Comparative Study of Traditional Devices and FACTS Controller for Enhancing the Transient Stability Margin

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Abstract: Instead of transmission lines expansion or building new substations in our present transmission system, the proper installation of FACTS (Flexible AC Transmission Systems) seems to be a promising strategy to support transient stability and increasing power demand. This paper narrates a correlative performance of traditional devices (AVR, TG, and PSS) with series FACTS controller on electric power network. Here, IEEE-14 bus system is considered to be the benchmark of the power network. This proposed approach is implemented with the power system analysis toolkit (PSAT) software and is applied to small case studies, IEEE 14-Bus. For the performance analysis the Eigen value analysis and time domain simulation results are compared for result validation. Results revealed that FACTS controller improve better stability as compared to other conventional used devices.

Key words: FACTS, TCSC controller, PSS, PSAT, steady state stability.

1. Introduction

In today's world, power demand is increasing significantly over the last few decades. This growing power demand, after all does not pursued by expansion in power generation and transmission capacity. Consequently, in order to fulfill the growing electric load requirement, power plants are operating at their maximum capacity [1]. Furthermore, transmission lines are also operating nearer to their thermal limits. So, the power systems are seemly less protected and ever awaiting the exposure of voltage instability which has led to many major network collapses world-wide. It was revealed that voltage instability was one of the major cause for the North American blackout in August 2003 [2].

The major reason of voltage instability perhaps by reason of inadequacy of reactive capacity of power system while interruptions like line outage contingencies. To maintain security of power systems, it is important to suggest relevant measures to enhance power system security and maximize voltage stability margins. Different preventive measures like appropriately rescheduling of generation and energy transfer, bringing backup generators in line, load shedding and VAR control by using series or shunt capacitors are taken up to conquered voltage instability controversy. The traditional sources of reactive power are not quick responses for the need of the reactive power of the power network. Also most of them are the electromechanical controller which got the disadvantages like slowness and wear [3].

Voltage stability can be classified into two sections particularly dynamic and static. The static voltage stability approaches are primarily relying on steady state model in the tests like the flow of power model [4]. Dynamic stability analysis presents the utilization of a model identified by nonlinear differential and algebraic equations comprises dynamics of generators, regulating transformers etc. A lot of approaches have been employed in static voltage stability analysis like the P-V and Q-V curves, model analysis, artificial neural networks [4]. Line stability index (LSI) gives essential knowledge to find the critical line and closeness of the network to voltage instability in the power system.

The new improvements and application of Flexible Alternating Current transmission system in the extended amount of power transmission network has been employed in large applications. These devices enhances the voltage and angle stability. A lot of specific static and dynamic models have been suggested to shows the FACTS analysis performance in network [5]. This paper describes the utilization of FACTS device TCSC (Thyristor Controlled Series Compensator). Thyristor controlled series compensators are connected in series with the power transmission lines [6]. TCSC provides continuous variable capacitive reactance that can give regularly control of power on the AC transmission line over the wide range. TCSC perhaps an individual big unit, or may subsist many same or various sized smaller capacitors for giving better performance [7]. Due to the considerable cost of TCSC, it is worthwhile to determine the suitable placement of thyristor controlled series Compensator in a power network to gain maximal merits [8]. The suitable placement of TCSC has been elected on the ground of line stability index (LSI) for enhancement of voltage stability of power network.

The remaining paper is proceeded as: Section 2 describes operating principle of TCSC. A description of Schematic Control system of TCSC is shown in Section 3. Section 4 describes the elected analysis case IEEE 14 bus system and software tool. Section 5, describes the results and discussion.

2. Operating Principle of TCSC

TCSC is a series compensating FACTS device. TCSC consists of a series capacitor bank shunted by TCR (Thyristor Controlled Reactor). The power flow in a particular branch may be controlled by operating the TCSC either in inductive or capacitive mode by increasing or decreasing the line reactance. It is modeled with variable series reactance. The structure of TCSC is given in Fig. 1, where XL and XC indicate inductive reactance and capacitive reactance. The current entering the capacitor branch is denoted as i_C and the current entering the TCR branch is denoted as i_L and the total current entering the TCSC module is i_T.

TCSC can be governed to perform in both capacitive and inductive fashions averting steady state resonance [8], as described in below Fig. 2.

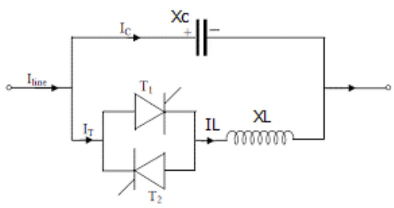

Fig. 1. Basic scheme of TCSC.

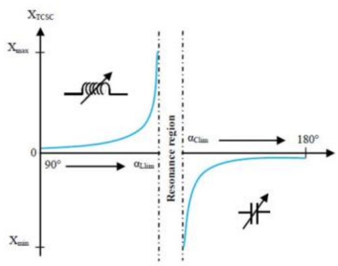

Fig. 2. Impedance characteristics of TCSC.

Thus, impedance characteristics of TCSC (X_{TCSC}) shows, both capacitive and inductive operating ranges are possible though different values of delay angle (α):

- *Blocking mode*

In this mode the thyristors are not gated and hence they can be operated as a fixed capacitor. In this fashion $\alpha_{L\,\text{lim}}$ and $\alpha_{C\,\text{lim}}$.

- *Thyristor valve by pass mode*

In this fashion thyristors are gated for full conduction such that TCSC reactance is parallel combination of a fixed capacitor and fixed inductor. This is called inductive operation zone.

- *Vernier control mode(Capacitive zone)*

The thyristors are continuously gated to run in capacitive zone operation. In this fashion angle vary as $\alpha_{L\,\text{lim}}$ to 180°.

3. Control System of TCSC

To achieve different control objectives a layered structure in the controller is used. The control scheme of TCSC denoted in Fig. 3, subsist of following control approaches.

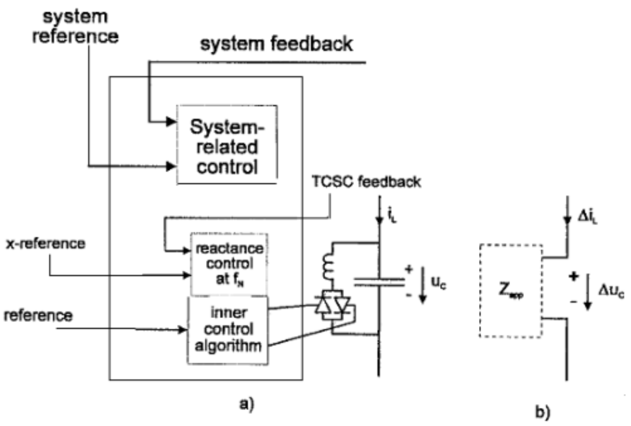

Fig. 3. Control scheme of TCSC.

3.1. Control Modes

- *Inner control algorithm*

Frequency components below 40 Hz cause the torsional vibrations in generator shafts due to which deviations in the injected current are introduced. These deviations change the apparent impedance. Therefore TCSC has to make immune to the SSR this is possible by designing the inner loop so that the probable impedance of the TCSC becomes resistive-inductive in the total sub-synchronous frequency range. By accomplishing so, no electrical resonance can appear between the transmission line and the TCSC.

- *Reactance control at f_N*

This second layer of control system is introduced to make sure that TCSC does not operate in inductive mode near the rated frequency.

- *System related control*

The third layer of control system is used to control the probable reactance of the TCSC at network frequency. By doing this performance of the system can be improved by providing additional damping to electromechanical oscillation. By using this control scheme it can be impermanent rises the amount of compensation of a line in place of pacifying the voltage drops at nodes that do not have plentiful reactive power support in the event of emergencies.

4. Simulation Model

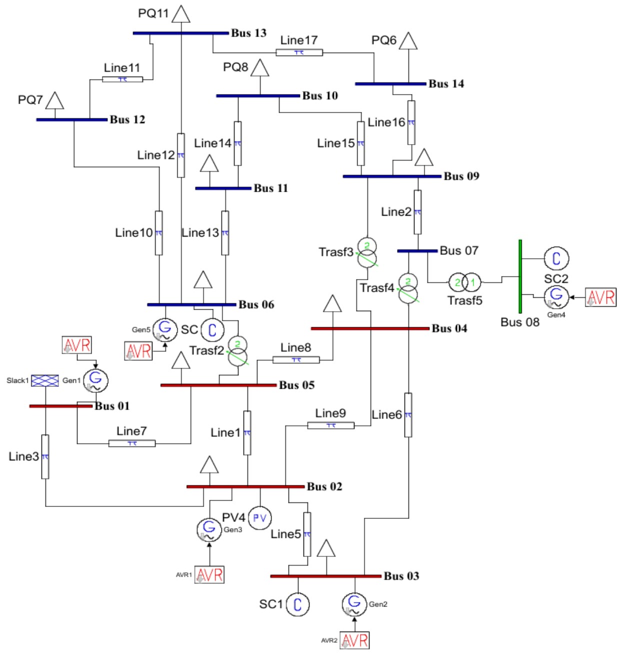

Fig. 4. System with AVR and TG installed.

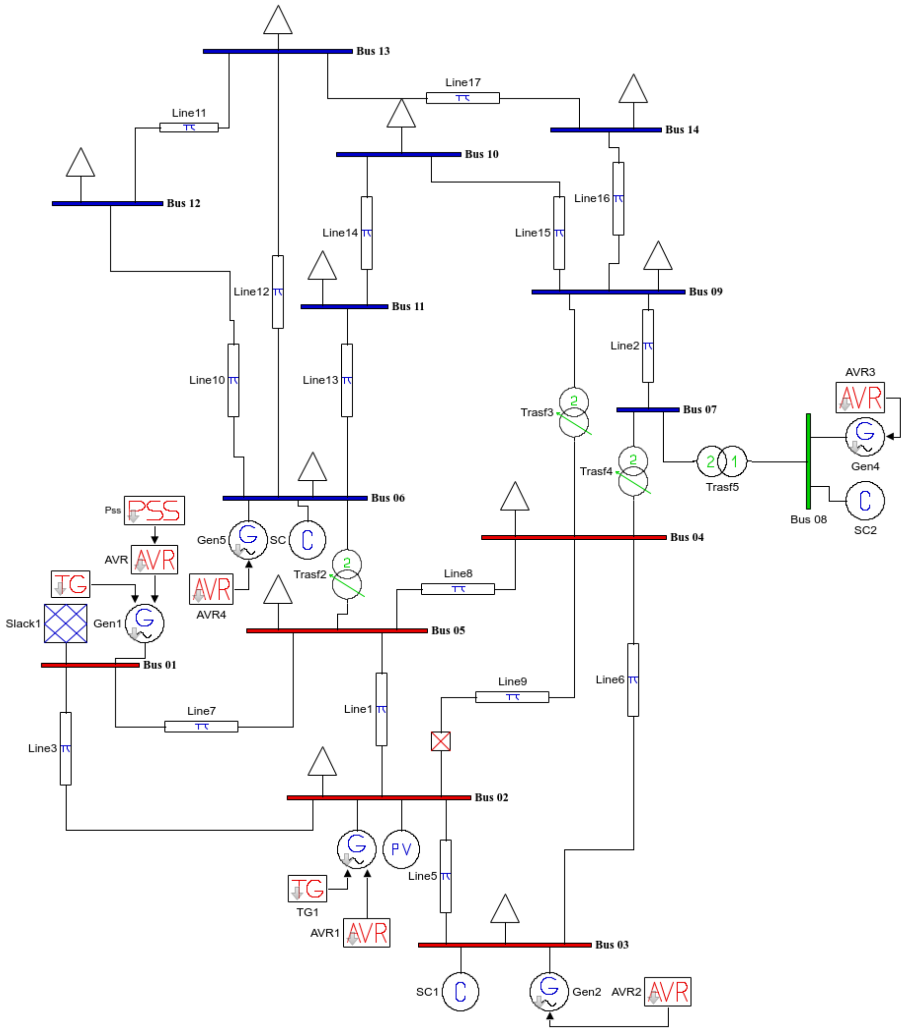

Fig. 5. System with PSS installed.

5. Results and Discussion

In this work the results got from simulation for proposed systems are presented. From the Fig. 6, it can be seen that there are no disturbances in the system but the system becomes unstable after some time. The Eigen value analysis shows that the system is steady state unstable with 2 positive Eigen values and hence the system parameters develop oscillations after some time. From Fig. 7, (a), (b), and (c) it can be evaluated that with only AVR installed, the time domain simulations show sustained oscillations.

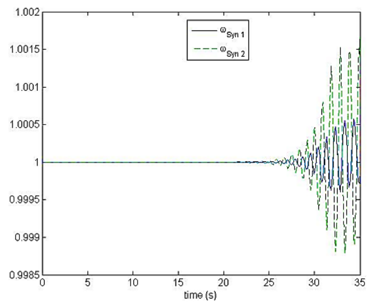

Fig. 6. Eigen value analysis of 14 bus system.

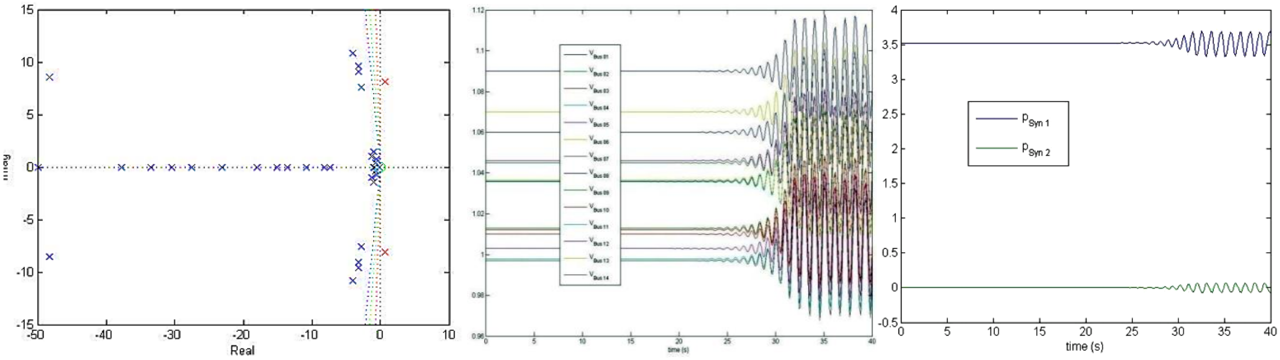

Fig. 7. (a) Speeds of generator 1 and generator 2. (b) Power of generator 1 and 2. (c) Voltages of system with AVR only.

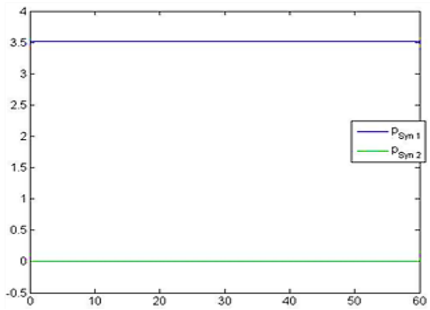

Fig. 8. Eigen value analysis for system with TG installed.

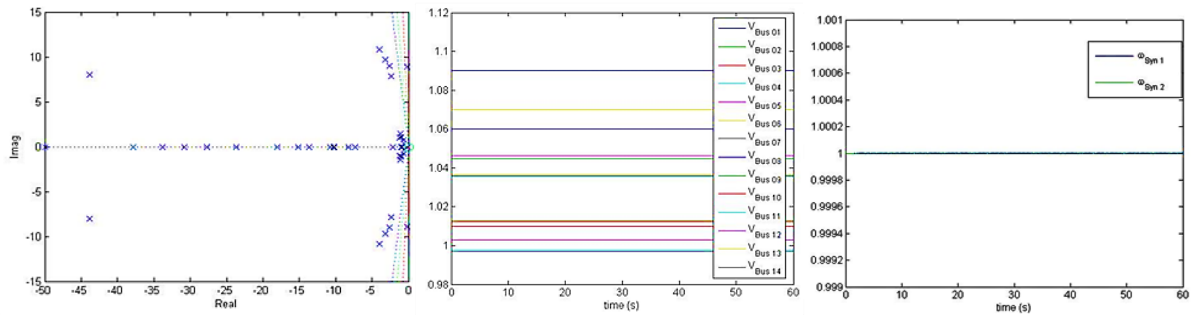

Fig. 9. (a) Generator power with TG installed. (b) Generator speeds with TG installed. (c) Voltages with TG installed.

From Fig. 8, it can be seen that with Turbine Governor (TG) installed there are no positive Eigen values and the system is steady state stable for no disturbances. The time domain simulation results with TG installed in proposed system are shown in Fig. 9 (a), (b), and (c).

5.1. Results for Transient Stability without TCSC

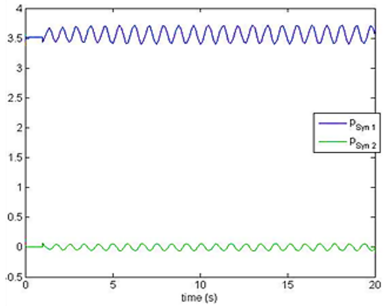

Fig. 10. Unstable due to line outage.

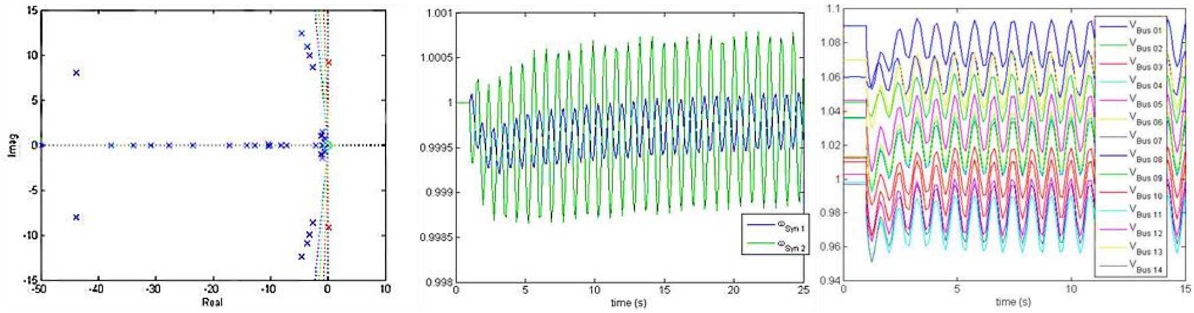

Fig. 11. (a) Power of generators. (b) Generator speeds after line outage. (c) Voltages of generators after line outage.

Now in the same system when a line24 is outage the system becomes unstable. Initially the system was stable but after line outage at t=1 seconds the system becomes unstable. From the Fig. 10, it can be seen that without TCSC installed, there are two positive Eigen values of the excitation of generator 1 indicating that the system has become unstable following a line outage.

From the Fig. 11 (a), (b), and (c) it can be seen that, without TCSC installed in the test system the time domain simulations indicating that the system has become unstable following a line outage.

5.2. Results for Transient Stability with TCSC

From Fig. 13 (a), (b), and (c) time domain simulation results shows that, after TCSC inserted (Fig. 12) between bus 1 and 5 the system becomes stable even for line contingency.

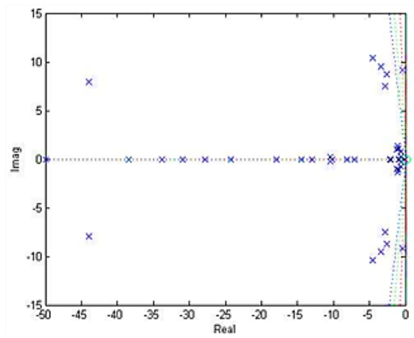

Fig. 12. Eigen value analysis with TCSC.

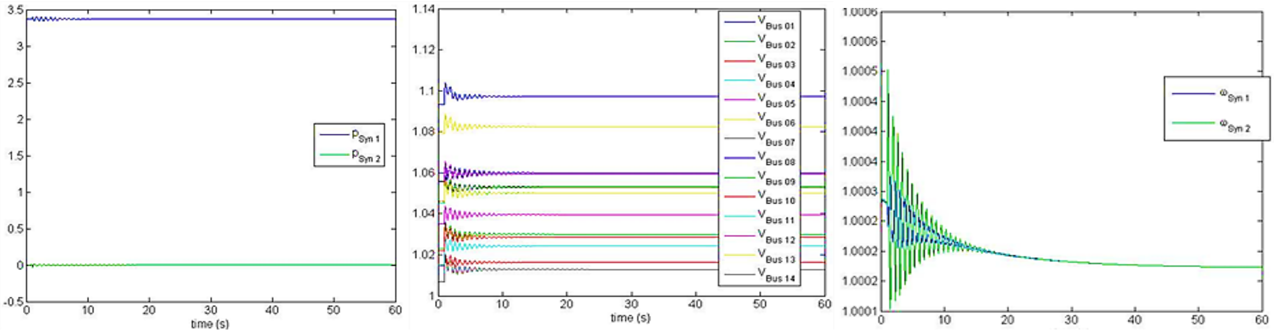

Fig. 13. (a) Power of generators with TCSC. (b) Generator speeds with TCSC. (c) Voltages after TCS.

6. Conclusion

This paper presents comparison of traditional devices Automatic voltage regulator, Turbine governor and Power system stabilizer with FACTS controller TCSC for transient stability improvement. The optimal location of TCSC for transient stability limit enhancement is determined. The performance of TCSC (when it is connected to IEEE-14 bus system) and conventional devices combination in stability enhancement is proved in results by correlating the power of the generators, speed of the generators and voltage profile in the system. It is obvious from the analysis of the results that the improvement of system stability by TCSC is better than that of traditional devices.

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