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# Enhancement of Transient Stability of a Series Compensated Long Transmission Line by Using Series Facts Controller

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***Abstract*: This paper show analysis for enhancement of transient stability of power system with variable series compensation of transmission line. The transient stability analysis is done for an IEEE 9 Bus system with a Three phase fault. Created at a Bus and the simulation is on PSAT in MATLAB. The time domain simulation that series FACTS Controller. Thyristor control series capacitor (TCSC) and Static Synchronous Series Compensated (SSSC) .TCSC,SSSC has enhanced that transient performance of the system by damping out the power oscillation under large disturbance condition with less settling time . In this paper three case are consider. (i) Steady State System (ii) Fault System (iii) Transient Stability enhanced system with TCSC & SSSC .**

**The simulation result show effective of variable series compensation.**

***Keywords*: IEEE-9 Bus System, PSAT (Power System Analysis toolbox, SSSC, TCSC, Transient stability, FACTS Controller.**

## 1. INTRODUCTION

A power system is a complex network comprising of numerous generator, transmission line variety of loads and transformer. As a consequence of increasing power demands . some transmission line are more loaded than was planned when they were built . with the increase loading of long transmission line the problem of transient stability after a major fault can become a transmission limiting factor. [1]Transient stability of a system refer to the stability when subject to long distance such as fault and switched of line. [2] The resulting system response involve a large excursion of generator rotor angle and is influenced by the nonlinear power analysis relationship stability depends upon both the initial operating condition of the system and the severity of the distance. The FACTS have gained a great interest during the last few years due to recent advance in power electronic. FACTS device have been mainly used for solving various power system steady state control problem such as voltage regulation, power flow control and transfer capability enhancement. As supplementary function damping the interea modes and enhancing power system stability using FACTS controller have been extensively studies and investigated. Generally it is not cost effective to install FACTS device for the sole purpose of power stability enhancement. The TCSC is the important member of FACTS family that is increasing applied with long transmission line by the utility in morden power system. It can have various role in the operation and control of power system such as scheduling power flow decrease unsymmetrically component reducing net loss; providing voltage support.

The SSSC is a member of FACTS family which is connect in series with a power system. It consist of a solid state voltage source convert which is generates a controllable alternating current voltage at fundamental frequency which in injected voltage is kept in quadrant with the line current it can emulate as inductive or capacitive reduce So as influence the power flow through the transmission line.

**Single Line Diagram of IEEE 9 Bus System**

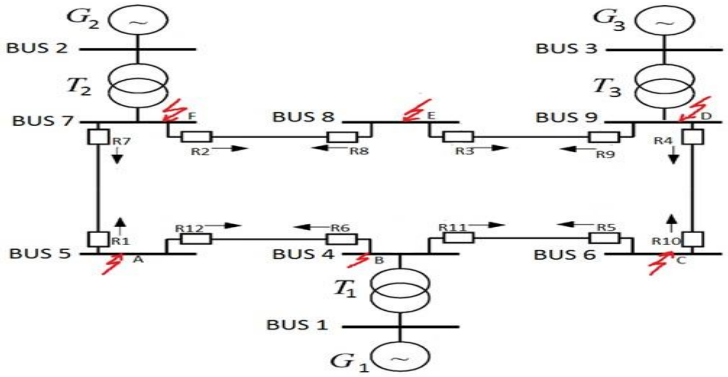


**Figure 1: Single Line Diagram of IEEE 9 Bus test system**

A single line diagram of IEEE 9 bus system is shown in Fig. 3 having loads assumes to be having constant impedance and all generators are operate with constant mechanical input power and with constant excitation. It consists of five synchronous machines with IEEE type-1 exciters, three of which are synchronous compensators used only for reactive power support with generator1 taken as reference generator. IEEE 9 bus data, line data, SSSC Data, TCSC data given in Appendix.

power system analysis tool box (PSAT) software is used for the simulation of the result. The main features of PSAT are power flow, continuation power flow, optimal power flow, small signal stability analysis, time domain simulation, phasor measurement unit placement, complete graphical user interface, CAD for network design, user define models, command line usage etc..

**PSAT MODEL IEEE 9 BUS SYSTEM PREFAULT**

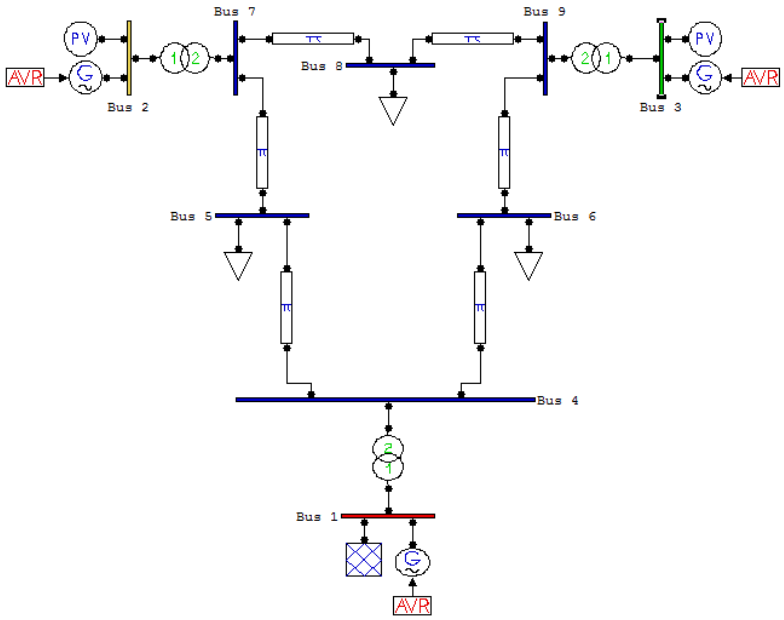


**Figure 2: PSAT model of IEEE 9 Bus system**

The pre fault line loading are typically available as output data from a load flow study. The voltage at different points in the power network depart from unit and zero in magnitude and phase value due to line loading. It is possible to calculate proper values for given load condition and use these values in a fault study. If the load happens to be synchronous motor it continue to run due to its store energy and supplied power to the fault. The motor circuit under fault condition will have current equal to that of phasor sum of motor current during pre- fault condition and the fault current contribution of the motor

**PSAT MODEL IEEE 9 BUS FOR FAULT CONDITION**

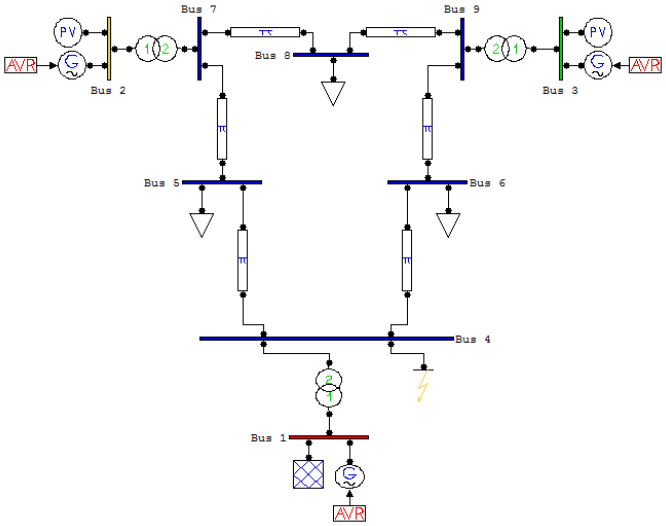


**Figure 3: IEEE 9 bus systems during fault condition**

Power system has been affected by high electromechanical oscillations whenever there is a disturbance occurs due to loss of a large load, due to fault, sudden loss of generation etc. which may lead to loss of synchronism of generators. Short circuit is a severe type of disturbance. The fault may be either be three phase in nature involving all three phase in a symmetrical manner or may be asymmetrical where usually only one or two phase may be involved. Fault may also be caused by either short circuit to earth or between live conductor or may be caused by broken conductor in one or more phase some time simulation fault may occurs involving. Both short circuit and broken conductor fault (also known as open circuit fault). Balance three phase fault may be analyzed using an equivalent single phase etc. With symmetrical three phase fault the use of symmetrical component help to reduce the complex of the calculation as transmission line and component are by and large symmetrical although the fault may be asymmetrical.

**PSAT MODEL OF IEEE 9 BUS WITH SSSC**

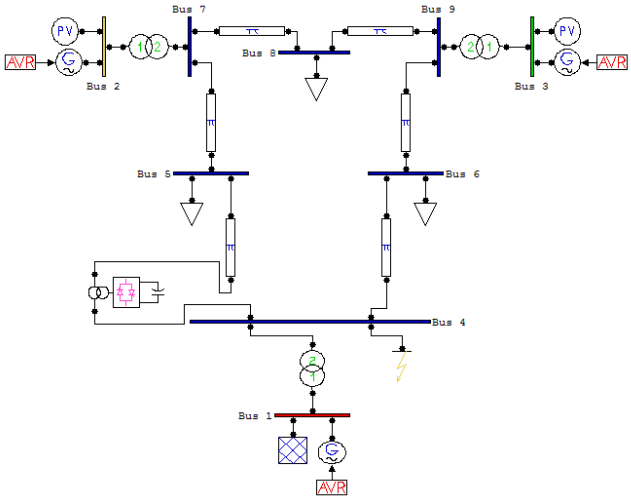


**Figure 4: IEEE 9 bus system using SSSC during fault**

Static Synchronous Series Compensator (SSSC) is a modern power quality FACTS device that employs a voltage source converter connected in series to a transmission line through a transformer. The SSSC operates like a controllable series capacitor and series inductor. The primary difference is that its injected voltage is not related to the line intensity and can be managed independently. This feature allows the SSSC to work satisfactorily with high loads as well as with lower loads.

## PSAT MODEL OF IEEE 9 BUS WITH TCSC

Thyristor Control Series Compensation (TCSC) is mainly used in the system to dynamically control the reactance of a transmission line in order to provide sufficient load compensation. The benefit of TCSC are seen in its ability to control the compensation of a transmission line and in its ability to different mode. These traits are very desirable since load are constantly changing and can't always be predicted.

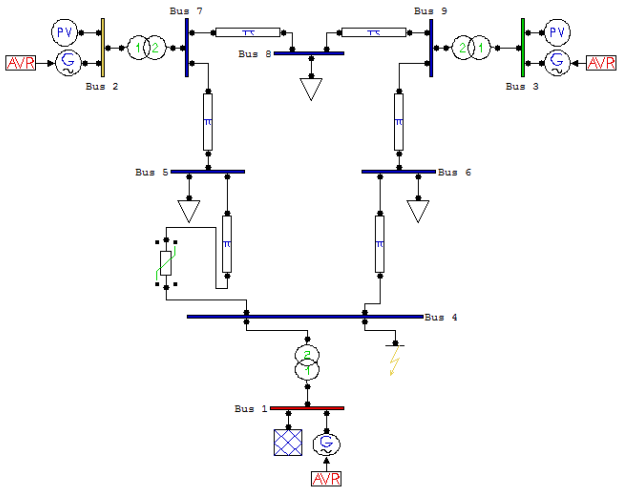


**Figure 5: IEEE 9 bus systems with TCSC**

## SIMULATION RESULTS

The output of generators during prefault, fault and post fault conditions is plotted using PSAT software. Using PSAT software we obtained the voltage time graph, synchronous generator active power graph with time.

### PREFAULT CONDITION

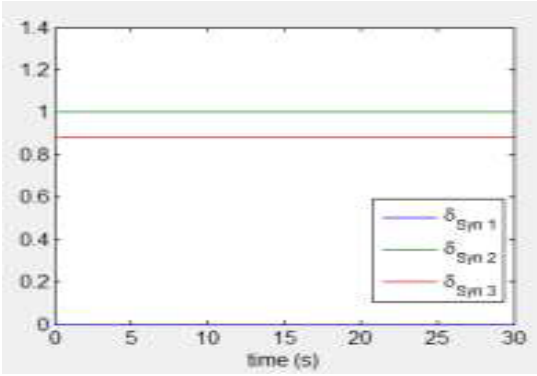


**Figure 6(a): Rotor Angle Curve Prefault Condition**

### FAULT CONDITION

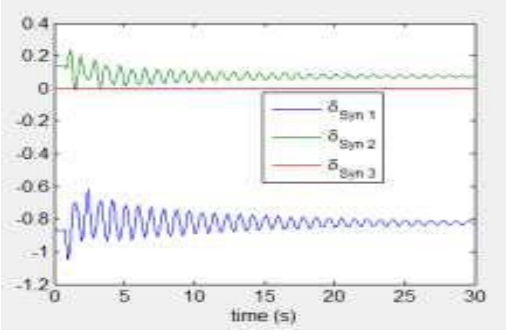


**Figure 6(b): Rotor Angle Curve Fault Condition**

**POST FAULT CONDITION WITH SSSC**

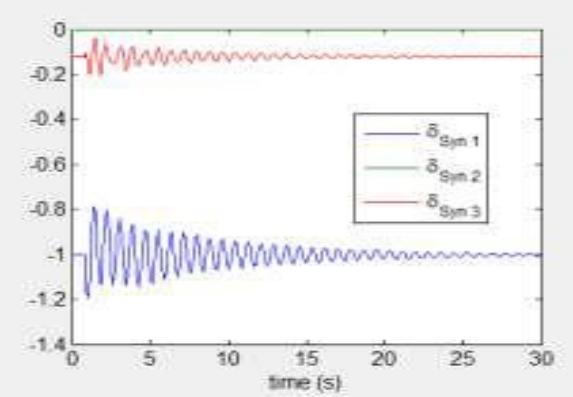


**Figure 6(c): Rotor Angle Curve with SSSC**

**POST FAULT CONDITION WITH TCSC**

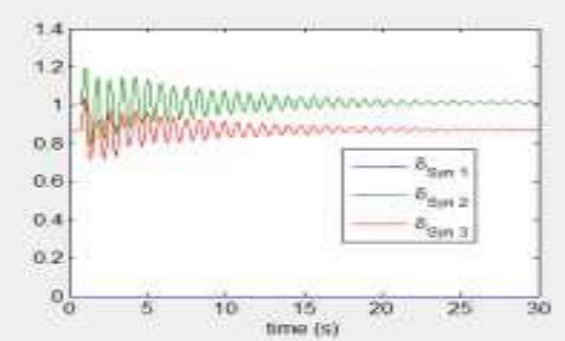


**Figure 6(d): Rotor Angle Curve with TCSC**

**PRE FAULT CONDITION**

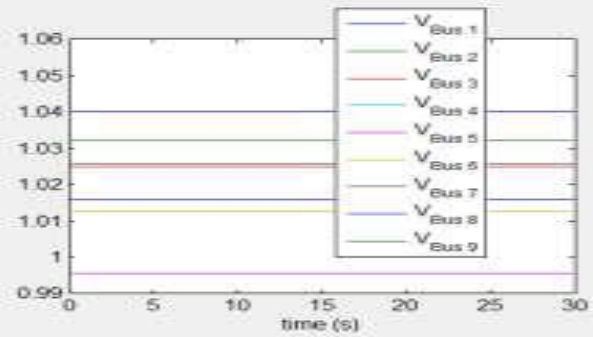


**Figure 6(e): Voltage Time Curve Prefault Condition**

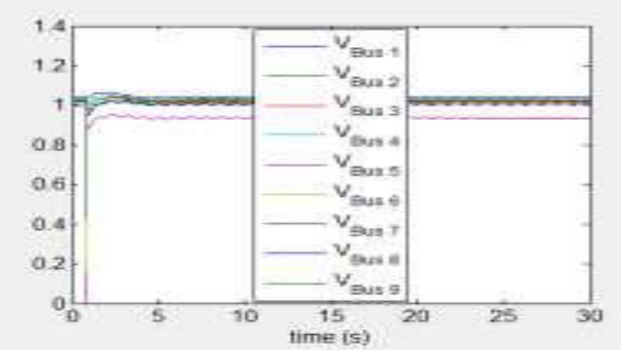


**Figure 6(f): Voltage Time Curve with Fault Condition**

**POST FAULT CONDITION WITH SSSC**

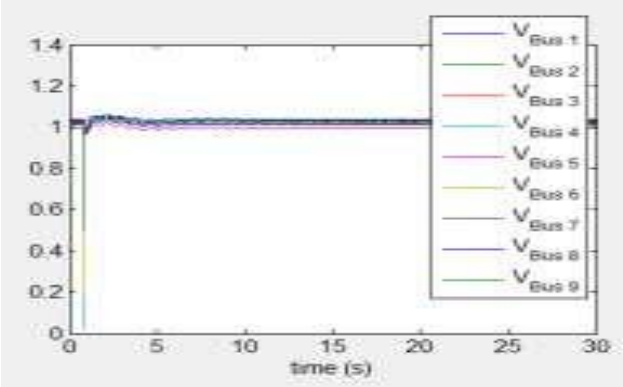


**Figure 6(g): Voltage Time Curve with SSSC**

**POST FAULT CONDITION WITH TCSC**

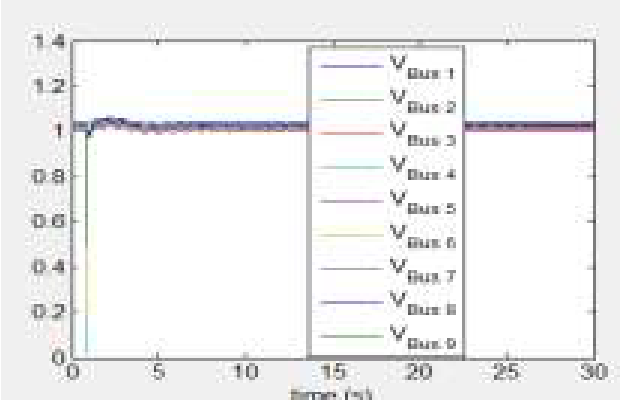


**Figure 6(h): Voltage Time Curve with TCSC**

## 2. CONCLUSION

In this paper the transient stability enhancement of multimachine system is analyzed. A three phase fault occurs at 0.15 sec and has been cleared at 0.25 sec. The simulation results using PSAT software shows clearly the impact of TCSC and SSSC have enhanced the transient stability of multimachine system. The stability has been shown by Simulation results by introducing the Series FACTS controller's i.e. TCSC and SSSC in the faulty system. Thus it is concluded that series FACTS controllers helps in enhancing the transient stability of multimachine system.

The purpose is to provide an analysis on the use of FACTS devices in improving voltage stability, minimizing power loss, and improving transmission system load ability that result from utilization of different types of shunt and series FACTS.

UPFC is better than the SSSC and TCSC because it is more stable.

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## APPENDIX - A

| LINE DATA | | | | | | |
|---|---|---|---|---|---|---|
| LINE No. | From Bus | To Bus | Line impedance (p.u) | | Half Line Charging SusceptanceB/2(p.u.) | MVA |
| | | | R (p.u.) | X (p.u.) | | |
| 1 | 4 | 5 | 0.01 | 0.085 | 0.0880 | 100 |
| 2 | 4 | 6 | 0.017 | 0.092 | 0.0790 | 100 |
| 3 | 5 | 7 | 0.032 | 0.161 | 0.1530 | 100 |
| 4 | 7 | 8 | 0.0085 | 0.072 | 0.7450 | 100 |
| 5 | 8 | 9 | 0.0119 | 0.1008 | 0.1045 | 100 |
| 6 | 6 | 9 | 0.039 | 0.170 | 0.1790 | 100 |

| BUS DATA | | | | | |
|---|---|---|---|---|---|
| BUS NO. | NO. OF I/P | NO. OF O/P | Voltage (KV) | Voltage (p.u) | Angle (rad) |
| 1 | 2 | 1 | 16.5 | 1.0 | 0.0 |
| 2 | 2 | 1 | 18 | 1.0 | 0.0 |
| 3 | 2 | 1 | 13.8 | 1.0 | 0.0 |
| 4 | 2 | 1 | 230 | 1.0 | 0.0 |
| 5 | 1 | 2 | 230 | 1.0 | 0.0 |
| 6 | 1 | 2 | 230 | 1.0 | 0.0 |
| 7 | 1 | 2 | 230 | 1.0 | 0.0 |
| 8 | 2 | 1 | 230 | 1.0 | 0.0 |
| 9 | 1 | 2 | 230 | 1.0 | 0.0 |

| GENERATOR DATA | | | |
|---|---|---|---|
| | GEN 1 | GEN 2 | GEN 3 |
| MVA | 100 | 100 | 100 |
| KV | 18 | 16.5 | 13.8 |
| HZ | 60 | 60 | 60 |
| Ra (p.u.) | 0.00 | 0.00 | 0.00 |
| $X_L$ (p.u.) | 0.00 | 0.00 | 0.00 |
| $X_d$ (p.u.) | 0.8958 | 0.1460 | 1.3125 |
| $X_d'$ (p.u.) | 0.1198 | 0.0608 | 0.1813 |
| $X_d''$ (p.u.) | 0.0000 | 0.0000 | 0.0000 |

| SUMMARY OF EIGEN VALUE ANALYSIS | | | | | |
|---|---|---|---|---|---|
| | PRE FAULT | WITH FAULT | WITH TCSC | WITH SSSC | WITH UPFC |
| Dynamic Order | 24 | 24 | 26 | 25 | 27 |
| Buses | 9 | 9 | 9 | 9 | 9 |
| Positive Eigens | 0 | 2 | 0 | 0 | 0 |
| Negative Eigens | 22 | 20 | 23 | 23 | 25 |
| Complex Pairs | 8 | 8 | 8 | 8 | 8 |
| Zero Eigens | 2 | 2 | 3 | 2 | 2 |