Effect Of SSSC In Compensation Of Multi-machine Perturbed Network

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***Abstract*—The synchronous series static compensator SSSC is one of the FACTS devices able to act not only on the reactive power, but also on the active power which makes it possible to improve the stability of the electrical networks by the management of the flows of power transiting the lines. Indeed, consisting of a pulse inverter connected in series with the transmission line, it is able to inject a variable voltage in module and phase on the network and thus contribute to managing the power flows. In this paper we will examine the effect of using a SSSC to improving the stability of IEEE 14 bus perturbed network.**

Keywords— FACTS, SSSC, Voltage drop, IEEE 14bus.

INTRODUCTION

Flexible AC Transmission Systems, called FACTS, got in the recent years a well-known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice. In most of the applications the controllability is used to avoid cost intensive or landscape requiring extensions of power systems, for instance like upgrades or additions of substations and power lines [1].

SSSC is one of important members of FACTS family that is increasingly applied by the utilities in modern power system with long transmission lines. 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 current; and enhancing transient stability [2].

The phenomena that impair the quality of electrical energy are of different natures: short circuit, voltage dips, breakdowns, harmonic pollution. Whatever the origin of these disturbances, it is essential to maintain or improve the quality of the electricity that passes through the transmission and distribution networks.

In this work we will study the advantage of the uses of SSSC to increase transit power stability in the case of multi bus, multi machines perturbed network.

FACTS SERIES

- *Thyristor controlled series capacitor*

The TCSC power circuit is similar to that of the SVC. The key difference is that it is connected in series with the transmission line. In this case a 12-pulse configuration is not necessary, since the current harmonics from the TCR are able to complete their path through the capacitor more easily than through the rest of the transmission system [1], [3].

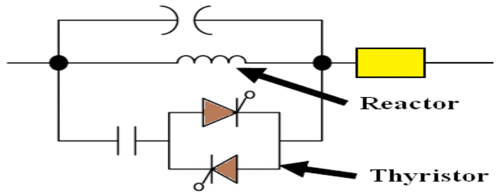

Fig. 1. Thyristor controlled series capacitor power circuit

The TCSC will have low level controls that generate the firing pulses. In this case the firing pulses will he synchronized with the line current. The line current should be used, not the TCR current, which will he discontinuous whenever there is any firing delay present. The response of the synchronization circuit can have a significant impact on system performance, so it is important to match this to the system to be modeled. If the TCSC has multiple modules connected in series, it is also important to model all of them for system studies. The global controls will generally produce a commanded V, or X to insert in the line. Again, it will be necessary to map these quantities hack to produce the firing delay angle through a lookup table. Converter over current protection functions need to he modeled carefully if the TCSC is to be included in system protection studies. This includes the external overvoltage protection such as MOVs and bypass breakers. Fig. 2 shows an example of the extemal protection circuitry. This circuitry is described in the system protection literature [4],[5],[6].

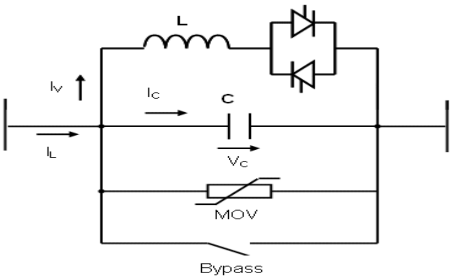

Fig. 2. TCSC with external overvoltage protection

A. *Statics synchronous series compensator*

The static synchronous series compensator of (SSSC) has a structure similar to that of the STATCOM described in the previous presentation. The SSSC is based on the use of a voltage sourced converter (VSC) to synthesize a voltage waveform to inject into the power system, unlike the TCSC which is a controlled impedance placed into the power system. The SSSC is interfaced to the power system through a series injection transformer. Therefore, it behaves as a controlled voltage source inserted into the line, as shown in Fig. 3 [7],[8].

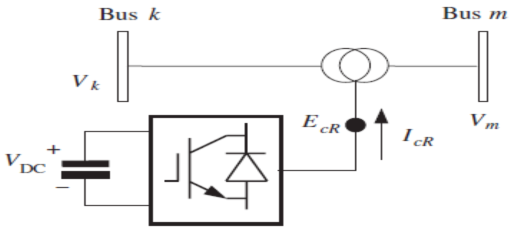

Fig. 3. Configuration of SSSC

MODELLING AND CONTROL OF SSSC

Fig.4 below shows the equivalent circuit of the network equipped with the synchronous series static compensator [9].

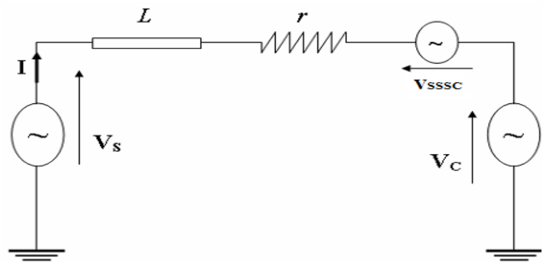

Fig. 4. SSSC model in the case of insertion between two generator bus

The r and L are parameters of including series transformer. The dynamic behavior of the currents in the Park coordinate system is given by the system of equations (1):

$$\frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} -\frac{r}{L} & \omega \\ -\omega & -\frac{r}{L} \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} + \frac{1}{L}\left(\begin{bmatrix} V_d \\ V_q \end{bmatrix} - \begin{bmatrix} V_{cd} \\ V_{cq} \end{bmatrix} - \begin{bmatrix} V'_d \\ V'_q \end{bmatrix} \right) \quad (1)$$

The active P and reactive powers Q to be controlled are given by equations (2) and (3) below:

$$P = \frac{3}{2}(V_d . i_d + V_q . i_q) \quad (2)$$

$$Q = \frac{3}{2}(V_q . i_d - V_d . i_q) \quad (3)$$

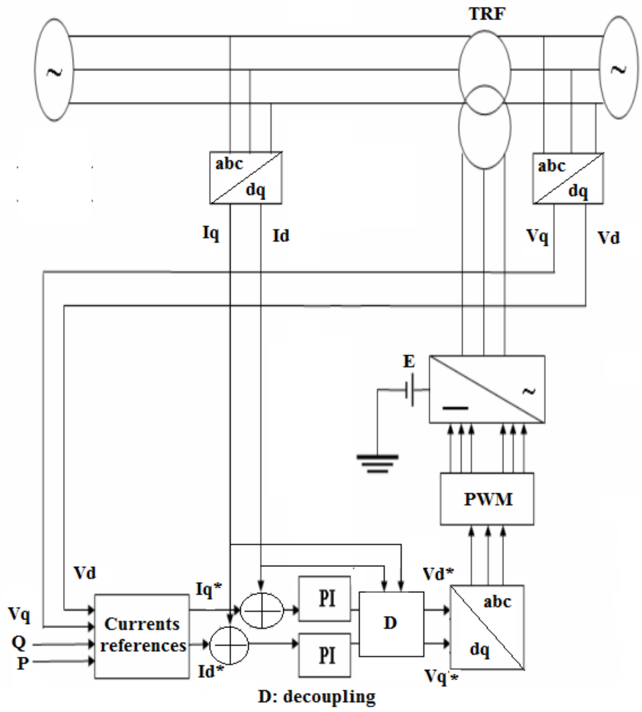

Fig. 5. Control circuit of SSSC

The inverter is controlled in PWM using the three signals obtained by the reverse Park transformation and this in relation with the PI setting of the currents function of the active powers and reactive set of P * and Q *[9]. A compensation decoupling block makes it possible to decouple the two currents and consequently the two types of power using equation below.

$$X_1 = \frac{1}{L}\left(V_d - V_{cd} - V_d^{'}\right)$$
$$X_2 = \frac{1}{L}(V_q - V_{cq} - V_q^{'}) \quad (4)$$

STUDIED SYSTEM

Our objective is to examine the effect of the synchronic static serial compensator on the stability of an IEEE-14 node network, and demonstrate its feasibility. In a first section, the IEEE-14 bus network will be presented, and after that in a second section, a fault near a generator node will be applied under the simulation study; and finally the SSSC will be introduced to solve the problem of voltage drop propagation.

The IEEE 14 Bus Test Case represents a portion of the American Electric Power System (in the Midwestern US).

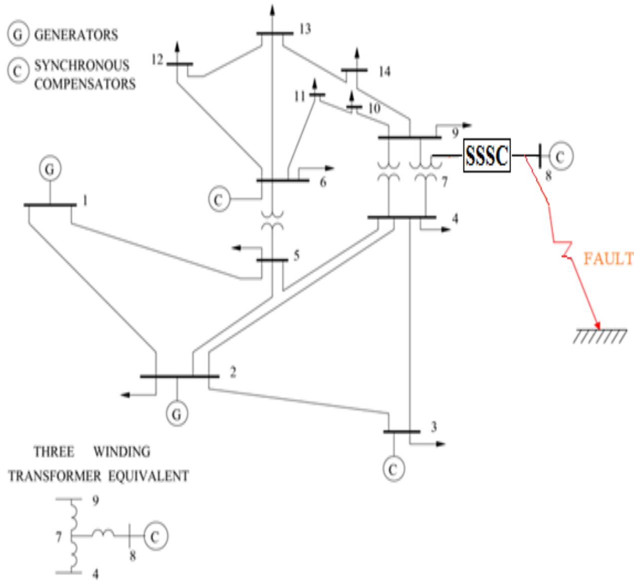

Fig. 6. Perturbed IEEE 14 bus network

A three-phase short circuit fault is applied in the generator node 8 in a time between 0.5 and 0.7 seconds.

A. *Without compensation*

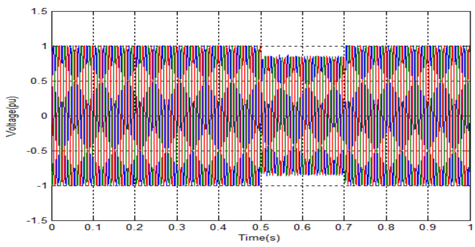

Fig. 7. Voltage at bus 1

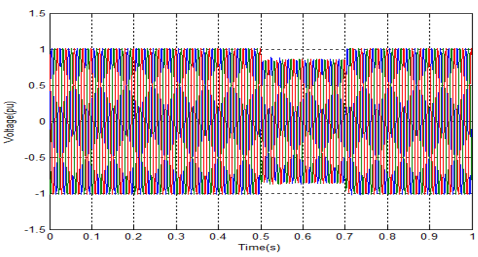

Fig. 8. Voltage at bus 2

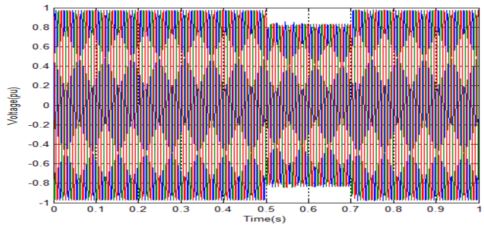

Fig. 9. Voltage at bus 3

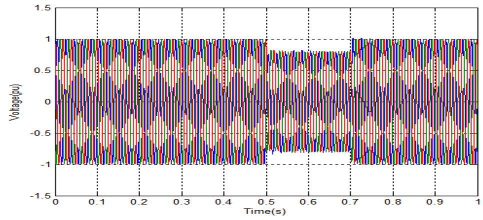

Fig. 10. Voltage at bus 4

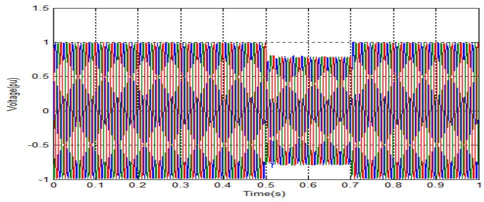

Fig. 11. Voltage at bus 5

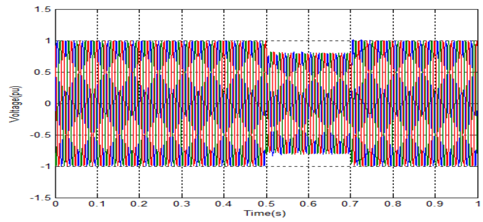

Fig. 12. Voltage at bus 6

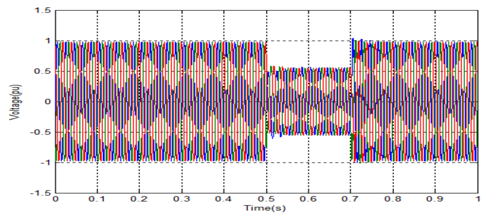

Fig. 13. Voltage at bus 7

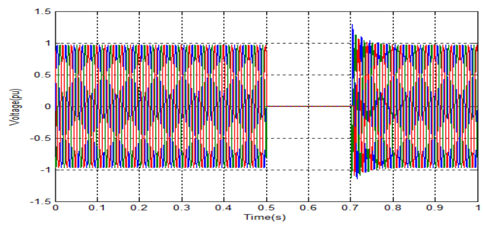

Fig. 14. Voltage at bus 8

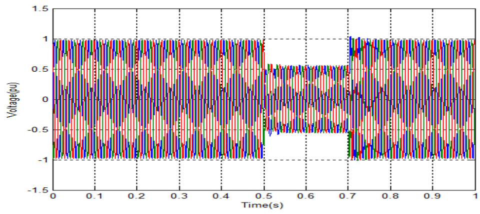

Fig. 15. Voltage at bus 9

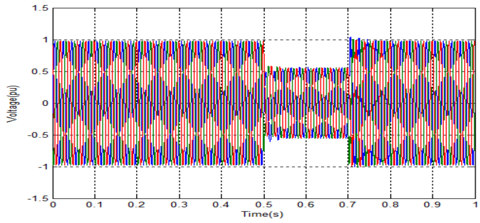

Fig. 16. Voltage at bus 10

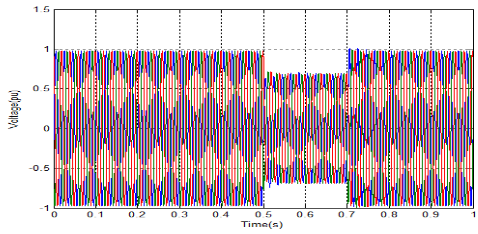

Fig. 17. Voltage at bus 11

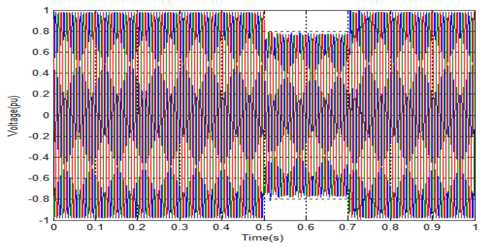

Fig. 18. Voltage at bus 12

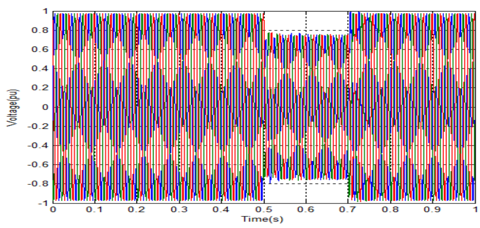

Fig. 19. Voltage at bus 13

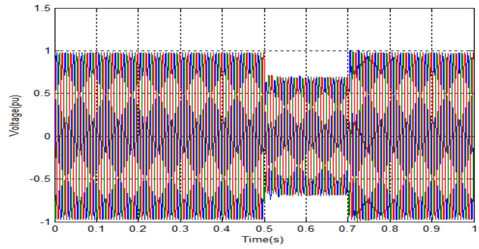

Fig. 20. Voltage at bus 14

B. *Uses of TCSC*

The TCSC is installed in the most perturbed zone in our case the TCSC is installed in the node 8 as shown in fig. 6.

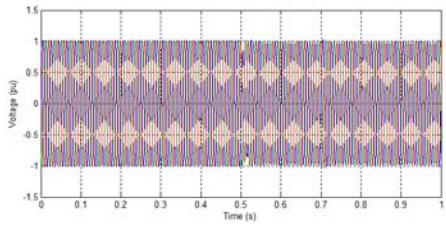

Fig. 21. Voltage at bus 1

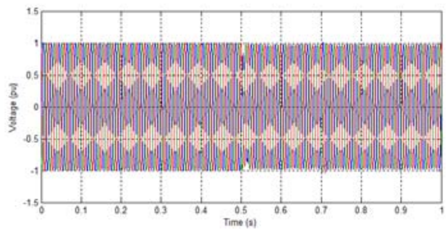

Fig. 22. Voltage at bus 2

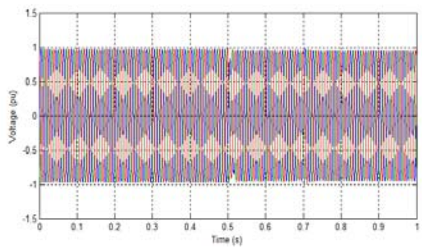

Fig. 23. Voltage at bus 3

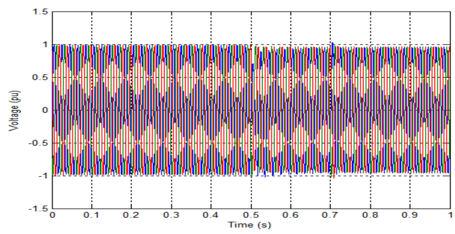

Fig. 24. Voltage at bus 4

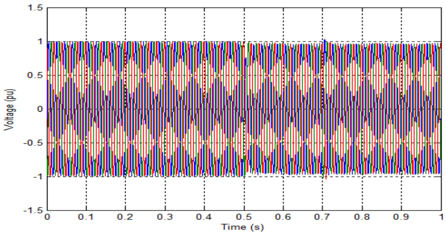

Fig. 25. Voltage at bus 5

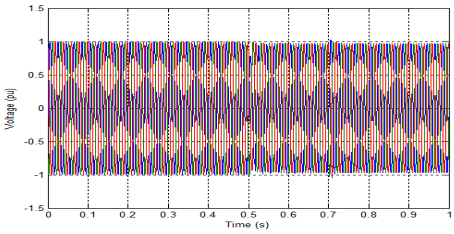

Fig. 26. Voltage at bus 6

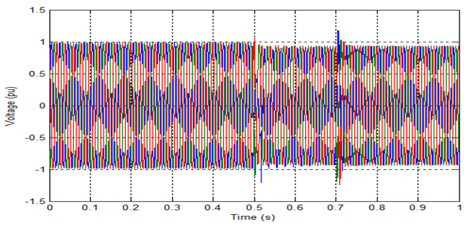

Fig. 27. Voltage at bus 7

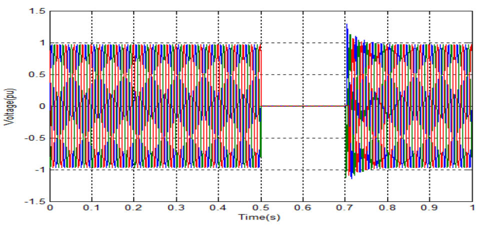

Fig. 28. Voltage at bus 8

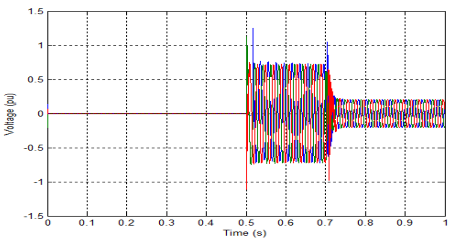

Fig. 29. Voltage gouverned with SSSC

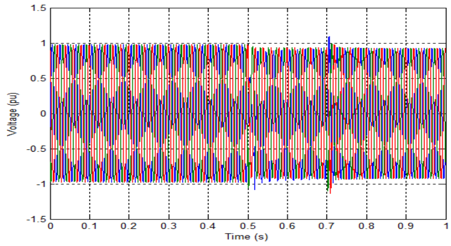

Fig. 30. Voltage at bus 9

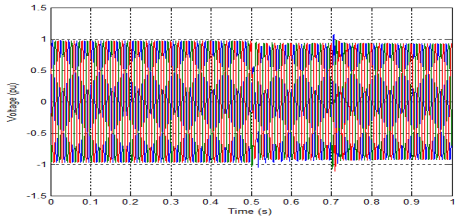

Fig. 31. Voltage at bus 10

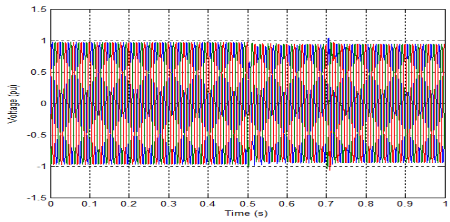

Fig. 32. Voltage at bus 11

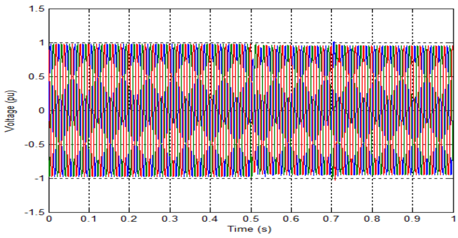

Fig. 33. Voltage at bus 12

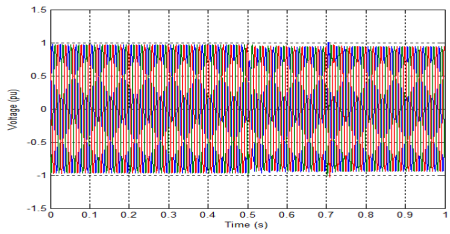

Fig. 34. Voltage at bus 13

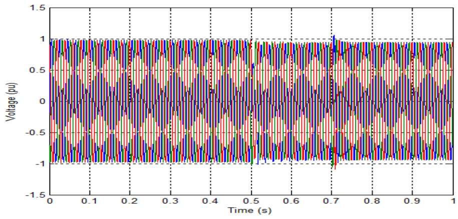

Fig. 35. Voltage at bus 14

C. Discussion of results:

This table shows the voltage drop in the nodes. There is a deletion almost total voltage drop for all nodes except bus 8 (the default location).

TABLE I. THE TAINSIENT VOLTAGE DROP

Bus	Without compensation	With TCSC
1,2	17%	1.5%
3	20%	3%
4,5,6	25%	5%
7,9,10	48%	8%
11,14	35%	8%
12	22%	5%
13	25%	5%

Table.1. The transient voltage drop

The SSSC prevents the consequences of the fault (voltage drop, harmonics,...) from reaching the other regions of the electrical network.

The SSSC can't manage to eliminate the consequences of the defect totally, and this amounts to the maximum compensation capacity delivered by the SSSC.

CONCLUSION

The SSSC is a FACTS system based three-phase converter capable to compensate the voltage. In our work we examine the impact of SSSC face of a voltage drop propagation in the case of IEEE 14 bus.

The results obtained show that the SSSC can play an important role in the field of voltage compensation and the reduction of losses in power lines. The uses of it allow the cancelation of voltage drop propagation in the network. However in the case of multi machines and lines looped network it is necessary to use several compensators to have a perfect compensation.

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