

Voltage Sag Mitigation Using Static VAR Compensator

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Abstract: Voltage sag is defined as a decrease of RMS Voltage from 0.1 to 0.9 per unit (pu) for a duration of 0.5 cycles to 1 minute. Voltage sags are caused by short circuit faults on the system, transformer energizing, overloads and starting of large motors. In this paper voltage sag due to short circuit faults such as Line-to-ground, Line-to-Line, three Phase-to-ground faults are created in the power system network using MATLAB SIMULINK. This project deals with modeling and simulation of static var compensator(FC-TCR) in order to mitigate the voltage sag occurred due to short circuit faults. To implement Automatic control circuit of SVC using MATLAB SIMULINK and observe the simulation results with and without Automatic control circuit.

Keywords: Power Quality, Voltage sag, Static Var Compensators(SVC), Fixed Capacitor(FC), Thyristor Controlled Reactor(TCR).

I.INTRODUCTION

Power Quality related issues are of most concern now a days. Wide use of electronics equipment such as information technology equipment, power electronics equipment viz. adjustable speed drives(ASD), Phase locked loops(PLL), Programmable logic controller (PLC) etc, change the nature of electric loads. These loads are major cause for power quality problems. The most severe power quality problems are voltage sags, interruptions, harmonics and flickering. Voltage sags are considered as one of the most important power quality problems, because they adversely affect the operation of the end user equipment. Voltage sag is defined as decrease in voltage from 0.1 to 0.9 per unit for short duration of time. Voltage sags are usually associated with system faults, energizing of transformers and starting of large induction motors. Figure 1 shows the voltage signal with sag. The faults in the system are more frequent. Voltage Sags are caused due to the faults in the system. A fault in the transmission line affects sensitive equipment up to hundreds of kilometers away from the fault. In this paper voltage sag due to short circuit faults are created using MATLAB/Simulink. Automatic control circuit of SVC is implemented in MATLAB/Simulink in order to mitigate these short circuit faults.

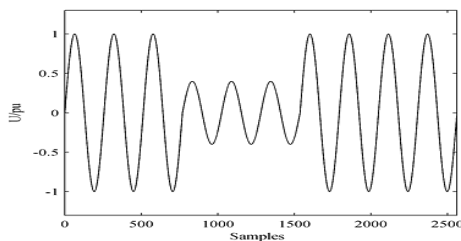


Fig 1:Voltage Sag

II.LINE FAULT SIMULINK MODEL

The line fault model consists of 11KV 50 Hz three phase source block connected to transmission line. Transmission line is connected to a 11KV/415V delta/star transformer, feeding a 200MW resistive load. Both the Instantaneous and RMS waveforms are measured at 11KV and 415V bus. The line fault model developed in MATLAB/simulink is as shown in figure 2.

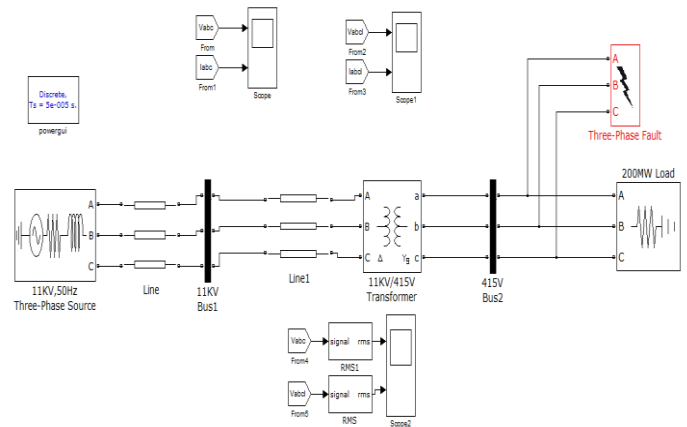


Fig 2:Power System Fault Simulated in MATLAB/ Simulink

A fault block is located at 415V bus(bus2). This line fault model is capable of simulating various line faults including single line to ground, double line to ground, line-to-line fault, three phase fault.

III.SIMULATION RESULTS WITH OUT SVC

Case 1:Line-to-Ground Fault

Line-to-Ground Fault is created using three phase fault block. Fault is created in phase A. Fault is considered for a duration of 0.1 seconds(0.1-0.2). A 0.25 seconds Simulation time is set. Figure 3 shows the voltage and current waveforms with sag at bus 2(415V). The voltage of phase A drops, while the voltage of phase B and C remain at its pre-fault value. Fault due to line-to-ground is unsymmetrical in nature.

Post fault voltage and current waveforms:

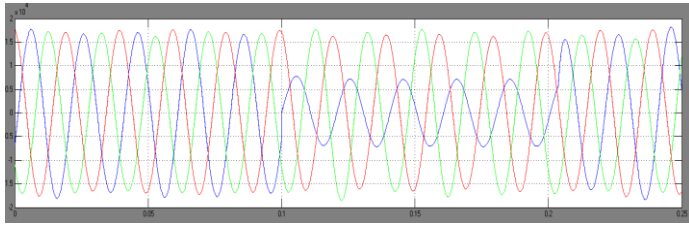


Fig 3(a) : Line-to-Ground Fault Voltage waveform

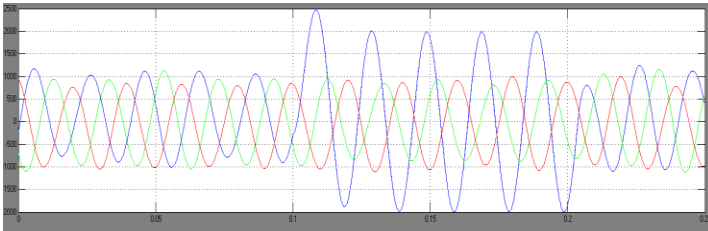


Fig 3(b):Line-to-Ground Fault Current waveform

In power Quality studies, the magnitude of voltage sag is determined using RMS waveform. Figure 4 shows the RMS waveform of Line-to-Ground fault. The magnitude of sag for each phase can be clearly visualized.

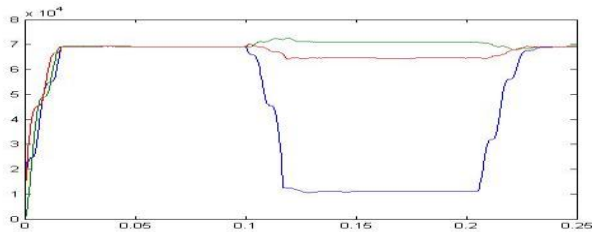


Fig 4:RMS waveform of Line-to-Ground fault.

Case 2: Line-to-Line Fault

Fault is considered in phase A and phase B for a duration of 0.1 seconds(0.1-0.2).Simulation time is set to 0.25 seconds. Figure 5 shows the voltage and current waveforms with sag at Bus2 at 0.1 to 0.2 seconds.

Post Fault Voltage and current waveforms:

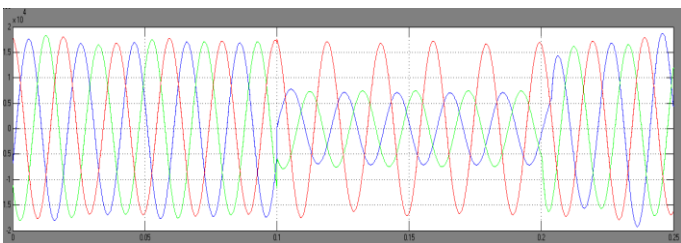


Fig 5(a):Line-to-Line Fault Voltage waveform

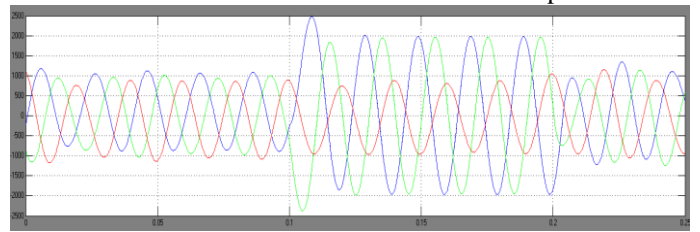


Fig 5(b):Line-to-Line fault Current waveform

Magnitude of sag is determined using RMS waveform. Figure 6 shows the RMS waveform. Sag magnitude in phase A and B can be clearly visualized.

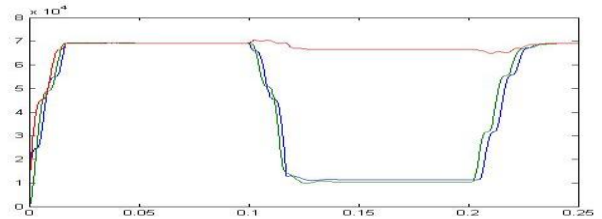


Fig 6:RMS waveform of Line-to-Line Fault

Case 3: Three phase to ground Fault

Fault is created in all three phases. Fault is considered for a duration of 0.1 seconds(0.1-0.2). Simulation time is 0.25 seconds. Figure 7 shows the voltage and current waveforms with sag at Bus2 at 0.1 to 0.2 seconds. Fault due to Three Phase fault to ground is symmetrical in nature.

Post Fault voltage and current waveforms:

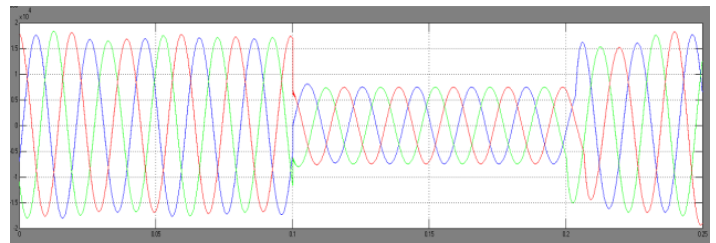


Fig 7(a):Three Phase to Ground fault Voltage waveform

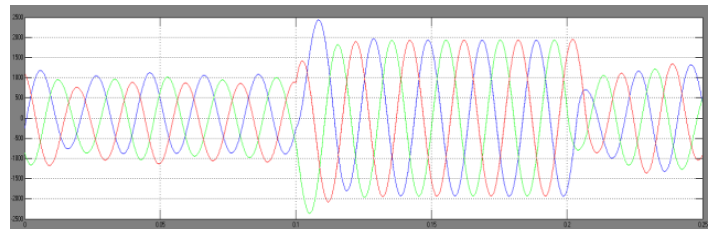


Fig 7(b):Three Phase to Ground fault Current waveform

Magnitude of sag is determined using RMS waveform. Figure 8 shows the RMS waveform. Three phase-to-ground fault is symmetrical in nature.

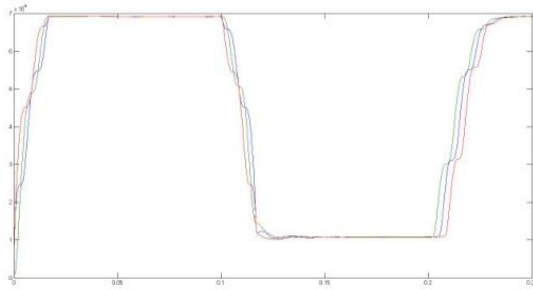


Fig 8:RMS waveform of Three Phase to Ground fault

IV.STATIC VAR COMPENSATOR

SVC is the first generation FACTS device which is connected in shunt with the power system. Shunt reactive power compensators are generally used to supply or absorb reactive power at their point of connection.SVC can be categorized into three types:(1) Thyristor Controlled Reactor and Fixed Capacitor(TCR-FC) (2) Thyristor switched Reactor and Thyristor Switched Capacitor(TSR-TSC) (3) Thyristor Controlled Reactor and Thyristor Switched Capacitor(TCR-TSC).

The proposed SVC model consists of shunt connected TCR branch and fixed capacitor(FC). Thyristor Controlled Reactor is a fixed reactor in series with bidirectional thyristor valve. Figure 9 shows single phase FC-TCR. In three phase system TCRs are connected in Star or Delta.SVC regulates Voltage by injecting reactive power or absorbing the reactive power at its terminals. When system voltage is low, it injects reactive power (SVC Capacitive). When voltage is high, it absorbs reactive power (SVC Inductive).

The basic Principle of SVC is supplying Variable leading or lagging VAR to lagging or leading systems. The flow of current through reactor is controlled by phase angle control of thyristor. The firing angle of thyristor is varied from 90 Deg to 180 Deg.

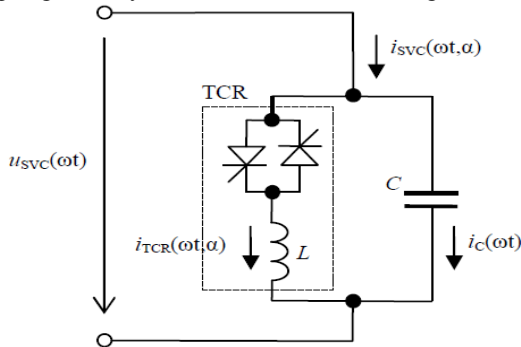


Fig 9:Single Phase FC-TCR

V. Control Structure

SVC model consists of three main parts: Measuring Unit, Control Unit, Power Unit. Figure 10 shows the block diagram of system with automatic control circuit of SVC in MATLAB simulink. The measuring block measures actual instantaneous voltages and currents(v,i). Voltage signals are

inputs to the control unit. The control unit performs various calculations as described below. Measured voltage is calculated by converting instantaneous value to magnitude value. Measured voltage and reference voltage are computed dynamically and manipulated variable is firing angle α .

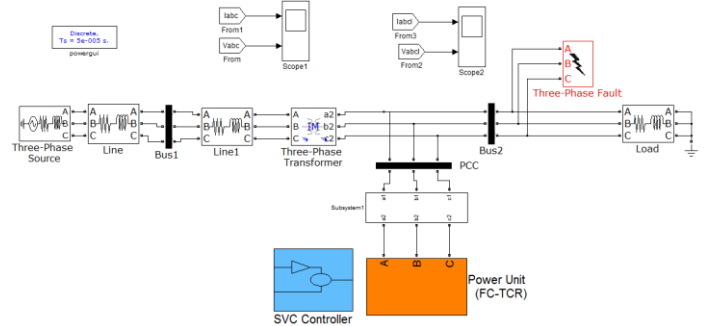


Fig 10:SVC simulation model in MATLAB Simulink

Power unit consists of FC-TCR connected in delta.FC-TCR simulink model is as shown in figure11. Power unit is controlled by Firing Pulse Generator(FPG) which generates Firing Pulses to thyristor.

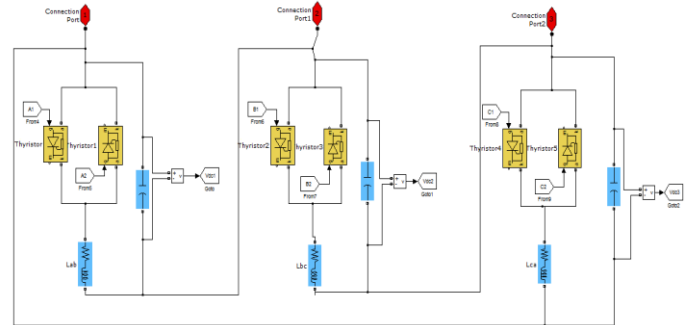


Fig 11: Power Unit in Simulink- Three Phase Delta connected FC-TCR's

In general, control unit regulates voltage automatically using three PI controllers. Figure 11 shows the proposed control circuit of SVC. It has four stages. They are

- 1.Voltage magnitude is calculated from instantaneous voltage.
- 2.Measured Voltage is compared with reference voltage and error ΔV continued to PI controller.
- 3.PI controller regulates the deviation between the actual voltage and desired voltage in order to reduce the difference to an accepted value with a tolerance of 5% . It is done by varying the firing angle α of thyristors.
- 4.Firing Pulse Generator generates switching pulses to turn on the thyristors.

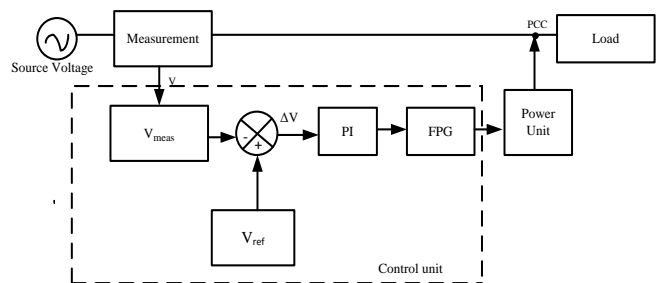


Fig 12:Proposed control circuit of SVC

VII.SIMULATION RESULTS WITH SVC

Case1:Line-to-ground Fault

Sag is mitigated automatically by SVC. By adjusting the values of proportional and integral controller, voltage sag due to various faults can be mitigated.

Voltage waveform at bus 2 with SVC:

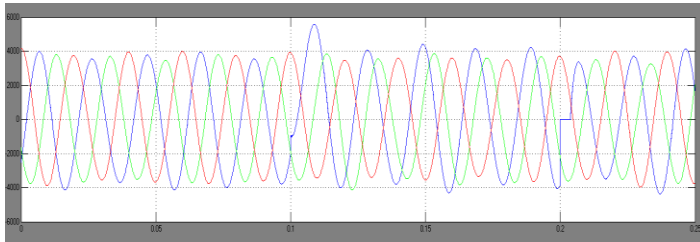


Fig 13:voltage waveform with SVC

Case2:Line-to-Line Fault

Voltage waveform at bus 2 with SVC:

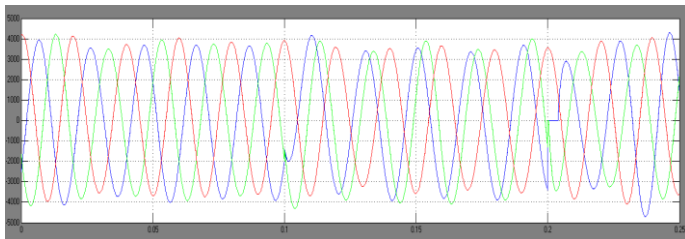


Fig 14: voltage waveform with SVC

Case3:Three Phase to ground fault

Voltage waveform at bus 2 with SVC

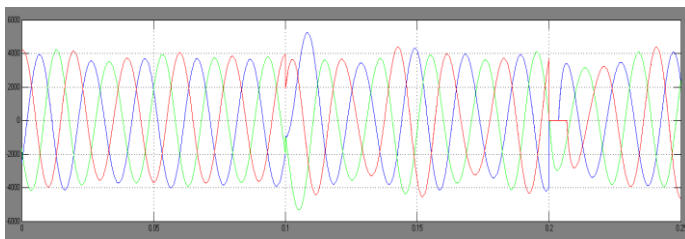


Fig 15: voltage waveform with SVC

VII.CONCLUSION

In this paper, Few Systems have been developed using MATLAB Simulink with and without voltage sag. Various faults viz. line-to-ground, double line-to-ground, three phase-to-ground faults have been created to generate voltage sag in the system. Automatic control circuit of SVC is modeled and simulated in MATLAB Simulink. The control circuit consists of PI controller for controlling the voltage. The simulation results with and without SVC shows that SVC mitigates voltage sag effectively and provides excellent power quality.

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