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Performance Comparison of Flexible Alternating Current Transmission System (FACTS) Devices with Distributed Generation System

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ABSTRACT

With deregulation, rising of technologies and concern about the environmental effects, competition is particularly fostered in the generation side, thus allowing increased interconnection of generating units to the utility networks. When the distributed generation upsurges by using older control techniques, it is expected that the voltage change at each node becomes a problem. Therefore, it is necessary to use different FACTs devices to improve the voltage profile both at the bus and end consumers. Analysis has been done to find out the best suitable FACTs device for a particular capacity of a distribution network.

Keywords: *FACTs Device, STATCOM, SVC, SSSC, Distributed Generation*

1. INTRODUCTION

In recent times, Economic and social development of the world is driven by energy, whether in the form of restricted sources such as Coal, oil and Gas or in the form of Non- Conventional sources such as Wind, Solar, Biomass and hydroelectric or it's converted forms. [13]. The electrical power system is playing a vital role in the development of human requirements. It has become a basic necessity in the lives of humans. These requirements have grown continuously and to cope with the demand, it has been achieved through better utilization of maximum energy resources and components to generate electricity, which is transmitted through a high efficiency transmission line to satisfy customer needs [2, 13]. With the increase in power demand, renewable energies such as solar panels and wind turbine plants have started to play a big role in the global energy system [2, 11-12]. Therefore, in recent years there has been a growing interest in moving away from large centralized power generation toward distributed energy resources. Solar energy generation presents several benefits for use as a distributed energy resource, especially as a peaking power source [2].

The integration of renewable energy into the power system networks can potentially cause several challenges for the control of large central generators and the distribution system. A careful design, planning, installation and operation of the complex distribution system with renewable energy resources have to be carried out [3]. In this context, the electrical transmission and distribution plays a significant role in transporting energy from the generator site to customers. Regardless of the capacity of such a complex network, constant disturbances remain in the system which may be dangerous both for the customers and the power electronics equipment in the network. It is therefore recommended that the damage cause by disturbances should be limited and isolated by fast switching protection devices without affecting the rest of the distribution system [2-3]. Once reform, race has been presented with respect to generation; nonetheless power transmission structure is tilled performed by county monopoly [14].

Evolution in the technology of renewable energy such as wind turbines and Solar Panels in the MW range has broadened the interest and its connection to the distribution network. Today large scale integration of wind turbine is connected to the Grid with bulk power and controllability [1]. If number of distribution generation increases, as a result distribution network becoming more complex network. As the complication of the network increases, thus a more difficult protection system design cannot be ignored. A more precise study is required for the stability of the distribution system with the impact of distribution Generation (DG) [1].

Many techniques have been proposed for voltage Profile Improvement in distribution networks. These methods can be engaged by the utility grid and its customers [5]. For the compensation of wind-farm-integrated transmission systems using Flexible AC Transmission System (FACTS) devices are progressively considered in power system operation [7].

A number of studies have shown that FACTS devices, such a static VAR (Volt-ampere-reactive) compensator (SVC), SSSC and STATCOM can aid grid integration of DG units by supplying dynamic VAR under post fault conditions [4, 9-12].

2. TYPES OF DISTRIBUTED GENERATION

There are mainly three parts of Distributed Generators: First is induction, second is synchronous and third are electronic power inverters. External excitation always needs to start up the induction generators like an induction motor. It runs at synchronous, sub synchronous and super synchronous speed. Induction generators are quite inexpensive, as compared to synchronous machines. Wind power applications often use induction generators. A DC excitation field requires in synchronous machines. They need to synchronize with the utility network before connection. They are most commonly used with gas turbines and small hydro power plants. Synchronous generators are transistor switched systems such as inverters. Asynchronous generator is most commonly used with micro turbines, photovoltaic, and fuel cells.

3. METHODOLOGY

3.1 TOPOLOGY

Nowadays, in Distributed Generation, we are widely used renewable energy sources and connecting it with directly to the distribution system. As we can see in the simulation model 25km long Distribution feeder is considered because in present distribution system also, we are using maximum 25km long distribution feeder line. Distributed generation system is connected with 11kv grid with realization that 11kv distribution transformer is connected to the substation and thereby it is connected to the interconnected power system network.

A wind farm consisting of one 1.5-MW wind turbine is connected to a 25-kV distribution system exports power to an 11KV grid through a 25-km 25-kV feeder. The 1.5-MW wind farm is simulated by 1.5 MW wind-turbines. Wind turbines use squirrel-cage induction generators (IG). The stator winding is connected directly to the 50 Hz grid and the rotor is driven by a fixed-pitch wind turbine. The pitch angle may control in order to limit the generator output power at its nominal value for winds exceeding the nominal speed (9 m/s). In order to generate power the IG speed must be slightly above the synchronous speed. Speed varies approximately between 1 pu at no load and 1.005 pu at full load.

Reactive power absorbed by the IGs is partly compensated by capacitor banks connected at each wind turbine low voltage bus. The rest of reactive power required to maintain the 25-kV voltage as bus B25 close to 1 pu will be provided by Different FACTs Devices used for the comparative study of performance. The 25Km long distribution line is taken with grounding transformer and distribution transformer of 25kv/11KV.

3.2 Performance of FACTs devices

All three FACTs Devices are used for the same topology and operating conditions that are without fault condition, fault condition with fixed load of 200kw of Resistive load and 1500kw of inductive load. The fault is created in between 10s to 10.11s and observed the condition of different electrical parameters like Voltage profile, Reactive power Compensation, Active power consumption, Flow of Current from all three sides and most importantly the response time of all the three FACTs Devices during fault conditions. The analysis of fault is done on L-G, LL-G, and LLL-G fault conditions. Keeping all above conditions same, only the FACTs device is to be changed.

In the below simulation model with fault with connecting STATCOM, the fault is done between 10sec to 10.11sec.By keeping the input wind speed constant at 9m/s and pitch angle at 0 degrees, will get constant output up to 10sec but after 10sec voltage profile is decreased to 0.65 pu and active power is decreased to 0MW and in negative also that is just to deliver the reactive power requirement of the system. At the same time reactive power requirement is increased drastically and that can be observed by output simulation graph. At the point of 10.11 second the reactive power requirement is at the peak and at the same time the reactive power requirement is compensated by STATCOM and within 20ms again reactive power requirement is becoming less and with that the voltage profile is improved up to 1.02 pu and maximum active power is generated by SCIG.

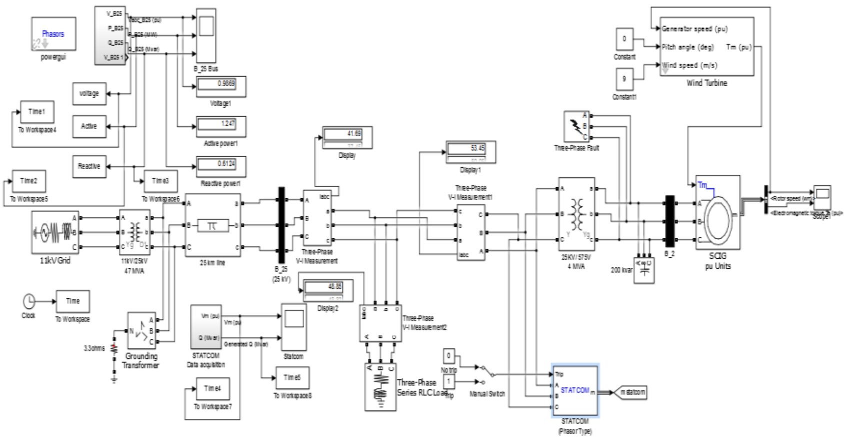

Figure 1. STATCOM with fault.

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In the below simulation model with fault with connecting SVC, the fault is done between 10sec to 10.11sec.By keeping the input winds speed constant at 9m/s and pitch angle at 0º will get constant output up to 10sec but after 10sec voltage profile is decreased to 0.71pu and active power is decreased to 0MW and in negative also that is just to deliver the reactive power requirement of the system. At the same time reactive power requirement is increased drastically and that can be observed by output simulation graph. At the point of 10.11sec the reactive power requirement is a maximum and at the same time the reactive power requirement is compensated by SVC and within 40ms again reactive power requirement is becoming minimum and with that the voltage profile is improved up to 1.01pu and maximum active power is generated by SCIG.

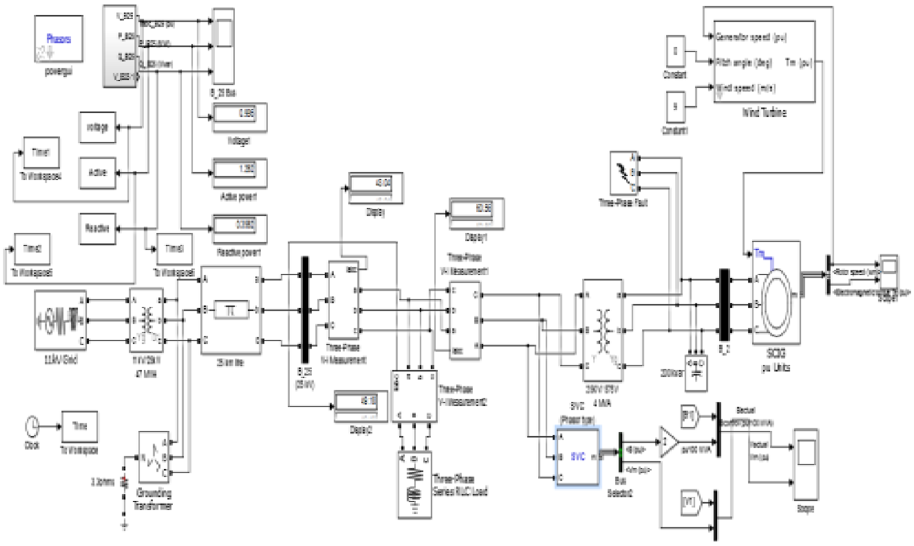

Figure 2. SVC with fault

In the below simulation model with fault with connecting SSSC, the fault is done between 10sec to 10.11sec.By keeping the input wind speed constant at 9m/s and pitch angle at 0º, will get constant output up to 10sec but after 10sec voltage profile is decreased to 0.6 pu and active power is decreased to 0MW and in negative also that is just to deliver the reactive power requirement of the system. At the same time reactive power requirement is increased drastically and that can be observed by output simulation graph. At the point of 10.11Sec the reactive power requirement is highest and at the same time the reactive power requirement is compensated by the SSSC and within 30ms again reactive power requirement is becoming minimum and with that the voltage profile is improved up to 0.94 Pu and maximum active power is generated by SCIG.

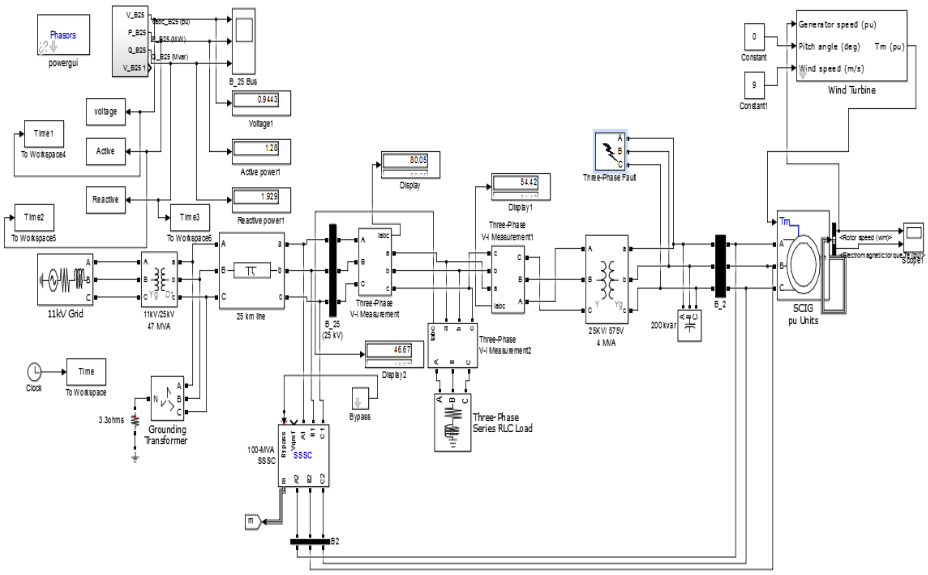

Figure 3. SSSC with fault

4. PERFORMANCE COMPARISION

4.1 VOLTAGE PROFILE AND REACTIVE POWER

Configuration	Electrical Parameters		
	Active Power	Reactive Power	Voltage (PU)
Without Fault Without FACTs Devices	1.288	2.007	0.9423
With Fault Without FACTs Devices	1.283	2.011	0.9416
With Fault, with STATCOM	1.247	0.6124	0.9869
With Fault, with SVC	1.262	0.3562	0.995
With Fault, with SSSC	1.28	1.929	0.9443

Table 1: Comparison of electrical parameters

Active Power consumption is less in STATCOM to compare to other two FACTs devices shown in table 1, but there is not much difference of Active Power consumption in all three FACTs Devices.

To Maintain the Voltage Profile of the system nearer to 1 PU, It is necessary to compensate reactive power requirement of the system. Here in this topological operating condition minimum reactive power compensation is required in SVC shown in table-1 thus the overall size and cost of compensation can be minimized by using SVC.

In Distribution System Maintenance of Voltage Profile is the basic and most important requirement and an excellent Voltage Profile is maintained by SVC nearer to 1 PU as shown in table-1.

If the Current flowing from the utility side or generation side will be minimized, so that it will reduce thermal overloading of the line and will increase the loading capability of the system. On the other hand, if the current flowing from the Load side is minimized then the energy billing of the customer will be reduced.

4.2 OUTPUT WAVEFORMS

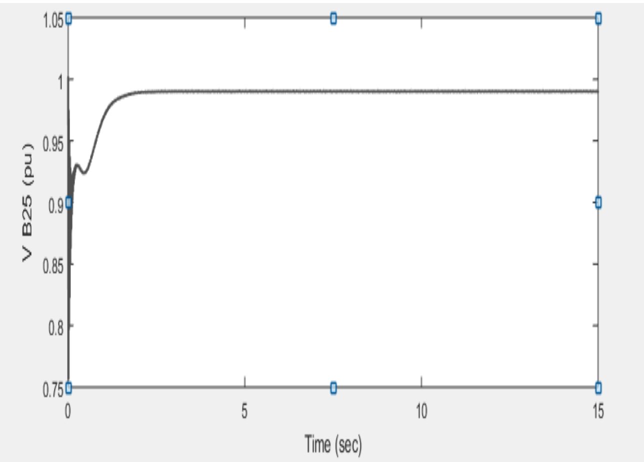

Figure 4: V_B25 v/s Time

Above figure 4 shows the results of voltage at bus 25 KV and it is cleared from the waveform that in without fault without FACTS device's condition, the voltage level is nearly at 0.9423 pa.

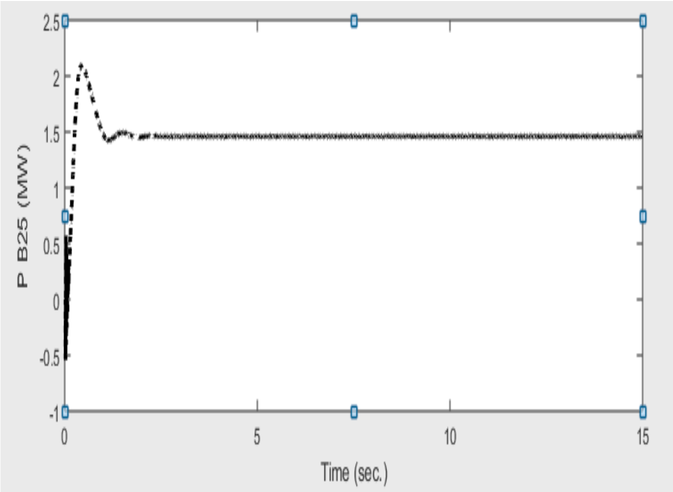

Figure 5: P_B25 v/s Time

From the figure 5, it is clear that the active power at bus 25 is nearly about 1.288 MW.

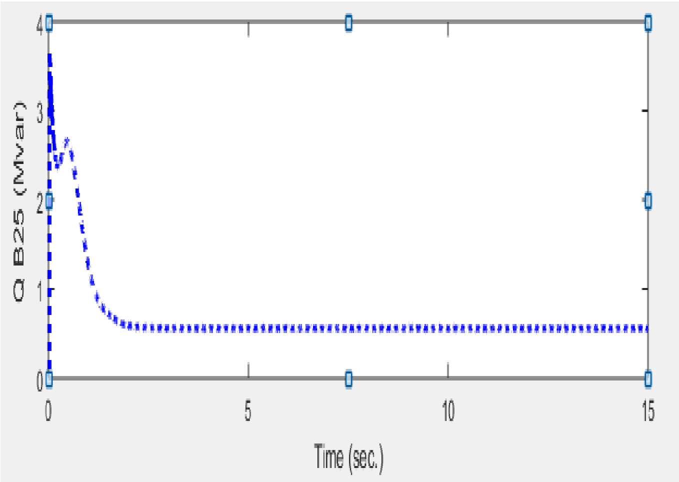

Figure 6. Q_B25 v/s Time

Figure 6 shows the result of reactive power at bus 25 in without fault without FACTS device condition and from the waveform it cleared that in such condition the reactive power on this bus is nearly about 2.007 Mvar.

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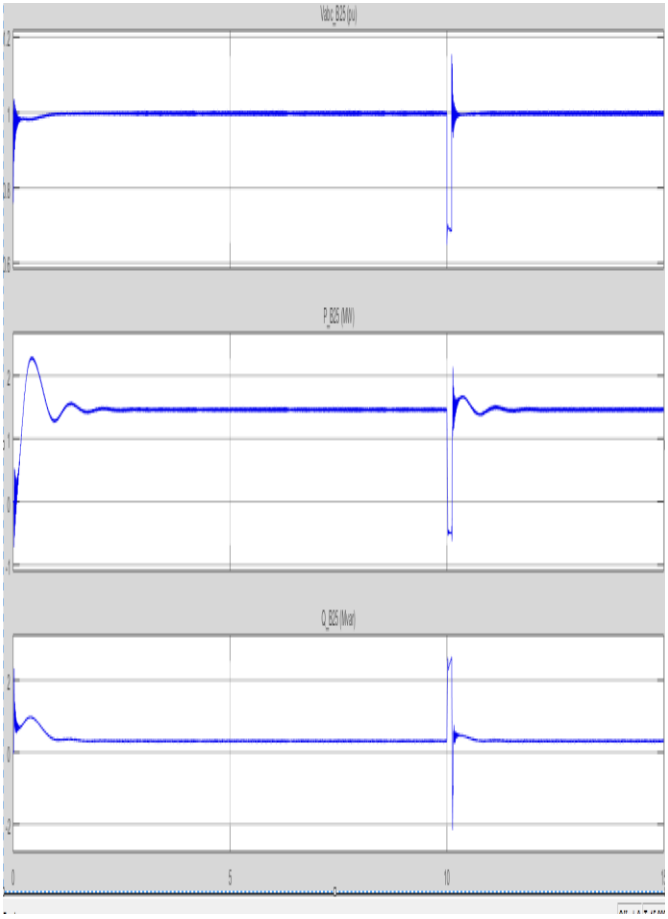

Figure 7. Output waveforms of with fault with STATCOM

Figure 8. Output waveforms of with fault with SVC

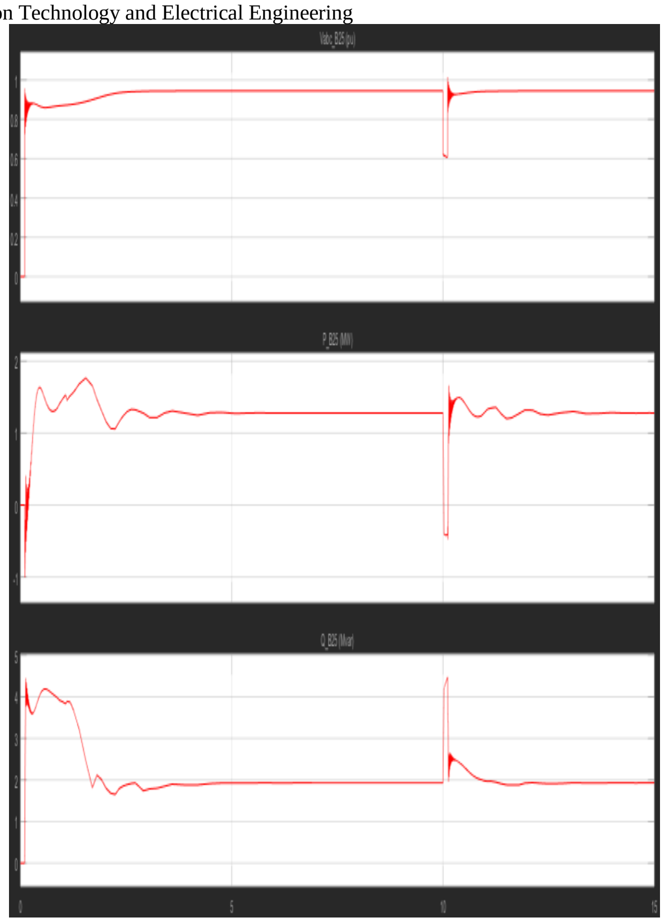

Figure 9. Output waveforms of with fault with SSSC

Figure-7 shows the output waveform of STATCOM which smooth compensation is observed with respect to SVC and SSSC Configurations shown in figure-8 and 9 as well as power output waveforms of STATCOM is taking minimum time to give stable output after being subjected to a Fault. The initial condition of Voltage profile, Active Power and Reactive power waveforms disturbance have lasted for approximately five seconds in SVC and SSSC, with a comparison to that Magnitude and time are both less and disturbance lasts for Two seconds in STATCOM.

4.3 RESPONSE TIME

Response time is the time taken by FACTs device to regain the steady state conditions, which was there before Fault condition.

In STATCOM, after being subjected to a fault and clearance of fault it is quickly recovering the steady state conditions of Voltage profile. It is found that the response time of STATCOM is 5ms as shown in figure-7.

In SVC, after clearance of the fault the disturbance is higher compared to STATCOM and it is found that the response time of SVC is 11ms as shown in figure-8.

In SSSC, after clearance of the fault the disturbance is quite higher compared to STATCOM and SVC. It is found that the response time of SSSC is 15ms as shown in figure-9.

5. CONCLUSION

No one device is preferable with respect to all parameters requirements. For particular requirement power engineer or operator has to select one or two parameters which are to be maintained to choice the FACTs device for specific application. Here in this configuration and operating conditions (Distribution network) the most important parameters are voltage profile and reactive power compensation for that SVC is preferable. But if operator consider the conditions and requirements of transmission networks STATCOM is preferable.

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