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Performance Analysis of ANN based Static VAR Compensator to Improve Voltage Stability in Transmission System

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ABSTRACT: Electricity has now been Interconnected power system has been an inherent part of the todays electrical generation. It has becoming more and more complex as there are multiple ways of generations, transmission and distribution. So there is 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 improved 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 effectual 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 absorb reactive power (inductive mode) [1].

However, the employment of a SVC in a transmission line createscertain problems for the protective relays and fault locatorsusing conventional techniques because of the rapid changes introducedby the associated control actions. Apparent line impedancesseen by conventional distance relays are affected due to the variationof the voltage at the point of SVC connection. It is worth notingthat distance relays estimate the fault location by calculating theapparent impedance using the voltage and current values at therelaying point [2,3]. When a single a phase fault occurs on a transmissionline compensated by SVC; the system voltage decreases, sothe SVC takes remedial actions to recover the voltage to its reference value (V_{Ref}). In this sense, reactive capacitive current is neededto be injected by SVC; therefore, the impedance seen by the distancerelay starts to change by the intervention of SVC.When faults occur in a system with built-in protection, changes in the loadmay cause small signal disturbances in the electrical powersystem. The disturbances may continue for an extended time,making the system fragile [1]-[3]. To overcome theseproblems, most major power plants in large interconnectedpower systems are equipped with an additional excitationcontrol, commonly referred to as the power system stabilizer(PSS). Power system stabilizers can provide additionaldamping for inter-area oscillations or for stabilizing a generatorwhose voltage regulator gain is such that it may result innegative damping. Several kinds of PSS signal, such as speeddeviation, acceleration power and frequency aberration, havebeen used as input signals. The parameters of a conventionalPSS are determined at a particular operating point, dependingon 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 tounpredictable disturbances. A conventional PSS cannotguarantee adequate performance in many practicalapplications, because its design is based on a linearized modelof the power system.In this paper, the proposed SANN-PSS technique is organized into two parts. The first section identifies themathematical model used to represent the dynamic model ofthe power system under study using MATLAB Simulink, andthe 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 capacitorscoupled with thyristor switches to control voltage or reactive power. One SVC maycontain multiple capacitor units and multiple reactor units connected in shunt througha step-up transformer. Each capacitor unit or reactor unit are switched using thyristors.The thyristor can be ON/OFF type or use phase angle control with reactors to givevariable 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). TheON/OFF switched reactor unit is referred to as thyristor switched reactor (TSR). Thephase angle controlled reactor is referred to as thyristor controlled reactor (TCR). TCRsrequire additional series capacitance to filter harmonics created due to the phaseangle control [2]. Each of these units can be combined to create an appropriate SVCdevice.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 alsoallowed to switch much more frequently because it uses thyristors instead of circuitbreakers or other mechanical switching device. Also, using TSC with TCR allows almostinfinitely variable VAR flow from its maximum VAR production to maximum VARabsorption [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. Thisvoltage support may prevent approaching the stability limits of nearby generators. Itmay 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 forproviding fast-acting reactive power on high-voltage electricitytransmission networks. SVCs are part of the Flexible ACtransmission system device family, regulating voltage, power factor, harmonics and stabilizing the system. Unlike a synchronouscondenser which is a rotating electrical machine,a static VAR compensator has no significant moving parts.Prior to the invention of the SVC, power factor compensationwas the preserve of large rotating machines such assynchronous condensers or switched capacitor banks. TheSVC is an automated impedance matching device, designedto bring the system closer to unity power factor. SVCs areused in two main situations:
1) Connected to the power system, to regulate the transmissionvoltage (”Transmission SVC”)
2) Connected near large industrial

III. MATHEMATICAL MODEL OF STATIC VAR COMPENSATOR

The mathematical modelling of any physical system beginswith the development of the relevant relationship betweenthe constraints and variables. Basically, SVC beinga control system mathematical modelling is an importantaspect of the design. The general control loop system of theSVC is shown in fig 1. Each of the blocks shown

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above isthe representation of the transfer function of the componentsof the SVC. The individual components of the SVC can bemodelled as developing the transfer function:

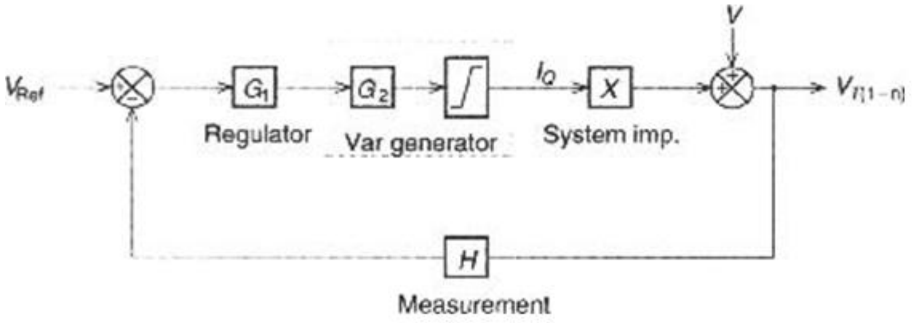

Fig. 1. Block Diagram of SVC

Each of the components shown in block diagram aboveand be modelled in mathematical way individually. Thefollowing are the components and their model

1) Measurement System:These systems provide the necessary inputs to the SVC con
troller for performingits control operations. The different inputs requiredby an SVC depend on the function that the SVCcontroller is intended to perform. The SVC controllerperformance and its robustness largely depend on theauthenticity of the measured signals. However, themeasurement units, together with their transducers,operate in environments that cannot be predicted fromsimulation studies of power-system component modelsbut can only be witnessed in the field. The voltage, current,power, and frequency transducers can potentiallyproduce spurious outputs from the effects of extraneousdynamics present in the input signals.

2) Voltage Regulator: The SVC voltage regulator processesthe measured system variables and generatesan output signal that is proportional to the desiredreactive-power compensation. Different control variablesand transfer functions of the voltage regulatorare used, depending on the specific SVC application.The measured control variables are compared with areference signal, usually Vref, and an error signal isinput to the controller transfer function. The outputof the controller is a per-unit susceptance signal Bref,which is generated to reduce the error signal to zero inthe steady state. The susceptance signal is subsequentlytransmitted to the gate pulse generation circuit. Theblock G represents the voltage regulator in the aboveblock diagram of the SVC. Generally, the use of theproportionate integral voltage regulator is used for thegeneration of the control signal.

3) Gate-Pulse Firing The susceptance reference outputfrom the voltage regulator is transmitted to the gatepulse generation (GPG) unit, which produces appropriatefiring pulses for all the thyristor-controlled andthyristor-switched devices of the SVC so that thedesired susceptance is effectively made available at theSVC 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 ofneurons. In practice, the input data is received from theelectronic sensors. The output layer of the neurons would givethe control signals. Within the hidden layer, the summedinputs are processed by a nonlinear squashing function whenthey 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 hastwo inputs, I and J, which are error and integral of error,respectively. This network is shown in Fig. 2

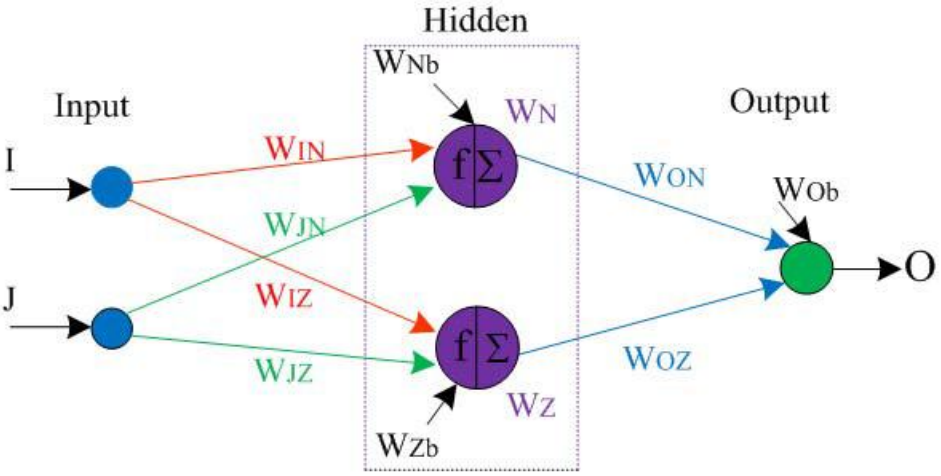

Fig. 2. Two hidden layers of the neural network

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

Equation shows how weights (W) can be used in amap to scale and shift the squashing function horizontally andvertically. The artificial neural network mimics the PIcontroller, 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 $b = JW_{JZ}$

The differentiation of the PI controller with respect to theinput I give the proportional gain Kp. Moreover, thedifferentiation of the PI controller with respect to the J of entrygives the integral gain Ki. Therefore, the differentiation of thereduced artificial neural network controller with respect to Iand 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

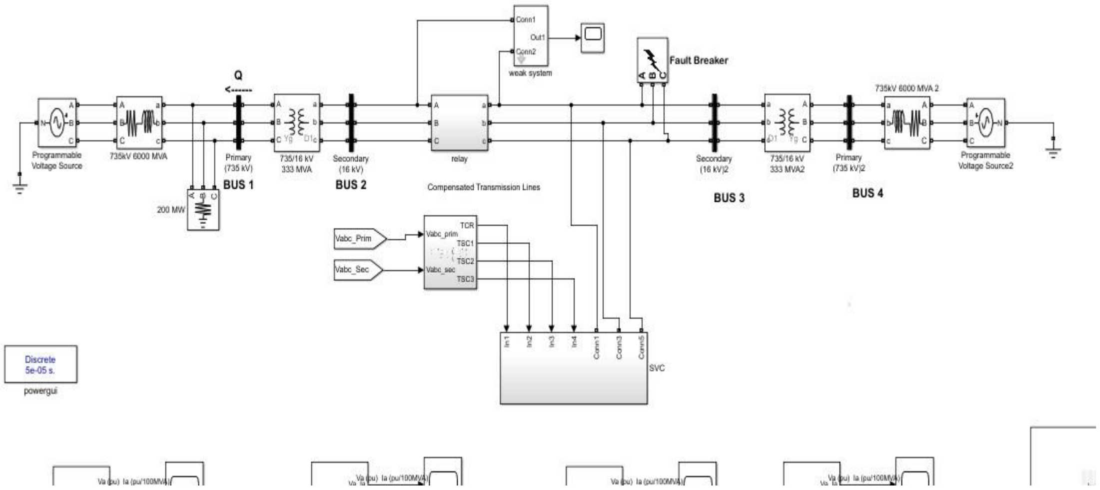

Fig. 4. Simulink model of Four Bus System for Analysis

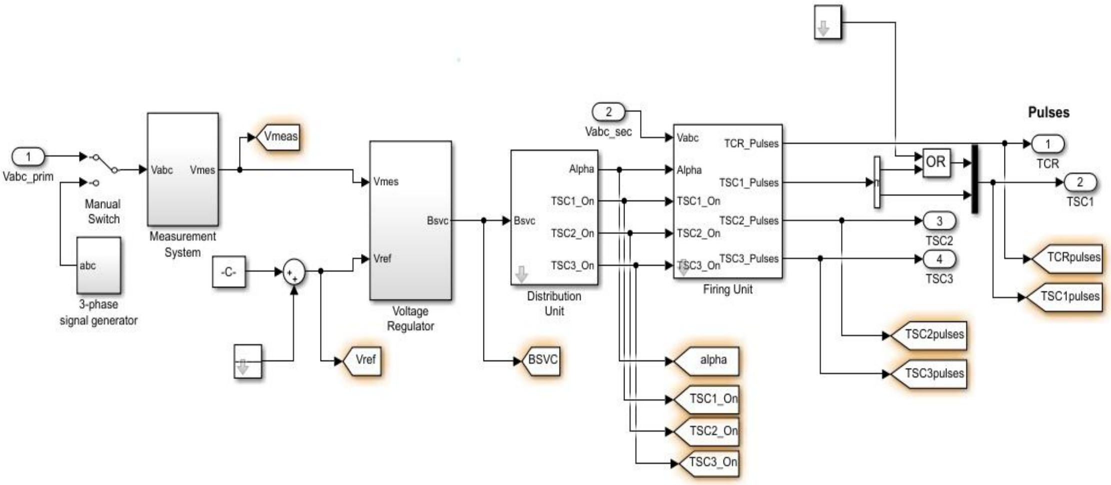

Fig. 5.Simulink model of SVC Controller

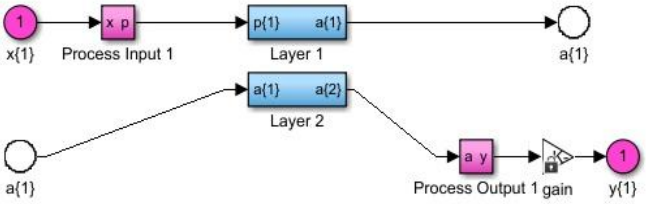

Fig.6. Simulink model of artificial neural network

VI. TEST SYSTEM SIMULATION RESULT

- **Test Model Result with 3 Phase Fault without using** SVC

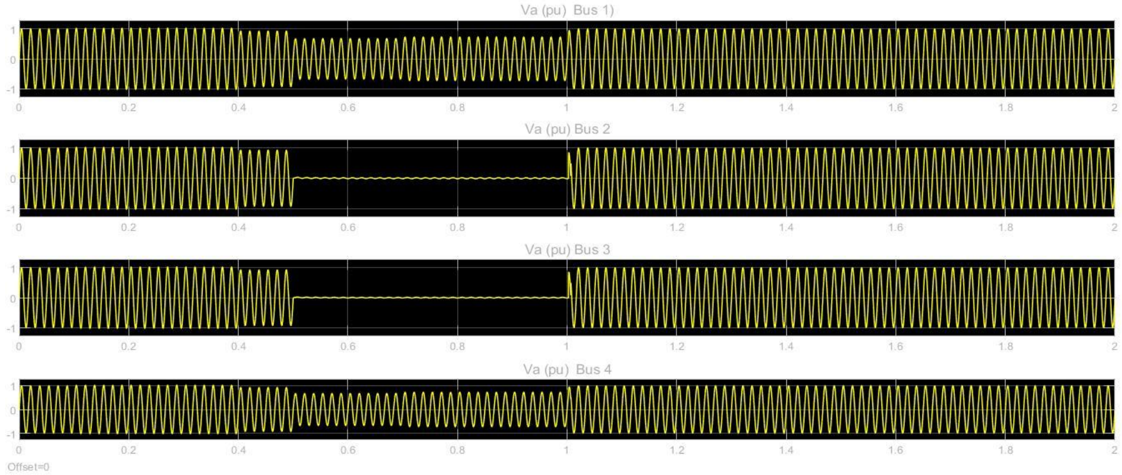

Fig.6. Voltage (pu) at Bus 1,2,3,4

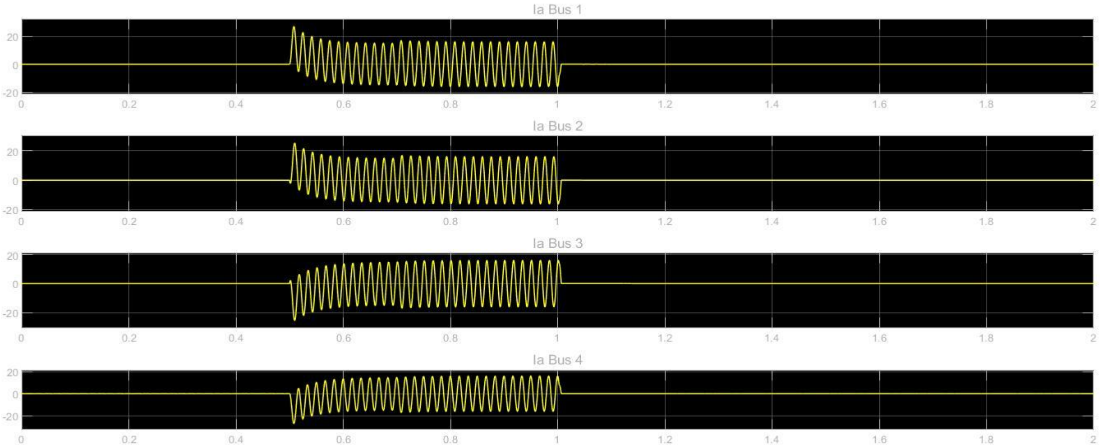

Fig.7. Current at Bus 1,2,3.

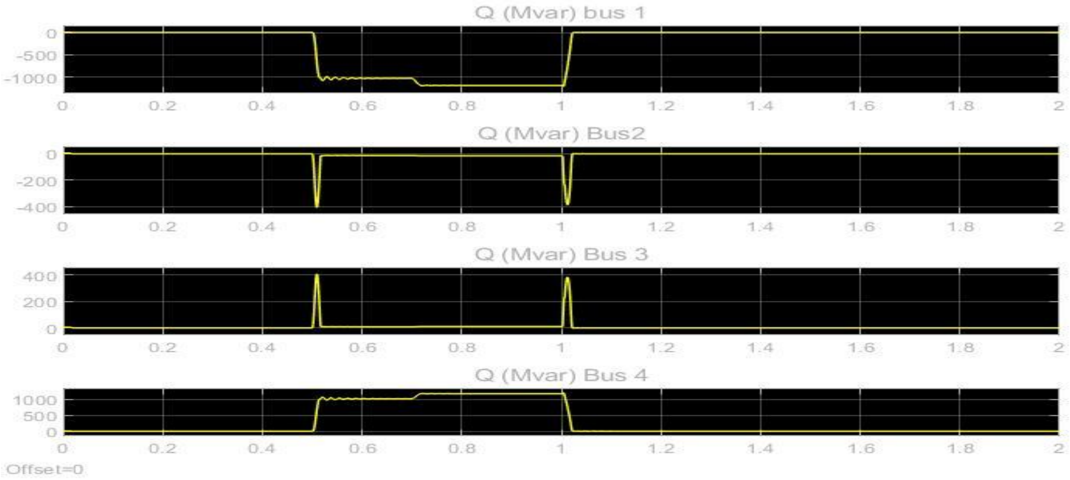

Fig.8. Reactive power at Bus 1,2,3.

- **Test Model Result with 3 Phase Fault with using SVC**

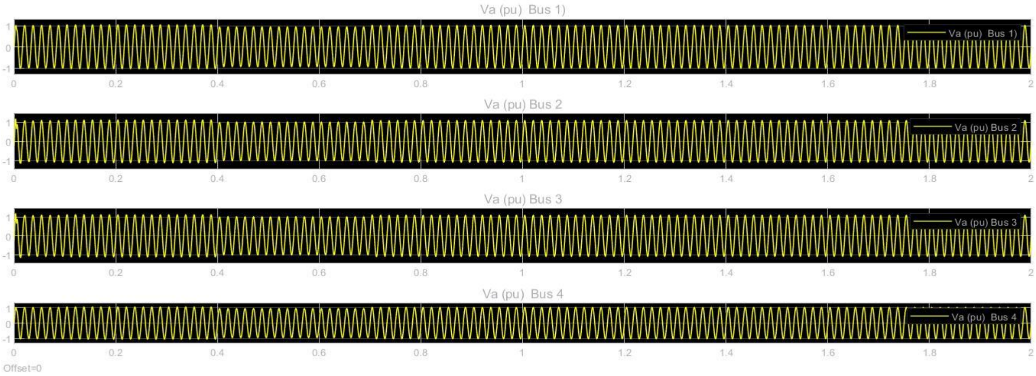

Fig.9. Voltage (pu) at Bus 1,2,3,4

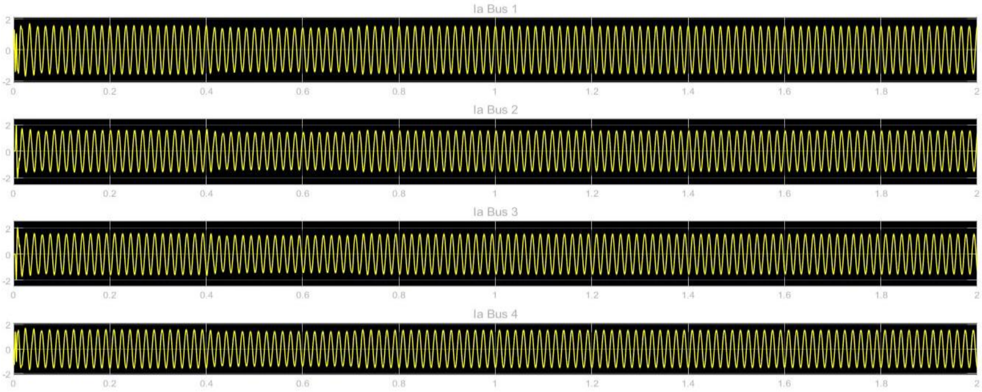

Fig.10. Current at Bus 1,2,3.

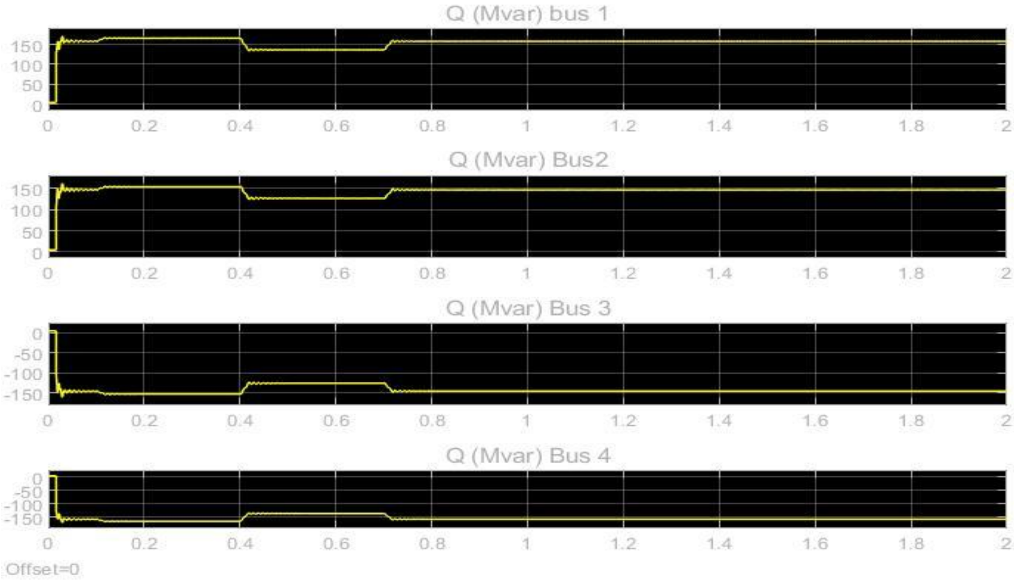

Fig.11. Reactive power at Bus 1,2,3.

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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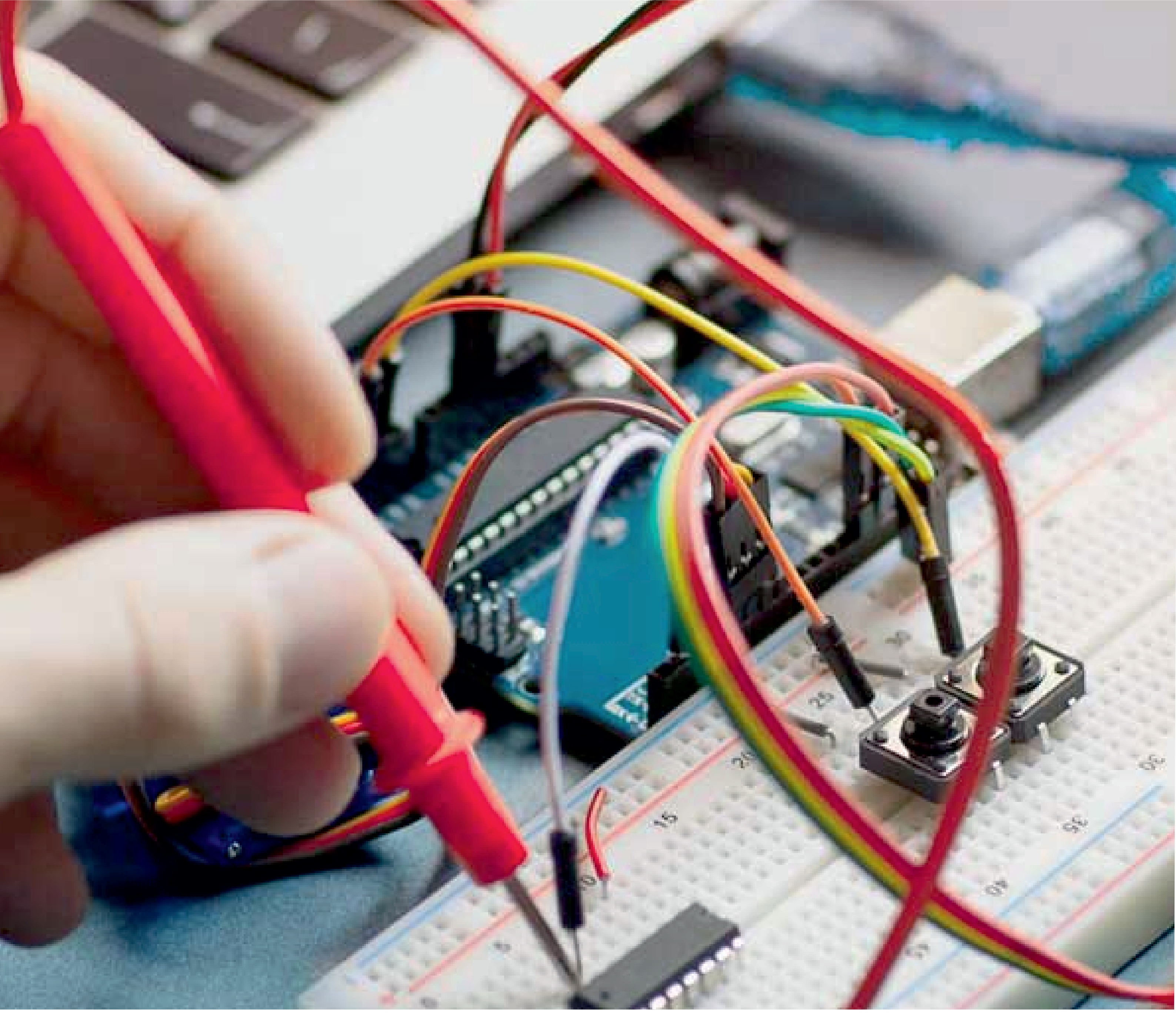

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