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Power Flow Analysis of Long Transmission Line Using SVC, SSSC and UPFC Integrated with Wind Power

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Abstract: ***This research work shows effect of different types of FACTS devices in power transmission line. Till now all the FACTS devices have its own DC source but this paper use wind energy based turbine to generate electrical power and use this power as source for FACTS devices. This paper deals with effect of Static VAR Compensator, Static Synchronous Series Compensator and Unified Power Flow Controller on the power quality at receiving end. The voltage at the receiving will be effected by different types of non-linearity present in power transmission which improved by wind turbine based FACTS devices. By result we will compare wind turbine based different FACTS devices by which we can conclude that UPFC will have maximum capability for power quality improvement.***

Keywords: SVC, SSSC, UPFC, Wind power, FACTS

1. Introduction

Modern power system relies on quality and stability of the transmitted power. The power flow can be controlled in many ways. One of these methods is to control reactive power. In past mechanical switched group of capacitor and inductor were used for power factor improvement and control overall power flow in power system. The controlling of these switches has been area of concern for engineers from many years. The option is the use of semiconductor switches which have faster response and smooth working due to small value of time constant as compared to mechanical switches. Thus these type of switches can improve dynamic stability of the system very effectively in all manner.

Such type of power electronics device known as facts devices by which it is possible to control the power flow of the power system. Basically facts are fast in operation and reliable in operation. With the use of these devices. The transient stability limit of the power transmission system is improved if the controllers tuning is proper. SVC has the ability of improving stability and damping by dynamically controlling its reactive power output. The transient stability improvement of the two area system with different loading conditions is investigated in this work. Shunt Flexible AC Transmission System (FACTS) devices, when placed at the mid-point of a long transmission line, play an important role in controlling the reactive power flow to the power network.

By providing dynamic reactive power, svc can be used for the purpose of regulating the system voltage, compensating the voltage at reasonable level, improving the capacity of the transmission line. From the operational point of view, the SVC adjusts its value automatically in response to changes in the operating conditions of the network. By suitable control of its equivalent reactance, it is possible to regulate the voltage magnitude at the SVC point of connection, thus enhancing significantly the performance of the power system. In its simplest form, SVC consists of a TCR in parallel with a bank of capacitors.

SSSC (Static synchronous series compensator) is one of the FACTS device connect in series with transmission line. Desire controllers are use for series compensation of power to get power quality improvement. It Controls reactance of the transmission line by injecting reactive power by means of a VSI (Voltage source inverter) and a control input by controlling voltage at connecting point of the system.

UPFC is the most versatile device among FACTS devices. It provides the control of transmission system parameters such as voltage, phase angle and line, having both type of connection in series and parallel with transmission line. There have been many studies intended for mathematical modeling, impacts on power systems and control system design for UPFC.

Wind energy is a form of source of energy is now becoming one of the most favorite sources of energy among the different researchers in world due to easy availability, low cost and pollution free. The growth in wind power is tremendous over the last decade. This is expected to be continued in the upcoming years because the use of wind power is vital for the future expansion of the energy sector. The main key features of wind energy are pollution free, easy availability, low maintenance, cost effective, and most of all renewable and everlasting. So the dependency upon wind energy would be a great scope for future. Thus these days have great emphasis towards use of wind energy in various technologies and to increase contribution of wind based technology in main power system.

2. Simulation Modeling

To study the performance of power system under the given three wind turbine based FACT devices, four Simulink models have been made.

Figure 1 shows Simulink model without any FACTS devices. In this first model a transmission line is connected to a grid and the grid voltage is taken as 11k volts. The transmission lines are used to transmit power at this voltage.

The voltage level is stepped down using transformer of proper rating to get operating voltage for load. The non-linearity present in the transmission line or inductive load in the grid system will generate harmonics at receiving end and as the result will shown in result section.

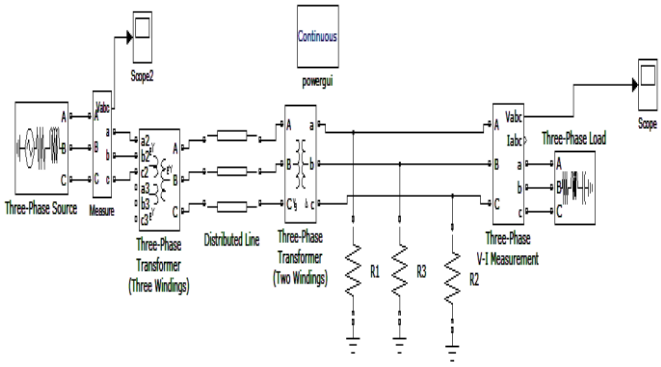

Figure 1: Simulink model without any FACTS device

Figure 2 shows connection of SVC with previously discussed transmission line. It is basically connection of shunt branch having a back to back convertor. The SVC gets energy from generator using wind turbine. Wind turbine have pitch angle 45^0, wind speed 14 m/s an induction generator will generate electrical power and feed into rectifier section of back to back convertor. Rectifier will provide DC at output which is stored into capacitor bank. This bank will again connect inverter section of back to back convertor. This inverter section will convert DC into compatible form of AC of power system network. For this purpose gate triggering circuit gets reference from grid voltage. The supply to convertor is given by wind turbine based generator.

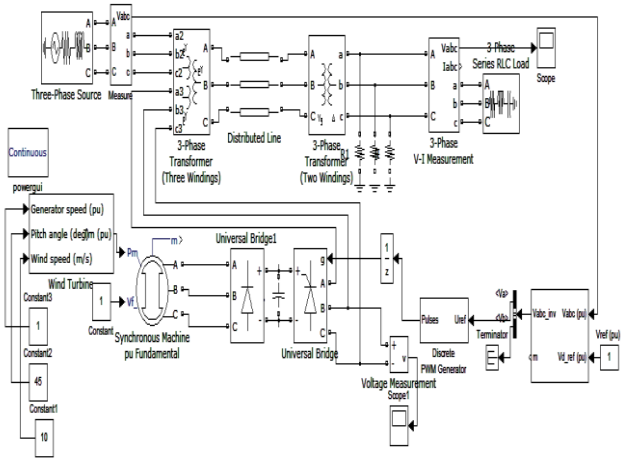

Figure 2: Simulink model with SVC

Figure 3 shows connection of SSSC with transmission line. For this purpose transformer of single phase winding rating are used. Where secondary is connected with transmission line and primary is available to get power from inverter section of back to back convertor circuit. One terminal of primary is connected with output of one phase of the inverter. Similar connections are also made for rest of the phases. Again here SSSC gets energy from wind turbine based induction generator. This induction generator will fed power to rectifier of back to back convertor and feed energy to connected capacitor branch. The supply to convertor is given by wind turbine based generator. The measurement unit is used at the receiving or load end will measure the value of voltage and response is shown by connected scope.

As we know that the UPFC is a FACT device having capability of both shunt and series compensation. Similar to both models the UPFC will get energy from connected wind turbine based induction generator. Figure 4 shows Simulink model for UPFC based Power supply system have one shunt connected transformer having two primary winding and one secondary winding. This type of connection will provide shunt compensation. Series Compensation will also be provided in the same transmission line. For this connection 3 single phase transformers are used. Primary of these is grounded at one end and other end is connected to the output of 3 – phase inverter along with each phase. The supply to convertor is given by wind turbine based generator. The measurement at receiving or load end has the similar technique.

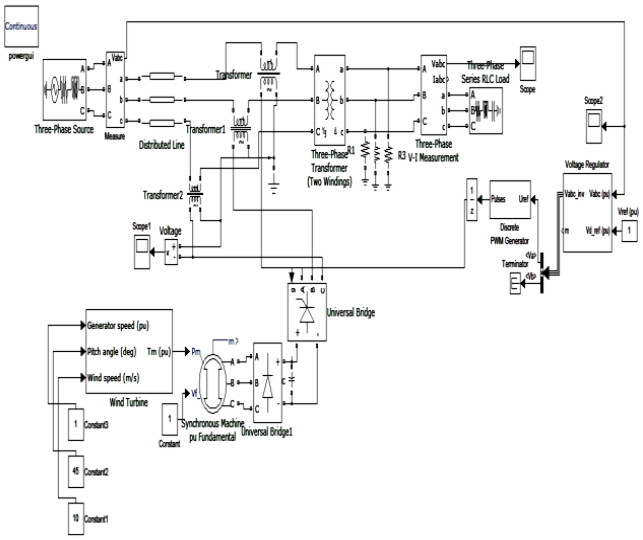

Figure 3: Simulink model with SSSC

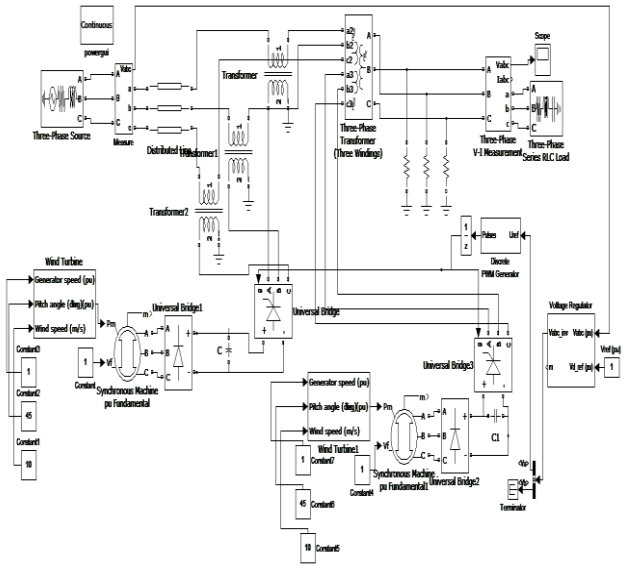

Figure 4: Simulink model with UPFC

3. Results and Discussion

As this research work is for comparative study of SVC, SSSC and UPFC

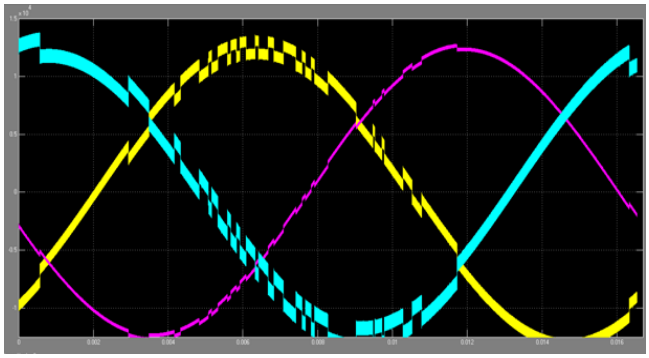

Figure 5: Output without any FACTS devices

The above figure shows the output of wind turbine based Induction generator. This supply has magnitude of voltage with stable nature used to feed as a source for connected different FACTS devices.

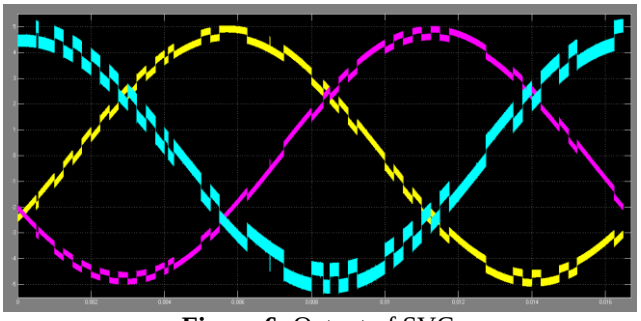

Figure 6: Output of SVC

Above figure shows voltage waveform of system based on wind turbine based SVC. This SVC injects voltage after being disturbed by non-linear load and thus waveform of these voltages will improve.

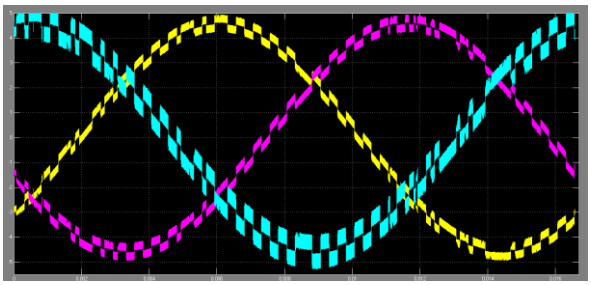

Figure 7: SSSC Output

Above figure shows voltage waveform of system based on wind turbine based SSSC. This FACTS device is place in series with transmission line of the power system and get in action after disturbance by non linear load.

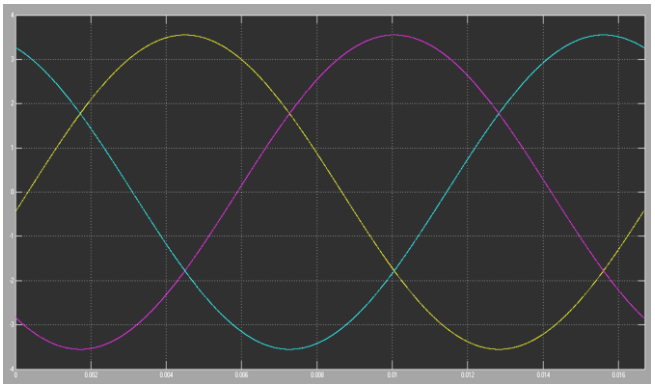

Figure 8: UPFC Output

Above figure shows voltage waveform at load end of power system which has UPFC system again this fact device will act and try to obtain the original voltage waveform as in supply ends.

All the three cases are get effect with same loading condition that means whatever the distortion is producing is just same for all system. But the effect of SVC, SSSC, UPFC this effect will be eliminated. By comparison of above voltage waveforms we can conclude that for improvement of distortion in supply due to different non-linearity in power system, UPFC is superior than any other types of power electronics based FACTS devices. Application of wind turbine provides better scope for increment in the contribution of renewable energy sector mainly in case of power system reliability and improvement in supply.

4. Conclusion

As we see by figure 5, that a transmission line without FACT device will have higher deviation from standard waveform. The result has been discussed for one cycle only. Transmission line with SVC will have improved waveform than previous line. Similarly by comparison of another two connected wind turbine based FACT devices will provide better waveform. Thus by comparison we get best result in case of UPFC based transmission line.

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