Transient Steadiness and Dynamic Response in Transmission Lines by SVC with TID and MPPT Controller

Ajay Kumar and T. S. Prasanna

Abstract In order to maintain stable and efficient power system with growing demand, there is a quick progress of power electronics, which introduces the FACTS device. That is able to resolve the volatility problem easily. The FACTS device static var compensator (SVC) helps in improving the active and reactive power of the system. Maximum power point tracking (MPPT) is an external controlling device, which is used with FACTS device. The controller has been tested on a two-machine and three-buses in a control system using MATLAB software. The model consumes lesser runtime for maximum number of oscillation and to damp out the unwanted harmonics in the system. TID and MPPT controllers are used to control the machine and SVC device.

Keywords Static var compensators (SVC) · Voltage regulator · PID controller · TID tuning · MPPT controller · Active power (AP) · Reactive power (RP) · Flexible AC transmission system (FACTS) MATLAB simulink

1 Introduction

In recent year, the customs power expertise, the low voltage counterpart of the more commonly known flexible AC transmission system (FACTS) technology, brings up with a feasible resolution to solve many problems relating to steadiness of supply at the consumer. To overcome these losses, we need to use different parameters which will reduce these losses with more stable operation. So that overall system performance can be increased. It is observed that the power control capability can be amplified by using static var compensation device [1, 2]. Most of the devices are control electronics based. FACTS devices are coupled in series for better performance. The power system is more affected by some factors such as AP, RP, reactance, susceptibility, control factor, quality, fluctuation of current, and voltage [3, 4]. The term steadiness specifies the capacity to sustain the machineries in

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synchronism. If the fluctuation in speed level of the machines, at that moment there will be a vibration in the system, which can be damp out by using PID controller [5]. The tilt integral derivative controller is a newly intended controller which has good performance and gives feasible results over PI or PID-based controller [6]. The analogous mode may work satisfactory. The main impartial of paper is to bring the system into stable condition by using MPPT algorithm [7, 8], which is employed in PV inverter endlessly to amend the impedance realized by the solar array to retain the PV system operating at, or close to, the peak control point of the PV panel under variable load conditions with change in solar irradiance, hotness, and load [9].

2 Static Var Compensator (SVC)

The controlling device which controls the real and RP tends to make system to be continual which sets voltage at its termini by monitoring the amount of RP injected into or absorbed from the power network. The SVC is a shunt device of the FACTS family using power electronics to regulate power flow and progress transient steadiness in power networks [3]. The SVC sets voltage at its workstations by adjusting the sum of RP vaccinated into engrossed from the power network. If network voltage is low, the SVC generates RP (SVC capacitive). If network voltage is high, it absorbs RP (SVC inductive). The deviation of RP is analyzed by changing three-phase capacitor banks and inductor banks linked on the secondary side of a coupling transformer. Each capacitor bank is switched on and off by three thyristor switches (thyristor switched capacitor or TSC). Reactors may be switched on-off (thyristor switched reactor or TSR) or phase-controlled (thyristor controlled reactor or TCR).

SVC has no rotary part unlike synchronous machine. SVC is used in voltage controller mode by controlling the reactive var in the network, where it is coupled. SVC can draw leading or lagging var to regulate the voltage variation or regulation in the network. If there is a drop in the voltage, then it delivers reactive control, and if there is a rise in the voltage, then it absorbs reactive control. So, the SVC can be used as a source or sink of reactive var in according to the necessity of user.

Here the objectives are:

a. Very fast control response time
b. Feasibility of individual phase control with parameter
c. Reduced losses
d. High reliability
e. Less maintenance (absence of rotator parts)
f. SVC voltage control.

2.1 Configuration of SVC

It has distinct types of SVC:

1. Fixed capacitor-thyristor controlled reactor (FCTCR)
2. Thyristor switched capacitor (TSC-TCR).

The second type is quite reliable than the first one and acquires reduced rating of the reactor and therefore generates fewer harmonic. The schematic diagram of a TSC-TCR type SVC is shown in Fig. 1. The illustrations of the TCR and TSC are allied on the secondary side of a step-down transformer. Tuned and high-pass screens are also allied in parallel which deliver capacitive RP at fundamental frequency. The voltage gesture is taken from the high voltage SVC bus by means of a potential transformer.

A. **Designed of PID Controller**

The procedure of selecting the control parameters to meet the given performance stipulations is called PID tuning. Here, PID controller is tuned by the triple integral differential (TID) method.

It has three term control signal,

$$U(t) = K_p e(t) + \frac{K_p}{T_i} \iiint e(t)\mathrm{d}t + K_p T_d \frac{\mathrm{d}^3 e(t)}{\mathrm{d}t^3} \tag{1}$$

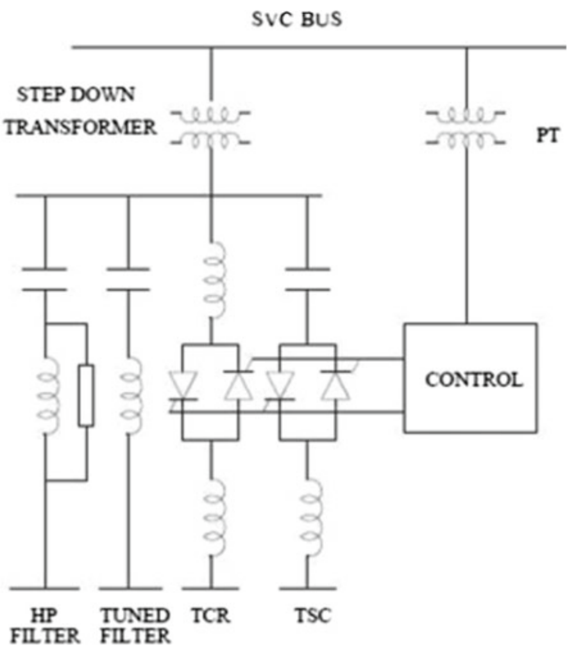

Fig. 1 Typical SVC (TSC-TCR) structure

$$\frac{U(s)}{E(s)} = K_{\mathrm{p}}\left(1 + \frac{1}{T_{\mathrm{i}}S^{3}} + T_{\mathrm{d}}S^{3}\right) \tag{2}$$

$$G_{\mathrm{c}}(s) = K_{\mathrm{p}}\left(1 + \frac{1}{T_{\mathrm{i}}S^{3}} + T_{\mathrm{d}}S^{3}\right) \tag{3}$$

$$G_{\mathrm{c}}(s) = 0.6 * K_{\mathrm{cr}}\left(1 + \frac{1}{0.5P_{\mathrm{cr}}S^{3}} + 0.125\,P_{\mathrm{cr}}S^{3}\right) \tag{4}$$

$$G_{\mathrm{c}}(s) = 0.6K_{\mathrm{cr}}S * 0.125P_{\mathrm{cr}}K_{\mathrm{p}}\left(S^{2} + \frac{1}{0.5P_{\mathrm{cr}}S^{2}0.125P_{\mathrm{cr}}} + \frac{1}{S * 0.125P_{\mathrm{cr}}}\right) \tag{5}$$

$$G_{\mathrm{c}}(s) = 0.075 * K_{\mathrm{cr}}P_{\mathrm{cr}}S\left(S^{2} + \frac{16}{P_{\mathrm{cr}}^{2}S^{4}} + \frac{8}{P_{\mathrm{cr}}S}\right) \tag{6}$$

$$G_{\mathrm{c}}(s) = 0.075K_{\mathrm{cr}}P_{\mathrm{cr}}S\left(S^{2} + 2 * \frac{4}{P_{\mathrm{cr}}S^{2}} + \frac{16}{P_{\mathrm{cr}}^{2}S^{2}}\right) \tag{7}$$

$$G_{\mathrm{c}}(s) = 0.075 * K_{\mathrm{cr}}P_{\mathrm{cr}}S\left(S + \frac{4}{P_{\mathrm{cr}}S^{2}}\right)^{2} \tag{8}$$

$$G_{\mathrm{c}}(s) = 0.075 * K_{\mathrm{cr}}P_{\mathrm{cr}}S\left(\frac{P_{\mathrm{cr}}S^{3} + 4}{P_{\mathrm{cr}}S^{2}}\right)^{2} \tag{9}$$

$$G_{\mathrm{c}}(s) = \frac{0.075 * K_{\mathrm{cr}}P_{\mathrm{cr}}}{S}\left(\frac{P_{\mathrm{cr}}S^{3} + 4}{P_{\mathrm{cr}}S}\right)^{2} \tag{10}$$

$$G_{\mathrm{c}}(s) = \frac{0.075 * 200 * 0.2}{S}\left(\frac{0.2S^{3} + 4}{0.2 * S}\right)^{2} \tag{11}$$

$$G_{\mathrm{c}}(s) = \frac{3}{S}\left(\frac{0.2S^{3} + 4}{0.2 * S}\right)^{2} \tag{12}$$

For choosing the appropriate controller constraints, TID is tuned as described above. In this process, limitation is selected as $T_{\mathrm{i}} = \infty$, $T_{\mathrm{d}} = 0$ by using the PID controller action as shown in Fig. 2, Simply increase in $K_{\mathrm{p}} = 0$ to a critical value $K_{\mathrm{cr.}}$ On which the output leading to continual alternations Fig. 4. Thus, the critical gain K_{cr} and the analogous period P_{cr} are experimentally carried out. It is advised that the values of the parameters K_{p} T_{i} T_{d} would be fixed according to the formulation as same as Zieglar–Nicles method. Figure 5 shows the Simulink of interior assembly of PID controller with change in angular speed of input (Fig. 3).

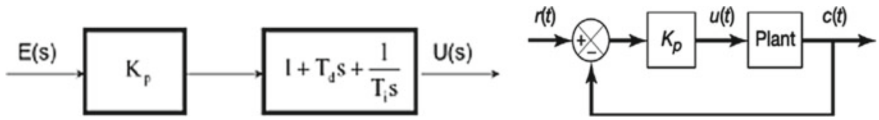

Fig. 2 Block diagram of PID controller

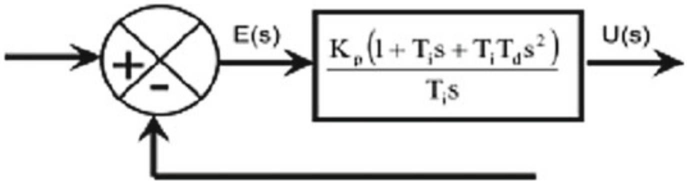

Fig. 3 PID controller is in proportional action

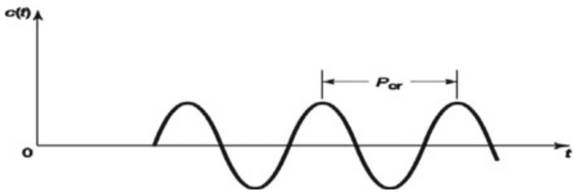

Fig. 4 Analysis of continuous swinging (P_{cr})

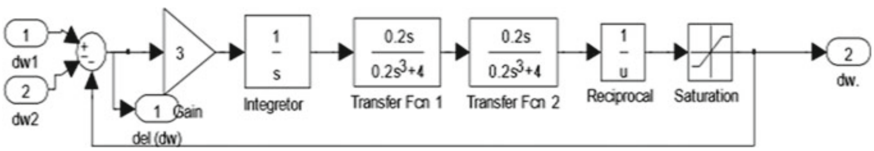

Fig. 5 Interior assembly of PID controller with dω

3 Maximum Control Point Tracking (MPPT)

The PV arrays are attached in series or in parallel. The PV array has V-I characteristic as alike to those of a single solar cell. Typical V-I characteristic of a solar cell array is shown in Fig. 5. The MPPT controller varies with irradiance as well as with temperature. A constant voltage load such as a battery cannot extract the maximum control under all conditions. MPPT is an algorithm implemented in PV inverters to endlessly alter the impedance seen by the PV arrays to keep the PV assembly functioning at, or near to the peak control point of the PV assembly under varying loading settings like changing solar irradiance, hotness, and load. MPPT

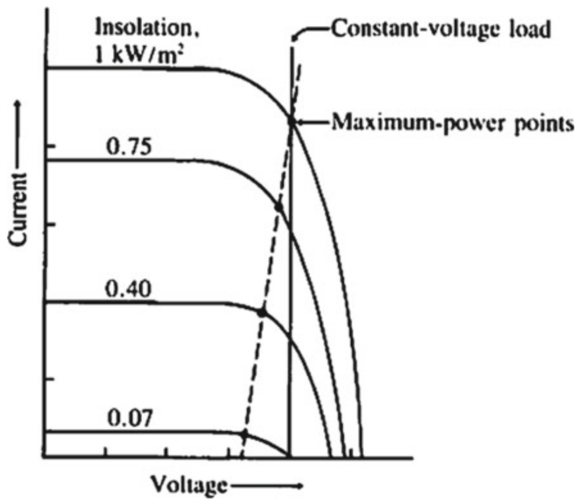

Fig. 6 Model diagram of MPPT controller

systems are usually used in the governing projects of PV system. It accounts for different reasons such as adjustable irradiance (sunlight) and heat to confirm that the PV structure breeds extreme control at all the time (Fig. 6).

The three communal MPPT algorithms are

a. Perturbation and observation (P&O)
b. Incremental conductance
c. Fractional open-circuit voltage.

Perturbation and observation (P&O): This algorithm agitates the operating voltage to ensure extreme control. While there are numerous progressive and other enhanced alternatives of this algorithm, a basic one is P&O MPPT algorithm.

Incremental conductance: It relates the incremental conductance to the prompt conductance in a PV system. It depends on various factors (i.e., V, I), based on it will rises or falls. The extreme control point is reached; unlike as in the above P&O process, the voltage residues continue once MPPT is reached (Figs. 7 and 8).

Fractional open-circuit voltage: This algorithm works on the maximum control at a point reached with a constant voltage.

Depending on the voltage profile, its value hikes or drops.

4 Control System Model

The modeling of a power network containing two hydraulic control plants with three-buses with SVC is used to mend the transient steadiness and in order to damp out oscillations. A single-line diagram represents a simple 500 kV conduction network as shown in Fig. 9.

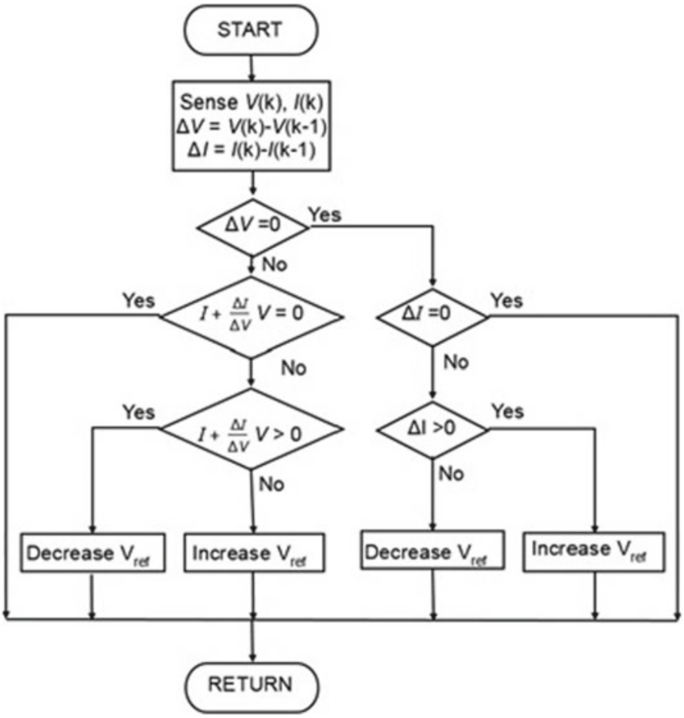

Fig. 7 Incremental conductance algorithm

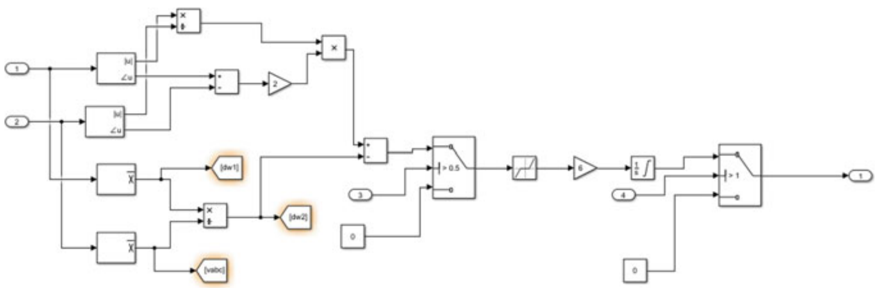

Fig. 8 Model diagram of MPPT controller

To maintain network steadiness after fault, the conduction line is shunt compensated at its center by a 200 MVAR using FACTS device. The two machineries are coupled with a hydraulic turbine and governor (HTG), which will help to damp out the oscillation, so that the machineries should not come out of synchronism (Table 1).

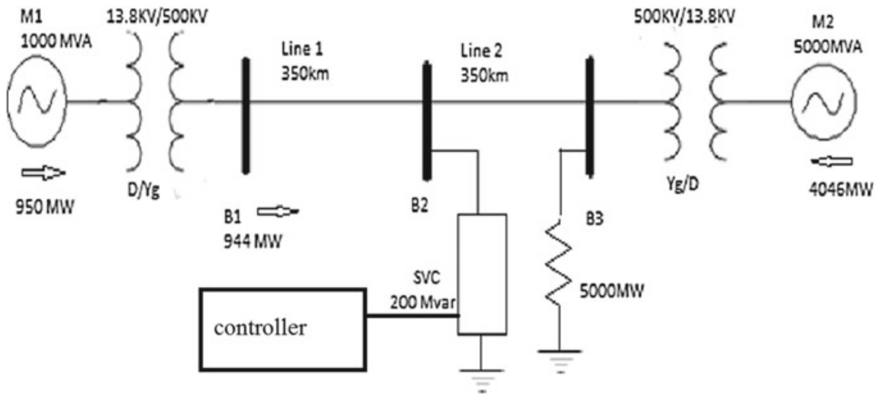

Fig. 9 Single-line diagram of two-machine three-buses control network using controller

Table 1 Parameter of single-line diagram of two-machines and three-buses

S. No.	Parameter	Machine 1	Machine 2
1	Generated MVA	1000 MVA	5000 MVA
2	Transformer	13.8 kV/500 kV (D/Yg)	500 kV/13.8 kV(Yg/D)
3	Generated MW	950 MW	4046 MW
4	At buses (MW)	944 MW (B1)	5000 MW (B2)
5	Distance between the buses	350 km (B1–B2)	350 (B2–B3)

The SVC is controlled by external MPPT controller which will mend the transitory steadiness and dynamic load on the conduction line.

5 Model

The above block diagram can be simulated using MATLAB. Model is carried out in three different forms

1. Model without using FACTS devices
2. Model with SVC device.

Model using MPPT controller with FACTS device (Figs. 10, 11, 12, 13, 14, 15, 16 and 17).

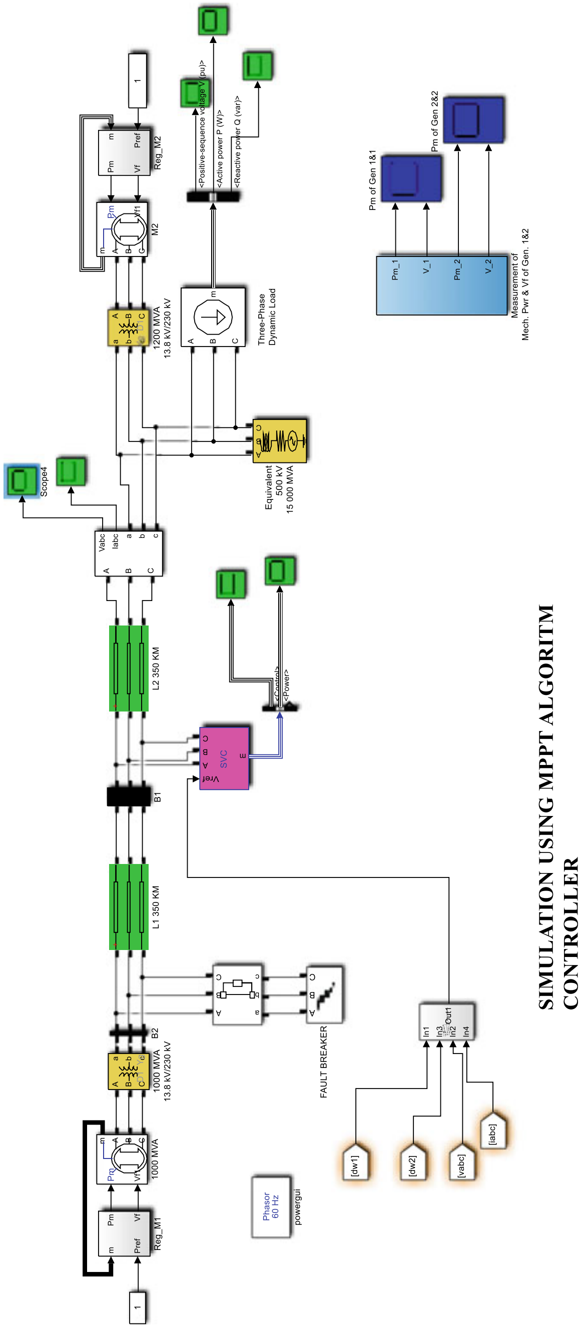

Fig. 10 Simulink diagram with SVC and MPPT Controller

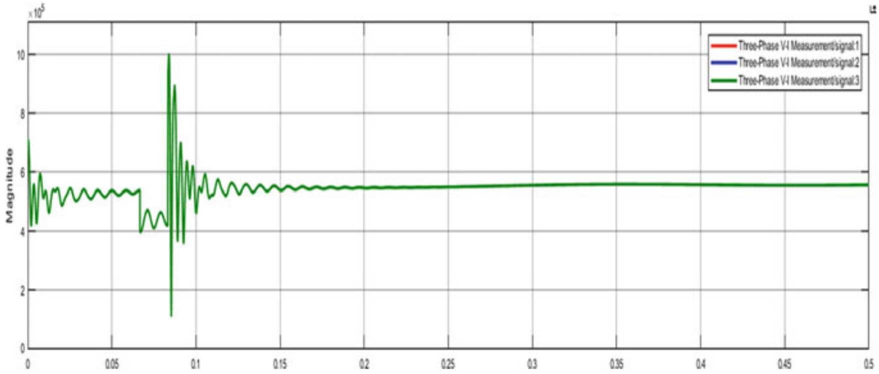

Fig. 11 Voltage across abc phases

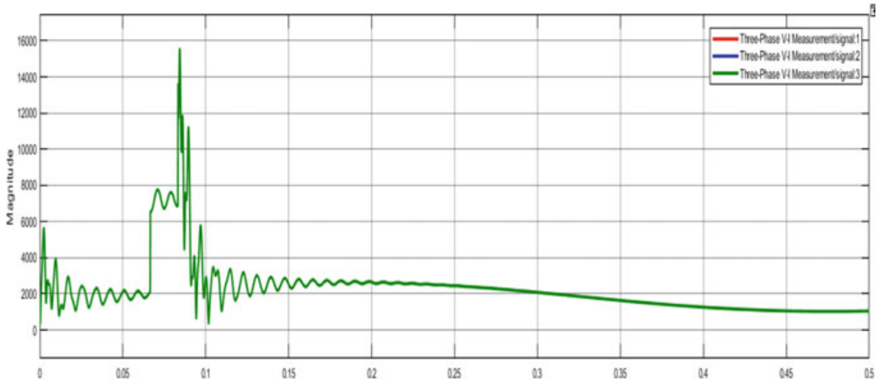

Fig. 12 Current across abc phases

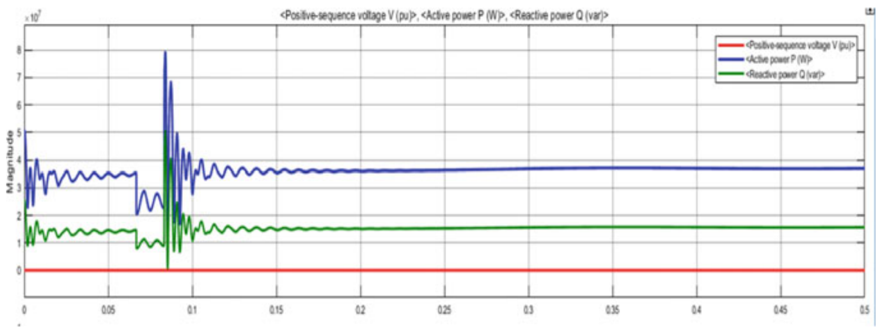

Fig. 13 Dynamic load

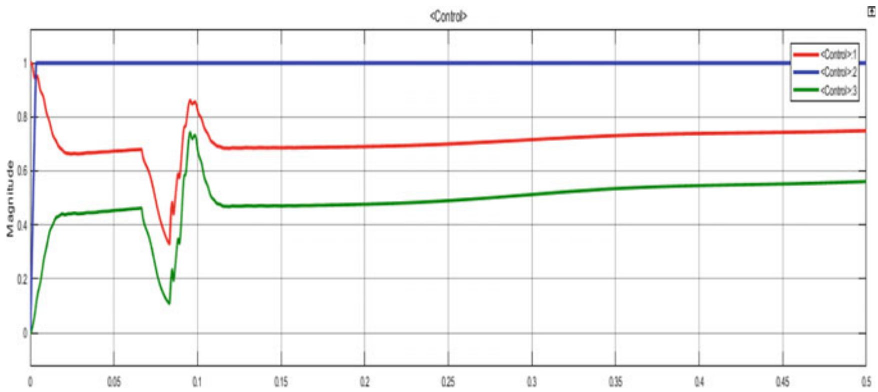

Fig. 14 I_{abc}, using SVC controller MPPT

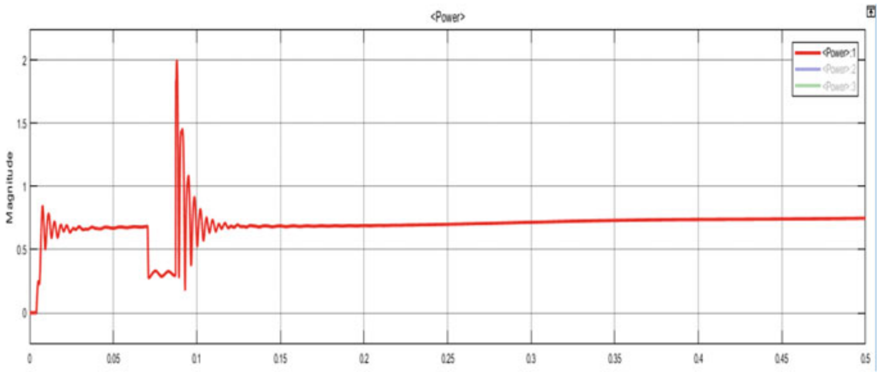

Fig. 15 V_m, B, and Q using SVC controller MPPT Figure

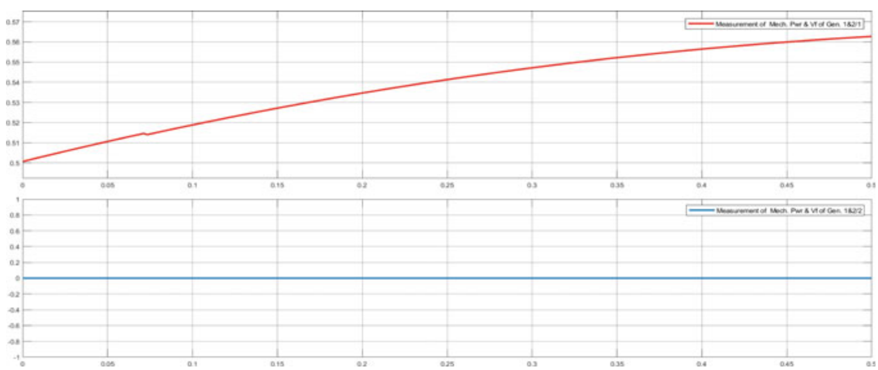

Fig. 16 Control, voltage of M1

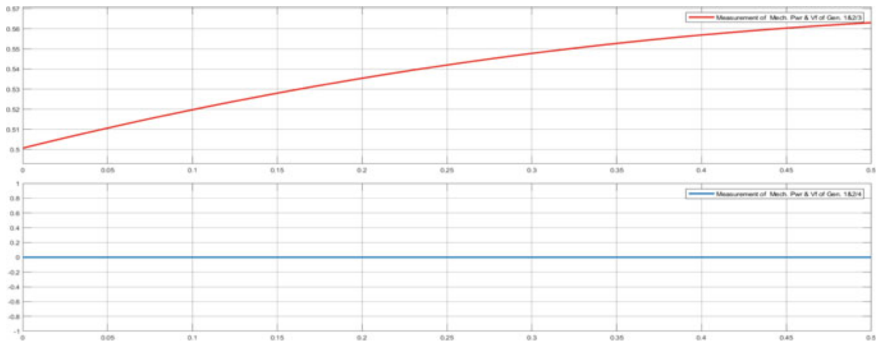

Fig. 17 Control, voltage of M2

6 Results and Discussions

The analysis of 2-machines, 3-buses system under various loading condition such as without SVC, with SVC and SVC with controlling device (MPPT controller).

The following table shows different readings for voltage, current, active, and reactive control for different loading conditions (Tables 2 and 3).

Table 2 Three-phase load

Parameters	Without SVC	With SVC	SVC with MPPT
Voltage	0.26 s	0.18 s	0.18 s
Current	0.24 s	0.184 s	0.183 s
M1 control	0.56 W	0.57 W	0.57 W
M1 voltage	7 V	7 V	0.1 V
M2 control	0.57 W	0.57 W	0.56 W
M2 voltage	2.57 V	2.58 V	0.12 V

Table 3 Three phase with Dynamic load

Parameters	Without SVC	With SVC	SVC with MPPT
Positive voltage	0	0.14 s	0.22 s
Active (*P*)	0.22 s	0.15 s	0.21 s
Reactive (*Q*)	0.2 s	0.149 s	0.198 s

7 Conclusion

From the simulation and analysis, we can conclude that SVC mechanism is controlled with MPPT and TID-based controller. The switch combines the advantages with cooperation of TID and MPPT controller. The two-machine three-bus Simulink model is tested in MATLAB. The design is performed on several factors like speed, angle difference, voltage, AP, and RP of the machineries. The model is related to the conventional SVC with MPPT controller. With the help of FACTS and other controlling device, we can improve the transient steadiness and dynamic reaction of the system. The performance of the designed controller is steadfast and is moderately constant. Upcoming work will be done on improving the transient steadiness and dynamic response of SVC using neural network-based TID controller or genetic algorithm with other controlling devices.

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