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Power System Stability Enhancement Using Fact Devices

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ABSTRACT
The development of the modern power system has led to an increasing complexity in the study of power systems, and also presents new challenges to power system stability, and in particular, to the aspects of transient stability and small-signal stability. So Power system engineers are currently facing challenges to increase the power transfer capabilities of existing transmission system. This is where the Flexible AC Transmission Systems (FACTS) technology comes into effect with relatively low investment, compared to new transmission or generation facilities. Flexible AC transmission system (FACTS) devices use power electronics components to maintain controllability and capability of electrical power system. The paper aims towards the performance of UPFC is compared with other FACTS devices such as Static Synchronous Series Compensator (SSSC), Thyristor Controlled Series Capacitor (TCSC), and Static Var Compensator (SVC) respectively. The simulation results demonstrate the effectiveness of the UPFC on transient stability of the system.
Keywords: FACTS, SSSC, SVC, TCSC, Transient stability, STATCOM, UPFC.

I. INTRODUCTION

Modern power system is a complex network comprising of numerous generators, transmission lines, variety of loads and transformers. As a consequence of increasing power demand some transmission lines are more loaded than was planned when they were built. With the increased loading of long transmission lines, the problem of transient stability after a major fault can become a transmission limiting factor.

The stability of a system determines whether the system can settle down to the original or close to the steady state after the transients disappear. Transient stability refers to the capability of a system to maintain synchronous operation in the event of large disturbances such as multi-phase short-circuit faults or switching of lines. The resulting system response involves large excursions of generator rotor angles and is influenced by the nonlinear power angle relationship. Stability depends upon both the initial operating conditions of the system and the severity of the disturbance. Recent development of power electronics introduces the use of flexible ac transmission system (FACTS) controllers in power systems. FACTS controllers are capable of controlling the network condition in a very fast manner and this feature of FACTS can be exploited to improve the voltage stability, and steady state and transient stabilities of a complete power system.

II. CLASSIFICATION OF FACTS DEVICES

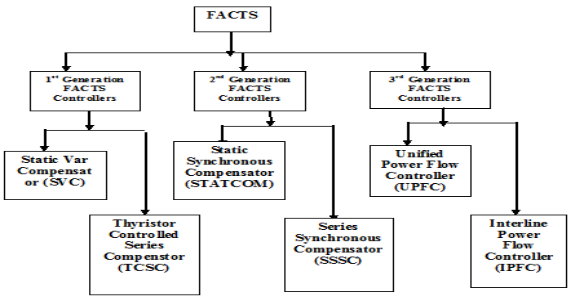

Fig2.1: Block Diagram of FACTS Controllers

2.1 THYRISTOR-CONTROLLED SERIES CAPACITOR

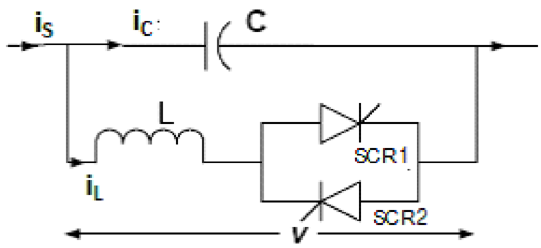

Fig2.2: Configuration of a TCSC

When the thyristors are fired, the TCSC can be mathematically
Described as Described as

$$i_c = C\frac{dv}{dt} \qquad v_l = L\frac{di}{dt}$$

$$X_{TCSC}(\alpha) = X_C - \frac{X_C^{\,2}}{(X_C - X_P)}\frac{(\sigma + \sin\sigma)}{\pi} + \frac{4X_C^{\,2}}{(X_C - X_P)}\frac{(\cos^2\sigma/2)}{(K^2-1)}\frac{K\tan\left(\frac{K\sigma}{2}\right) - \tan\left(\frac{\sigma}{2}\right)}{\pi}$$

Xc = Nominal reactance of the fixed capacitor C
X p = Inductive reactance of inductor L connected in parallel with C.
$\sigma = 2(\pi - \alpha)$ is conduction angle of TCSC controller.
K= $\sqrt{\frac{X_C}{X_P}}$ = compensation ratio.

Thyristor Controlled Series Capacitor (TCSC) is one of the important members of FACTS family that is increasingly applied with long transmission lines by the utilities in modern power systems. It can have various roles in the operation and control of power systems, such as scheduling power flow; decreasing unsymmetrical components; reducing net loss; providing voltage support; limiting short-circuit currents; mitigating sub synchronous resonance (SSR); damping the power oscillation; and enhancing transient stability.

2.2 UNIFIED POWER FLOW CONTROLLER (UPFC)

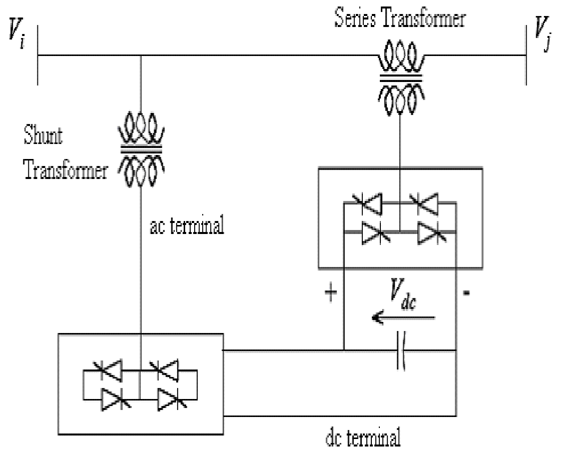

Fig2.3. Configuration of UPFC

The real and reactive power equations are as follows:

$$P = \frac{V_1 V_2}{X}\sin(\delta_1 - \delta_2)$$

$$Q = \frac{V_2}{X}(V_1 - V_2)$$

Among the available FACTS devices, the Unified Power Flow Controller (UPFC) is the most versatile one that can be used to improve steady state stability, dynamic stability and transient stability. The UPFC can independently control many parameters since it is the combination of Static Synchronous Compensator (STATCOM) and SSSC. These devices offer an alternative mean to mitigate power system oscillations. It has been reported in many papers that UPFC can improve stability of single machine infinite bus (SMIB) system and multimachine system. A Static Synchronous Series Compensator (SSSC) is a member of FACTS family which is connected in series with a power system. It consists of a solid state voltage source converter which generates a controllable alternating current voltage at fundamental frequency. When the injected voltage is kept in quadrature with the line current, it can emulate as inductive or capacitive reactance so as to influence the power flow through the transmission line. While the primary purpose of a SSSC is to control power flow in steady state, it can also improve transient stability of a power system.

2.3 STATIC VAR COMPENSATOR (SVC)

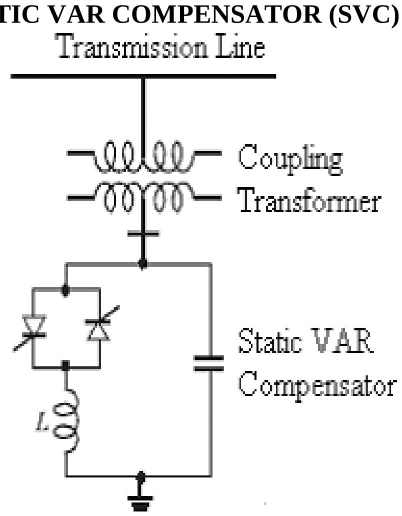

Fig2.4. Configuration of SVC

Static VAR Compensator (SVC) is a first generation FACTS device that can control voltage at the required bus thereby improving the voltage profile of the system. The primary task of an SVC is to maintain the voltage at a particular bus by means of reactive power compensation (obtained by varying the firing angle of the thyristors). SVCs have been used for high performance steady state and transient voltage control compared with classical shunt compensation. SVCs are also used to dampen power swings, improve transient stability, and reduce system losses by optimized reactive power control.

III. SIMULATION DIAGRAMS AND RESULTS:

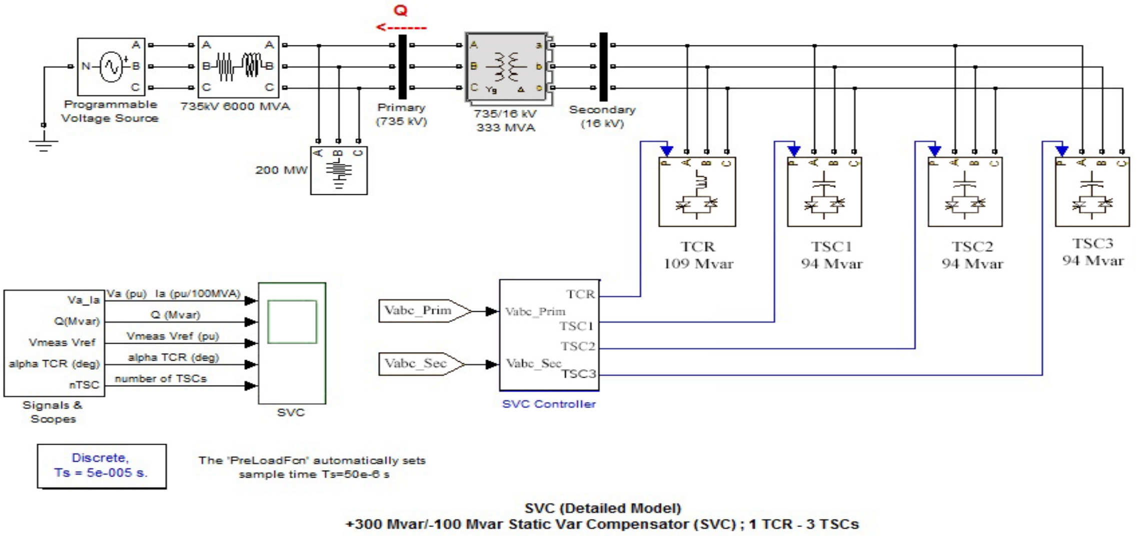

Fig3.1 : Simulink block of Static var compensator(SVC)

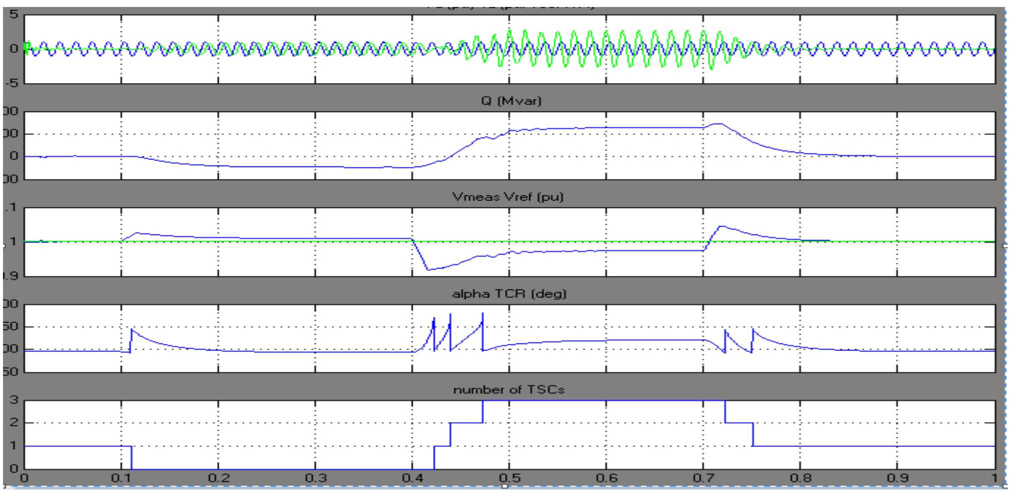

Fig3.2 : SVC output

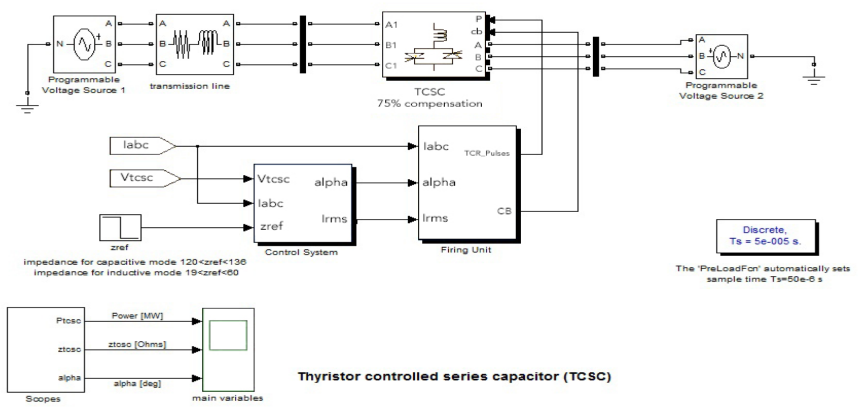

Fig 3.3:Simulink block of Thyristor controlled series capacitor

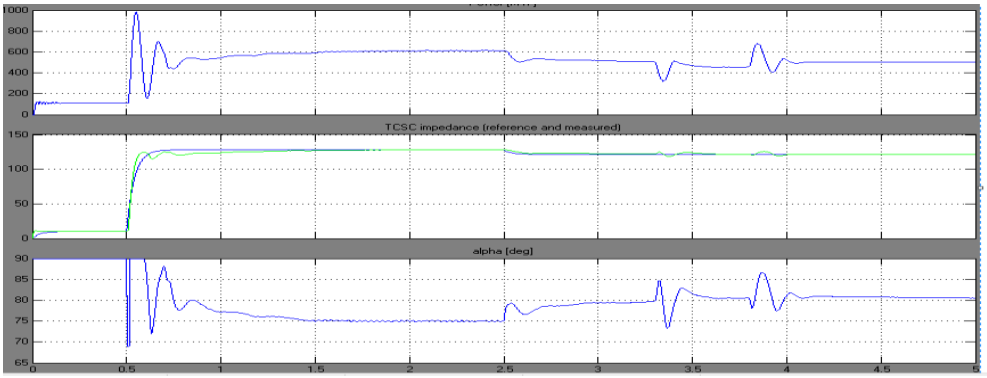

Fig:3.4:TCSC output

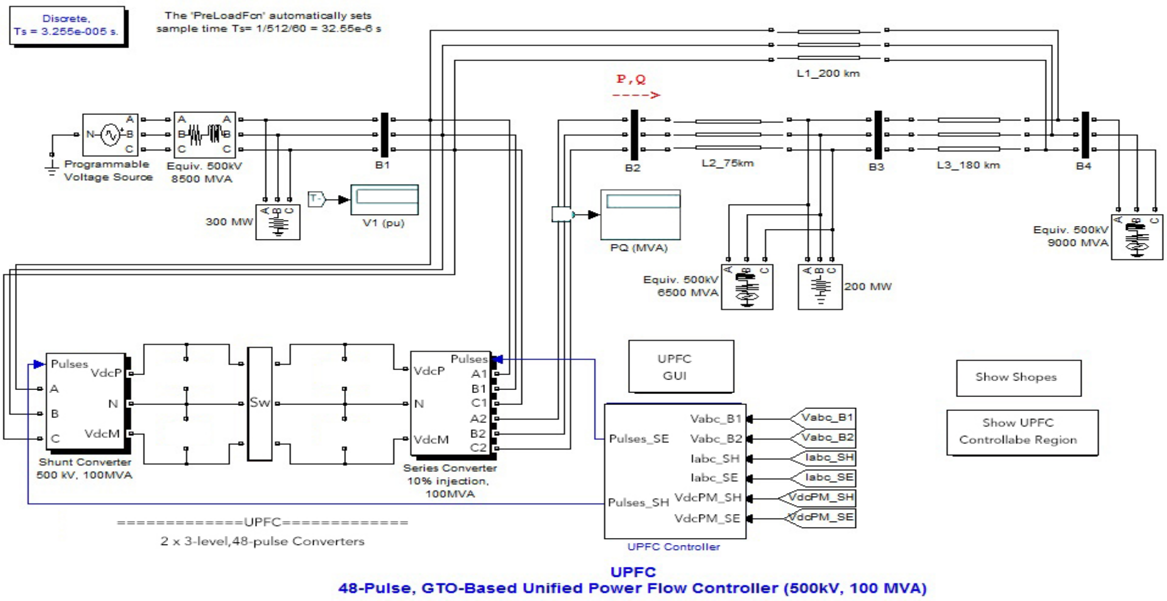

Fig 3.5: Simulink block of unified power flow controller

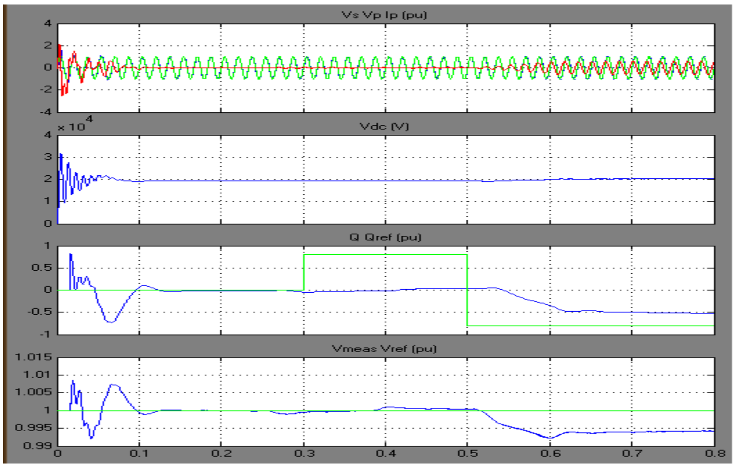

Fig 3.6:STATCOM(shunt) output

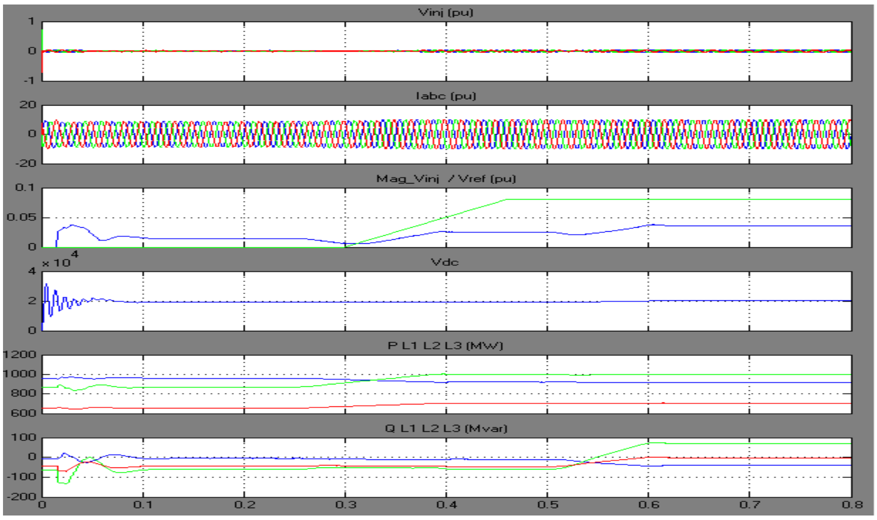

Fig 3.7:SSSC (series)output

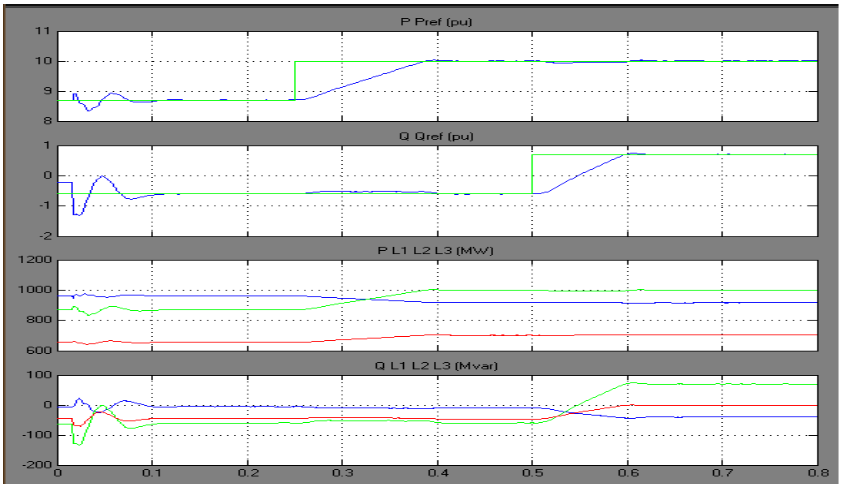

Fig 3.8:UPFC(series) output

IV. IV.COMPARISON BETWEEN FACTS DEVICES FOR POWER SYSTEM STABILITY ENHANCEMENT

TYPE OF FACTS DEVICE	POWERSYSTEM STABILITY	SETTLING TIME PERIOD
TCSC	LESS EFFECTIVE	4.2
SVC	EFFECTIVE	0.4
UPFC	**MORE EFFECTIVE**	**0.36**

V. CONCLUSIONS

In this paper, the power system stability enhancement of a power system by various FACTS devices is presented and discussed. The power stability of the system is compared with different FACTS devices. The performance of the UPFC for power system stability improvement is better compared with the other FACTS devices such as SVC, TCSC, which is clear from the simulation results and there is a considerable improvement of the system stability with UPFC. The essential features of FACTS controllers and their potential to improve system stability is the prime concern for effective & economic operation of the power system

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