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Voltage Stability Improvement in Multi-bus System Using Static Synchronous Series Compensator

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Abstract: Network stability has become a major worry as the power system has become increasingly complicated as a result of open access electricity market activities and increased demand. Voltage unbalance and collapse have become a global issue for a variety of reasons. FACTS devices are used to manage system stability issues. Use of a static synchronous series compensator (SSSC) to enhance the voltage stability of a power system is investigated in this paper. IEEE 9 bus networks are modelled using MATLAB Simulink software to investigate voltage management and reactive power compensation. For a multibus system, the effectiveness of SSSC on voltage stability is examined. Using a static synchronous series compensator enhances voltage stability.
Keywords: SSSC, Faults, voltage improvement

I. INTRODUCTION

Because the power grid is becoming more interconnected, stability is a major concern. The power system's stability is affected by constantly changing load requirements and abnormal conditions[1]. Under extreme load scenarios or changes in system conditions, voltages can drop dramatically and even collapse[2,3]. A lack of reactive power from generators and transmission lines causes voltage instability or voltage collapse. Managing reactive power with FACTS devices can improve voltage profile due to numerous advantages over traditional regulating devices. The ability of a static synchronous series compensator (FACTS device) to improve stability is proven. The SSSC's job is to control power transfer efficiency and thereby promote power system stability. By adding inductive and capacitive inductance to the power line, SSSC can improve power transmission capacities [4,5,6]. A lot of effort has gone into employing FACTS devices to improve power system stability in recent years. One of the FACTS devices used to explore the effect of voltage stability is the static synchronous series compensator (SSSC). It consists of a power electronic converter and a coupling transformer coupled to the transmission system in series. The average reactive voltage drop across a link can be changed. The line current is proportional to the output voltage. By managing the reactive power exchange between the SSSC and the AC system, the SSSC may control the current and power flowing through the line. By managing the reactive power exchange between the SSSC and the AC system, the SSSC may control the current and power flowing through the line. In transitory situations, it can help to improve the voltage profile. The influence on current, voltage, active, and reactive power in real time is investigated by SSSC [7-8]. It is investigated whether an SSSC may be used to control and regulate power flow in a transmission system. The control circuits for twelve pulse and PWM powered SSSCs, as well as the approach, are shown.

This research investigates the use of a static synchronous series compensator to increase voltage stability via stable voltage injection. The utilisation of SSSC to boost voltage stability was tested using a nine-bus system. The basic model of a nine-bus system with and without SSSC is studied first[10]. MATLAB software is then used to model the IEEE 9 bus system. A static synchronous series compensator was used to improve the voltage profile in all of the output results of the nine bus systems.

II. VOLTAGE STABILITY

Voltage stability refers to a power system's ability to support consistent, acceptable voltages across all system buses during normal and abnormal operating situations. The system enters a state of voltage instability when a disturbance, increase in load demand, or change in system stability produces a progressive and unpredictable fall in voltage.

The inability of the power system to meet the demand of reactive power is the primary cause of instability. As the amount of reactive power injected into the same bus is increased, the magnitude of the bus voltage increases. The bus voltage magnitude decreases as the reactive power injection at the same bus rises, indicating that system is voltage unstable.

Voltage instability can occur for a variety of reasons, however the following are among the most significant contributors:
1) Generators, synchronous condensers, or SVCs reach reactive power limits as a result of increased load
2) Line tripping or generator outages
3) Tap altering transformer action
4) Load recovery dynamics

The bulk of the these changes have a significant impact osn the system's generating plant, consumption, and transmission. These below are some countermeasures to prevent voltage collapse:
- Shunt capacitor switching
- Tap-changing transformer blocking
- Redispatch of generation
- Load shedding
- Generator temporary reactive power overloading

III. STATIC SYNCHRONOUS SERIES COMPENSATOR

A. Principle of Static Synchronous Series Compensator

Instead of just adding a series capacitor, the SSSC acts as a synchronous voltage source. It adjusts the power system with reactive power by infusing a three-phase AC compensation voltage that is 90 ° to the line current. As shown in figs. 2 and 3 [11], the SSSC injects the compensating voltage in series with the system.

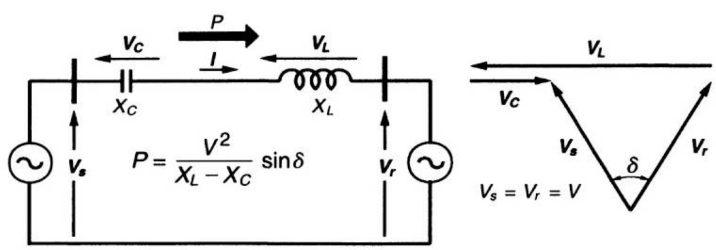

Fig 1 (a) (b)

1) Basic two machine system for SSSC
2) Phasor diagram of a system including SSSC

As it operates in the inductive and capacitive zones, the compensating voltage alternately leads or lags the line current. The product of the compensating voltage Vq and line current is the SSSC rating [7].

With SSSC, the power system has actual and reactive power flow, which can be represented by the equations below:

$$P = \frac{VS*VR*sin\delta}{XL} \_ \frac{V2*sin\delta}{XL} \qquad (1)$$

$$P = \frac{VS*VR*(1-cos\delta)}{XL} \_ \frac{V2*(1-cos\delta)}{XL} \qquad (2)$$

The system's functional reactance, including the injected resistor in the transmission line, is Xeff. For inductive compensation, injected reactance Xq is negative, whereas for capacitive remuneration, injection reactance Xq is positive [8].

B. Advantages of SSSC

During power system interruptions, the SSSC is widely employed to level the voltage and restore it to its original level. Apart from that, SSSC has a number of benefits under steady-state conditions, some of which are listed below[13]:
1) Assists in system power flow control under typical conditions.
2) It can also aid in the management of reactive and capacitive power.
3) Load balancing is a serious issue in interconnected distribution networks, but SSSC can successfully mitigate it.
4) It minimizes harmonic distortion with the help of active filtering.
5) SSSC aids in the enhancement of power factor through continuous voltage injection or in conjunction with a properly set controller.

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IV. TEST SYSTEM DESCRIPTION:

A single line diagram of a 9-bus system is shown in Figure 2. The system is set up in a loop, with nine buses (B1 to B9) connected by transmission lines with periods varying from one to three phases and three 18 kV/230 kV transformer banks totaling 100 MVA. The system was powered by two power plants with a phase to phase voltage of 13.8 KV. The test system model, shown in Figure 3, has an IEEE 9 bus, three machine systems, 300 km, and 500 kV. Three generators are attached to Bus 1, Bus 2, and Bus 3.

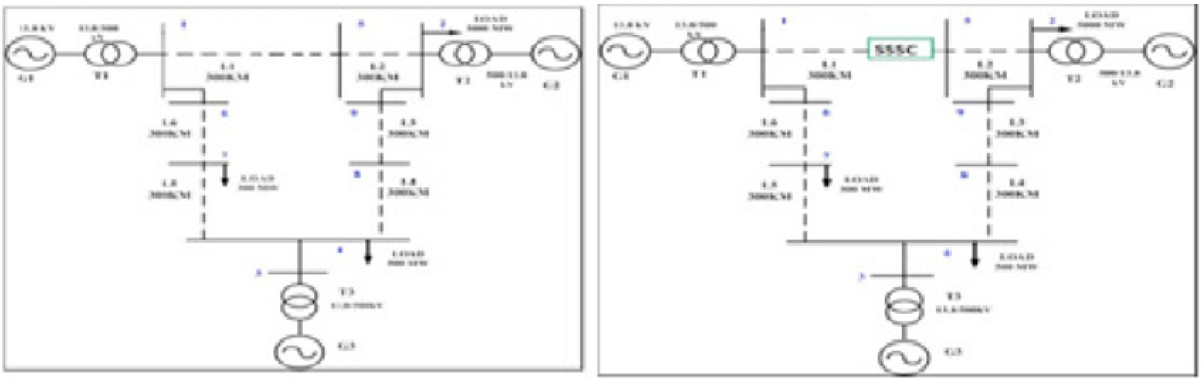

Fig 2: Single line diagram of IEEE nine bus systems without and with SSSC.

V. SIMULATION AND RESULTS

The implementation of SSSC to improve voltage stability was tested using a nine-bus system. First, a nine-bus system with and without SSSC is investigated[10]. MATLAB software is then used to simulate the IEEE 9 bus system. A static synchronous series compensator was used in all of the output results of the nine bus systems to improve the voltage profile.

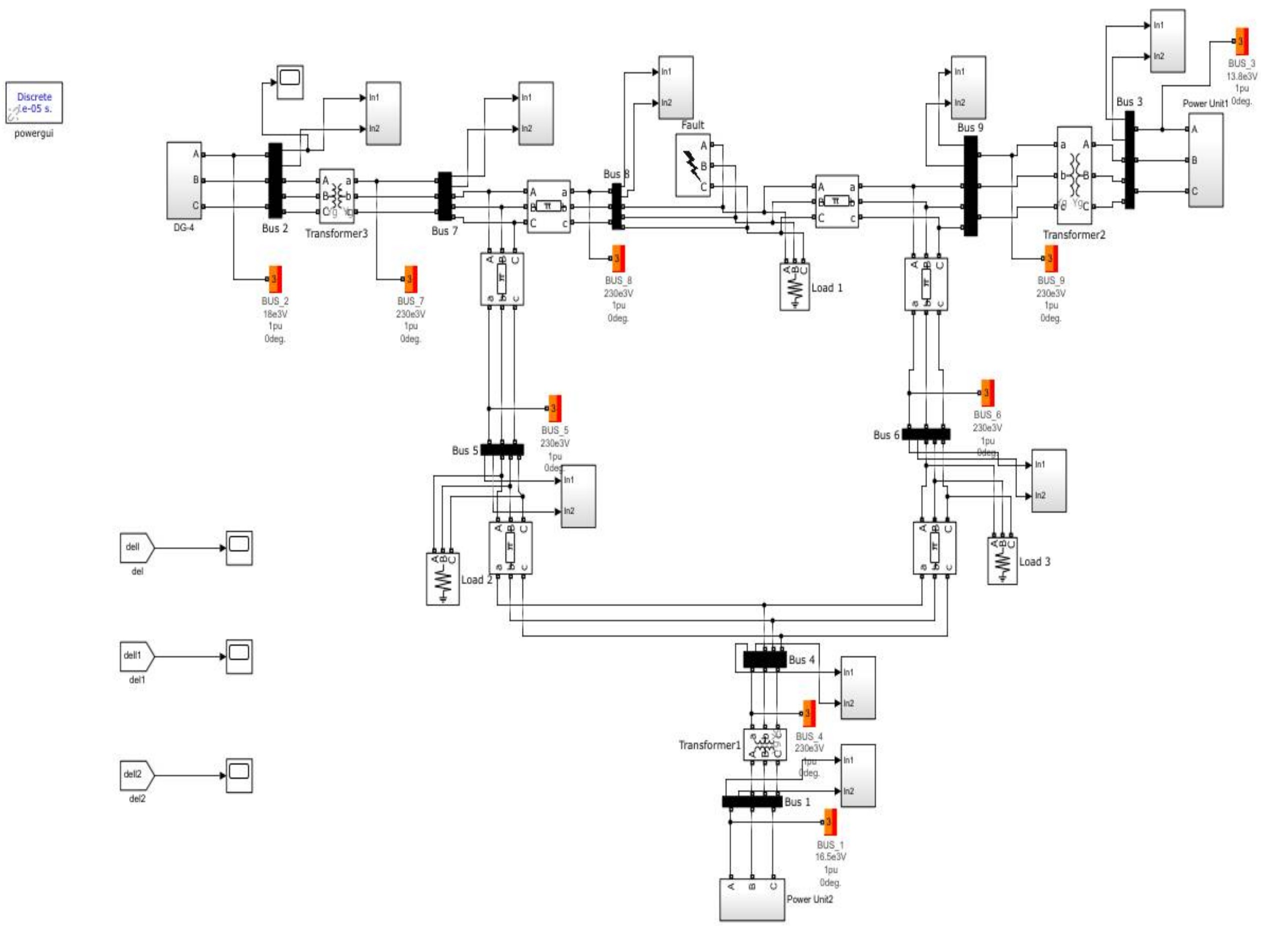

Fig 3: Nine bus system simulation diagram without SSSC

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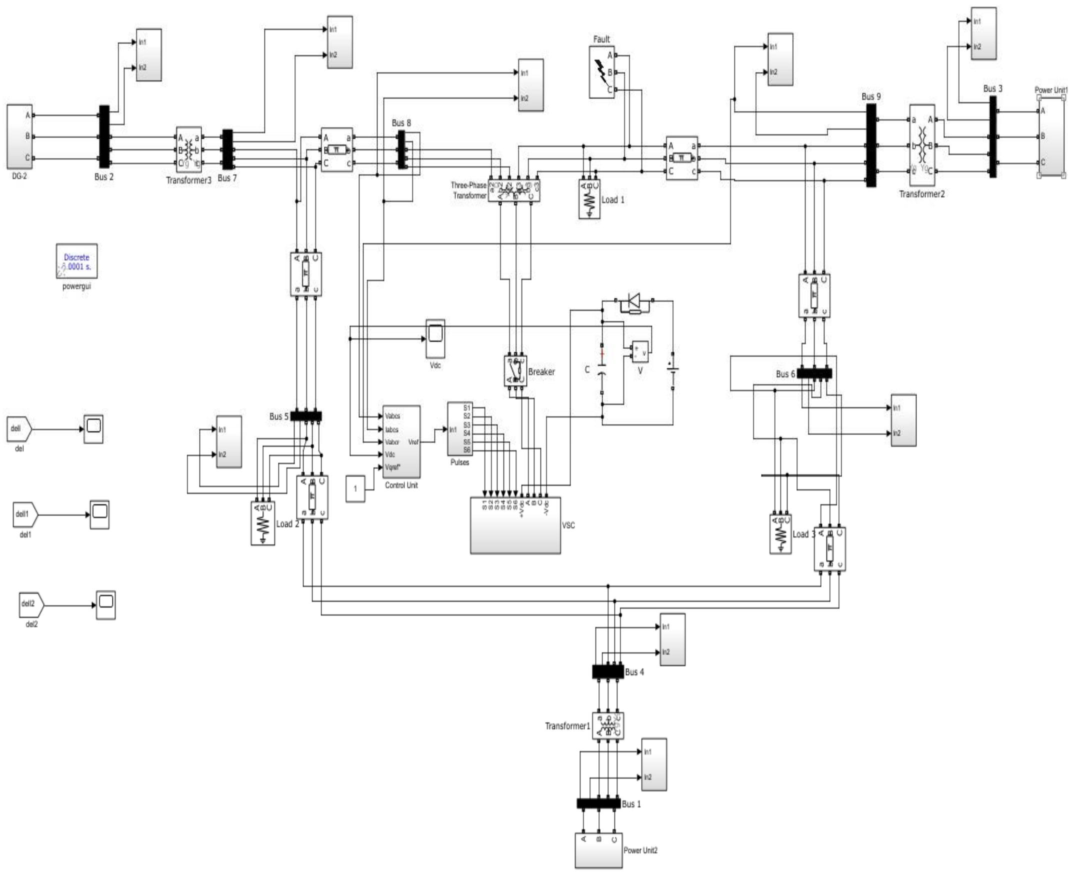

Fig 4: Nine bus system simulation diagram with SSSC

A. Fault in the System

For the test system, we are introducing different types of faults (SLG, DLG, TLG) on the load side at bus 8 and a time period between 0.2 to 0.3 seconds, and the system parameter such as voltage and current are observed by Three-phase measurement block using a scope and its waveform.

1) Pre Fault Condition

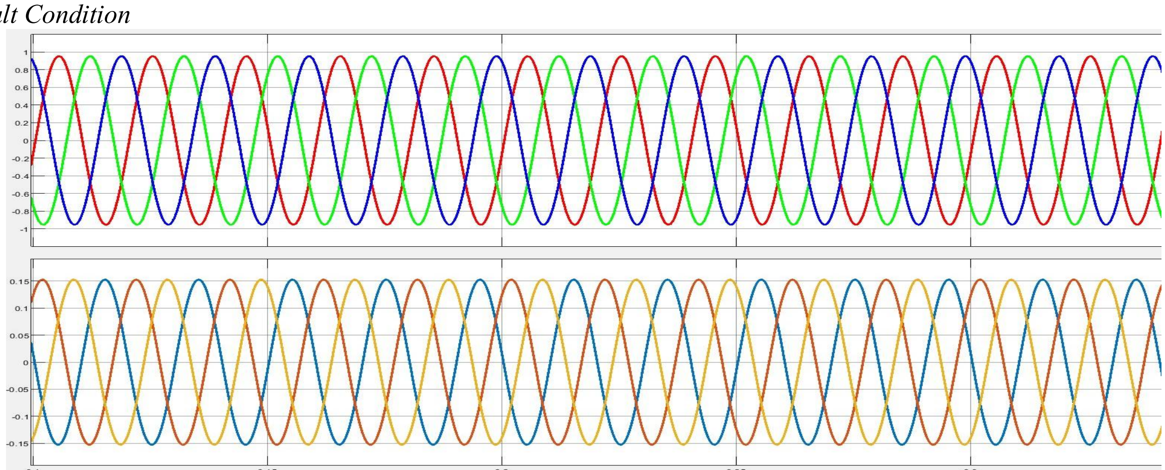

Figure 5.1: voltage and current waveforms

In this case voltage and current wave form are sinusoidal there is no disturbance in the system.

B. Single Line to Ground Fault

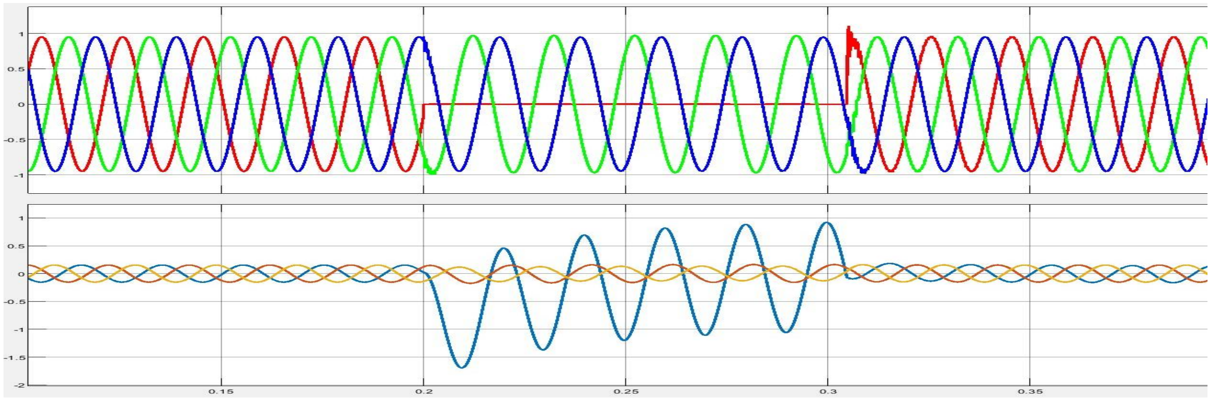

Figure 5.2.1: SLG fault voltage and current Waveforms

In this case, Single line to ground fault at bus No 8 during this condition the current through the faulted phase is more than that of the other two phases and voltage at faulted phase is zero, SLG fault for a period between 0.2 to 0.3seconds and It is observed that current is doubled that of other2 phase and voltage is zero for the faulted phase waveform.

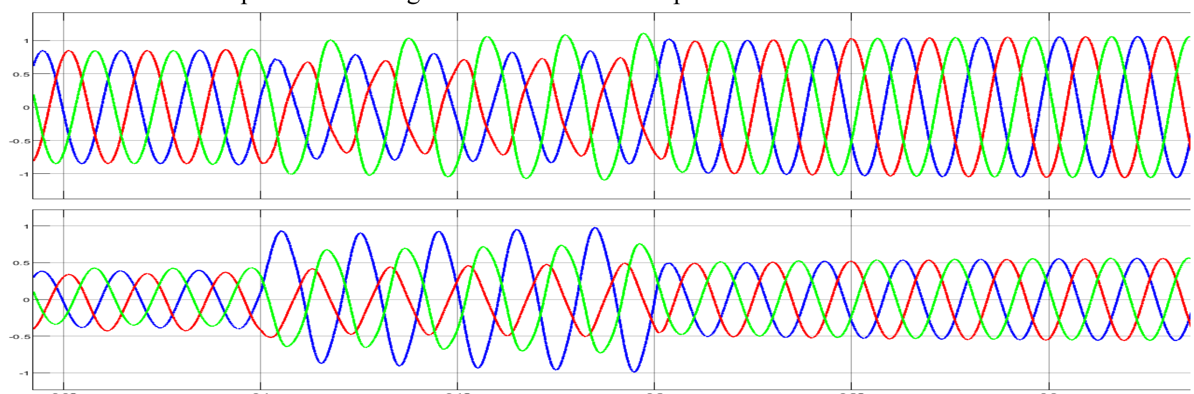

Figure 5.2.2: SLG fault voltage and current Waveforms with SSSC

After placing SSSC in between bus no 8 and bus no 9 it is clearly show that the faulted voltage is improved 0.8v and current magnitudes is also reduced.

C. Double line to a Ground Fault

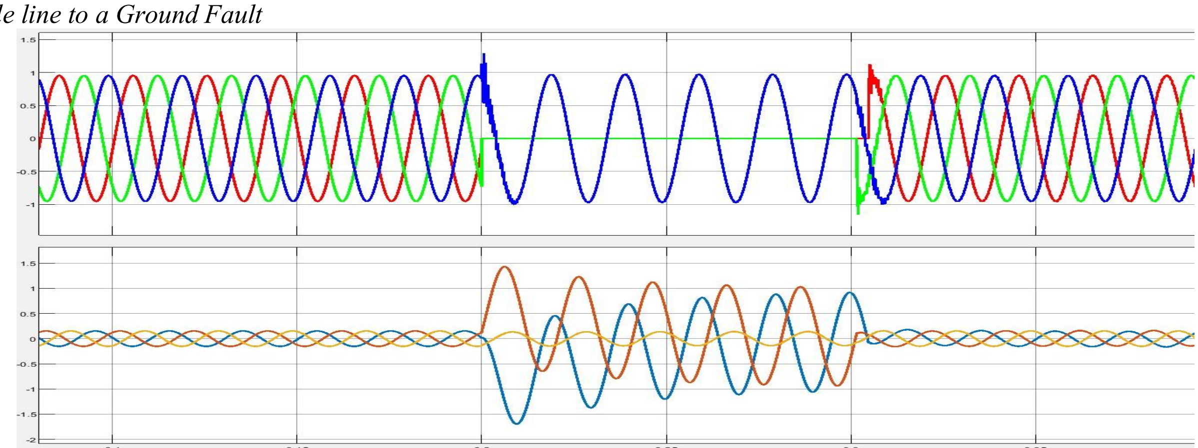

Figure 5.3.1: DLG fault voltage and Current Waveforms

In this case, Double line to ground fault at bus No 4 during this condition Double line to ground fault the current through the faulted phases is more than that of other phase and voltage is zero, here we introduced fault for a period between 0.2 to 0.3 seconds and It is observed that current in faulted phase is more that of non faulted phase and voltage is zero at 2 phase by the wave form.

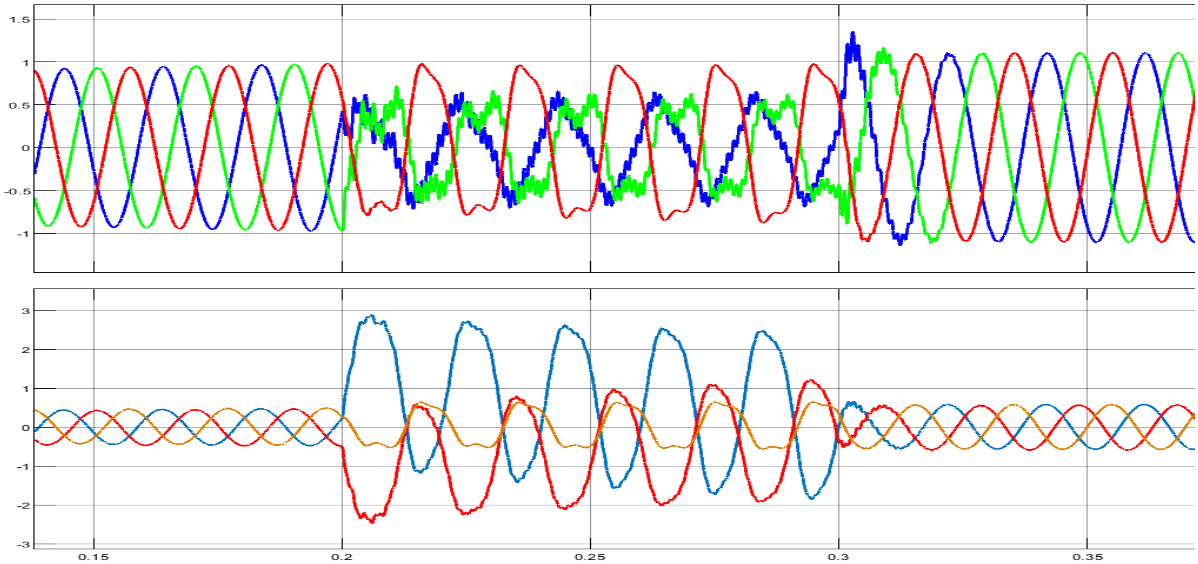

Figure 5.3.2: DLG fault voltage and current Waveforms with SSSC

Single phase to ground Fault occurs at bus No. 4 during the fault period 0.2 to 0.3 seconds, SSSC is placed in between bus No 2 and bus No 4 to correct the fault transients. Observe waveforms, the voltage is increasing **0** to **0.6V** at **0.3** seconds.

D. Three Phase to Ground Fault

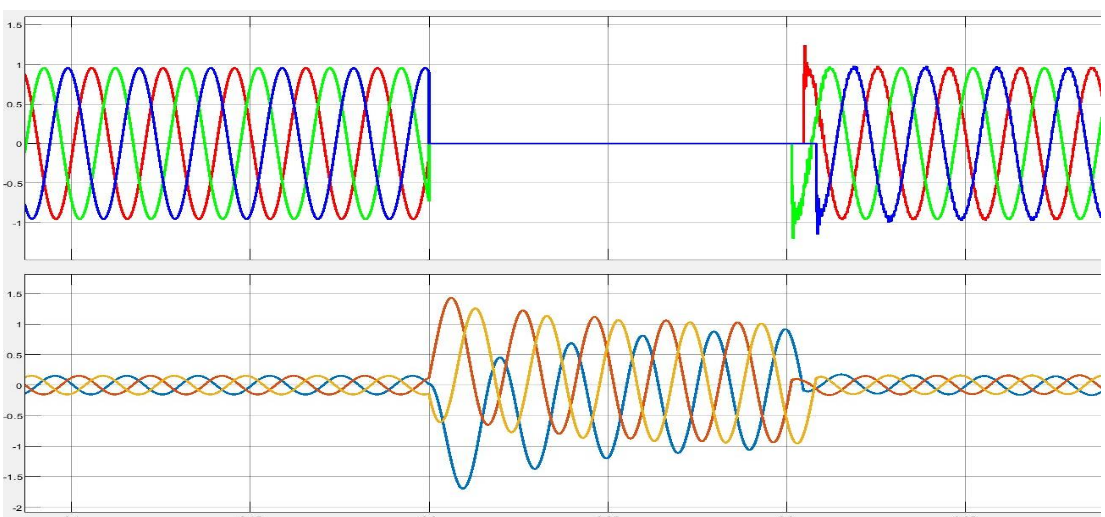

Figure 5.4.1: TLG fault voltage and current Waveforms

In this case, Three phase to ground fault at bus No 4 during this condition the current through the faulted phase is more and voltage at faulted phase is zero, TLG fault for a period between 0.2 to 0.3 seconds and we are observing that current is doubled that all three phase and voltage is zero for the all three phase waveform.

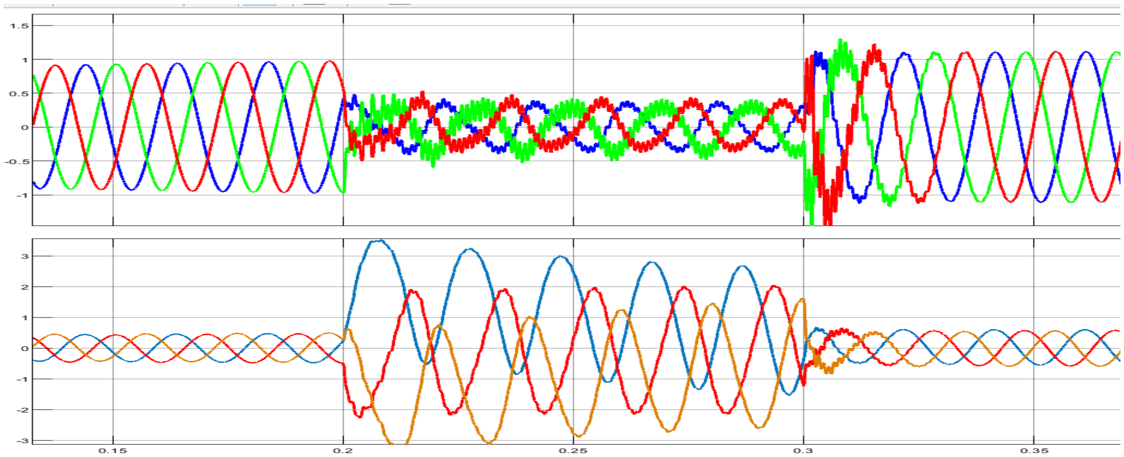

Figure 5.4.2: TLG fault voltage and current Waveforms with SSSC

Three phase to ground Fault occurs at bus No. 4 during the fault period 0.2 to 0.3 seconds, SSSC is placed in between bus 2 and bus 4 to correct the fault transients. Observe waveforms, the voltage is increasing 0 to 0.4Vat 0.3 seconds.

Table 1: 9 bus system results without SSSC

Bus No.	Voltage(pu)	Current(pu)	P(Pu)	Q(pu)
1	0.656	0.6687	2.196	-0.5851
2	0.662	0.4734	1.727	-0.5321
3	0.6548	0.261	1.169	-0.4936
4	0.7257	0.6606	2.183	-0.773
5	0.7834	0.4101	0.7224	0.1228
6	0.7786	0.3508	0.5254	0.2233
7	0.7257	0.467	1.716	-0.6969
8	0.7666	0.4131	0.9778	-0.1258
9	0.7361	0.2567	1.161	-0.6077

Three machines power the system. Nine buses have been simulated in a MATLAB environment after including SSSC. When a fault arises on one bus, it affects all of the others, and once SSSC was deployed, all of the buses' voltages, power, and active and reactive systems improved. The findings are summarised in Tables 1 and 2. The obtained data indicated that the power supply's voltage stability had improved.

Table 2: 9 bus system results with SSSC

Bus No.	Voltage(pu)	Current(pu)	P(pu)	Q(pu)
1	1.007	1.518	2.3	-0.4903
2	0.198	1.071	1.628	-0.481
3	1.009	0.7646	1.147	-0.4139
4	1.021	1.513	2.284	-0.6705
5	1.016	0.5322	0.8255	0.03622
6	1.023	0.1766	0.3068	0.2538
7	1.022	1.067	1.617	-0.6324
8	1.023	0.5044	0.7737	-0.0443
9	1.031	0.7622	1.139	-0.5089

VI. CONCLUSION

The simulation of a three-machine nine-bus power system model with a static synchronous series compensator is carried out in this research. The findings show that voltage regulation has been achieved and that the voltage profile on all buses has improved. Voltages at bus no 8 are compensated in series by 0.8v, 0.6v, and 0.4, respectively. As a result, SSSC is used in the power system to provide reactive power compensation and voltage regulation. The system's power flow is successfully controlled by the SSSC. In the future, the SSSC will be used to a more sophisticated system to investigate a problem involving many power systems.

VII. ACKNOWLEDGEMENT

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BIOGRAPHIES

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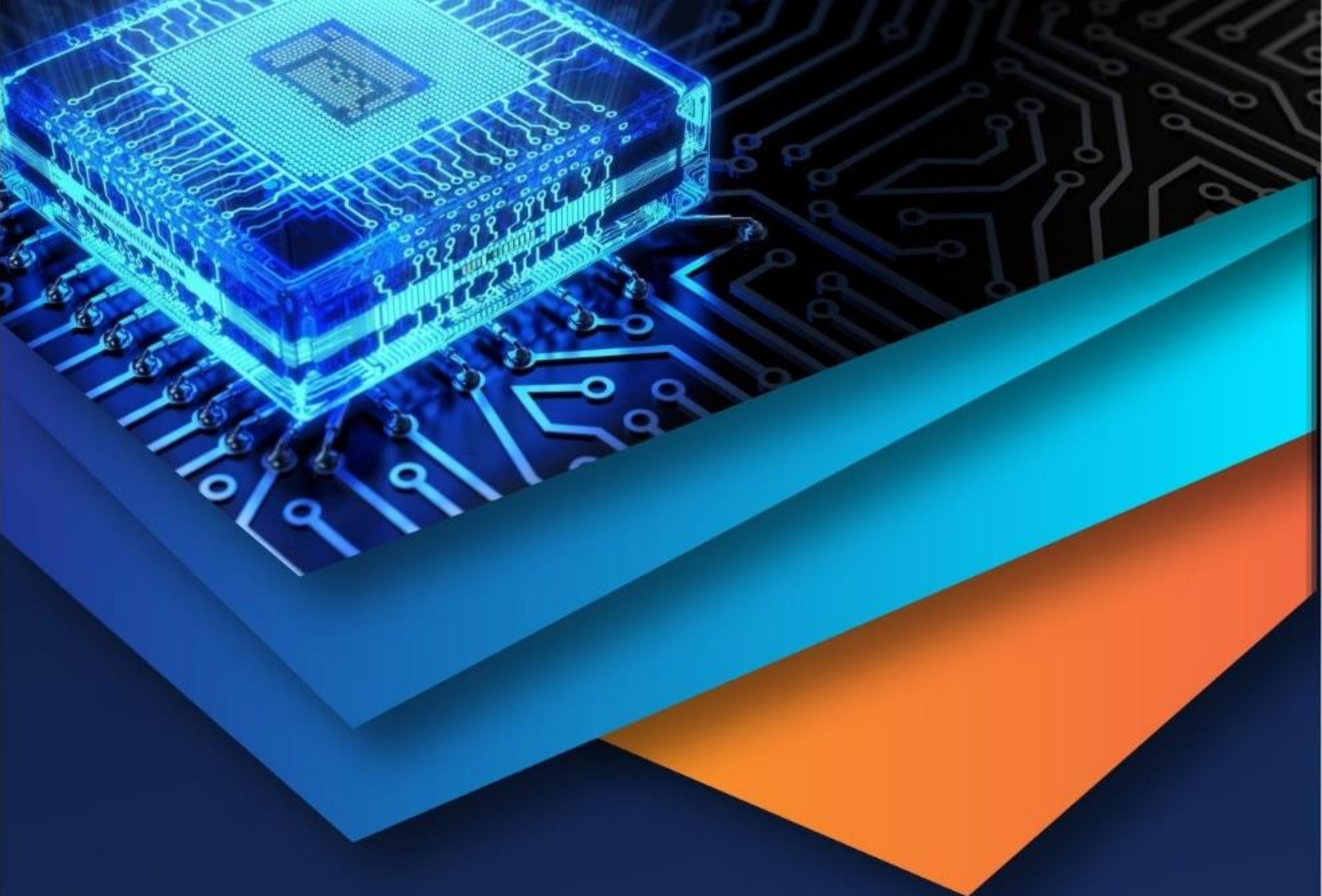

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