Multi-Machine Stability Assessment in Power System Using SVC

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Abstract — The evolution of power systems via integrated behaviour, innovative-technologies implementation and controls, and stressed operating conditions, results in numerous instability issues. For example, frequency as well as voltage instability, and interred oscillations etc., are few reasons for concern. Also, when talking about transmission system faults can cause sever power quality issues. Faults generates voltage instability and con completely damage the devices connected. Seeing to the severity of instability in power system, numerous devices are been foresighted in literature to retain the stability under dynamic operating conditions. In this paper for a high voltage transmission system, SVC is presented to retain the system stability under the condition of single phase fault. Stability analysis of the system is presented for with and without SVC connected.

Keywords: Flexible Alternating Current Transmission System (FACTS); Power System Quality (PSQ); Subsynchronous Resonance (SSR); Active Power Filter (APF); Static VAR Compensators (SVC).

I. INTRODUCTION

Power System Quality (PSQ) particularly in transmission system needs precise attention, since transmission system are interconnected at wide region and poor PSQ at one region will affect the other connected system leading to system collapse [1, 2]. Earlier static compensators like synchronous generators, capacitors or reactors were used depending upon the type of instability conditions. These static compensators are either mechanically switched or are of fixed type which not solve the problem efficiently or even they can worsen if they are of fixed type under normal operations [3, 4].

Then the era of power converters or automatically switched controller with thyristors or semiconductor-based devices came into existence which can be connected automatically as per the system conditions. The more advanced form of these types of converters which are widely adopted in MPS transmission side is FACTS controllers [5,6]. Flexible Alternating Current Transmission System (FACTS) have been discovered that are used in the transmission system to improve the power quality and to compensate the reactive power [1-5].

FACTS have different devices for the above mentioned functions like Static VAR Compensators (SVC), United Power Flow Compensators (UPFC) and the Static Synchronous Compensator (STATCOM) [6]. This work presents the performance analysis of one such FACTS controller named SVC. SVC stands for Static Var Compensator which is semiconductor based used to restore the condition of transient stability when subjected to large system disturbances.

In this work condition of power system faults both single and three phase faults are analysed as the contingency condition and the stability analysis is carried out with and without SVC. One more tool named as Power System Stabilizer is also used to retain stability. Many of the ideas upon which the foundation of FACTS rests evolved over a period of many decades.

Nevertheless, FACTS an integrated philosophy is a novel concept that was brought to fruition during the 1980s The concept of FACTS involves high power electronic controllers in AC networks dedicatedly transmission one. This enables quick and reliable control of power and voltages. FACTS are the group of controller whose application benefits the system but a cost analysis must be carried out to judge its utility.

Damping of oscillations which can threaten security or limit the usable line capacity. 5. Prevention of voltage collapse by providing reactive power support. The active and reactive power flows in a transmission line can be precisely controlled by injecting a series voltage phasor with desirable magnitude and phase angle, leading to an improvement in system stability and system reliability and reduction in operating cost and new transmission line investment cost. It is also possible to force power flow through a specific line and regulate the unwanted loop and parallel power flows by varying the impedance of the line. FACTS controllers have a significant impact on damping power system oscillations and compensating dynamic reactive power. FACTS can be divided into four categories based on their connection in the network. This paper presents the stability analysis of mult machine system under the condition of Single -Phase Ground Fault (SPGF) with SVC and without it.

II. POWER SYSTEM STABILITY

The Power system stability is defined as the condition of normal operation of all the power system elements with stable equilibrium even though it is subjected to the contingency [7]. Contingency is a common term given to all type of abnormal operating condition of power system like; faults, sudden load variations, switching in off high power devices, integration of high rating power converters, high penetration of renewable resources, etc. all these events have different operating states and may lead to various stability issues which are presented in figure 1 [8].

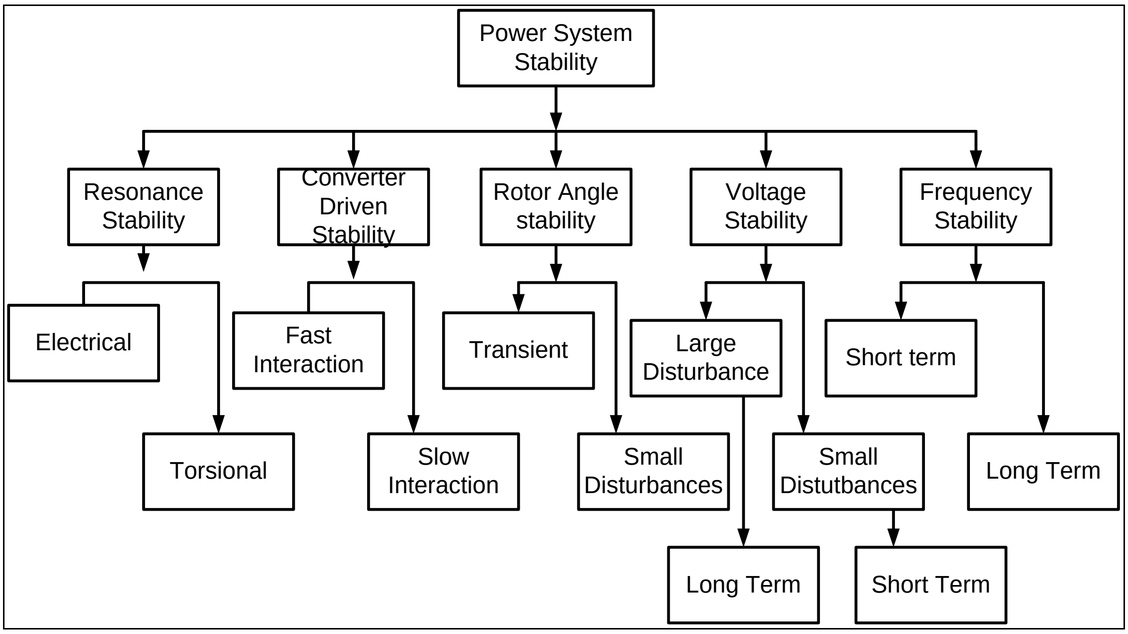

Fig. 1: Classification of Stability

The term resonance stability is related with subsynchronous resonance (SSR), it can be either associated with an entirely electrical resonance or with an electromechanical. The SSR, can manifest in two possible forms: (i) due to a resonance between series compensation and the mechanical torsional frequencies of the turbine-generator shaft, and (ii) due to a resonance between series compensation and the electrical characteristics of the generator [9].

In present day system, a new class of stability is introduced due to wide spread use of power converters. these converters use both DC and AC power for their operation and generates harmonics due to continues AC-DC or vice-versa conversion. This harmonic degrades the PQ of the system and generates stability issues due to changes in the flows on major tie-lines, which may in turn affect damping of inter-area modes and transient stability margins.

The job-tenure of a power engineer is spent in maintaining the voltage stability of the power system. Since the power system is heavily stressed and always undergoes the events which results in the condition of instability. The voltage stability may be small signal which can be overruled using available transmission capability enhancement or short duration load shedding. For restoring the transient instability compensation devices are installed.

The condition of frequency instability occurs when the system undergoes deviation in frequency. In transmission system the allowable frequency deviation is ±3%. More than this frequency restoration measures needed such as [10];

1) The initial inertial response of synchronous generators,
2) The primary frequency response of generators and load damping, and
3) Automatic generation controls bringing the frequency back to its nominal value.

This paper focuses on the restoration of voltage stability when subjected to large disturbances caused by SPGF.

III. STATIC VAR COMPENSATOR (SVC)

Static VAR Compensator is a FACTS device which is basically connected in shunt and its inductive and capacitive current in output can be controlled in conjunction or independently to obtain AC output [11, 12]. A schematic representation of the structure of an SVC is shown in Figure 2, where it is a shunt connected device comprises of several modules built of a fixed capacitance in parallel with a thyristor-circuits.

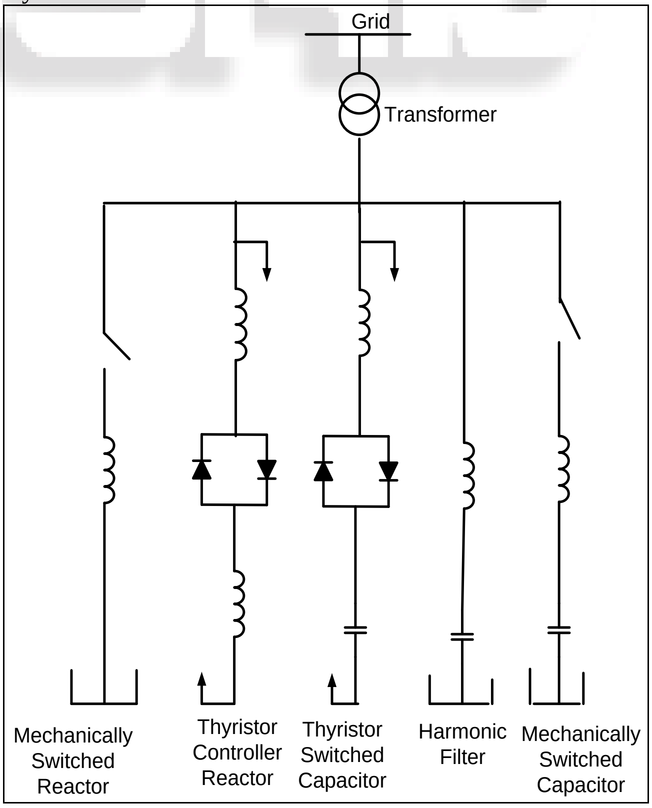

Fig. 2: Schematic of SVC

An SVC is a reactive-power controlled source. The exchange of reactive power between the converter and the AC power system can be controlled by varying the amplitude of the three-phase output voltage, of the converter which can be represented as by eq. (1-3) [13-15];

$$I_{ac} = \frac{V_{out} - V_{AC}}{X} \quad (1)$$

$$Q = \frac{V_{out}^2 - V_{out}V_{AC}cos\alpha}{X} \quad (2)$$

$$P = \frac{V_{out}V_{AC}sin\alpha}{X} \quad (3)$$

IV. SIMULATION MODEL AND RESULTS

In this work performance analysis of SVC is presented under the condition of contingency to restore the system voltage as well as rotor angle stability. In the proposed work two Salient Pole Synchronous Machine (SPSM) is considered to analyse the stability affect. The rating of SPSM is 1000MVA with 60 Hz frequency. A SPGF is created which results in voltage as well as rotor angle instability. The system is analysed for without any compensation to restore system stability. Hence after occurrence of fault system loses synchronism. To restore the system a SVC is connected having 200MVA rated capacity at 60 Hz frequency. Simulation results for both the system is presented.

The Matlab simulation model for the proposed multi-machine system connected with SVC is given in Fig. 3. Two machines are connected at bus B1 and B3. A load of 5000 MW is connected at B2. A SPGF is created at 5 sec which last for 5.1 sec. Firstly, SVC is disconnected and results for bus voltages for B1, B2 and B3 is shown in figure 4. The rotor speed of machine 1 and 2 is shown in figure 5 and rotor angle is given in figure 6. From the figure it can be seen that though fault is cleared after 0.1 sec, and the system tries to retain it stable condition from 5-10 sec but system go out of synchronism and losses stability after 10 sec. The voltages suffers from undamped oscillations after the occurrence of system fault.

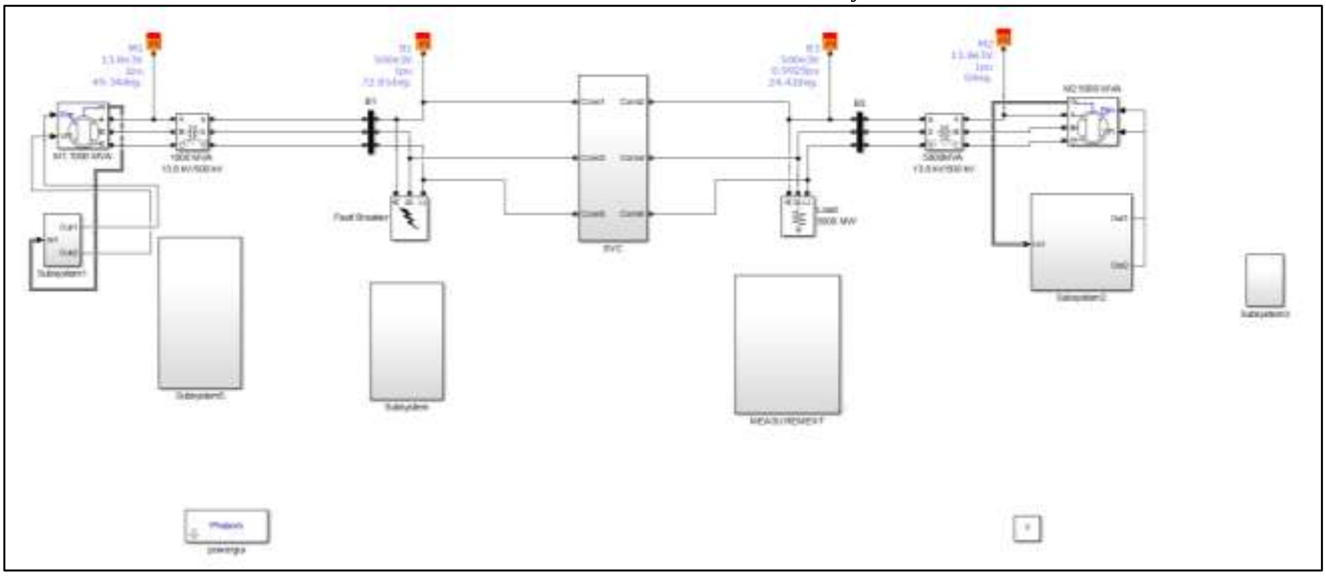

Fig. 3: simulation model of PV module

To retain the system stability, SVC is connected with 500KV, 50Hz, 200MVA rating. The reactive power limit of the SVC is ± 200MVAr. Results for bus voltages for B1, B2 and B3 is shown in figure 7. The rotor speed of machine 1 and 2 is shown in figure 8 and rotor angle is given in figure 9. From the figure it can be seen that after fault is cleared at 5.1 sec, and the system tries to retain it stable condition after 10 sec. and retains the PU rated system value. Also the rotor angle of machine 1 and machine two attains stable value after the fluctuations for 5-6 cycles.

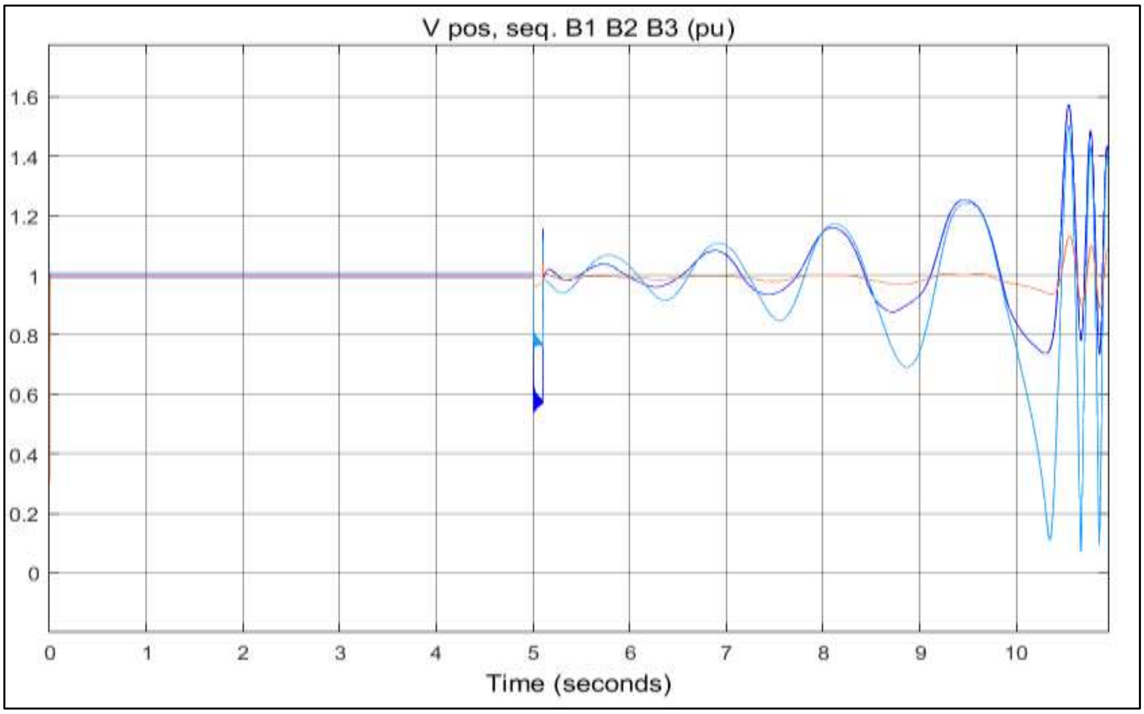

Fig. 4: Bus voltages under contingency condition without SVC

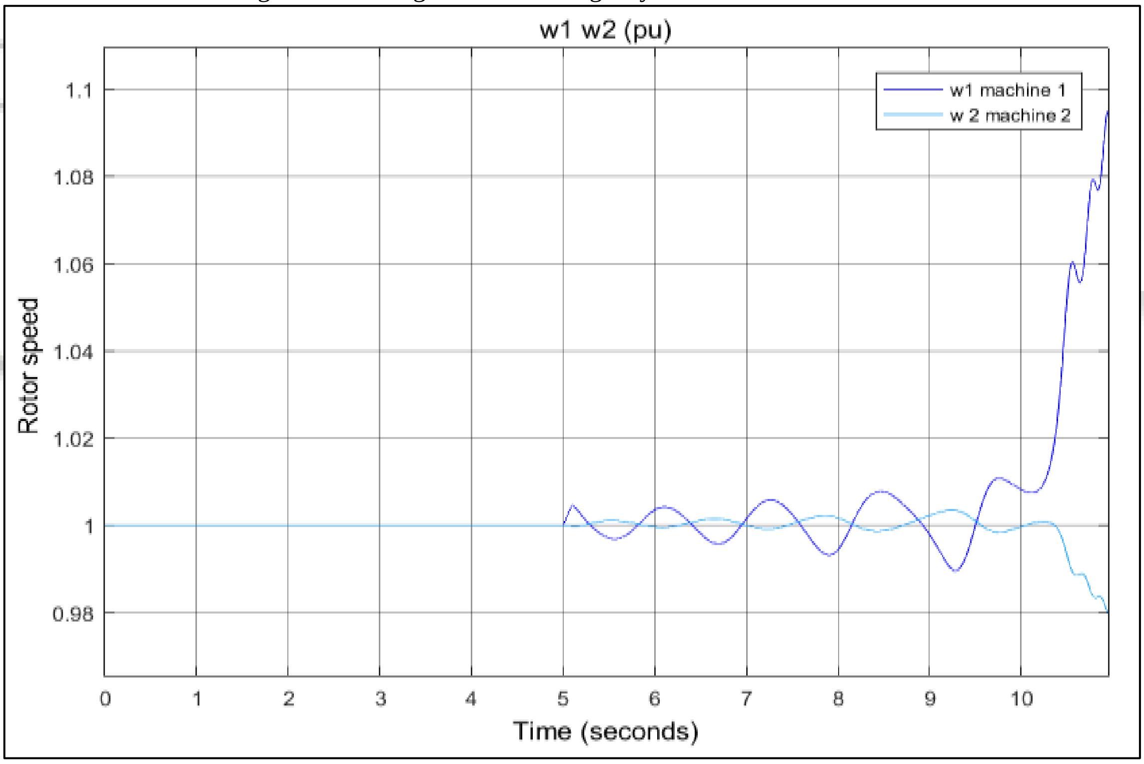

Fig. 5: Rotor speed of machine 1 and machine 2 without SVC

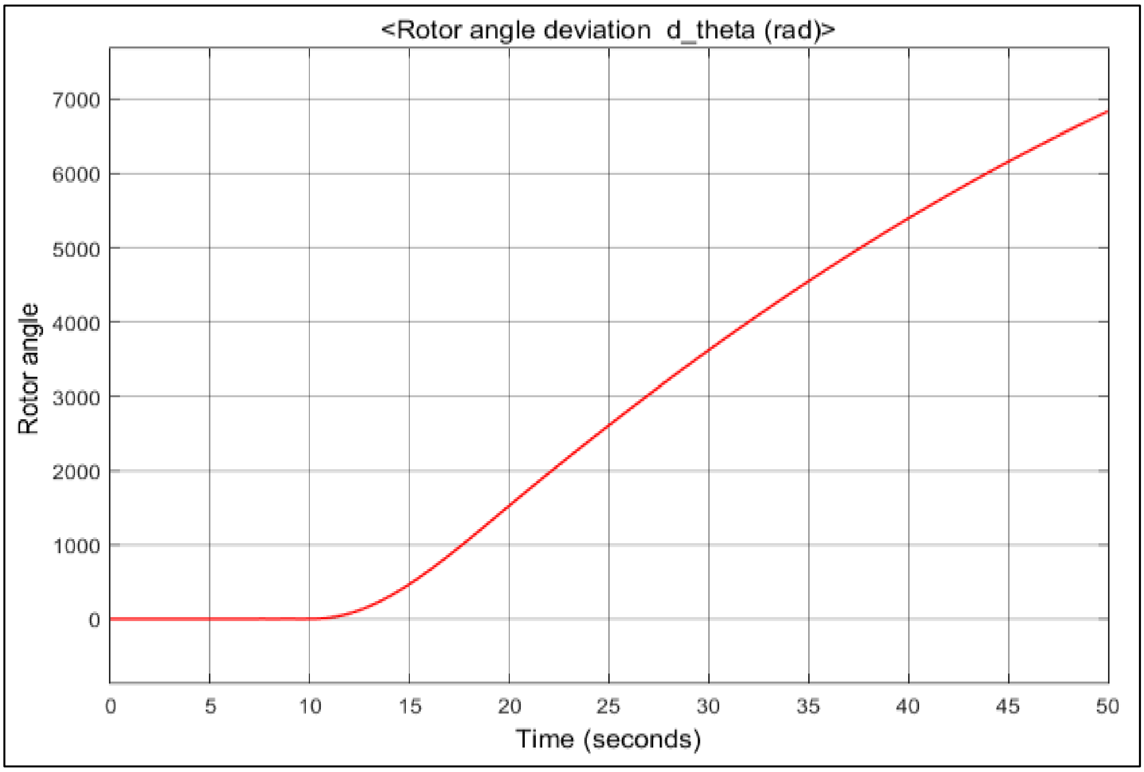

Fig. 6: Rotor angle without SVC

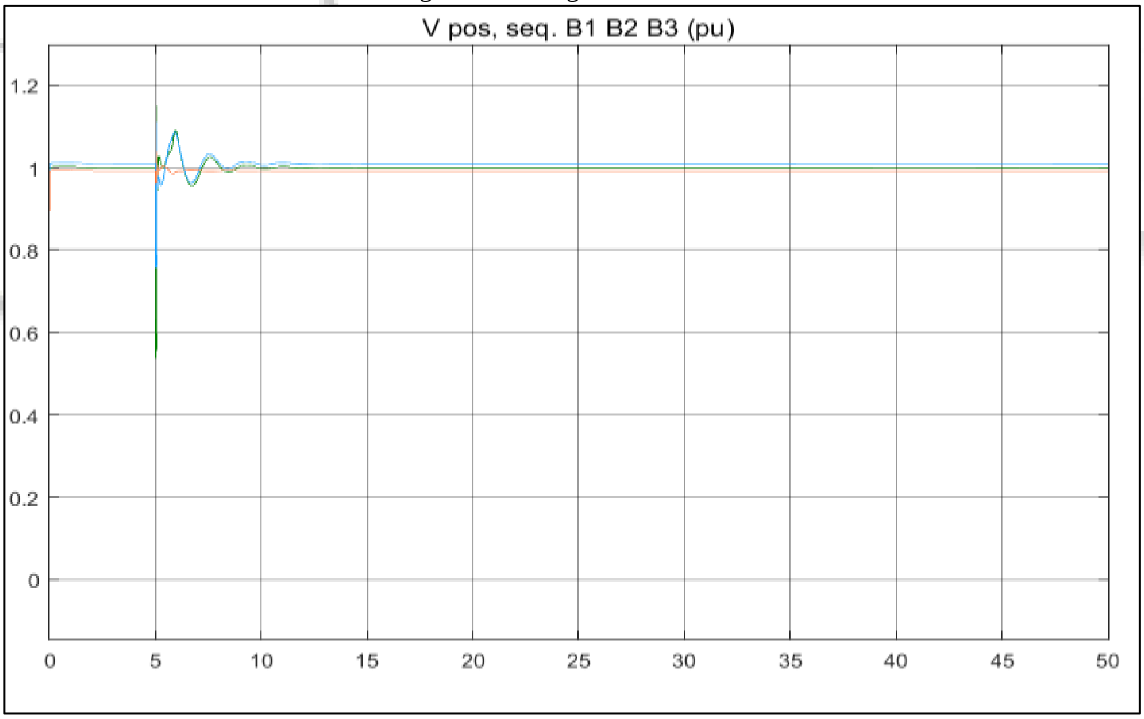

Fig. 7: Bus voltages under contingency condition with SVC

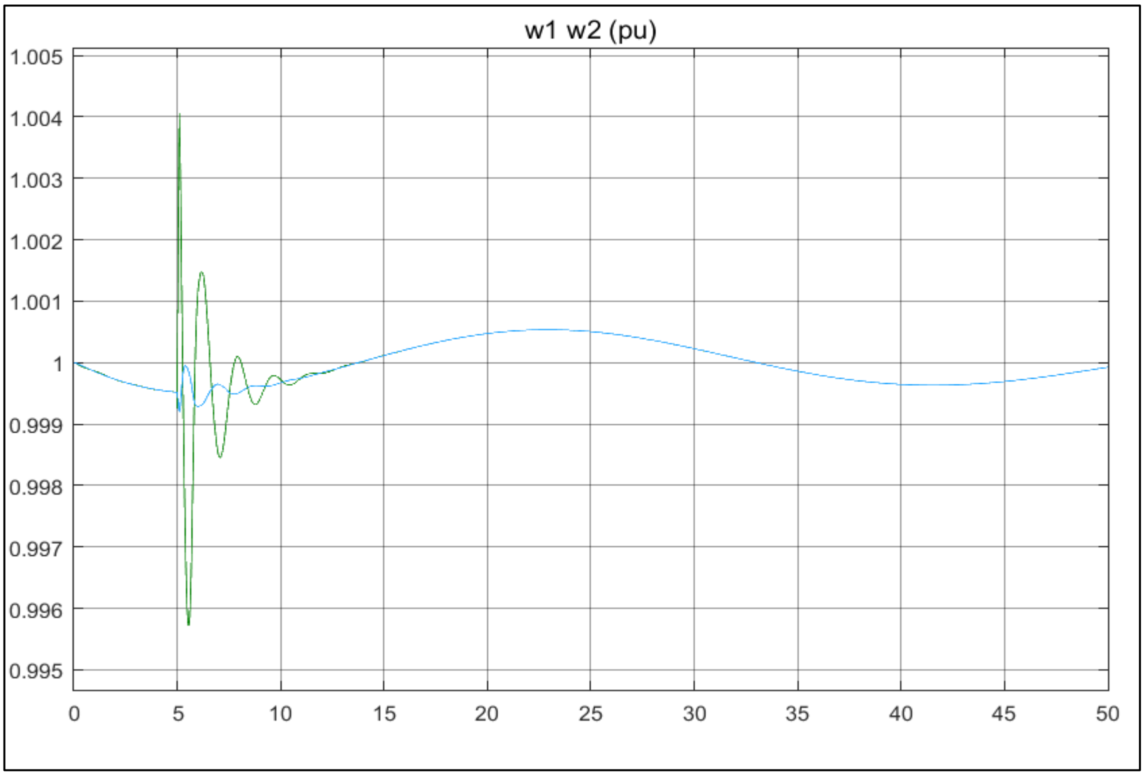

Fig. 8: Rotor speed of machine 1 and machine 2 without SVC

Fig. 9: Rotor speed of machine 1 and machine 2 without SVC

V. CONCLUSION

For the proper stable operation of the system it is very important that system must operates in synchronism after any mishappening events like faults. In this work SVC is installed to retain the system stability under various continency condition. It is widely adopted type of FACTS controller used in transmission to supply or observe the reactive power of the system in order to retain stability. It helps in maintaining system voltage, prevent the rotor angle to deviate from its fixed value hence retain the rotor angle stability and fast restoration of the system is possible with its application which is proved in this paper. From the results presented it can be seen that without SVC system is unstable, rotor angle varies widely which leads the condition of out of synchronization of machines.

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