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DESING OF FUZZY LOGIC CONTROLLED SVC FOR LONG TRANSMISSION LINE

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ABSTRACT: The Flexible AC Transmission System (FACTS) is used to improve the exiting transmission capabilities of transmission system by making it more flexible & independent operating. Static VAR Compensator (SVC) is a shunt connected FACTs device, used for voltage control and for reactive power compensation. An efficient Fuzzy Logic Controller is used to improve the transient stability of the Power System, to improve the controllability of a SVC and it also complements the voltage control function and provides better performance in damping the power system oscillations. Effectiveness of this kind of proposed technique is demonstrated by simulation studies on long transmission line.

I. INTRODUCTION

Due to the vast increase in the demand of electric power, the industry supplying electricity undergoes a profound transformation worldwide. To meet this increasing demand, there is need of improving the transmission system. This can be done by increasing the transmitted power either by installing new transmission lines or by improving the existing transmission lines by adding new devices. By installation of these new transmission lines in power system will lead to the technological complexities such as economic and environment considerations that includes cost, delay in construction and so on. Now for overcoming these problems, Flexible Alternating Current Transmission System (FACTS) gave up new ways for controlling the power flow and increasing the usable capacity of transmission lines. FACTS are systems that comprised of static equipment that are used for the AC transmission of electrical energy. There are wide varieties of FACTS devices like as shunt type, series type, combined shunt-series type & combined series-shunt type. Among the various FACTS devices, the Static Var Compensator (SVC), a shunt connected controller that provides more reliable operation damping the power oscillations, improves the transient stability, helps in voltage regulation & reactive power control and improves the power factor in distribution system. FACTS devices play an important role in reactive power flow in the power network. In large power systems low frequency electro-mechanical The Static Var Compensator (SVC) is the one most widely used shunt type FACTS devices in power system regulation, which is based on power electronics. It can be ideally inserted in the middle of a line. Its main objective is to increase the power that transits in the existing line oscillations often follow the electrical disturbances. To achieve damping, a shunt FACTS device - "Static Var Compensator (SVC)" is designed with auxiliary controllers. As PSS been applied to damp local oscillation modes, Static VAR Compensator (SVC) which is one of the FACTS devices, has been used as a supplementary controller to improve transient stability and power oscillation damping of the system. Most of these controllers are designed based on conventional method i.e, designed based on the linearized model for the sake of simplicity. However, conventional controller cannot provide satisfactory performance over a wide range of operation points and under large disturbances since power system is a non-linear system. Recently, fuzzy logic controller (FLC) draws quite an attraction for researchers to design an effective control theory in enhancing power system stability due to its easiness in design also capability of tolerating uncertainty and imprecision in system parameters and operation condition changes. This paper discussed one of the methods in SVC implementation based on a simple fuzzy logic combined with the conventional proportional-integral (PI) controller. The fuzzy-based SVC (F-SVC) controller combining both advantages of FLC and the existing PI controller so that it can give better performance in damping inter-area oscillation as well as other parameters such as terminal voltage and transmission line active power. The FSVC controller is been tested in a 2-machines 3-bus power system. Simulation is done in MATLAB/Simulink to perform its effectiveness in damping oscillation after being subjected to a three phase fault at Bus 1 for 0.1 second. Performance of the system implemented with the F-SVC controller is compared with the system implemented with the conventional SVC.

II. STATIC VAR COMPENSATOR (SVC)

A. Introduction

The Static Var Compensator (SVC) is the one most widely used shunt type FACTS devices in power system regulation, which is based on power electronics. It can be ideally inserted in the middle of a line. Its main objective is to increase the power that transits in the existing line.

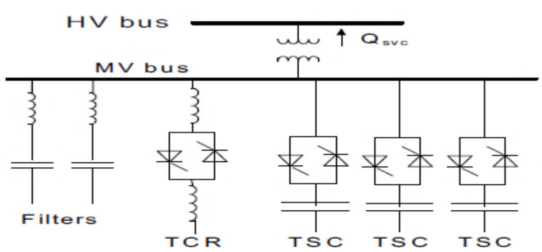

Fig. 1: Configuration of SVC

Typically, the SVC comprises one or more banks of fixed or switched shunt capacitors or reactors, of which at least one bank is switched by thyristors. Mechanically switched banks can be included on both side of SVC transformer to increase the total reactive power support outside the dynamic range.

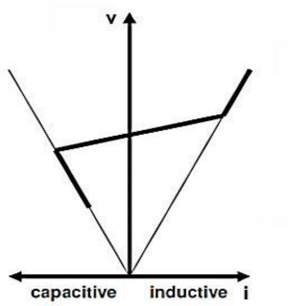

Fig. 2: V-I Characteristic of SVC

Here, when system voltage is low the SVC will generate reactive power (SVC capacitive). When system voltage is high, it will absorb reactive power (SVC inductive). 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.

B. Configuration Control Scheme

Figure 3 shows the basic architecture of SVC Control Scheme. This kind of model can be used in three phase power systems together with synchronous generators, motors, and dynamic loads to perform transient stability studies and observe the impact on SVC in electromechanical oscillations and transmission capacity.

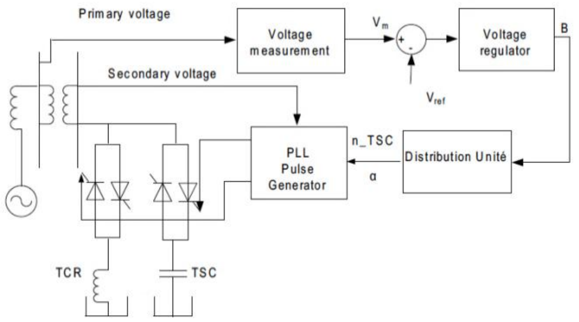

Fig. 3: Configuration of SVC Control Scheme

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.

III. FUZZY LOGIC CONTROLLER (FLC)

The Fuzzy Logic is a rule based controller, where a set of rules represents a control decision mechanism to correct the effect of certain causes coming from power system. This approach utilizes qualitative knowledge of a system while designing the controller. The block diagram structure of Fuzzy controller is shown in Figure 4.

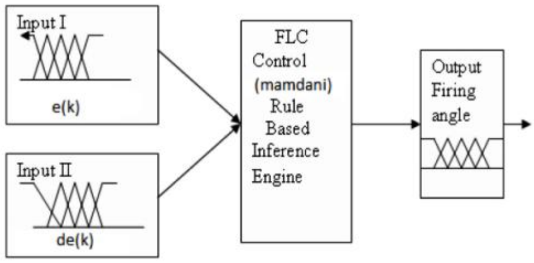

Fig. 4: Structure of Fuzzy Logic Controller

There, Fuzzy Logic Controller has three stages and they are as follows;

A. Fuzzyfication:

To calculate fuzzy input (i.e. to evaluate the input variables with respect to corresponding linguistic terms in the condition side). The Fuzzification process is concerned with finding a fuzzy representation of non-fuzzy input values where it is achieved through application of the MF (Membership Function) associated with each fuzzy set in the rule input space. Fuzzification is the input stage that allows converting the variables of the real domain into a fuzzy domain. Here, the real world measurements (crisp values) are fuzzified as described below to obtain the membership grades.Here, a fuzzy set is a collection of distinct elements with a varying degree of inclusion or relevance. If X is a set of elements, then a fuzzy set A in X defined to be a set of ordered pairs,

$$A = \{(x, \mu A\,(x)\ / x \in X\}$$

B. Rule Based Inference Engine:

To calculate fuzzy output (i.e. to evaluate the activation strength of every rule base and combine action sides). As per its name, Rule Based Inference Engine contains two contents, they are as follows;

C. Rule Based System:

In the fuzzy model, the relationship between the input and output features are represented by IF premise THEN consequent .A rule base consisting if-then rules is developed based on then system understanding with several runs of simulation. The fact that every rule must have a real meaning is also considered for the rule base development. The fuzzy rules can be generated and framed with the help of an expert operator’s experience and knowledge.

Here,

Rule 1: IF voltage error, *e(k)* is *low* AND change of error *de(k)* is *ok,* THEN the output (Susceptance) is *low.*

Rule 2: IF voltage error, *e(k)* is *ok* AND change of error *de(k)* is *ok*, THEN the output (Susceptance) is *ok*.

Thus, two inputs and single output of Fuzzy Logic Controller will result in a total of 9 rules, which are listed in Table 1 given below;

e[k]	ė[k]Δuf[k]		
	Low	Ok	High
Low	Low	Low	Ok
Ok	Low	Ok	High
High	Ok	High	High

Table 1: Rule Base of Fuzzy Controller

D. Inference Mechanism:
In inference mechanism, the task of the inferencing process is to map the fuzzified inputs (received from the fuzzification process) to the rule base, and to produce a fuzzified output of each rule. For Fuzzy based SVC, the fuzzy inference of prod-probor is used. The prod-probor inference method is similar to AND-OR logical operation.

E. Defuzzification
In many situations, for a system whose output is fuzzy, it is clear to take a crisp decision if the output is represented as a single scalar quantity. This conversion of fuzzy set to single crisp set value is called defuzzification and it is the reverse process of fuzzificzion. Here, Centroid Method is used in the defuzzification method.
Also known as the centre of gravity or the centre of are method, it obtains the centre of area (u*) occupied by the fuzzy set. It is given by the following expression,

$$u^* = \frac{\sum_{i=1}^{5} bi \int \mu i}{\sum_{i=1}^{5} \int \mu i}$$

Where, bi denotes the centre of the membership function and μi is the membership of member i of fuzzy set.

IV. TEST SYSTEM

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 Figure 5.

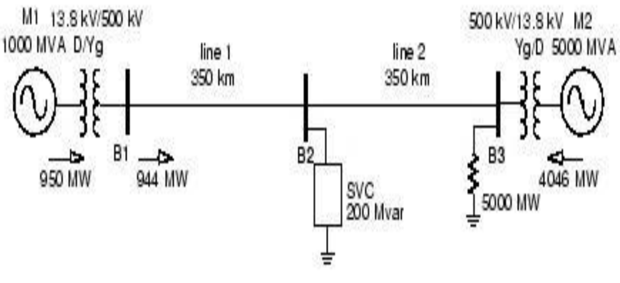

Fig. 5: 2 Machine 3 Bus System

A. SVC with the Combination of PI and Fuzzy Logic Controller (FLC)
Here, the proposed new controller of SVC consists the combination of PI and Fuzzy Logic Controller

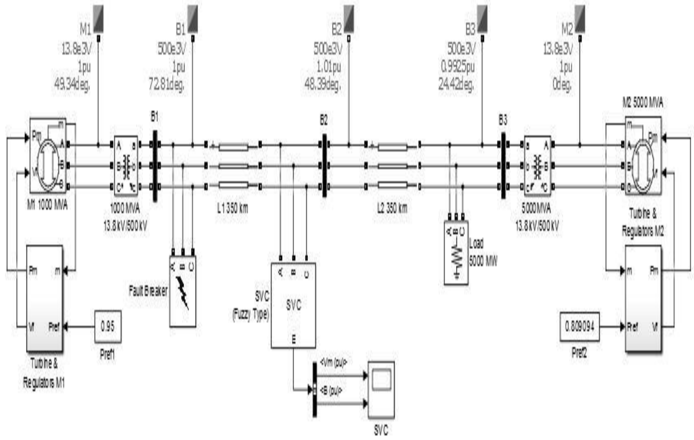

Fig. 6: 2 Machine 3 Bus System modelled in Simulink/MATLAB

B. Voltage Regulator in the proposed new SVC Controller

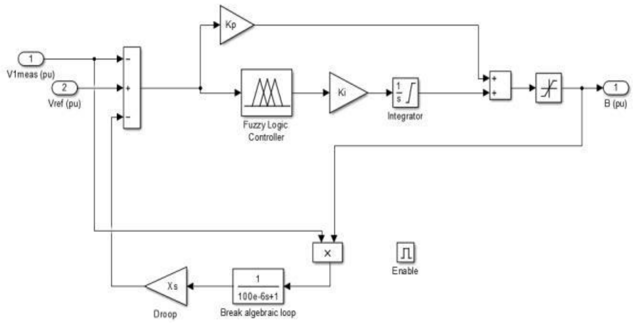

Fig. 7: Fuzzy Logic Controller modelled in Simulink/MATLAB

V. SIMULATION RESULTS

The performance of the F-SVC controller in power system oscillation damping after subjected to a disturbance was examined on a 2-machines 3-bus power system. Figure 6 shows the modelled system in Simulink/MATLAB. A single phase to ground fault occurred at Bus 1 for 0.1 second from t1=5s to t2=5.1s. The effectiveness of the F-SVC controller is been observed in comparison with the system implemented with the conventional SVC controller. Figure 7 shows the F-SVC modelled in Simulink/MATLAB. After the fault occurred, the SVC will try to support the voltage by injecting reactive power on the line when the voltage is lower than the reference voltage (1.009 pu). Figure 8 shows the rotor angle difference of Generator, G1 of the test system. For a single to phase to ground created t1= 5 second, both the generators quickly falls out of synchronism. On analysing the simulation results, the rotor angle difference is stabilized faster with SVC with Fuzzy Logic Controller at t= 9.85 second which is 4.75 second fault clearance compared to t= 13.04 second which is 7.94 second after fault clearance with SVC with PI Controller.

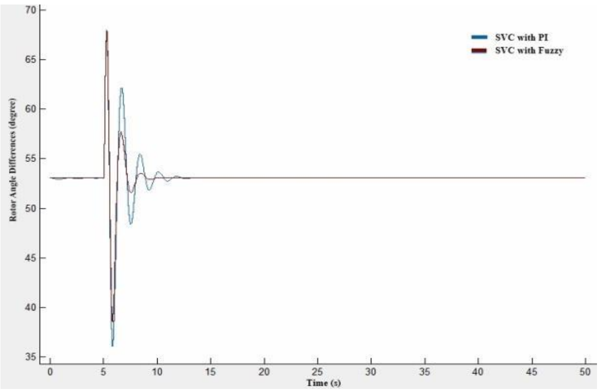

Fig. 8: Rotor Angle Differences of the System

In the Figure 9, the speed of Generator, G1 is synchronized faster at t= 9.12 second with SVC with Fuzzy Logic Controller as compared to t= 11.5 second with SVC with PI Controller. In addition of the oscillation of G1 speed is lessens.

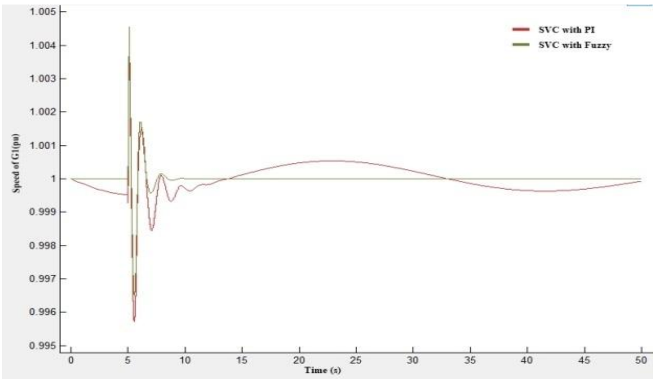

Figure 9: Speed of Generator 1 (G1) of the System

As fault occurred between Bus 1 and Bus 2, and also as seen given in the Figure 10, we can say that terminal voltage $Vt_1$is also affected. Here, $Vt_1$is less oscillated and stabilized faster with the SVC with Fuzzy Logic Controller used in the system.

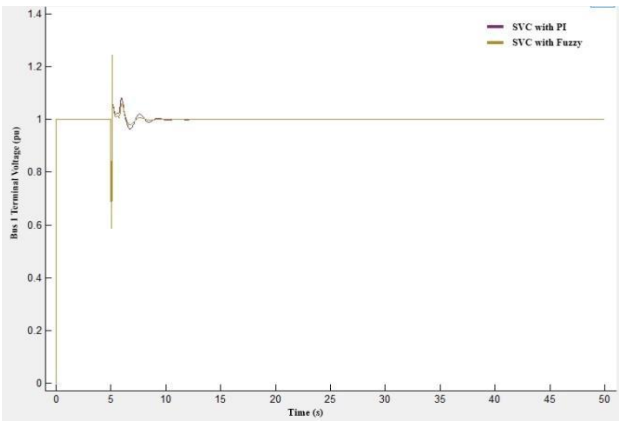

Fig. 10: Bus 1 Terminal Voltage of the System

From the Figure 11, it is known that the line active power is less oscillated and stabilized faster at t= 8.53 second after subjected to disturbance with SVC with Fuzzy Logic Controller implemented in the system compared to SVC with PI Controller where the oscillation of the line active power is stabilized at t= 11.13 second.

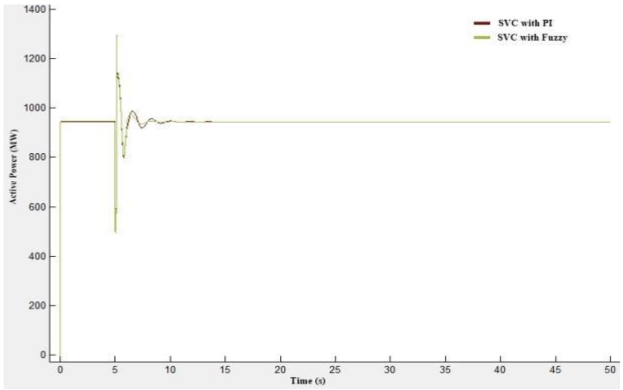

Fig. 11: Transmission Line Active Power

The simulation results shown above clearly highlights the improved performance of the newly designed controller in terms of reduced angular oscillations, regulating the terminal voltage, synchronizing the speed compared to the PI controller used in conventional SVC.

VI. CONCLUSION

A Fuzzy controller combined with a PI controller for SVCmechanism is discussed in this paper. The idea is to combine the advantages of both the controllers to derive a betterperformance out of SVC. Mamdani based Fuzzy logic is employed in the proposed model and the design is tested in a 2machine 3 bus power system. The simulation is done using MATLAB software. The simulation studies are carried out on various parameters like rotor angle difference, machine speed, terminal voltage and transmission line active power. The controller performance of both types are also compared in above areas and it is observed that the combined PI and Fuzzy based SVC controller gives enhanced performance in terms of stability and reliability of the system during the disturbances.

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