Effect Of Distributed Generation And STATCOM In Multi-Machine System For Real Power Loss Minimization

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Abstract: The importance of Distributed Generation (DG) can be understood by studying the effect of DG with Static Synchronous Compensator (STATCOM) in the multi-machine system. The DG system uses renewable energy sources which are connected to the conventional power system in order to minimize the real power losses in the power system. 9-bus system will be considered for this analysis. The appropriate location of the DG is identified based on the base case power result, bus voltage and total losses in the system. The STATCOM size and the appropriate location is decided by the voltage profile improvement and real power loss minimization in the system. The proposed work is carried out in PSAT with MATLAB / Simulink environment. The results ensure that the real power losses in the power system network will be minimized by placing DG and STATCOM at suitable locations.

Index Terms: DG, STATCOM, wind system, real power loss

1 INTRODUCTION

The demand of electrical energy is rapidly increasing, to meet out the demand new power plant, transmission lines are need to be installed. This involves cost and another one is the time factor. Generally, a new power generation must be from the renewable energy sources due to limitations of conventional energy sources. The advantages of using renewable energy sources are available free of cost in nature and but for energy harvesting need some equipment. Nowadays the wind power plant and solar PV power generation are becoming more popular and it can be installed nearer to the load center, so that transmission loss will be minimized. The real power loss minimization by optimal VAR control using differential evolution algorithm is discussed in [1]. The importance of FACTS device and location their selection are discussed in [2]. The STATCOM characteristics and installation of STATCOM at load bus to improve the bus voltage profile are discussed in [3]. The voltage stability of the system with integrated system is analyzed in [4]. The bus voltages, real and reactive power losses in the northern Nigeria 330 kV network is analyzed by using PSAT [5]. The effect of wind turbine system based on Doubly Fed Induction Generator(DFIG) and FACTS device on the power system are discussed to improve the stability of voltage and quality of power in the electric power system [6]. The 16 bus distribution systems with DFIG wind turbine using FVSI Index is discussed for Voltage profile improvement [7]. The particle swarm optimization and genetic algorithm based optimal reactive power calculation for in Konya Eregli distribution network for reducing real power loss is discussed in [8]. The real power loss minimization by using whale optimization algorithm and yin-yang-pair optimization algorithm was applied to solve optimal dispatch of reactive power problems are discussed in [9].

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2 PROBLEM FORMULATION

2.1 DFIG for Wind Power Generation

Nowadays, the DFIG setup will becomes more popular for the wind power generation. Basically the fixed speed wind turbine system and variable speed wind turbine systems are available. For the maximum power point tracking from wind system, the variable speed wind turbine system will be suitable. The DFIG is a slip ring induction generator, the advantage of this generator, there is a provision at the rotor side to control the speed and tap the slip power at slip frequency. When converters are connected at the rotor side, the converter power rating will be reduced compared to stator side. This is the main advantages of DFIG compared to the Singly Fed Induction Generator (SFIG). The power electronic converters are used to controls the rotor currents to attain the variable speed which is necessary for the maximum energy harvesting. In DFIG system the rating of power electronic converter required is reduced, the reason is that here the power electronics converter connected to the rotor side of the generator, the rotor power typically less than 25% of the overall output power. The DFIG system provides variable rotor speed control which will helpful for reducing power losses.

2.2 Static Synchronous Compensator (STATCOM)

The property of the STATCOM is that it can able to provides variable reactive power with respect to the variations in bus voltage and help the power grid to maintains its grid stability. The voltage source converter based STATCOM is more suitable for better controllability. The STATCOM which converts the DC input voltage into AC output voltage, it will maintain the active and reactive requirements of the system. STATCOM provides required amount of reactive power irrespective of the load bus voltage, whereas SVC output depends on the load bus voltage. It provides constant current characteristics when the voltage variation at the minimum limit. The Installation STATCOM at the appropriate locations of the power system will be increases the power transferring capability of the system by enhancing stability of voltage. The STATCOM also act as active filter for improvements in power quality. The fig.1 shows the basic structure of the STATCOM

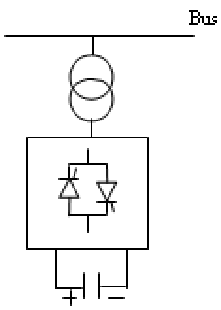

Fig. 1 STATCOM basic structure

3 ALGORITHM FOR THE PROPOSED WORK

a) Read the 9-bus system information such as line data, bus data and also read STACTCOM and DFIG wind system data
b) Initially run the base case load flow analysis using PSAT and observe bus voltage and losses in the system.
c) Next, consider the modified system (60% increased load), again load flow analysis repeated and observe bus voltage and losses in the system. By observing bus voltages identify the location of STATCOM.
d) Next, modified system with STATCOM at bus-6 is analyzed by conducting load flow analysis and observed the slack bus active and reactive power generation, bus voltages & total losses in system
e) Next, modified system with DFIG wind system at bus-6 is analyzed by conducting load flow analysis and observed the slack bus active and reactive power generation, bus voltages & total losses occur in system
f) Then, compare the slack bus generation, bus voltages and total losses in the system for the above different cases.
g) Then, make the conclusion about the effect of distributed generation (i.e., DFIG wind system consider as distributed generation system) in the multi-machine system.

4 TEST SYSTEM

This section will discuss about the test system which is used to analyze the effect of distributed wind energy system in the multi-machine system. Here, the standard Western System Coordinating Council (WSCC) 9-bus Test system is considered for these analyzes. This system which consists of 9 buses in which one slack bus, two PV bus, three PQ bus and others components are three two winding transformers and 6 lines. The base KV levels are 13.8 kV, 16.5 kV, 18 kV,230 kV and base MVA is 100 MVA. The Fig. 2 shows the modified test system with STATCOM at 6th bus. The Fig. 3 represents the modified system including DFIG wind generation system at 6th bus. The models are developed in PSAT and MATLAB Simulink environment.

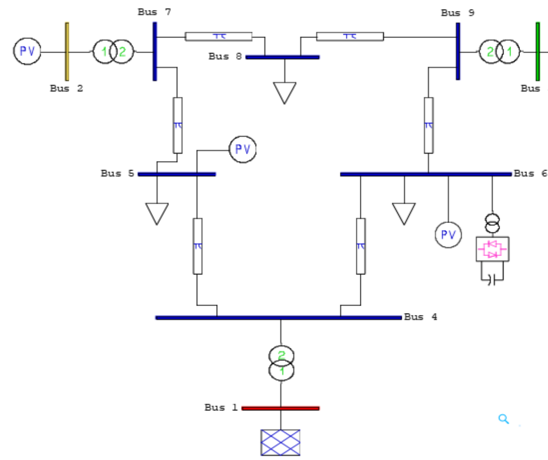

Fig. 2 Modified test system with STATCOM at 6th bus

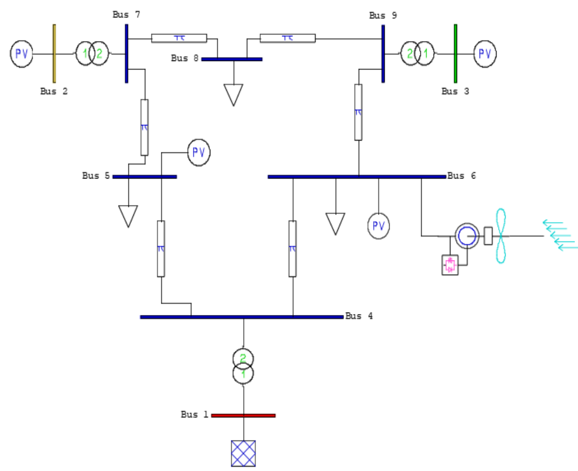

Fig. 3 Modified test system with DFIG wind system at 6th bus

5 RESULTS AND DISCUSSION

This section will discuss about the result obtained for the base case test system and modified system (60% increased load). After implementation of STATCOM at 6th bus and DFIG wind system at 6th bus the results are made further analyzed and compared. The Table 1. shows the power flow result for the base case system. It is observed from the table .1 that all the bus voltages are above 1 p.u. and there is no stability issue and no need of any improvement in the system. So, for the analyze purpose consider the modified system in which load bus real and reactive power demand is increased to 1.6 times the base value (60% increased load) and this modified system is considering for further analysis.

TABLE 1

POWER FLOW RESULT: BASE CASE SYSTEM

Bus No.	Voltage (p.u)	Phase (rad)	P gen (p.u)	Q gen (p.u)	P load (p.u)	Q load (p.u)
1	1.0400	0	-0.1353	0.1132	0	0
2	1.0250	0.2504	1.6300	-0.0493	0	0
3	1.0250	0.1541	0.8500	-0.1545	0	0
4	1.0338	0.0072	0	0	0	0
5	1.0250	0.0362	0.8500	0.2498	1.25	0.5
6	1.0182	-0.0087	0	0	0.9	0.3
7	1.0328	0.1540	0	0	0	0
8	1.0211	0.0954	0	0	1	0.35
9	1.0350	0.1072	0	0	0	0

The Table 2. shows the power flow result for the modified test case system. It is observed from the table that, compared to all other buses, the bus-6 has the low voltage of 0.9936 p.u. Based on the analyses, it is noted that, there is requirement of reactive power at bus-6 and it may be supplied by slack bus-1. This will increase loading of transmission line and additional burden to the slack bus. The real power supplied by slack bus is 1.7614 p.u. and reactive power supplied by slack bus is 0.2570 p.u. Hence, it is planned to install the STATCOM at bus-6, the results are further analyzed.

TABLE 2

POWER FLOW RESULT: MODIFIED SYSTEM (60% INCREASE IN LOAD)

Bus No.	Voltage (p.u)	Phase (rad)	P gen (p.u)	Q gen (p.u)	P load (p.u)	Q load (p.u)
1	1.0400	0	1.7614	0.2570	0	0
2	1.0250	0.0178	1.6300	0.1162	0	0
3	1.0250	-0.0722	0.8500	0.0611	0	0
4	1.0304	-0.0948	0	0	0	0
5	1.0250	-0.1518	0.8500	0.7047	2	0.8
6	0.9936	-0.1852	0	0	1.44	0.48
7	1.0228	-0.0795	0	0	0	0
8	0.9963	-0.1604	0	0	1.6	0.56
9	1.0227	-0.1197	0	0	0	0

The Table 3. shows the power flow result for the modified test system with STATCOM at bus-6. From the table, it is observed that, when installing STATCOM at bus-6, bus voltage will be improved from the value of 0.9936 pu to 0.9950 pu. The reactive power generation from slack bus is reduced from 0.2570 p.u. to 0.2499 p.u. By comparing Table.2 and Table.3 real power supplied by slack bus is same for the system with and without STATCOM. Hence, it planned to install the distributed generation (DFIG wind generation system) at the bus-6 the results are further analyzed.

TABLE 3

POWER FLOW RESULT: MODIFIED SYSTEM WITH STATCOM AT BUS-6

Bus No.	Voltage (p.u)	Phase (rad)	P gen (p.u)	Q gen (p.u)	P load (p.u)	Q load (p.u)
1	1.0400	0	1.7613	0.2499	0	0
2	1.0250	0.0179	1.6300	0.1151	0	0
3	1.0250	-0.0721	0.8500	0.0557	0	0
4	1.0308	-0.0948	0	0	0	0
5	1.0250	-0.1517	0.8500	0.6996	2	0.8
6	0.9950	-0.1852	0	0.0164	1.44	0.48
7	1.0228	-0.0794	0	0	0	0
8	0.9965	-0.1603	0	0	1.6	0.56
9	1.0230	-0.1196	0	0	0	0

The Table 4. shows the power flow result for the modified test case system with DFIG wind generation system at 6th bus. When installing DFIG wind generation system at bus, the power required bus-6 is supplied locally by distributed generation. Hence, it will reduce the transmission line loading and slack bus burden further reduced. From the Table 3 & 4, is noted that slack bus real power generation reduced from 1.7613 p.u to 0.3050 p.u. and reactive power generation reduced to 0.2499 p.u. to 0.2232 p.u.

TABLE 4

POWER FLOW RESULT: MODIFIED SYSTEM WITH DFIG WIND SYSTEM AT BUS-6

Bus No.	Voltage (p.u)	Phase (rad)	P gen (p.u)	Q gen (p.u)	P load (p.u)	Q load (p.u)
1	1.0400	0	0.3050	0.2232	0	0
2	1.0250	0.1431	1.6300	0.1079	0	0
3	1.0250	0.0876	0.8500	0.0663	0	0
4	1.0278	-0.0164	0	0	0	0
5	1.0250	-0.0579	0.8500	0.7573	2	0.8
6	0.9950	0.0090	1.4400	-0.2742	1.44	0.48
7	1.0233	0.0458	0	0	0	0
8	0.9967	-0.0207	0	0	1.6	0.56
9	1.0224	0.0400	0	0	0	0

The Table 5. shows the Comparison of power flow result for different cases. From the comparison table, it is observed that, real power and reactive power generation on slack bus is reduced when installing STATCOM and DFIG wind system in the bus-6. Similarly, total real power loss and reactive power losses also reduced. The modified system without STATCOM and DFIG wind system the total active power loss is 5.1425 MW and then when installing STATCOM at 6th bus the total active power loss is being reduced from 5.1425 MW to 5.1256 MW. The total active power loss is reduced from 5.1425 MW to 3.5004 MW when installing the DFIG wind system at 6th bus. Hence, form the comparison table, is noted that the active power losses in the system is reduced when installing the distributed generation and DFIG wind system at the suitable locations.

TABLE 5

COMPARISON OF POWER FLOW RESULT FOR DIFFERENT CASES

		modified system	with STATCOM	with DFIG wind system
Slack bus generation	Real power [MW]	176.1425	176.1256	30.5004
	Reactive power [MVAR]	25.6976	24.9923	22.3214
Total generation	Real power [MW]	509.1425	509.1256	507.5004
	Reactive power [MVAR]	113.8981	113.6674	88.0576
Total Load	Real power [MW]	504.0000	504.0000	504.0000
	Reactive power [MVAR]	184.0000	184.0000	184.0000

The Fig. 4 shows graphical representation of slack bus power generation for different cases such as Modified system, with STATCOM and with DFIG wind system. It is clear from the graph, slack bus burden on power system network is reduced when installing distribution generation.

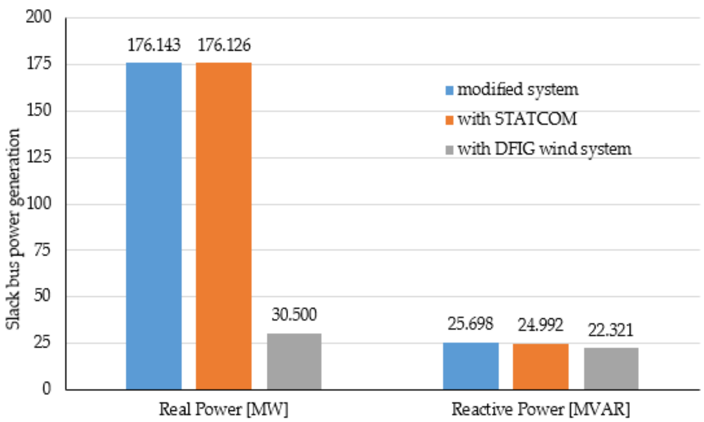

Fig. 4 Comparison of slack bus power generation

The Fig. 5 shows graphical representation of total real power losses in the system for different cases such as Modified system, with STATCOM and with DFIG wind system. It is clear from the graph, total active power losses in 9 bus test system will be reduced when installing distribution generation.

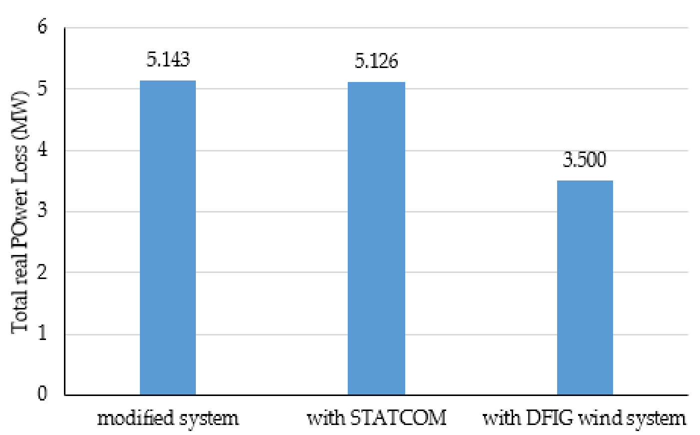

Fig. 5 Comparison of real power loss in the system

6 CONCLUSION

The WSSC 9 bus test system is to be considered for the analyzes of the proposed work. Base case load of the system is increased to 60% higher and considered as a modified test system for further analyzes. Here, the DFIG based wind system is considered as a distributed generation system. The effect of DG with STATCOM in the multi-machine system is analyzed for different cases. The analyzes is carried out in PSAT with MATLAB / Simulink environment. In modified test system, the additional requirement of real and reactive power load is supplied by slack bus, it will increase transmission loss and also increase the burden to the slack bus. But, when installing STATCOM at the load bus will supply sufficient reactive power locally and improve the load bus voltage. When installing a DFIG wind system nearer to the load, it will supply required real power and reduce th e slack bus burden and total real power losses. Hence, it can be concluded that, the DG with STATCOM in the multi-machine system will reduce the real power losses in the system.

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