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Reactive Power Compensation Using Fuzzy Controlled SVC

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Abstract: *Transmission networks of modern power systems are becoming stressed due to growing demand. This will cause poor voltage regulation and reduce power handling capacity of power system. These problems can be removed by FACTS devices. These FACTS devices are used for power factor correction, flicker mitigation, and steady-state voltage control, stability enhancement. In this Paper the reactive power compensation is done in 2 machine 3 bus system using SVC and Fuzzy controlled SVC. The simulation results show that the new controller logic gives better performance as compared to the other types.*

Keywords: *FACTS; SVC; Reactive Power Compensation; Fuzzy Logic.*

I. INTRODUCTION

Modern electric power utilities are facing many challenges due to ever increasing demand and voltage is attending instability by increment in losses and various power quality problems. The rapid development of the high-power electronics industry has made Flexible AC Transmission System (FACTS) devices attractive for utility applications. Static Var Compensator (SVC) has been widely used for compensating reactive power.

The conventional SVC consists of a PI controller, which is easier to design, implement and control. But, they do not provide satisfactory performance in case of large disturbances and for different operating points, since the power system is non-linear. The Fuzzy logic is an effective technique with the capability of tolerating uncertainty and imprecision in the system parameters and operation condition changes.

In this Paper a fuzzy logic based SVC controller is proposed. The model is tested using a 2 machine 3 bus test system and MATLAB software is used to perform the simulation studies. The performance analysis of the new controller is done by subjecting the system to a three phase fault. The results obtained shows that the proposed controller gives better performance.

The report structure is as follows: In Section II, the SVC modeling is explained. The controllers used in conventional SVC and the importance of Fuzzy Logic Controllers are briefed in Section III. The Fuzzy based rules, input-output membership functions are also discussed in this section. Section IV gives a view of the simulated results obtained by creating a disturbance in the test system. Finally, Section V gives a description of the work done in this paper.

II. SVC OPERATION AND MODELING

The Static VAR Compensator (SVC) is one of the shunt connected FACTS devices, which is based on power electronics. It helps in voltage regulation, reactive power control and improving the transient stability of the system. The voltage regulation by SVC is done, by controlling the amount of reactive power injected into or absorbed from the power system. It generates reactive power (capacitive mode), when the system voltage is low and absorbs reactive power (inductive mode), when the system voltage is high[4].

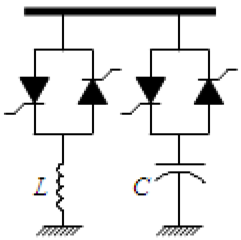

Fig. 1. SVC Structure

As shown in Fig. 1, a typical SVC comprises one or more banks of fixed or switched shunt capacitors or reactors, of which at least one bank is switched by thyristors. The reactive power variation can be achieved by switching the capacitor banks and inductor banks. The capacitors are switched ON and OFF by Thyristor Switched Capacitor (TSC) and the reactors are controlled by Thyristor Controlled Reactor (TCR)

Fig. 2.shows the basic architecture of SVC Control scheme.

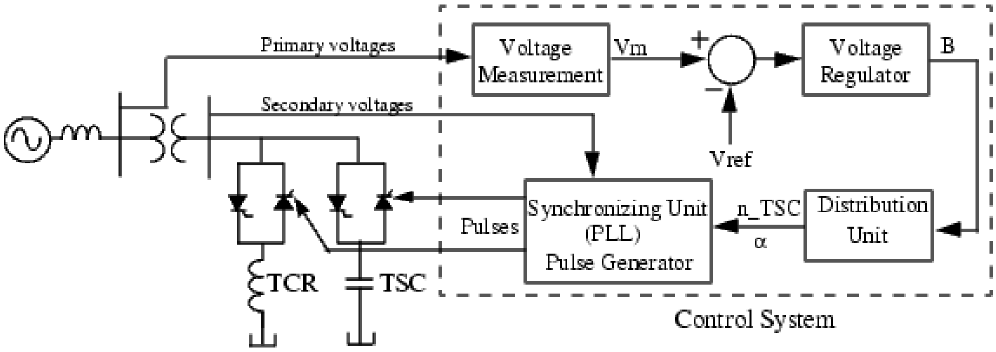

Fig 2. Basic configuration of SVC Control Scheme

The block consists of a Step down transformer, Voltage regulator, TCR and TSC units, a Phase Locked Loop (PLL). The functions of the above blocks are:
• Positive sequence voltage is measured using a Voltage Measurement system.
• The Voltage regulator uses the voltage error to calculate the susceptance (B) of SVC in order to maintain a constant system voltage.
• The distribution unit computes the firing angle (α) for TCRs.
• The synchronising unit uses a PLL to synchronise secondary voltage and the pulse generator sends the required pulses to the thyristors[4]

III. FUZZY LOGIC CONTROLLER

The SVC Voltage regulator employs PI Controller, which is both economical and simpler. Hence, the PI controller is utilized in most of the current industrial applications. However, this controller fails when the controlled object is highly nonlinear and uncertain. Therefore, Fuzzy logic based controller is proposed.
Here fuzzy controller is designed with two inputs i.e. voltage error and change of error and a single output i.e. Susceptance. The advantage of this controller is that it doesn"t required detailed information about the system.
The Fuzzy controller has three stages namely, Fuzzification, Rule-Base and Defuzzification.

A.Fuzzification

Fuzzification is the process where the crisp quantities are converted to fuzzy. Broadly functions of fuzzification classified as:

- Determine the value of input variables.
- Scale Mapping technique i.e. converts the range of input variables values into corresponding universe of discourse.
- Fuzzification i.e. converts input data into suitable linguistic value which may be viewed as labels of fuzzy sets.

B. *Rule-Base*

In the fuzzy model, the relationship between the input and output features are represented by IF premise THEN consequent. The fuzzy rules can be generated and framed with the help of an expert operator's experience and knowledge.
The logic behind rule can be easily derived. For example
Rule 1: If voltage error, e(k) is NB AND change of error de(k) is NB, then the output (Susceptance) is NB.
Rule 2: If voltage error, e(k) is NM AND change of error de(k) is NB, then the output (Susceptance) is NB.
Thus the two inputs and single output of Fuzzy Logic Controller will result in a total of 49 rules, which are listed in TABLE I.

TABLE I. RULE BASE OF FUZZY CONTROLLER

CE /E	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	ZE
NM	NB	NM	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB

PM	NS	ZE	PS	PM	PM	PM	PB
PB	ZE	PS	PS	PM	PB	PB	PB

C. Defuzzification

Defuzzification is a process of converting the conclusions of a rule-based system into a final crisp quantity. There are various methods like Centroid method, Weighted Average method and Max-membership method available for this purpose.

Here Mamdani Fuzzy Model is use for the purposed fuzzy controller and “if-Then” rules use for inference engine. There is fuzzy variable corresponding to each controller input and these inputs are fuzzified by using membership function and crisp output is calculated using Centroid Method.

IV. SIMULATION RESULTS

The proposed controller is tested for various operating conditions in a multi-machine system, whose details are as follows. A system setup consisting of 2 machines with 3 buses are considered for the study. Plant 1 (M1) is a 1000 MW hydraulic generation plant connected to a load centre through a long 500 KV, 700 km transmission line. The Load centre is modeled as 5000 MW resistive load and supplied by the remote plant 2 (M2) of 1000 MVA capacity and a local generation of 5000 MVA. The test system is shown in the Fig.3.

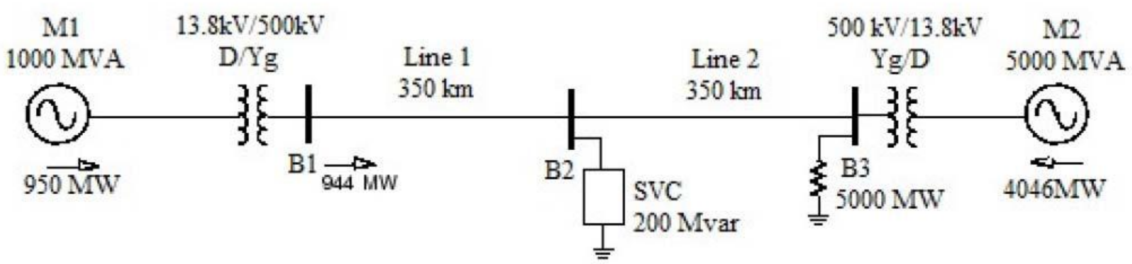

Fig. 3. Single Line diagram of 2-Machine 3-Bus system

The 2 machine 3 bus system with SVC and STATCOM were simulated using MATLAB/SIMULINK 2011b which is shown below:

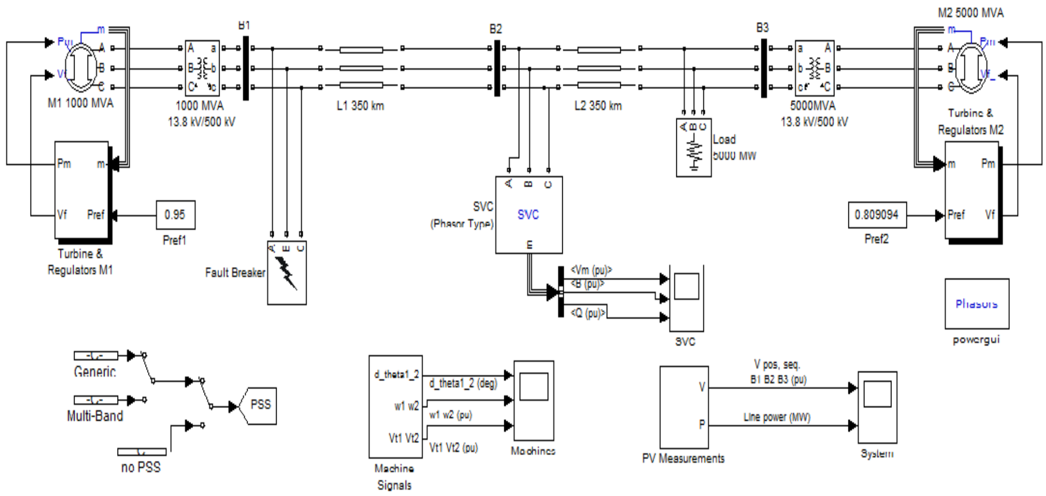

Fig. 4 2 machine 3 bus system with SVC

When three-phase to ground fault is created for 0.1 second between 1.4s to 1.5s; the results are shown below with SVC. The SVC will now try to support the voltage by injecting reactive power on the line when the voltage is lower than the reference voltage and the system is stable at 7.3s after clearing the fault.

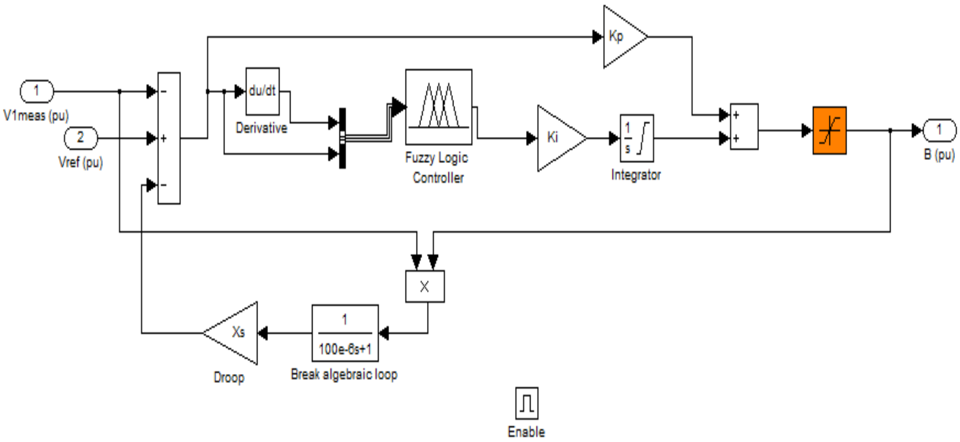

Fig. 5 Design of fuzzy SVC controller

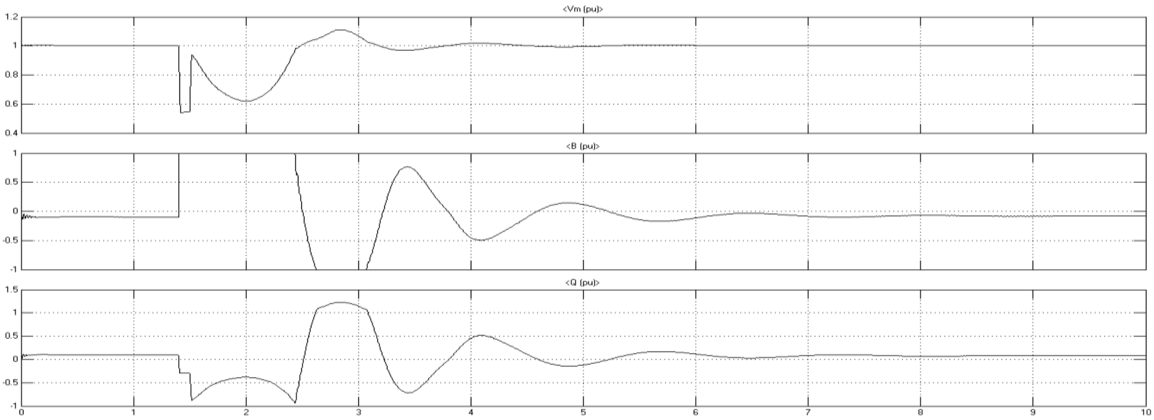

Fig. 6 Reactive power and voltage with three phase fault with SVC

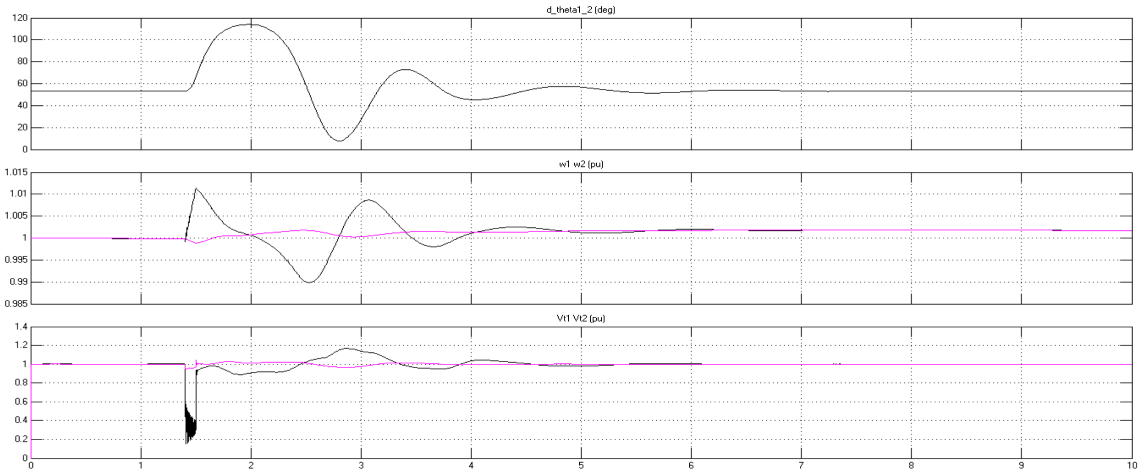

Fig. 7 Machine Signals with three phase fault with SVC

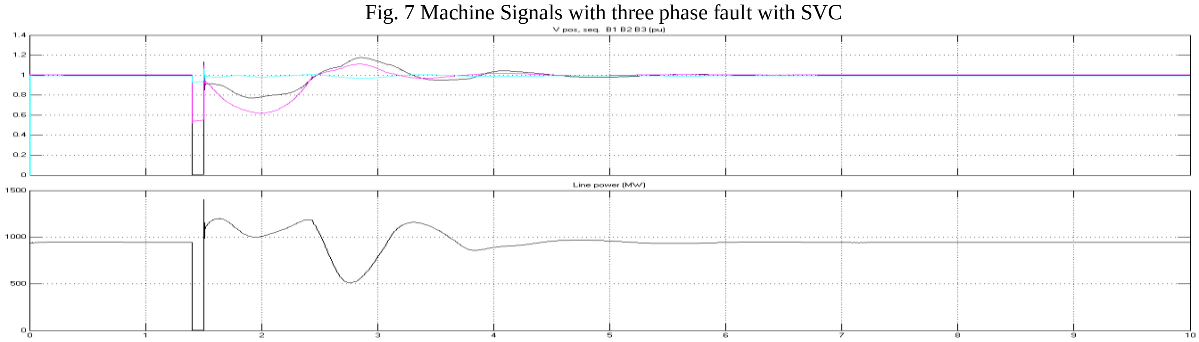

Fig. 8 P-V measurements with three phase fault with SVC

When the conventional SVC controller is replaced with the Fuzzy Based SVC controller and simulated for the three phase to ground fault following results shows that terminal voltages are less oscillated and stabilized faster with the Fuzzy based SVC controller. The power has less oscillations as compare to conventional SVC controller.

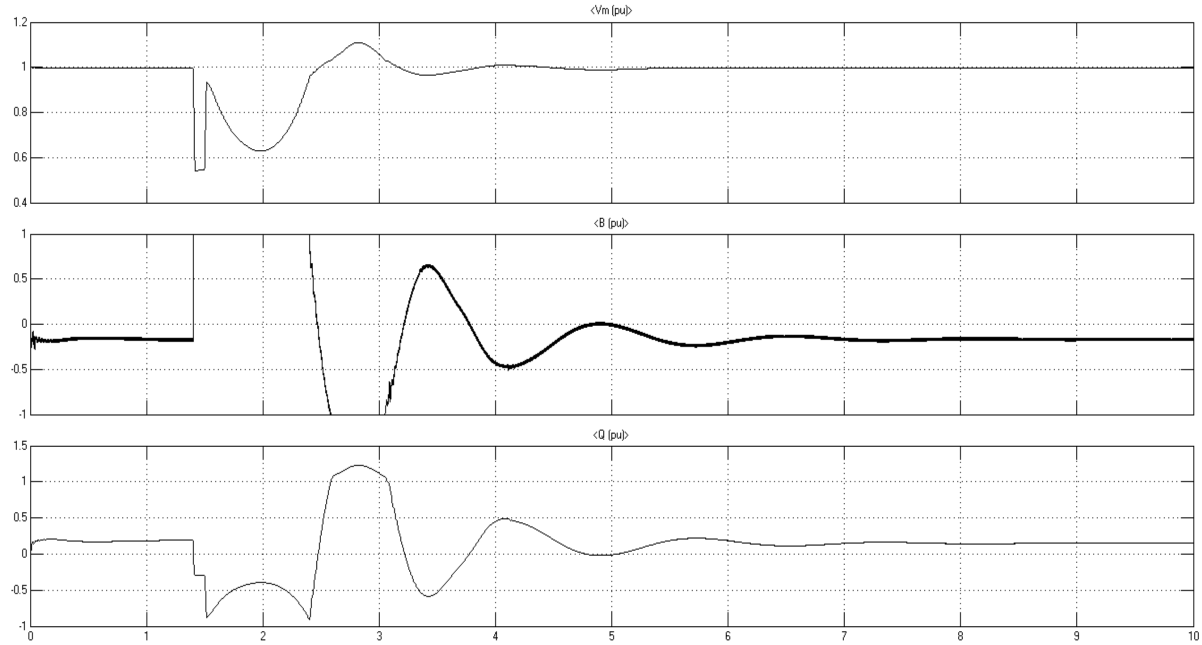

Fig. 9 Reactive power and voltage with three phase fault with fuzzy controlled SVC

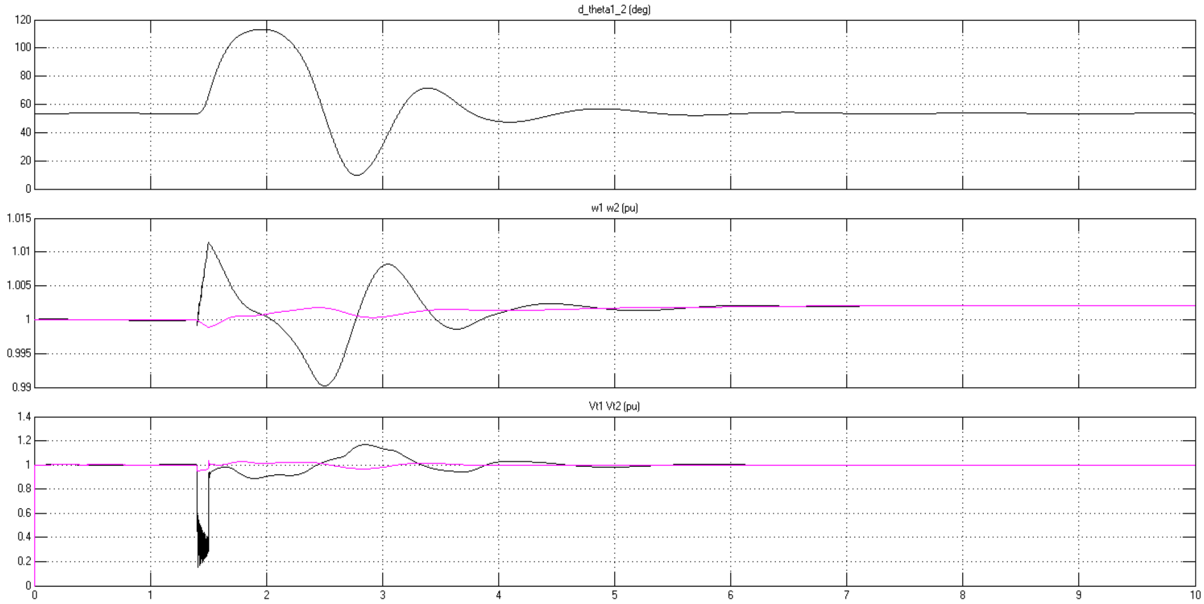

Fig. 10 Machine Signals with three phase fault with fuzzy controlled SVC

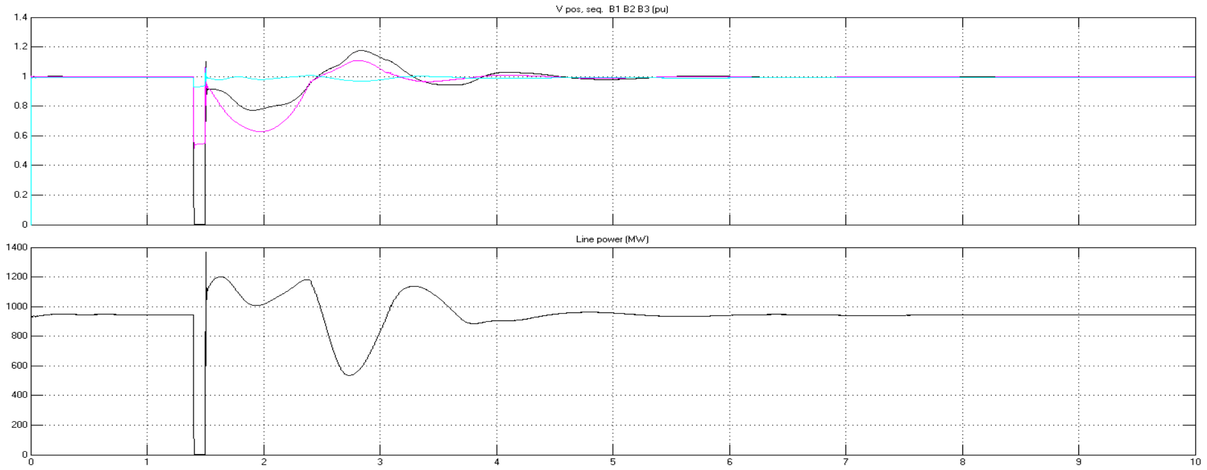

Fig. 11 P-V measurement with three phase fault with fuzzy controlled SVC

TABLE II COMPARISON BETWEEN PI BASED AND FLC BASED SVC

Parameter	Vt1	Vt2	D_theta	Line Power
PI	7.4 sec	4.9 sec	7.3 sec	7.3 sec
FLC	6.2 sec	3.7 sec	6.2 sec	6.0 sec

V. CONCLUSION

In this paper, an application of Fuzzy Logic Controller (FLC) to determine the control signal of SVC for reactive power compensation of the Multi-machine power system is presented. The performance of the proposed fuzzy logic controller for SVC was analyzed for a three phase fault in 2-machines 3-bus system. Various parameters like rotor angle deviation, terminal voltage of buses and transmission line active power are observed. The results obtained are compared with that of conventional PI controller and it is proved that the Fuzzy controlled SVC gives better results than SVC with conventional PI controller.

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