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Mustak Ahamad
M. Tech Student, Department of Electrical Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Vinay Kumar Tripathi
Assistant Professor, Department of Electrical Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Correspondence
Mustak Ahamad
M. Tech Student, Department of Electrical Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India

Power quality improvment in a grid connected wind farm using SVC

Mustak Ahamad and Vinay Kumar Tripathi

Abstract
Unbalancing due to reactive power leads to issues like deviation in voltage in conditions of load change and limitation in power transfer. Poor voltage quality is received due to reactance in AC loads which leads to heavy consumption of power which is reactive in nature. Thus in various power distribution systems, the reactance in transmission of power has caused a significant effect. Therefore to maintain the quality of electricity in the distribution system of electricity is currently a major issue. The term energy quality usually refers to maintain the best quality of energy in the production, transmission, distribution and use of energy.

The power which is generated from renewable source of energy fluctuates because of the environmental conditions. Integrating these energy systems which are renewable can lead to problems which can affect the functioning of the grid. As we know that the nature of the wind energy is fluctuation thus injection of the wind power in the grid causes fluctuations. In our project we have shown that how the problems arise as the wind power source is connected to the grid. Therefore in our project we have proposed a scheme to mitigate the problems of power quality by using a facts device called SVC connected to PCC. We will then compare the output with the outputs without any compensating device at the end. Matlab Simulink is used to implement the control scheme for wind energy generation system which is connected to the grid.

Keywords: Thermal energy storage, latent heat, energy efficiency

Introduction
For a wind power plant connected to a grid the techniques of improvement in power quality have been presented in this paper. Because of dominating kind of wind power being cost effective and robust it is asynchronous in nature. There is no contribution of the induction generators to regulate the grid voltage and also reactive power is substantially absorbed by them.

As there are fluctuation in wind speed, these are transmitted to the mechanical torque produced in the operation of a fixed speed wind turbine. Therefore large fluctuations in the generated electrical power are received with respect to generation of wind. These fluctuations can be seen as harmonic distortions, sags and swells in the system. For our project main requirements involve.

a. Power supply with reactive component
b. Voltage control power
c. Quality controller
d. Frequency controller

Power quality problems
There are various factors which influence the power quality which can be type of loads at the consumer end, design of the equipment and utility operations. Power quality problems are also generated and propagated by manufacturers of the utility equipment's, vendors and by their customers. Also power quality problems can be notices even if the supply is constant because of various loads at the consumers end. So a collective effort is demanded to overcome the problem of the power quality [8].

Static VAR compensator
The reactor can be regulated by assembling the device with a thyristor switch and the values of current and voltage that flow through the inductor are regulated by providing required firing angle. Thus the reactive power of the inductor can be regulated in correspondence to this.

Our proposed model can be used for reduction of regulation of reactive power which are even showing time delay of zero across extended ranges. Some of the schemes followed by the SVC devices are shown below.

- Thyristor regulated capacitor
- Thyristor regulated reactor
- Self-reactor
- Thyristor regulated reactor having a constant capacitor
- Thyristor regulated capacitor with thyristor regulated reactor

Design

In the one-line configuration of the SVC, through the PAM type of modulation by the thyristors, the reactor might be shifter internal to the circuit and this shows a constantly variable type of VAR to the electrical system. In this mode, extended levels of voltages are regulated by the capacitors and this is mostly known for providing efficient control. So, the TCR mode provides good control and enhanced reliability. And the thyristors can be regulated in an electronic way.

As the other semiconductors do, the thyristors are also known for their delivery of hot and cold condition purposes as deionized water is used. To restrict harmonics which are unwanted as an effect of reactive load, the waves are smoothened by introducing high range of filters generally. MVAR in the required power circuit is spread because of the filter's functionality which is capacitive in nature. Below is the block diagram of the system being discussed.

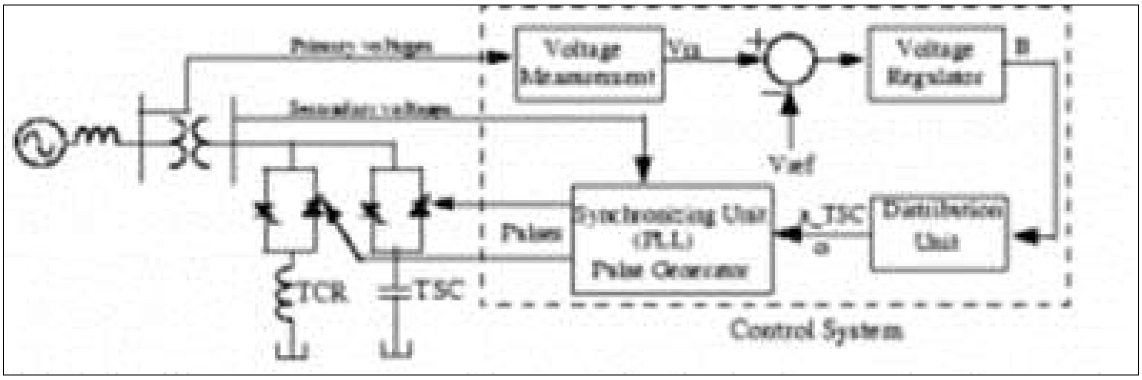

Fig 1: Block Diagram of SVC

The device has a control system and it is included with

- A distribution section which defines the thyristor switched capacitors and reactors those need to be switched internally and externally and calculates the firing angle
- A synchronizing section including a phase-locked loop which is synchronized on the pulse generator and the secondary level of voltages where those transmit a required number of pulses to the thyristors
- A calculating section measures the positive voltage that has to be regulated.
- A voltage controlling system that determines the variation in between the calculated and reference voltage levels.

The static VAR compensator device needs to be operated in a phasor simulation technique which is simulated using a powerful section. It can also be utilized in 3-phase power networks along with the synchronous type of generators, dynamic loads for the execution, and observation of the device on electromechanical variations. High-end designs of static VAR compensators can also be designed where the exact level of voltage control is necessary. Voltage controlling can be done through a closed-loop controller. This is the static VAR compensator design.

Static VAR compensator operation

In general, SVC devices cannot be operated at the line voltage levels, some transformers are required to step down the transmission voltage levels. This decreases the equipment and the size of the device necessary for the compensator even though the conductors be required to manage the extended levels of currents related to the minimum voltage.

Whereas in few of the static VAR compensators used in commercial purposes like electric furnaces, where there might be prevailing mid-range of bus bars are present. Here, a static VAR compensator will have a direct connection so as to conserve the transformer price. The other general point for connection in this compensator is for the delta tertiary winding of Y-type autotransformers which are used for the connection of transmission voltages to the other kinds of voltages. The dynamic behavior of the compensator will be in the format that how thyristors are series-connected. The disc type of SC's will have a high range of diameters and these are usually placed in the valve houses.

Static VAR compensator VI characteristics

Two approaches can be used for the operation of the static variable compensator:

- Voltage Controlling Mode: where the regulation of voltage is done within the threshold values
- Var Regulation Mode: Which means the device susceptance values are maintained at a constant level

The VI characteristics for the voltage controlling mode, are given as below

As far as the value of susceptance stays constant within the lower and high threshold limits demanded by the entire reactive power of the reactors and capacitors, then the value of voltage is controlled at the point of equilibrium which is termed as a reference voltage.

The decrease of the voltage is generally seen at the range of the values in between 1% and 4% at conditions when the output reactive power is extremely high. Under-shown are equations and the VI characteristics:

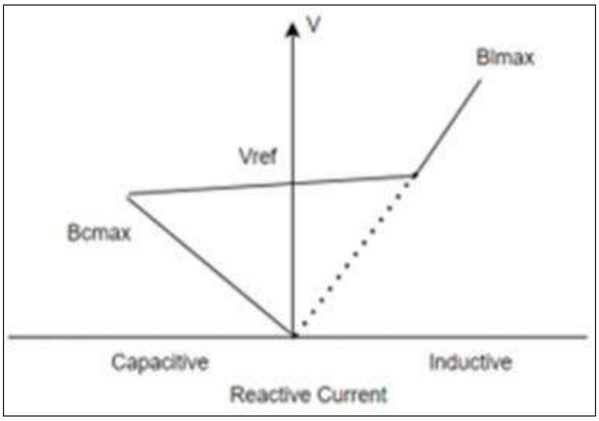

Fig 2: SVC VI Characteristics

$V = V_{ref} + Xs. I$ (When the susceptance lies in between high and low ranges of capacitor and reactor banks)
$V = -(I/Bc_{max})$ at the condition $(B = Bc_{max})$
$V = (I/Bc_{max})$ at the condition $(B = Bl_{max})$

Methodology

A three phase Asynchronous Machine is implemented by an Asynchronous Machine block with properties (wound rotor, single squirrel-cage, or double squirrel-cage) in our project. The mechanical torque dictates the mode of operation as it can operate as a generator as well as motor shown below:

- For negative values of Tm, the machine works as a generator.

The electrical part of the machine is represented by a fourth-order (or sixth-order for the double squirrel-cage machine) state-space model, and the mechanical part by a second-order system. All electrical variables and parameters are referred to the stator, indicated by the prime signs in the following machine equations. All stator and rotor quantities are in the arbitrary two-axis reference frame (dq frame). The subscripts used are defined in this table.

In our project the asynchronous machine works as a generator in which the input parameter is torque. The torque is supplied from a wind mill system which id shown in fig 3.

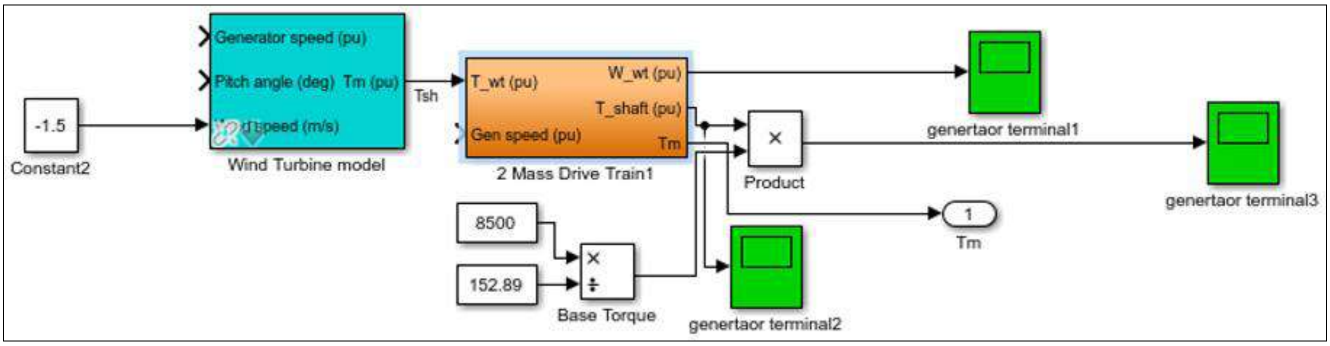

Fig 3: Wind mill connected to the generator terminal

The generator provides three phase voltage to the load and a SVC is connected in parallel to the three phase line. A RLC branch is connected in parallel before the SVC is installed. A balanced 3-phase voltage is generated by SVC and the solid state switches can be used to rapidly adjust phase and magnitude. Fundamental frequency voltages, signal generation control circuit, dc fixed capacitor and coupling transformer are fixed in a voltage source inverter which form components of the SVC. In power quality studies using the basic model SVC connected to source end in power system shown in Fig. The controller can be represented. Where various generators and loads are connected in a through an electrical transmission line and power is transmitted the case becomes analogous. The point to be noted is that in practice all the parameter of the transmission system are not known accept the control parameters of SVC.

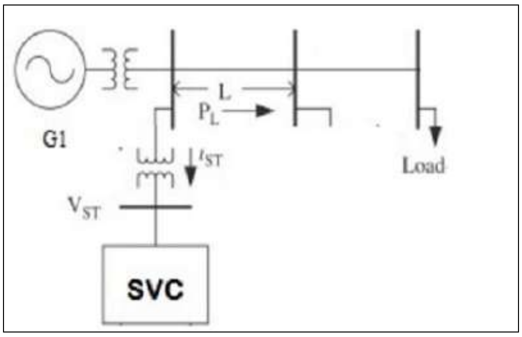

Fig 4: Single line diagram of SVC model connected to source end in power system

The pulse subsystem compares the reference current and the actual current and generates the pulses accordingly to switch on and off the thyristorsas shown in fig 5.

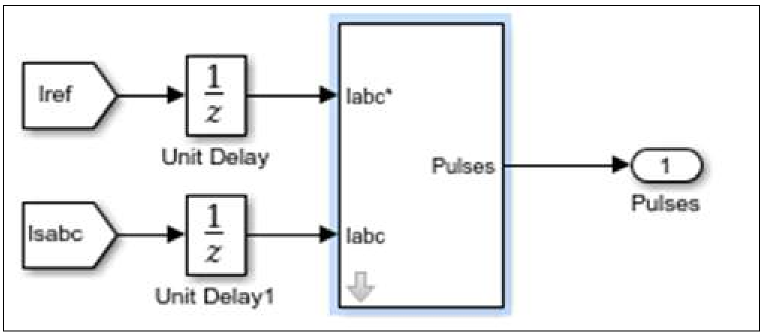

Fig 5: Pulse generating block

The thyristors get the gate pulse and generate the compensating current to eliminate the harmonics in the line. A universal bridge is used to generate the compensating current which has a configuration as shown in the fig. 6. The figure under shows the complete model of SVC based grid connected wind farm.

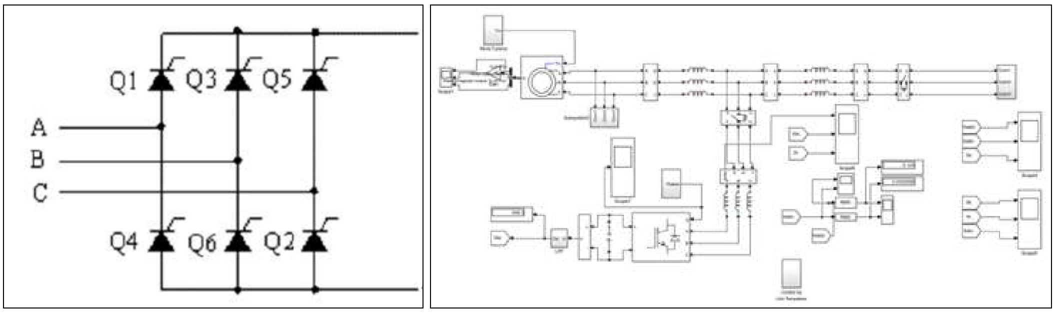

Fig 6: Model of grid connected wind farm using SVC

Results and Discussion

The results on running the system designed by us are shown in the form of wave forms where it is seen that the source current which has a waveform resembling square waveform but as SVC is installed the overshooting of the current is minimized and the graph follows sinusoidal path as shown in fig 7.

By executing our model we can see in fig as the wind speed increases the voltage in the source increases. In the graph the first part shows the source voltage Vsabc. The second part shows the source current. In the second part it is seen that the waveform is not pure and not purely sinusoidal but after applying the svc in parallel to the line the current is uniformly sinusoidal as shown in the figure.

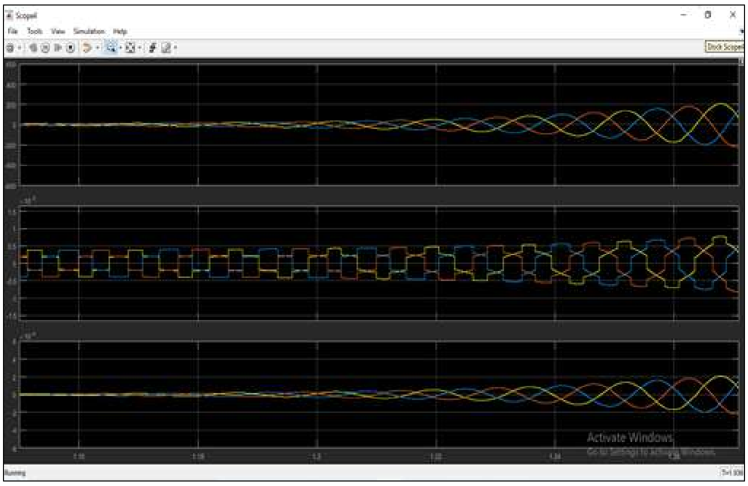

Fig 7: Source voltage Vsabc, Source current Isabc and Load Current Ilabc

Figure 8 shows the line current across the load along phase a, b and c separately which is shown under.

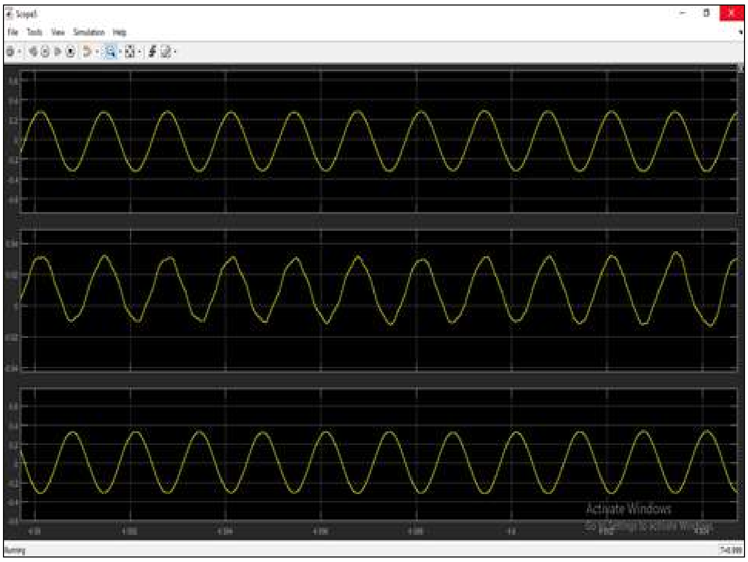

Fig 8: Ila, Ilb and Ilc

Here we can see that all the phases provide sinusoidal waveforms without distortions.
We can also see the pulses provided to the svc for switching the IGBT in SVC which is done by comparing the reference current and the source current according to which the compensating current is produced.

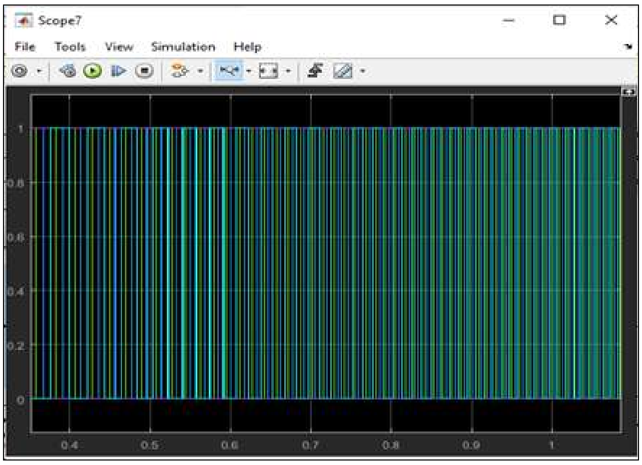

Fig 9: Pulses used to trigger Thyristors in SVC

Figure 10 shows the terminal voltage and DC voltage used to trip the Thyristors.

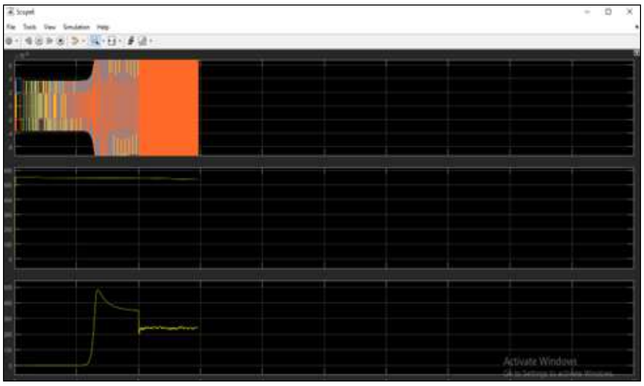

Fig 10: Shows the RMS value of source voltage and current

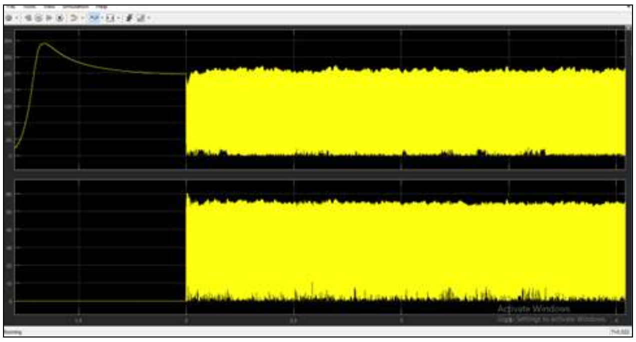

Fig 11: RMS value of source voltage and current

Conclusion

In this paper power quality issues have been discussed including various causes of distortions and harmonics. These harmonics are compensated by use of Static Variable Compensator. The load end of transmission line and source are shown in the results part of the paper. The System compares and load and the source conditions and compensates the harmonics as shown in the results. The effects of the system on terminal voltages, power compensation line power, rotor deviations, bus voltages, angular velocity and of power system using SVC installed at source end and load end for the same transmission line of power system were studied and compared based on the simulation. Thus it can be seen that the compensation of the harmonics is done by the SVC on the Simulink platform. So it has been found on the basis of simulation result that by the installation of SVC management of power quality is batter controlled at load side by comparing it to the source side.

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