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POWER SYSTEM STABILITY ENHANCEMENT USING STATIC SYNCHRONOUS SERIES COMPENSATOR (SSSC)

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Abstract *– In this study, a Static Synchronous Series compensator (SSSC) is used to investigate the effect of this device in controlling active and reactive powers as well as damping power system oscillations in transient mode. The SSSC equipped with a source of energy in the DC link can supply or absorb the reactive and active power to or from the line. Simulations have been done in MATLAB/SIMULINK environment. Simulation results obtained for selected bus in two machine power system shows the efficacy of this compensator as one of the FACTS devices member in controlling power flows, achieving the desired value for active and reactive powers, and damping oscillations appropriately.*

Keywords *– Static synchronous series compensator (SSSC), FACTS, Two machine power system, active and reactive powers*

I. INTRODUCTION

The rapid development of power electronics technology provides exciting opportunities to develop new power systems equipment for better utilization of existing systems. During the last decade a number of control devices under the term Flexible AC Transmission Systems (FACTS) technology have been proposed and implemented. The FACTS devices can be used for power flow control, loop flow control, load sharing among parallel corridors, voltage regulation, and enhancement of transient stability and mitigation of system oscillations. FACTS have become an essential and integral part of modern power systems. Modeling and digital simulation plays an important role in the analysis, design, testing and commissioning of such controllers.

Static Synchronous Series Compensator (SSSC) is a series compensator of FACTS family. It injects an almost sinusoidal voltage with variable amplitude. It is equivalent to an inductive or a capacitive reactance in series with the transmission line[1].The heart of SSSC is a VSI (voltage source inverter) that is supplied by a DC storage capacitor. With no external DC link,the injected voltage has two parts: the main part is in quadrature with the line current and emulates an inductive or capacitive reactance in series with the transmission line, and a small part of the injected voltage is in phase with the line current to cover the losses of the inverter. When the injected voltage is leading the line current, it will emulate a capacitive reactance in series with the line, causing the line current as well as power flow through the line to increase. When the injected voltage is lagging the line current, it will emulate an inductive reactance in series with the line, causing the line current as well as power flow through the line to decrease.

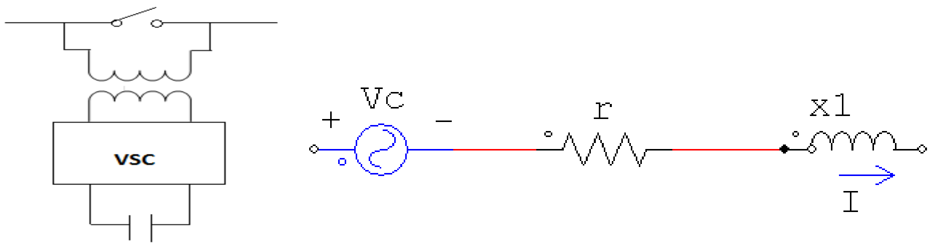
SSSC is superior to other FACTS equipment and the benefits of using SSSC are:

- Elimination of bulky passive components - capacitors and reactors,
- Symmetric capability in both inductive and capacitive operating modes,
- Possibility of connecting an energy source on the DC side to exchange real power with the AC network.

II. STATIC SYNCHRONOUS SERIES COMPENSATOR (SSSC)

The basic scheme of the SSSC is shown in Fig.1. The compensator is equipped with a source of energy,which helps in supplying or absorbing active power to or from the Transmission line along with the control of reactive power flow.

As the name suggests, Static synchronous series compensator (SSSC) is a Series compensator.It is connected in series with the transmission line. Three phase series transformers are used to connect the compensator in series with the power system.



(a) Symbol of SSSC **(b) Equivalent circuit of SSSC[7]**

Fig. 1 Schematic of SSSC

The static sysnchronous series compensator (SSSC) is a series device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids. In place of using capacitor and reactor banks, a SSSC use self-commutated voltage-source switching converters to synthesize a three-phase voltage in quadrature with the line current. The main interest is to use the SSSC for controlling flow of power (active and/or reactive) in transmission lines, whereas the SSSC is mainly recommended for damping electromechanical oscillations. Thus, the SSSC control system may be made by a compensation control loop, to accomplish its steady-state function, and by a fast response control, to act during electromechanical transients.[2][3]

An SSSC comprises a voltage source inverter and a coupling transformer that is used to insert the ac output voltage of the inverter in series with the transmission line. The magnitude and phase of this inserted ac compensating voltage can be rapidly adjusted by the SSSC controls.

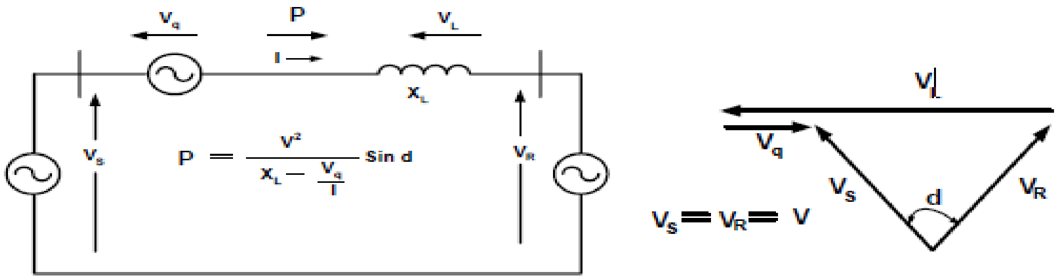


Fig 2.Elementary two-machine system with an SSSC and the associated phasor diagram[6]

The power flow (P) in the transmission line of system is given by,

$$P = \text{VI}\cos\frac{\delta}{2} = \frac{V{,}Vc}{X}\cos\delta + \frac{V^2}{X}\sin\delta$$

The reactive power supplied at the two end of the line are equal (Q).the expression for Q,

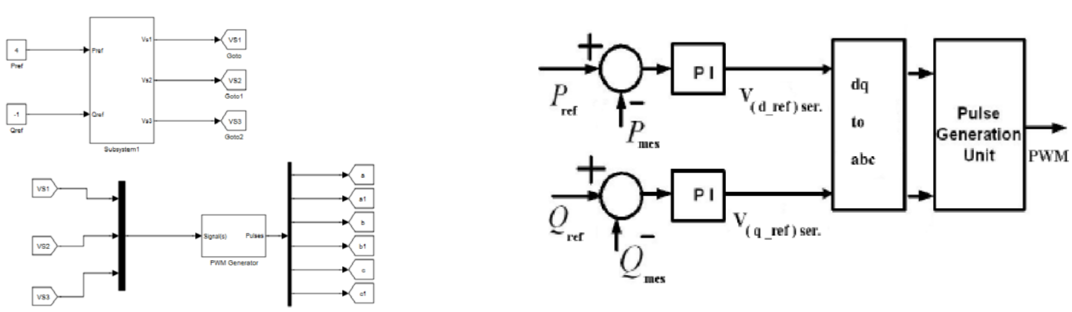
$$Q = \text{VI}\sin\frac{\delta}{2} = \frac{V{,}Vc}{X}\sin\frac{\delta}{2} + \frac{V^2}{X}(1 - \cos\delta)$$

The SSSC injects the compensating voltage in series with the line irrespective of the line current. The transmitted power Pq, therefore becomes a parametric function of the injected voltage, and can be expressed as follows.

$$P_q = \frac{V^2}{X_L}\sin\delta + \frac{VV_q}{X_L}\cos\frac{\delta}{2}$$

The SSSC, therefore can increase the transmittable power, and also decrease it, simply by reversing the polarity of the injected ac voltage. The reversed (180° phase-shifted) voltage adds directly to the reactive voltage drop of the line as if the line impedance was increased. Furthermore, if the injected voltage is made larger than the voltage impressed across the uncompensated line by the sending- and receiving end systems, that is if |Vq| > |V1 - V2|, then the power flow can.Apart from the stable operation of the system with both positive and negative power flows, it can also be observed that the SSSC has an excellent (sub-cycle) response time and that the transition from positive to negative power flow through zero voltage injection is perfectly smooth and continuous.

III. TWO MACHINE SYSTEM WITH SSSC



(a)Simulated control signal generation using pwm generator (b) Single line diagram circuit

Figure 4. The control circuit of SSSC

Active and reactive powers injected by power plants 1 and 2 to the power system are presented in per unit by using base parameters Sb = 100MVA and Vb=500KV, which active and reactive powers of power plants 1 and 2 are (24-j3.8) and (15.6-j0.5) in per unit, respectively.

IV. SIMULATION RESULTS WITH MATLAB/SIMULINK

The dynamic Performance of SSSC is presented by real time voltage and current waveforms.Using MATLAB software the system shown in fig.5 has been obtained

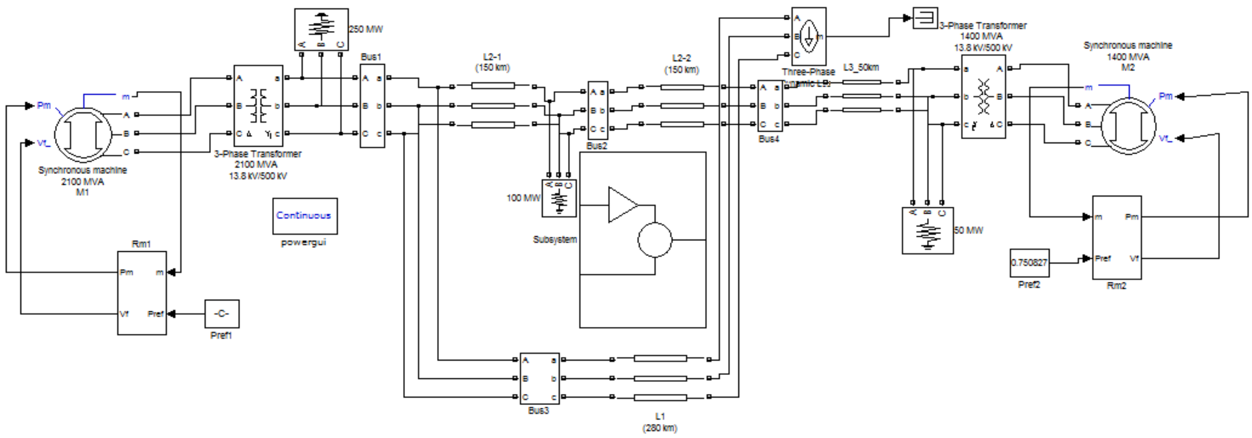


Fig 5. The Configuration Two Machine System Without SSSC

Simulation Result With Matlab and Simulation

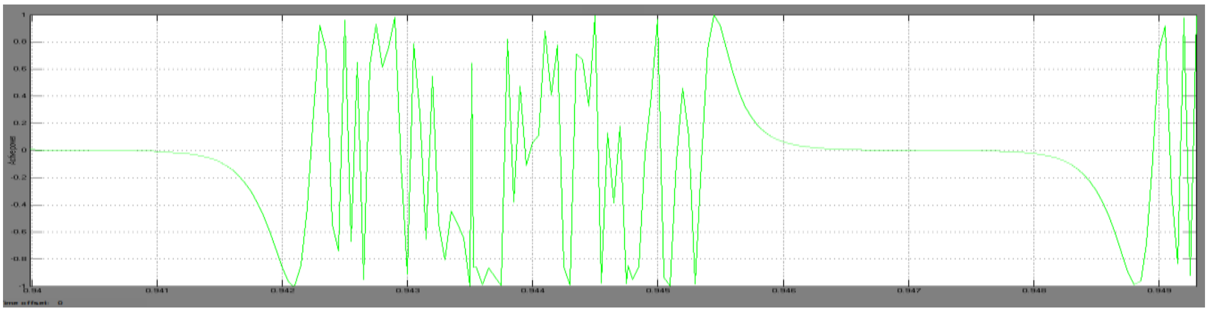


Fig.6 Active Power Without SSSC

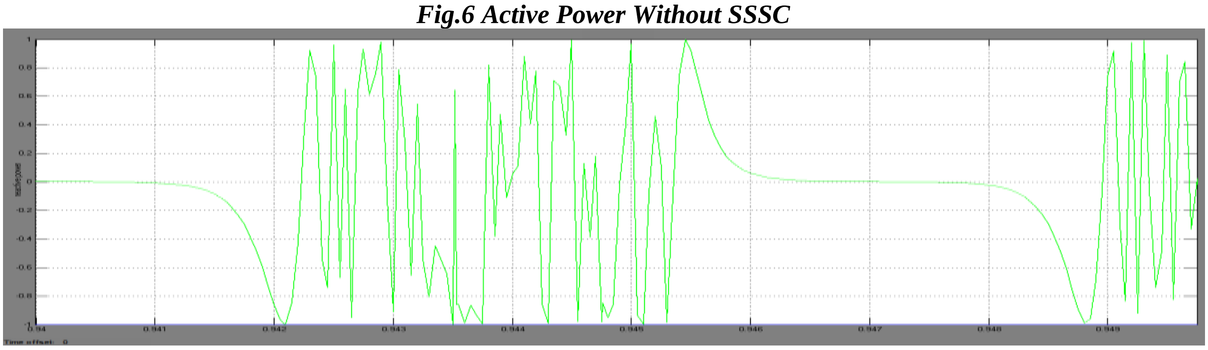


Fig.7 Reactive Power Without SSSC

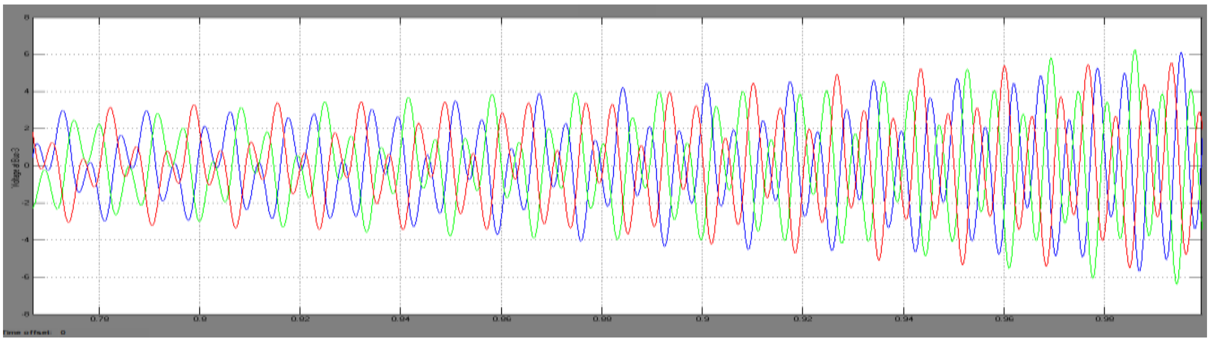


Fig.8 Voltage at Bus 2 Without SSSC

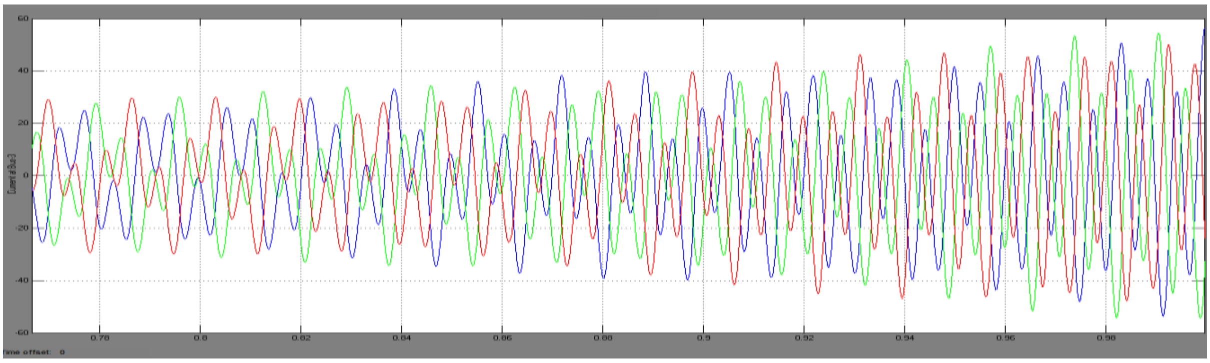


Fig.9 Current at Bus 2 Without SSSC

Bus 2 Parameter without SSSC

Change in current, voltage, active and reactive powers of bus 2 have been obtained in real time. According to the fig.6 & fig.7,at first due to large loads of the system active power of bus-2 got oscillations which keep continuing for 3 seconds. However, the controlling systems in power plants 1 and 2 such as governor, PSS and other stabilizing devices are used for damping these oscillations. As shown in Fig.6 & Fig 7, because of the abovementioned reasons reactive power of bus-2 got oscillations at first and then will be damped properly. Oscillations amplitude for active power is more than reactive power, and this is because the ohmic parts of loads of system are much more.

According to Fig.8 & Fig.9,after transient mode created at first in system ,voltage and current waveforms of bus 2 got closer to sinusoidal waveforms.

V. TWO MACHINE SYSTEM WITH SSSC

First, power system with two machines and four buses has been simulated in MATLA environment,and then powers and voltages in all buses have been obtained. The results have been given in Table. Using obtained results bus-2 has been selected as a candidate bus to which the SSSC be installed. Therefore, the simulation results have been focused on bus-2.

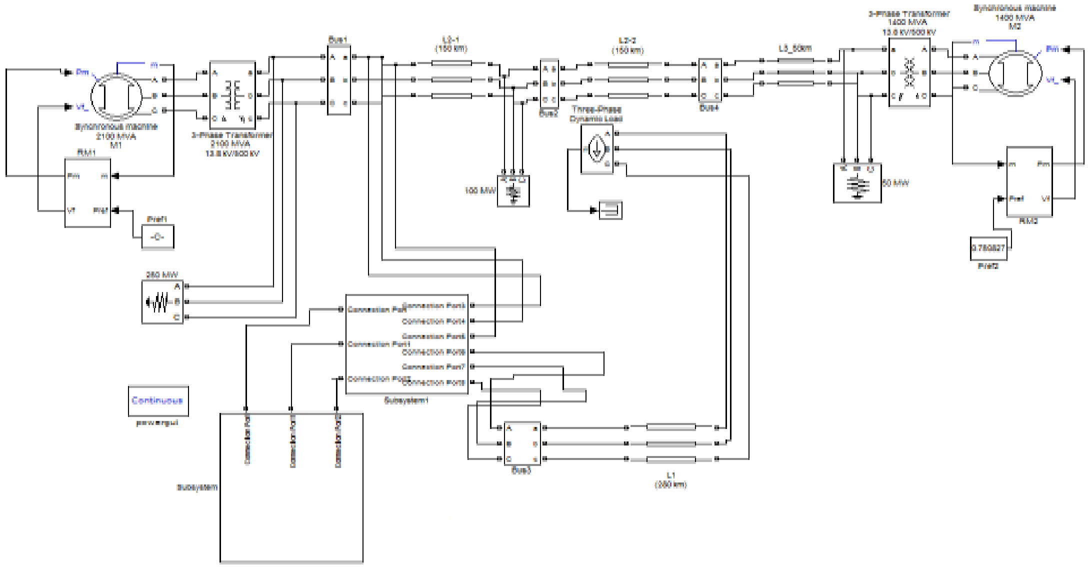


Fig 10.The Configuration Two Machine System with SSSC.

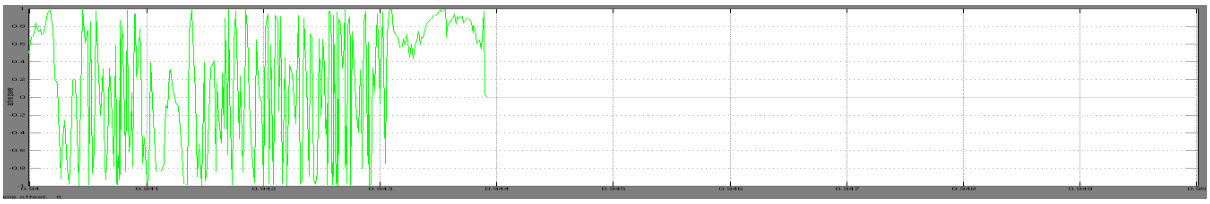


Fig 11. Active Power with SSSC

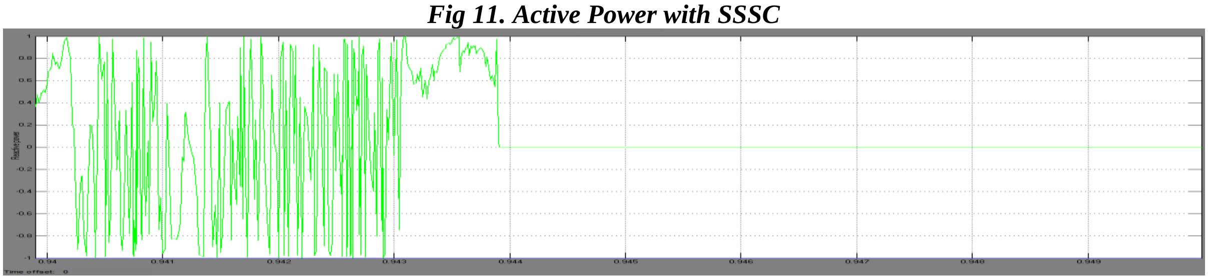


Fig 12. Reactive Power With SSSC

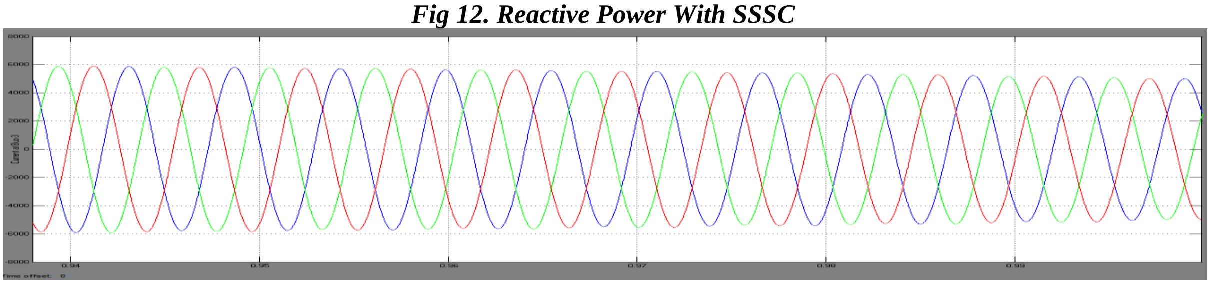


Fig 13. Current at bus 2 with SSSC

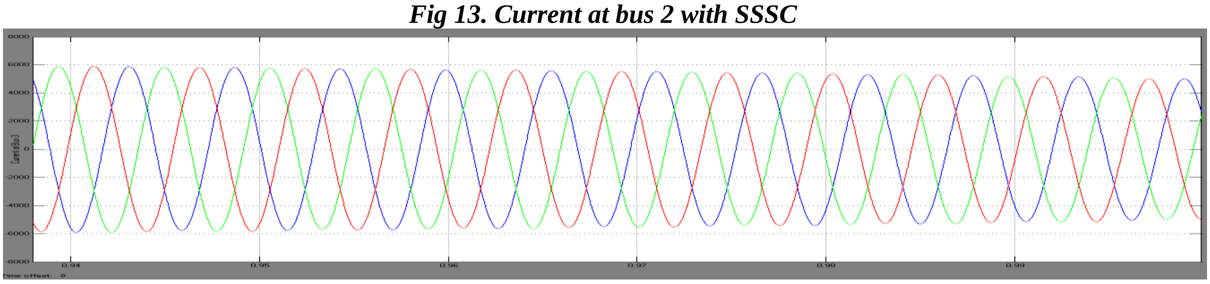


Fig 14. Voltage at Bus 2 With SSSC

Bus 2 Parameter With SSSC

When SSSC is placed at bus-2 the main role of SSSC is to control the active and reactive power.as shown in fig.11. active power oscillation are damped out and voltage value is in 1pu constant, active power damping time is less in system with SSSC compared to system without SSSC also in fig.12 the reactive power damping time is decreased compared to system without SSSC. Fig. 13 and fig. 14 shows the voltage and current waveform are sinusoidal and hence disturbance removed.

VI. CONCLUSION

It has been found that the SSSC is capable of controlling the flow of power at a desired point on the transmission line. It is also observed that the SSSC injects a fast changing voltage in series with the line irrespective of the magnitude and phase of the line current. This paper, the SSSC is used to damp power oscillation on a power grid following a three-phase fault Based on obtained simulation results the performance of the SSSC has been examined in a simple two-machine system simply on the selected bus-2, and applications of the SSSC will be extended in future to a complex and multi machine system to investigate the problems related to the various modes of power oscillation in the power systems.

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