

# Analysis of ANN Based SVC Controller to Improved Dynamic Performance of Transmission Line

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**ABSTRACT:** Electricity has now been Interconnected power system has been an inherent part of the today's electrical generation. It has become more and more complex as there are multiple ways of generations, transmission and distribution. So there is a great challenge for proper flow of power and ensuring the system stability. Static Var Compensators (SVC) is widely used in shunt compensation of transmission lines. Static Var Compensators are being increasingly applied in electric transmission systems to economically improve voltage control and post-disturbance recovery voltages that can lead to system instability. In this paper, a simple artificial neural network power system stabilizer (SANN-PSS) is presented for a Compensated transmission line to improve dynamic performance of power system. The power system is highly nonlinear, with configurations and parameters that change with time, the conventional PSS cannot guarantee good performance in a realistic operational environment. Therefore, a SANN-PSS has been simulated to improve the system dynamics performance and to adapt the controller's parameters in real time due to any changes in operating conditions using MATLAB Simulink. The results validate the efficacy of the proposed SANN-PSS over a wide range of operating conditions.

**KEYWORDS:** static var compensator (SVC), shunt compensation, Transmission line, artificial neural network

## I. INTRODUCTION

In recent years, power demand has increased substantially while the expansion of power generation and transmission has been severely limited due to limited resources and environmental restrictions. As a consequence, some transmission lines are heavily loaded and the system stability becomes a power transfer-limiting factor. One of the most important requirements during the operation of the electric power system is the reliability and stability. Maintaining stability of such an interconnected multi area power system has become a cumbersome task. Owing to the environmental and economic pressures, electric power system becomes more heavily loaded and system oscillations are increased. Inadequate damping of these oscillations will restrict the power transfer capability. The conventional PSS (CPSS) is widely utilized to enhance the system damping. In some cases, if the utilization of PSS cannot provide sufficient damping for inter-area power swing, Flexible AC transmission systems (FACTS) devices are substitute effective solutions. The principle of these FACTS devices is to regulate the reactance and voltage. SVC is the most popular FACTS device utilized to improve the reliability of power systems [1]. It has different capability to improve the operation of power systems by mitigating network loss, providing voltage regulation, compensating active power, improving transient stability, limiting short circuit currents and damping the power system oscillation [2]. The system damping can be enhanced by incorporating supplemental damping controller. Static Var Compensator (SVC) is one of the earliest Flexible AC Transmission System (FACTS) devices. It generates or absorbs reactive power at its point of connection, usually in the middle of a high voltage transmission line. Before the evolution of SVC in the 1960s, synchronous compensators performed such compensation. Generally, SVC is used to maintain the voltage magnitude at the middle of a long transmission line, thereby to increase the power transfer capability in a given transmission line. Since SVC cannot generate or absorb real power (neglecting its relatively low internal losses), the power transmission of the system is affected indirectly by the voltage control. SVC regulates the voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When the system voltage is low, SVC generates reactive power (capacitive mode) and when the voltage is high, it absorbs reactive power (inductive mode) [1]. However, the employment of a SVC in a transmission line creates certain problems for the protective relays and fault locators using conventional techniques because of the rapid changes introduced by the associated control actions. Apparent line impedance seen by conventional distance relays are affected due to the variation of the voltage at the point of SVC connection. It is worth noting that distance relays estimate the fault location by calculating the apparent

impedance using the voltage and current values at the relaying point [2,3]. When a single phase fault occurs on a transmission line compensated by SVC; the system voltage decreases, so the SVC takes remedial actions to recover the voltage to its reference value ( $V_{Ref}$ ). In this sense, reactive capacitive current is needed to be injected by SVC; therefore, the impedance seen by the distance relay starts to change by the intervention of SVC. When faults occur in a system with built-in protection, changes in the load may cause small signal disturbances in the electrical power system. The disturbances may continue for an extended time, making the system fragile [1]-[3]. To overcome these problems, most major power plants in large interconnected power systems are equipped with an additional excitation control, commonly referred to as the power system stabilizer (PSS). Power system stabilizers can provide additional damping for inter-area oscillations or for stabilizing a generator whose voltage regulator gain is such that it may result in negative damping. Several kinds of PSS signal, such as speed deviation, acceleration power and frequency aberration, have been used as input signals. The parameters of a conventional PSS are determined at a particular operating point, depending on the linearized power system to provide reliable performance [4]. Interconnected power systems are highly nonlinear, having a broad range of operating conditions and being subjected to unpredictable disturbances. A conventional PSS cannot guarantee adequate performance in many practical applications, because its design is based on a linearized model of the power system. In this paper, the proposed SANN-PSS technique is organized into two parts. The first section identifies the mathematical model used to represent the dynamic model of the power system under study using MATLAB Simulink, and the second part describes the design of the proposed SANN-PSS in Transmission line.

## II. STATIC VAR COMPENSATOR

Static VAR compensators (SVCs) are devices which use reactors and/or capacitors coupled with thyristor switches to control voltage or reactive power. One SVC may contain multiple capacitor units and multiple reactor units connected in shunt through a step-up transformer. Each capacitor unit or reactor unit is switched using thyristors. The thyristor can be ON/OFF type or use phase angle control with reactors to give variable ON time, providing variable reactive power [1]. SVCs are available in several combinations of the aforementioned configurations. The ON/OFF switched capacitor unit is referred to as thyristor switched capacitor (TSC). The ON/OFF switched reactor unit is referred to as thyristor switched reactor (TSR). The phase angle controlled reactor is referred to as thyristor controlled reactor (TCR). TCRs require additional series capacitance to filter harmonics created due to the phase angle control [2]. Each of these units can be combined to create an appropriate SVC device. SVCs provide fast and variable VAR control relative to fixed shunt capacitors and reactors. Thyristor control gives the SVC almost immediate response. The SVC is also allowed to switch much more frequently because it uses thyristors instead of circuit breakers or other mechanical switching devices. Also, using TSC with TCR allows almost infinitely variable VAR flow from its maximum VAR production to maximum VAR absorption [1]. SVCs can be used to control voltage and VAR flow. Due to their fast and variable nature, SVCs are capable of providing voltage support during system disturbances. This voltage support may prevent approaching the stability limits of nearby generators. It may also be used to control voltage following the switching in or out of lines and other system components.

A static VAR compensator is a set of electrical devices for providing fast-acting reactive power on high-voltage electricity transmission networks. SVCs are part of the Flexible AC transmission system device family, regulating voltage, power factor, harmonics and stabilizing the system. Unlike a synchronous condenser which is a rotating electrical machine, a static VAR compensator has no significant moving parts. Prior to the invention of the SVC, power factor compensation was the preserve of large rotating machines such as asynchronous condensers or switched capacitor banks. The SVC is an automated impedance matching device, designed to bring the system closer to unity power factor. SVCs are used in two main situations:

- 1) Connected to the power system, to regulate the transmission voltage ("Transmission SVC")
- 2) Connected near large industrial

## III. MATHEMATICAL MODEL OF STATIC VAR COMPENSATOR

The mathematical modelling of any physical system begins with the development of the relevant relationship between the constraints and variables. Basically, SVC being a control system mathematical modelling is an important aspect of the design. The general control loop system of the SVC is shown in fig 1. Each of the blocks shown above is the representation of the transfer function of the components of the SVC. The individual components of the SVC can be modelled as developing the transfer function:

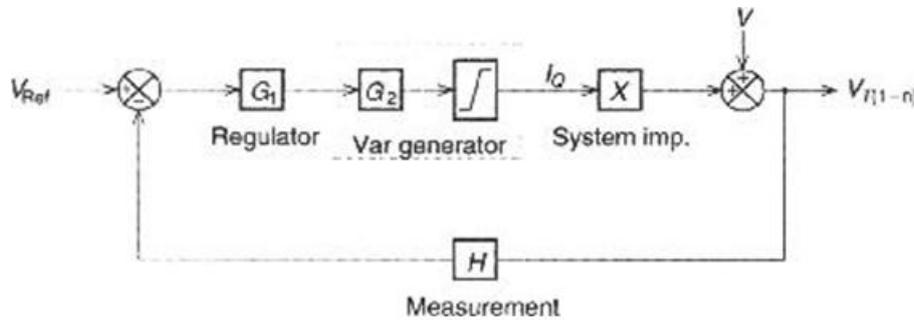


Fig. 1. Block Diagram of SVC

Each of the components shown in block diagram above and be modelled in mathematical way individually.

The following are the components and their model

1) Measurement System: These systems provide the necessary inputs to the SVC controller for performing its control operations. The different inputs required by an SVC depend on the function that the SVC controller is intended to perform. The SVC controller performance and its robustness largely depend on the authenticity of the measured signals. However, the measurement units, together with their transducers, operate in environments that cannot be predicted from simulation studies of power-system component models but can only be witnessed in the field. The voltage, current, power, and frequency transducers can potentially produce spurious outputs from the effects of extraneous dynamics present in the input signals.

2) Voltage Regulator: The SVC voltage regulator processes the measured system variables and generates an output signal that is proportional to the desired reactive-power compensation. Different control variables and transfer functions of the voltage regulator are used, depending on the specific SVC application. The measured control variables are compared with a reference signal, usually  $V_{ref}$ , and an error signal is input to the controller transfer function. The output of the controller is a per-unit susceptance signal  $B_{ref}$ , which is generated to reduce the error signal to zero in the steady state. The susceptance signal is subsequently transmitted to the gate pulse generation circuit. The block  $G$  represents the voltage regulator in the above block diagram of the SVC. Generally, the use of the proportionate integral voltage regulator is used for the generation of the control signal.

3) Gate-Pulse Firing The susceptance reference output from the voltage regulator is transmitted to the gate pulse generation (GPG) unit, which produces appropriate firing pulses for all the thyristor-controlled and thyristor-switched devices of the SVC so that the desired susceptance is effectively made available at the SVC bus to achieve the specified control objectives.

#### IV. PROPOSED SANN-PSS POWER SYSTEM STABILIZER

An artificial neural network usually contains three layers, which are an input layer, a hidden layer, and an output layer of neurons. In practice, the input data is received from the electronic sensors. The output layer of the neurons would give the control signals. Within the hidden layer, the summed inputs are processed by a nonlinear squashing function when they pass through the neuron. This paper uses only two hidden neurons  $N$  and  $Z$ , which makes the network easy to train [13]-[16]. The network has two inputs,  $I$  and  $J$ , which are error and integral of error, respectively. This network is shown in Fig. 2

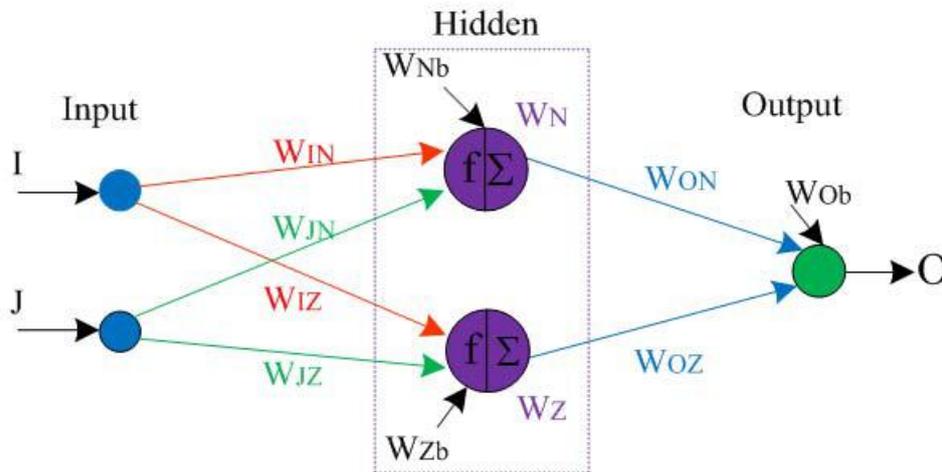


Fig. 2. Two hidden layers of the neural network

$$O = W_{Ob} + W_{ON}f(IW_{IN} + JW_{JN} + W_{Nb}) + W_{OZ}f(IW_{IZ} + JW_{JZ} + W_{Zb})$$

Equation shows how weights (W) can be used in a map to scale and shift the squashing function horizontally and vertically. The artificial neural network mimics the PI controller, which has an output signal as shown in (14).

$$O = K_P I + K_I J$$

For the artificial neural network to mimic the PI controller, this paper sets

$$W_{IN} = W_{JZ} = 0, W_{Nb} = W_{Zb} = 0, W_{Ob} = -(W_{ON} + W_{OZ})/2$$

The saturation limits of the controller are set to be the values of  $W_{ON}$  and  $W_{OZ}$ , which are determined by hardware, so the value  $W_{ob}$  would be known. The artificial neural network controller reduces to:

$$O = W_{ON}f(a) + W_{OZ}f(b) + W_{Ob}$$

where  $a = I W_{IN}$  and  $b = J W_{JZ}$

The differentiation of the PI controller with respect to the input I give the proportional gain  $K_p$ . Moreover, the differentiation of the PI controller with respect to the J of entry gives the integral gain  $K_i$ . Therefore, the differentiation of the reduced artificial neural network controller with respect to I and J when both are equal to zero gives:

$$W_{JN} = 4K_P/W_{ON}$$

$$W_{JZ} = 4K_I/W_{OZ}$$

V. TEST SYSTEM SIMULATION MODEL OF SVC USING MATLAB/SIMULINK

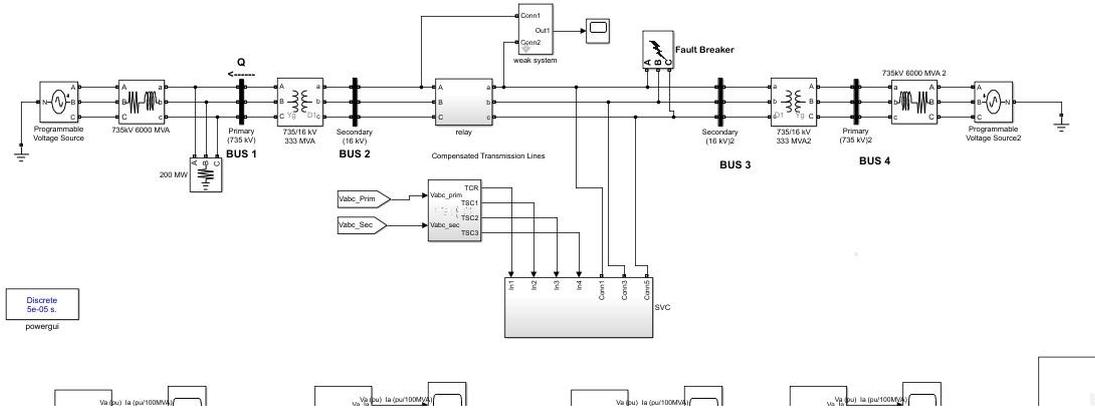


Fig. 4. Simulink model of Four Bus System for Analysis

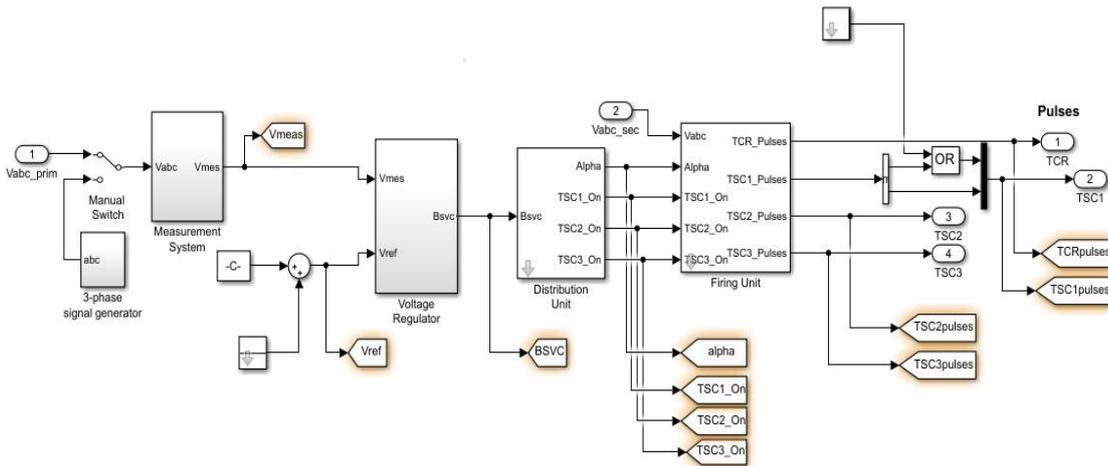


Fig. 5. Simulink model of SVC Controller

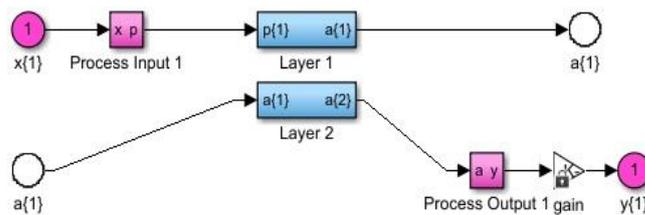


Fig.6. Simulink model of artificial neural network

### VI. TEST SYSTEM SIMULATION RESULT

➤ Test Model Result with 3 Phase Fault without using SVC

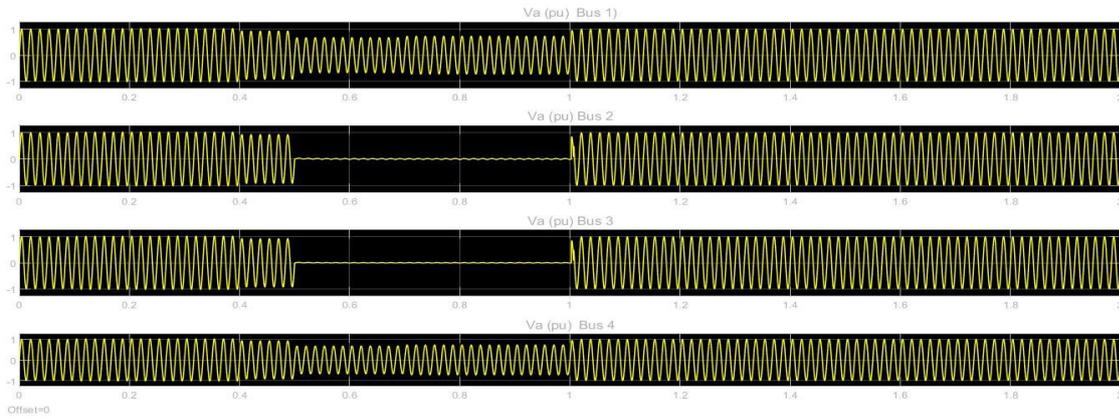


Fig.6. Voltage (pu) at Bus 1,2,3,4

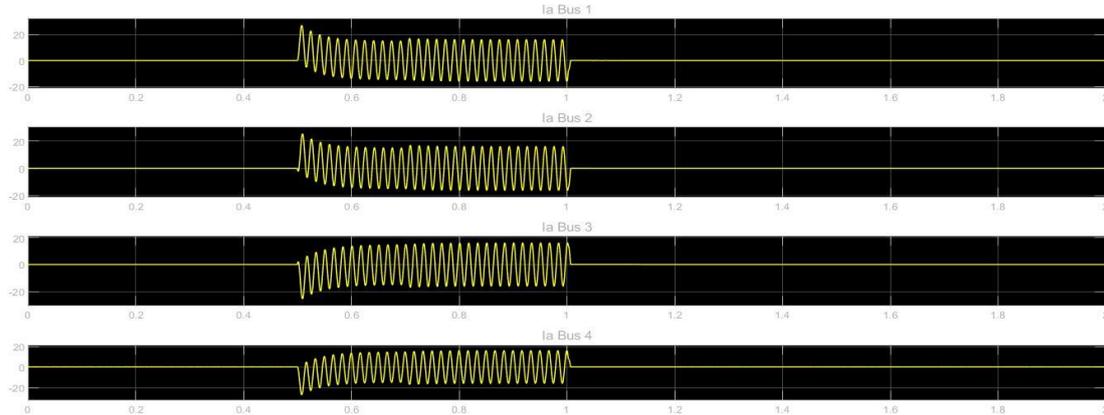


Fig.7. Current at Bus 1,2,3.

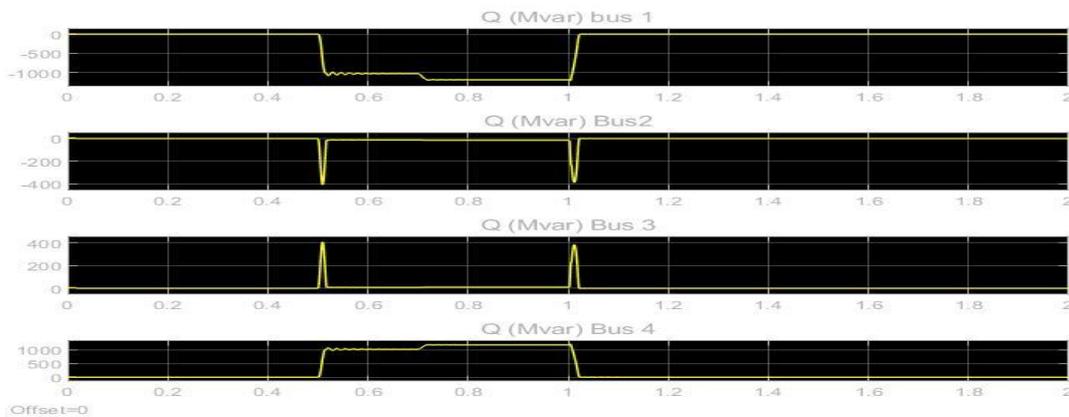


Fig.8. Reactive power at Bus 1,2,3.

➤ Test Model Result with 3 Phase Fault with using SVC

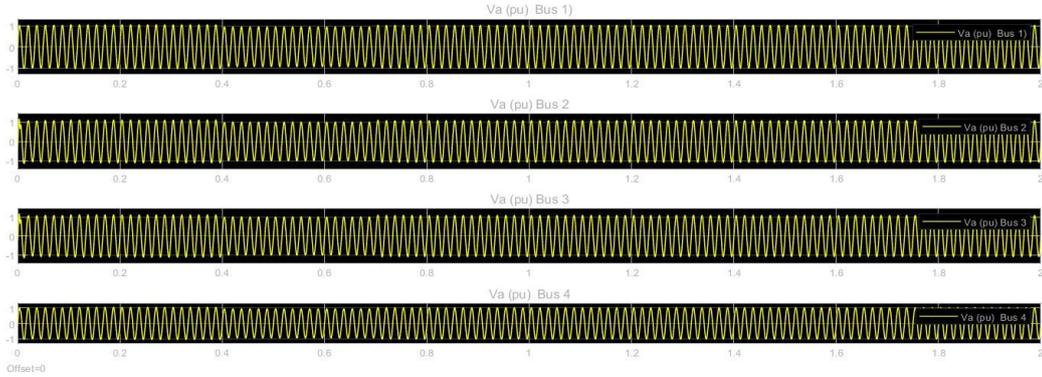


Fig.9. Voltage (pu) at Bus 1,2,3,4

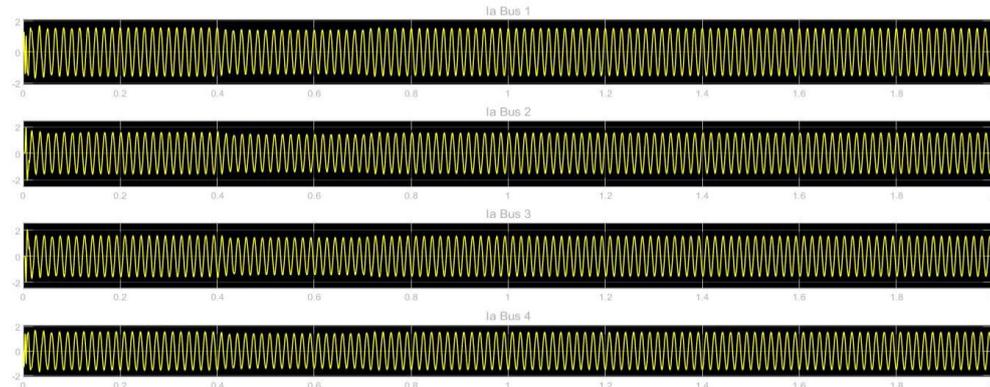


Fig.10. Current at Bus 1,2,3.

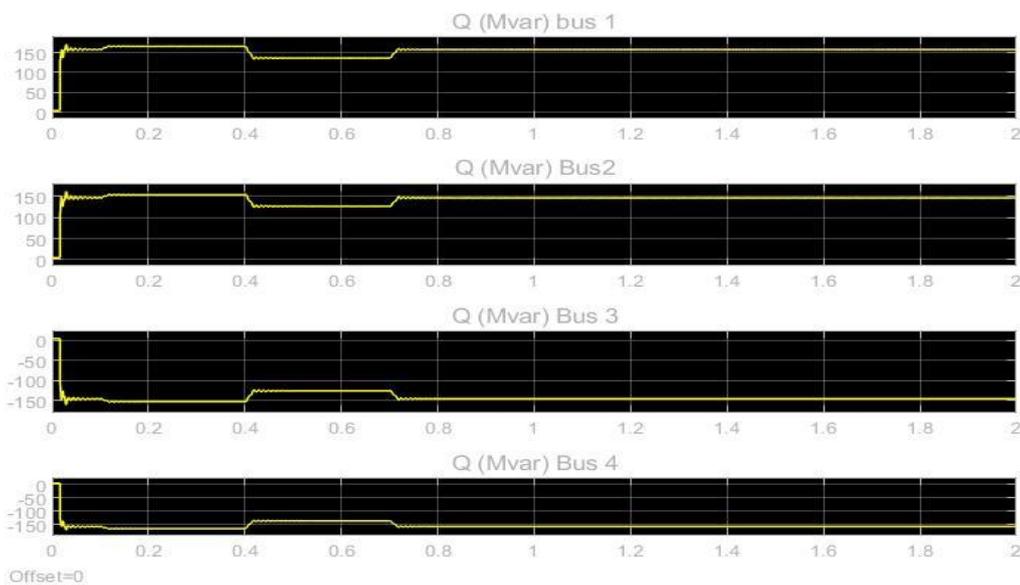


Fig.11. Reactive power at Bus 1,2,3.

## VII. CONCLUSION

In this paper, Static Var Compensator with a simple artificial neural network power system stabilizer (SANN-PSS) is presented for a Compensated transmission line to improved dynamic performance of power system and modelled on mathematical basis and simulated in MATLAB/ SIMULINK. The use of static var compensator has shown an improvement in voltage profile in two bus system. It consumes or supplies reactive power that is either excess or deficient in the system bus so regulates the voltage.

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