A Stability Enhancement under 3 Phase Fault with Flexible Ac Transmission System Devices TCSC, STATCOM and UPFC

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Abstract: -With the regularly expanding complexities in control frameworks over the globe and the developing need to give steady, secure, controlled, monetary and astounding force particularly in the deregulated control advertise. It is conceived that FACTS controllers will assume an essential part in control frameworks. This paper explores the change of transient strength of a test framework under three stage blame utilizing actualities devise. TCSC-Thyristor Controlled Series Capacitor and STATCOM-Static Synchronous Compensator are used as an arrangement and shunt remuneration individually. UPFC-Unified Power Flow Controller is considered as a shunt-arrangement compensator.

Index Terms- TCSC; STATCOM; UPFC; Transient stability.

I. INTRODUCTION

Presently a day's energy framework is a perplexing system containing generator, transmission lines, assortment of burdens and transformers. With the ever increment in control request some transmission line is more stacked than was arranged when they were assembled [1]. With expanded stacking of long transmission line the issue of transient security after real aggravation, will make the whole framework die down. Power framework soundness is the capacity of electric power framework, for a given beginning working condition to recapture a condition of working balance subsequent to being subjected to a physical aggravation, with most framework factors limited so basically the whole framework stays in place [2]. Furthermore, the fundamental difficulties of present day control framework is transient dependability is alluded as the ability of the framework to keep up synchronous operation in case of expansive aggravation and this sort of solidness relies upon parameters of framework and force of unsettling influence [3] [4].

The current improvement of energy gadgets presents the utilization of adaptable air conditioning transmission framework (FACTS) controllers in control framework [5]. Certainties innovation gives the chance to [6] [7]–

- Increase stacking limit of transmission lines.
- Prevent power outages.
- Improve age efficiency.
- Reduce flowing responsive power.
- Improves framework dependability restrain.
- Reduce voltage glimmer.
- Reduce framework damping and motions.
- control stream so it moves through the assigned courses.
- Congestion administration

The traditional control gadgets like synchronous condenser, immersed reactor, thyristor controlled reactor, settled capacitor thyristor controlled reactor, thyristor exchanged capacitor having less framework strength restrict, less improvement of framework damping, less voltage glimmer control when contrasted with developing realities gadgets like TCSC, STATCOM and UPFC [8][9]. This paper explores the change of framework solidness with different rising FACTS gadgets and their correlations. [10] - [13]

II. DESCRIPTION OF FACTS DEVICES

A. TCSC

The basic conceptual TCSC module comprises a series capacitor, *C*, in parallel with a thyristor-controlled reactor, *LS*, as shown in Fig.1. A TCSC is a series-controlled capacitive reactance that can provide continuous control of power on the ac line over a wide range. The principle of variable-series compensation is simply to increase the fundamental-frequency voltage across an fixed capacitor in a series compensated line through appropriate variation of the firing angle. This enhanced voltage changes the effective value of the series-capacitive reactance and control the reactive power [9] [14].

B. STATCOM

STATCOM is a controlled reactive-power source. It provides the desired reactive-power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a voltage-source converter (VSC). A single-line STATCOM power circuit is shown in Fig.2

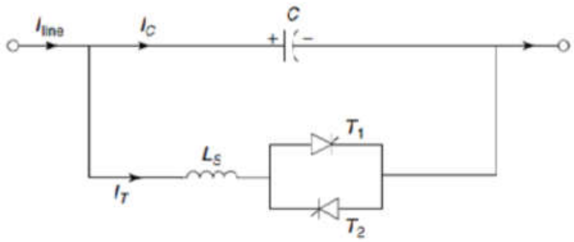

Figure1-Configuration of TCSC

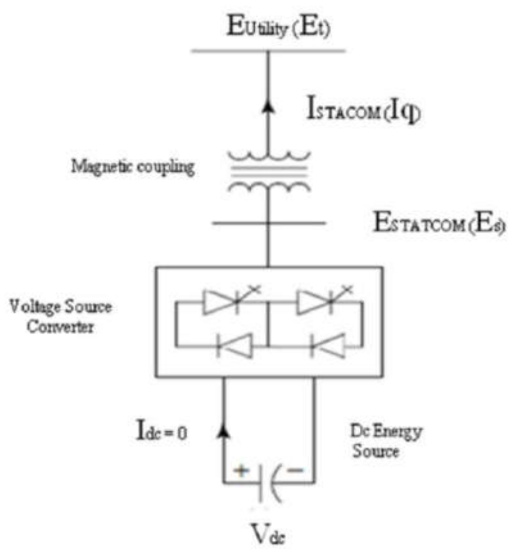

Figure 2-Configuartion of STATCOM

where a VSC is connected to a utility bus through magnetic coupling. The exchange of reactive power between the converter and the ac system can be controlled by varying the amplitude of the 3-phase output voltage, *Es*, of the converter. That is, if the amplitude of the output voltage is increased above that of the utility bus voltage, *Et*, then a current flows through the reactance from the converter to the ac system and the converter generates capacitive-reactive power for the ac system. If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows from the ac system to the converter and the converter absorbs inductive-reactive power from the ac system. If the output voltage equals the ac system voltage, the reactive-power exchange becomes zero, in which case the STATCOM is said to be in a floating state [9] [15] – [16].

C. UPFC

The UPFC is the most versatile FACTS controller developed so far, with all encompassing capabilities of voltage regulation, series compensation, and phase shifting. It can independently and very rapidly control both real- and reactive power flows in a transmission line. It is configured as shown in Fig.3 and comprises two VSCs coupled through a common dc terminal. One VSC-converter 1 is connected in shunt with the line through a coupling transformer, the other VSC-converter 2 is inserted in series with the transmission line through an interface transformer. The dc voltage for both converters is provided by a common capacitor bank. The series converter is controlled to inject a voltage phasor, *Vpq*, in series with the line, which can be varied from 0 to

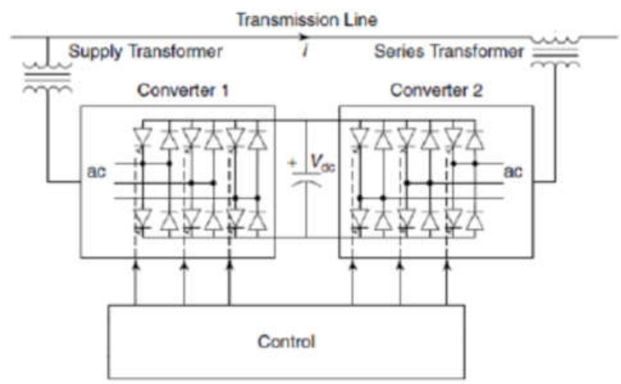

Figure3-Configuartion of UPFC

Vpq max. Moreover, the phase angle of *Vpq* can be independently varied from 0 to 360 degree. In this process, the series converter exchanges both real and reactive power with the transmission line. Although the reactive power is internally generated/ absorbed by the series converter, the real-power generation/ absorption is made feasible by the dc-energy storage device that is, the capacitor. The shunt-connected converter 1 is used mainly to supply the real-power demand of converter 2, which derives from the transmission line itself. The shunt converter maintains constant voltage of the dc bus. Thus the net real power drawn from the ac system is equal to the losses of the two converters and their coupling transformers. In addition, the shunt converter behaves like a STATCOM and independently regulates the terminal voltage of the interconnected bus by generating/ absorbing a requisite amount of reactive power [9] [17] – [18].

III. MODEL OF TEST SYSTEM

The below test network is tested with TCSC, STATCOM, and UPFC separately to investigate the behavior with five parameters such as generator voltage (Vg), generator current (Ig), generated load angle (δ), voltage near infinite bus (Vb) and current near infinite bus (Ib). These are done through MATLAB/SIMULINK with following stages

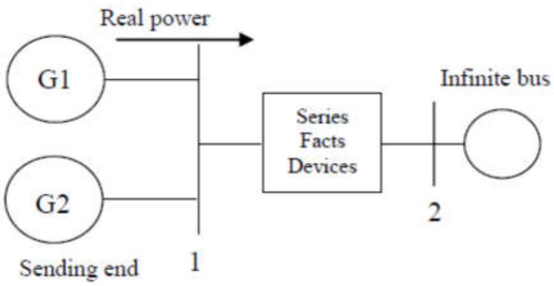

Figure 4. Test system with series FACTS device

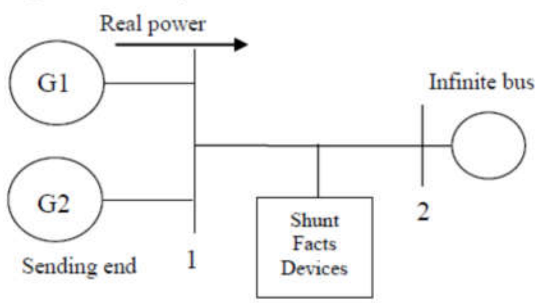

Figure 5. Test system with shunt FACTS device

- Stage 1 -To design test system shown in fig 6.
- Stage 2 - To measure five parameters under normal operating condition.
- Stage 3 -To create three phase fault near to infinite bus in test system. Fault duration 0.5 to 0.6 seconds. Shown in fig 7.
- Stage 4- To measure five parameters under three phase fault conditions
- Stage 5 - To design FACTS devices (TCSC, STATCOM and UPFC) Shown in fig 8, fig 9 and fig 10 respectively.
- Stage 6- To connect FACTS devices (0.6 to0.8 seconds) in test system under three phase fault condition and to measure behavioral change of system.

The test system specification is

- Generator 1, 2 - 10KV, 110MW, 300 rpm,
- TCSC - 10MVAR, 10KV,
- STATCOM - 10MVAR, 10KV and
- UPFC - 10MVAR, 10KV.

IV. RESULT AND DISCUSSION

As per the above SIMULINK work the five distinct parameters - generator voltage (Vg), generator current (Ig), created stack edge (δ), voltage close unending transport (Vb) and current close interminable transport (Ib) of test framework is measured and the settling time of every parameter is ascertained for framework strength and furthermore to amplify the power stream in transmission line.

The reproduction result for generator voltage (Vg) of stage An is appeared in fig 11. Unmistakably under three stage blame, without FACTS gadget the voltage vacillation of generator is more, though, it is less when the FACTS gadgets are included. A table for generator voltage (Vg) under various time interim is built from the watched result. Amid the time interim of 0.5 to 0.8 seconds and 0.8 to 3.2 seconds the voltage ascends from 3200 to 5000 volts and from 5000 to 8000 volts individually which is more noteworthy than the generator voltage (Vg) without the association of FACTS gadget. In this way, when FACTS gadgets are associated with the framework, it takes 2.4 seconds for TCSC, 2.0 seconds for STATCOM and 1.4 seconds for UPFC to achieve the dependability level.

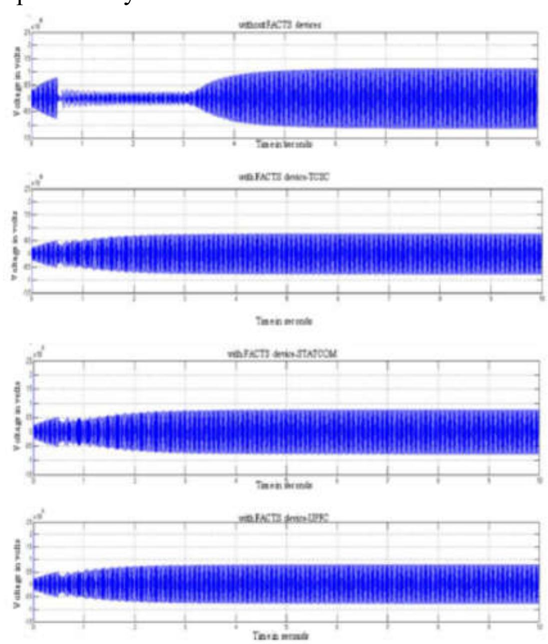

Figure 11. Simulation Result for Generator Voltage (Vg)

Table 1. Generator Voltage (Vg) in volts

Generator Voltage (Vg) in volts	Time in seconds	0 to 0.5	0.5 to 0.6	0.6 to 0.8	0.8 to 3.2	3.2 to 10
	Without FACTS device	0 to 5000	2000 to 0	4000	4000	4000 to 11000
	TCSC	0 to 5000	3200	3200 to 5000	5000 to 8000	8000
	STATCOM	0 to 5000	3200	3200 to 5000	5000 to 7000	7000 to 8000
	UPFC	0 to 5000	3200	3200 to 5000	5000 to 7600	7600 to 8000

The fig 12 shows the generator current (Ig) of phase A. The generator current (Ig) is reached to stable at 4.4 seconds when the FACTS devices are not connected. After incorporating the FACTS devices TCSC, STATCOM and UPFC, the settling time of generator current (Ig) is reduced as 2.4, 3.4 and 2.3 seconds respectively for reaching the stable condition, Which is understood through table 2.

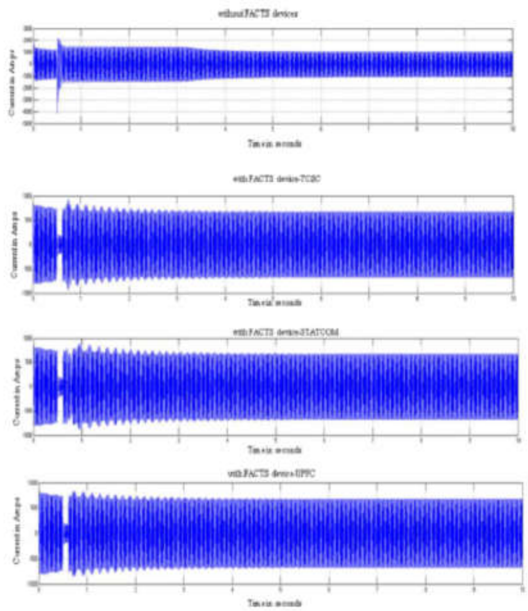

Figure 12. Simulation Result for Generator Current (Ig)

Table 2. Generator Current (Ig) in Amps

Generator Current (Ig) in Amperes	Time in seconds	0 to 0.5	0.5 to 0.6	0.6 to 0.8	0.8 to 3.2	3.2 to 10
	Without FACTS device	1500 to 1250	5000	1500	1500	1500 to 1050
	TCSC	800 to 750	200	1000	1000 to 700	700
	STATCOM	800 to 750	200	800	800 to 700	700
	UPFC	800 to 750	200	800	800 to 700	700

Before connecting the FACTS devices in test system the load angle (δ) of generator is varied up to 18 degree and takes around 7.4 seconds to settle down to stable region after the fault recovery. But due to the interfacing of FACTS device the settling time is reduced to 4.2, 4.4 and 4.2 seconds for TCSC, STATCOM and UPFC respectively is shown in fig 13 and table 3.

Table 3. Generator Load Angle (δ) in degree

Generator Load Angle (δ) in degree	Time in seconds	0 to 0.5	0.5 to 0.6	0.6 to 0.8	0.8 to 3.2	3.2 to 10
	Without FACTS device	1.5	3.5	18	18	18 to 0
	TCSC	2.5	4	4 to 2	2 to 0.2	0.2 to 0
	STATCOM	2.5	4	4 to 3	3 to 0.4	0.4 to 0
	UPFC	2.5	4	4 to 2.5	2.5 to 0.1	0.1 to 0

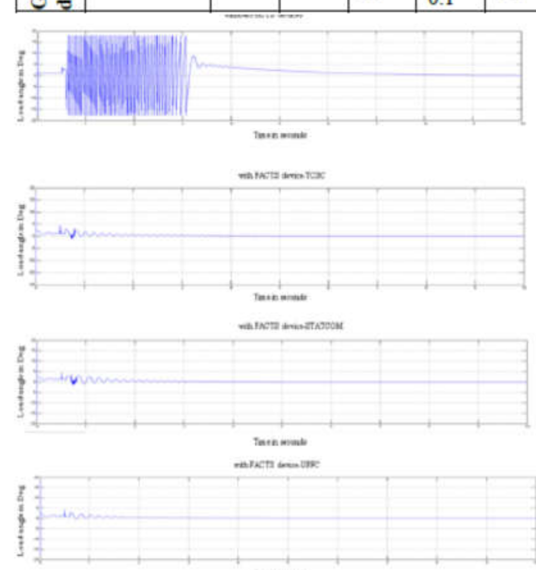

Figure 13. Simulation Result for Generator Load Angle (δ)

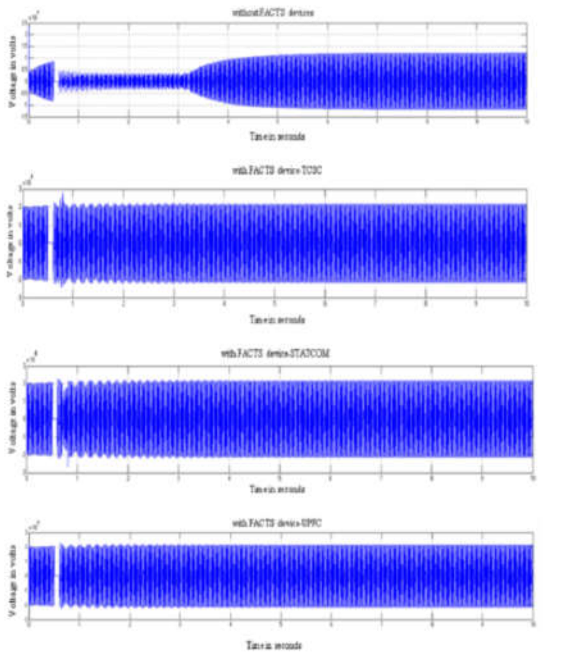

Figure 14. Simulation Result for Voltage near Infinite Bus (Vb)

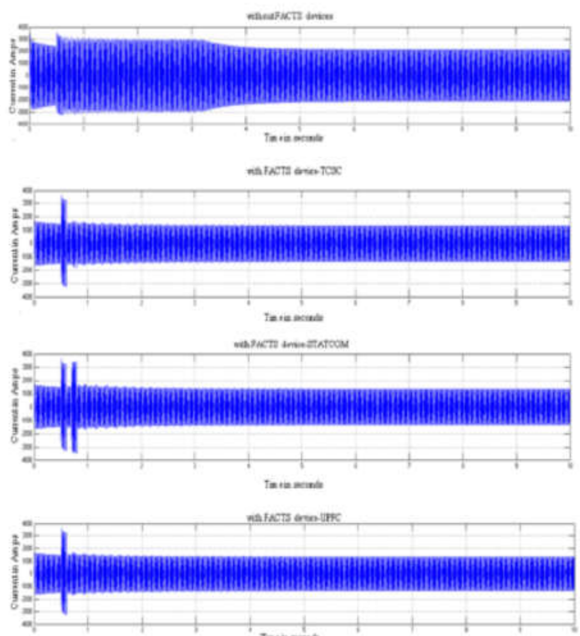

Figure 15. Simulation Result for Current near Infinite Bus (Ib)

From Fig 14 it is observed that the settling time for the voltage near infinite bus (Vb) is 5.4 seconds when the FACTS devices are not connected. After connecting the FACTS devices settling time is reduced as 0.4, 0.5 and 0.2 seconds for stable condition. Similarly the current near infinite bus (Ib) comes to stable within 0.4, 0.5 and 0.2 seconds for TCSC, STATCOM and UPFC respectively after the fault recovery. But without those devices it takes 3.4 seconds to reach stability is shown in fig 15.

The settling time of Vg, Ig, δ, Vb, Ib for TCSC, STACOM and UPFC are studied and shown in table 4. It is found that the system stability is achieved in short interval while interfacing UPFC.

TABLE 5. COMPARISON OF SETTLING TIME

Settling time in seconds				
Parameters	*Without FACTS devices*	*TCSC*	*STATCOM*	*UPFC*
Generator voltage (Vg)	4.4	2.4	2	1.4
Generator Current(Ig)	4.4	2.4	3.4	2.3
Generator load angle(δ)	7.4	4.2	4.4	4.2
Voltage near infinite bus(Vb)	5.4	0.4	0.5	0.2
Current near infinite bus(Ib)	3.4	0.4	0.5	0.1

V. CONCLUSION

In this paper the power framework steadiness upgrade of test connect with FACTS gadgets TCSC, STATCOM and UPFC is displayed and talked about under three stage cut off. Unmistakably the framework recaptures its steadiness under any of the FACTS gadget is included. Additionally the settling time to achieve the dependability of the framework with UPFC for various parameters (Generator Voltage – 1.4 secs, Generator Current – 2.3 secs, Generator Load Angle – 4.2 secs, Voltage close Infinite Bus – 0.2 secs and Current close Infinite Bus – 0.1 secs) is relatively much superior to STATCOM and also TCSC.

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