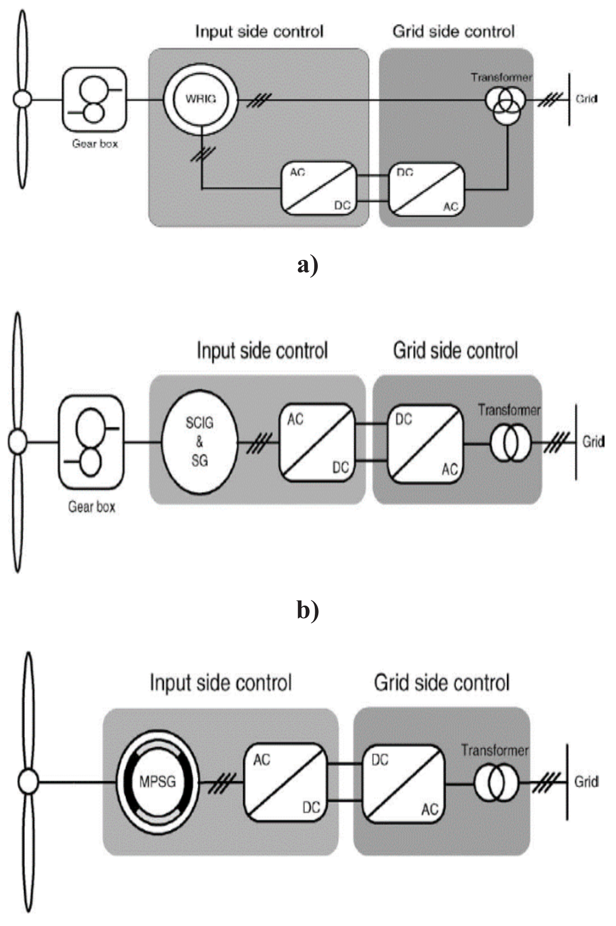

Figure 3. Topology of connected wind turbines to grid [1]

The studies are considered by Matlab with helping of Genetic algorithm for optimal placemen of TSSC and wind farm which there are already placed on suitable buses. So that, optimal wind farm placement is in bus no. 8 and TSSC are between buses (1-5), (4-7), (4-9), (7-9), (9-14). In this case, we use two scenarios of the genetic

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algorithm aspect of reactive power to improve voltage stability grid index and minimize the losses in the network, proposed flowchart is shown in Fig. 1. In the first scenario, we assume that each of the three-power compensator with a maximum capacity of 1 MVAr is used to optimize the objective function. In the second scenario, we assume a maximum of three compensator sources, each with a capacity of 500 KVAR is used to optimize the objective function [2].

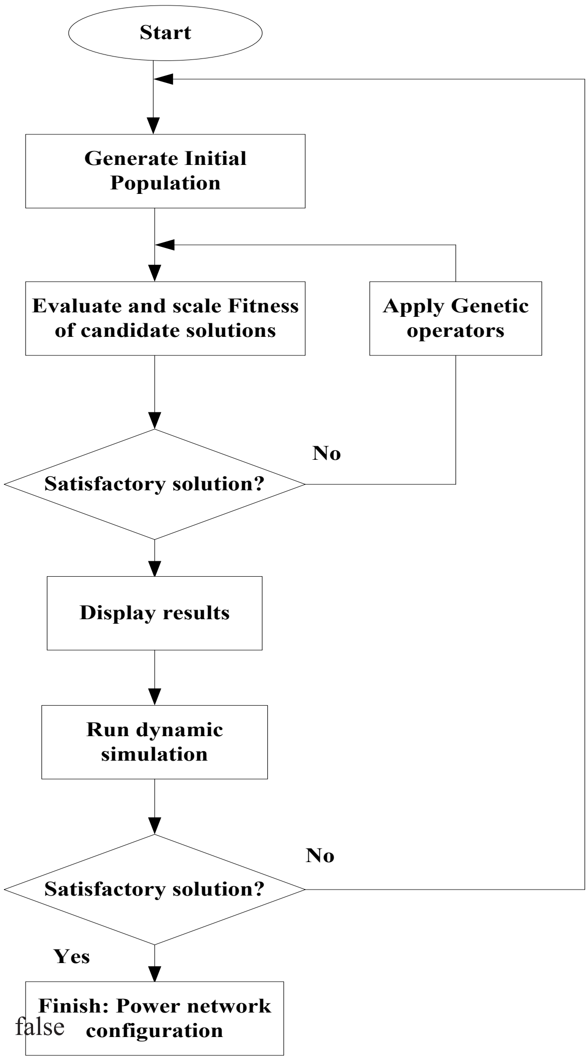

Figure 4. Flowchart of GA for optimal allocate of compensator resources

3. Simulation

This part of the simulation is conducted on MATLAB by genetic algorithms at the faulty state of in the power network: in the absence of wind turbines and TSSC and in the presence of wind turbines and TSSC. In these scenarios, we suppose a maximum of three compensator sources (each one 500 kVAR) is used to optimize the system. The results of this study are presented in the next part. The condition of the system with/without wind farms and TSSC are already surveyed in [2] in a normal state of the network.

3.1. Optimal Load Flow with Considering the Faulty Network

Considering the aforementioned constraints, at this step, one of the lines is randomly removed from the circuit. The optimum state is the simultaneously integration of the wind turbines and TSSC.

In this state, it is supposed that the network is in the normal state without any wind turbines and TSSC and there is a short circuit on the line 6-12. In that case, the active and reactive power losses on lines are demonstrated on Table 1. The bus voltages with short circuit on the line 6-12 is shown in Figure 5 and active power losses on lines are depicted in Figure 6 and the reactive power losses on lines at the state of short circuit is shown in Figure 7.

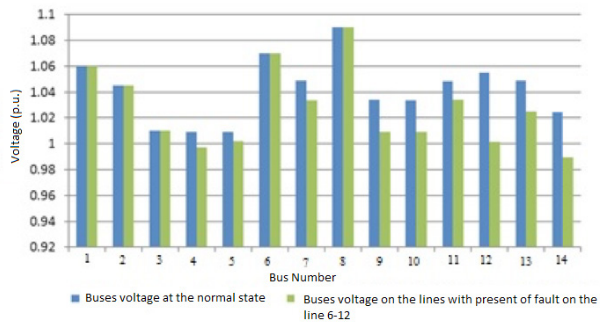

Figure 5. Bus voltages with short circuit in line 6-12

Table 1. Active and Reactive Power Losses in Line 6-12 in the Presence of short Circuit

From Bus	To Bus	Line	Q Loss p.u.	P Loss p.u.
Bus 02	Bus 05	1	0.019748	0.018142
Bus 06	Bus 12	2	0	0
Bus 12	Bus 13	3	0.00023	0.000255
Bus 06	Bus 13	4	0.010771	0.005469
Bus 06	Bus 11	5	0.006212	0.002967
Bus 11	Bus 10	6	0.003008	0.001285
Bus 09	Bus 10	7	0.000103	3.89E-05
Bus 09	Bus 14	8	0.002887	0.001357
Bus 14	Bus 13	9	0.005327	0.002616
Bus 07	Bus 09	10	0.026919	5.55E-17
Bus 01	Bus 02	11	0.255103	0.102712
Bus 03	Bus 02	12	0.152966	0.047287
Bus 03	Bus 04	13	-0.0104	0.009586

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Bus 01	Bus 05	14	0.193559	0.059572
Bus 05	Bus 04	15	0.015599	0.009004
Bus 02	Bus 04	16	0.059553	0.032492
Bus 04	Bus 09	17	0.005511	4.95E-05
Bus 05	Bus 06	18	0.105502	-3.3E-16
Bus 04	Bus 07	19	0.04226	-1.7E-16
Bus 08	Bus 07	20	0.017384	1.53E-16

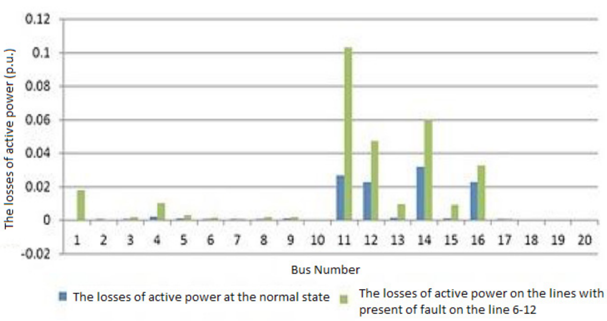

Figure 6. Lines' active power with short circuit in line 6-12

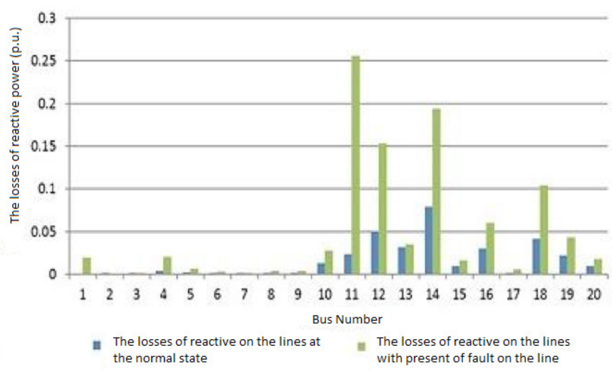

Figure 7. Lines' reactive power with short circuit in line 6-12

Based on the figures, the total generated active power on the faulty network and the reactive power are respectively 392.62 MW and 206.8 MVAR respectively, in which the total active and the reactive load on the network are respectively 362.6 MW and 113.96 MVAR. It is expected that the network losses increase by removing a line from it and the total active and reactive power losses are respectively 30.021 MW and 92.843 MVAR. Compared to the normal state, the network without wind turbines and TSSC [2], will face an increase of 1.93% in the active loss and 1.38% in the reactive power, in which, the percentage of the active power loss is 7.64%. These percentages are compared to active and reactive powers of normal condition in the network.

It is supposed that there is a short circuit on the same previous line along with the presence of the wind farm and TSSC on the network.

Bus voltage is shown in Figure 8, while reactive power losses are depicted in Figure 9 and Figure 10 illustrates reactive power losses with wind farm and TSSC and with short circuit in line 6-12.

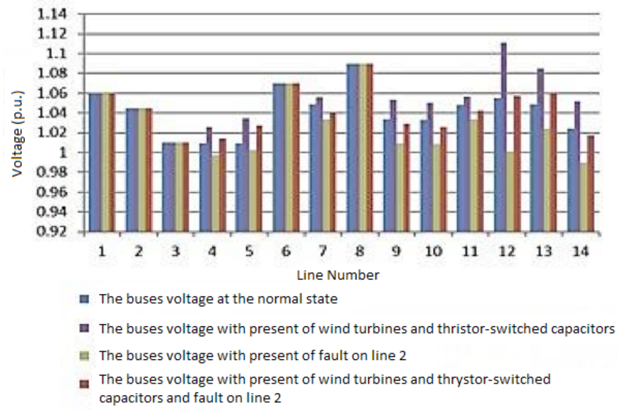

Figure 8. Comparison of bus voltage with/without wind farm and TSSC and short circuit in line 6-12

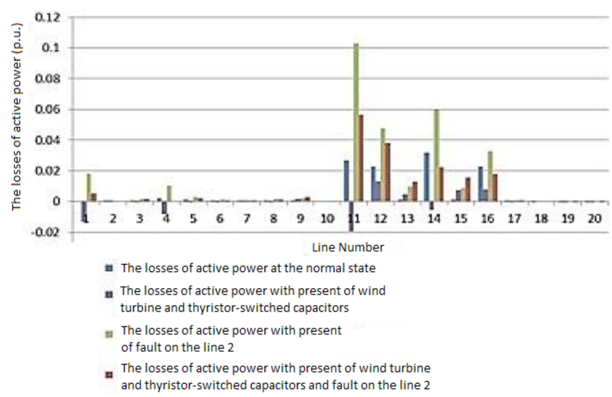

Figure 9. Lines' active power losses with/without wind farm and TSSC and short circuit in line 6-12

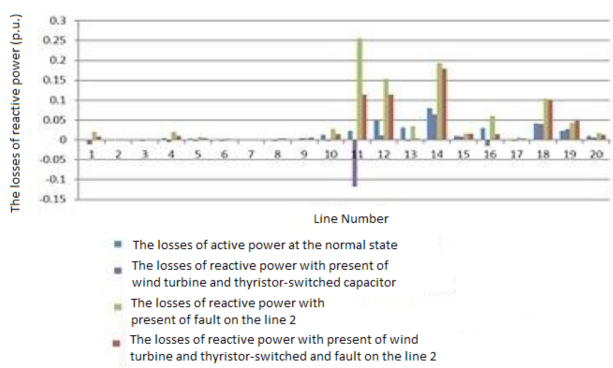

Figure 10. Lines' reactive power losses with wind farm and TSSC and short circuit in line 6-12

In that case, the total generated active power on the network and the reactive power are respectively 377.98 MW

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and 184.82M, and total active and the reactive load on the network are respectively 362.6 MW and 113.96 MVAR; the total active and reactive power loss on the network are respectively 15.389 MW and 70.865 MVAR, in which, the percentage of the reactive power loss is 4.07%.

4. Conclusion

As one of the most significant sources of renewable energies, the act of wind turbines is a very sensitive subject in the power system. In recent years, some methods are applied to decrease the losses of this kind of systems. We can use wind farms to control the voltage of buses in power lines. If the wind farm is allocated in a suitable place, we can enhance the voltage network. In this paper, wind farm and TSSC are already placed. With using these devices reactive power, losses and voltage of the whole system are controlled. TSSC supply reactive power for the system, therefore reactive power losses will be reduced and voltage profile will be placed in a suitable condition. The critical condition is when a fault in one part of the system will be occurred. In this condition, voltage profile will be changed, so that in some buses system will be unstable. In this situation two factors can be used: decreasing of the load in some busses are unstable or placing TSSC at the end of lines for these kinds of buses. In this paper, the bus voltage profiles were improved by placing TSSC. Using the wind farm and TSSC, by comparison to the other states (normal state, removing the line from the circuit state, etc.), may improve the stability of the system and reduce its loss while occurring the fault.

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DOI: https://doi.org/10.30564/ese.v1i1.977