

Static Var Compensator: Effect of Fuzzy Controller and Changing Membership Functions in its operation

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Abstract

The basic limitations of a classic ac power transmission, which have lead to the under utilization of transmission lines and the other assets, and the potential of mitigating these limitations cost effectively by controlled compensation, provided the early incentives to introduce power electronics based control for reactive compensation. Flexible AC Transmission System Controllers was the result of these incentives. The Static Var Compensator is one such device that serves the function of power flow control, and improves the voltage profile of transmission systems. This paper investigates the operation of an Static Var Compensator model in the operation of a generation system. It compares the response of the generating station to a Static Var Compensator with conventional voltage regulator unit along with a fuzzy based voltage regulator for Static Var Compensator. The paper investigates the effect of fuzzy based Static Var Compensator in the power system operation and also the effect of membership function in the operation of fuzzy controller in Static Var Compensator operation.

MATLAB/Simulink based simulation is utilized to demonstrate the application of fuzzy controller based Static Var Compensator for voltage regulation and their contribution in enhancing the performance of power systems. The results confirmed that the fuzzy based Static Var Compensator can add considerable improvement in the voltage profile of the system with minimum overshoots. The results also depicted the changing effects of triangular, trapezoidal, Gaussian and bell shaped membership functions in the operation of fuzzy controller.

Keywords: FACTS controller, Static Var compensator, Fuzzy controller, Membership function

1. Introduction

An electric power network integrates generation and load centers within each utility system and, through interconnection among neighboring systems, share power with vast regional grids. The purpose of interconnection of utilities is to take advantage of the diversity of loads in vast areas, changes in peak demand due to weather and time differences, the availability of different generation reserves in various geographic regions, power sharing arrangements among utilities, shifts in fuel prices, regulatory charges and other discrepancies[1].

One of the major criteria, deciding the power system operation is its stability. Stability of the power system is the ability to maintain the machines connected to the system in synchronism. But disturbances always occur either due to the sudden addition or removal of load, short circuit of lines, lightning etc[2]. Advancements in semi-conductor electronics have helped in the development of new control technologies for stability enhancement, which includes the use of FACTS controllers.

FACTS controllers[3] are high power electronic controllers, which can be applied individually or collectively in power system, to control the line parameters like series and shunt impedances effectively. For economical and environmental reasons, the growth of the power system in future will rely on increasing the capability of existing transmission systems, rather than building new transmission lines and power stations. This gives rise to the requirements of the new power flow controllers, which are capable of increasing the transmission capability. FACTS devices enhance the stability of the power system with its fast control characteristics and continuous compensating capability. The control of power flow and increase in the transmission capacity of the existing transmission lines are the two main objectives of FACTS technology[6]. These objectives help in the optimal utilization of the existing power system and increase the controllability of the power system. Static Var Compensator is one such FACTS device, capable of improving the dynamic control of real and reactive power flow.

2. Static Var Compensator

With the increasing necessity to utilise the existing transmission systems, to the fullest extent, several electronically controlled, extremely fast reactive compensators and power flow controllers have been developed, with the overall framework of FACTS [4] initiative. These compensators and controllers made use of conventional reactive components and tap changing transformer arrangements with thyristor valves and control electronics initially. With advancements in technology, these controllers have started employing switching power converters as synchronous voltage sources, which can internally generate reactive power for, and also exchange real power with, the ac system. Static Var Compensator (SVC) [5] is a member of this category, which helps in improving the transient stability of power grids. SVC is a shunt device that helps in regulating the voltage at its terminals by controlling the reactive power either injected to or absorbed from the power system network. SVC becomes capacitive for low system voltages and inductive for high system voltages. The reactive power is varied by switching operations of capacitor or inductor banks. The basic configuration of

SVC control is as shown in Figure 1.

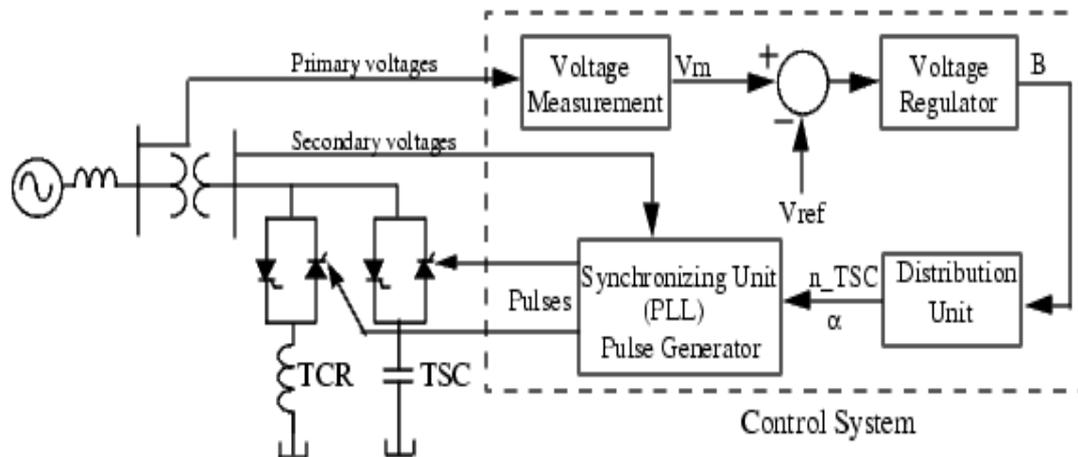


Fig.1: Basic configuration of SVC Control Scheme

The voltage regulator unit uses the voltage error to determine the SVC susceptance that is required to keep the system voltage constant. In this paper, the conventional PI regulator in the voltage regulator unit of SVC control is replaced with fuzzy based controller and the effect of this intelligent controller in the performance of SVC connected to a power system network are analysed.

3. Fuzzy Logic Controllers

Fuzzy control has tremendous potential in various control applications. Over the past few years, many control equipments were built using fuzzy control. Fuzzy systems are nothing but knowledge-based or rule-based systems. The general input to the Fuzzy controller is the error signal and the rate of error signal. The rate of error signal is the difference between the variation of error at current sampling and its previous sampling[7].

The heart of the fuzzy system is a knowledge base, consisting of the so called fuzzy IF-THEN rules. These rules are defined by taking help from expert's experience and knowledge about the system behavior. The performance of the system is improved by the correct combinations of these rules. The Fuzzy Logic Controller (FLC)[8] consists of three stages: the fuzzification, rule execution, and defuzzification. The basic operation of FLC is as shown in Figure 2.

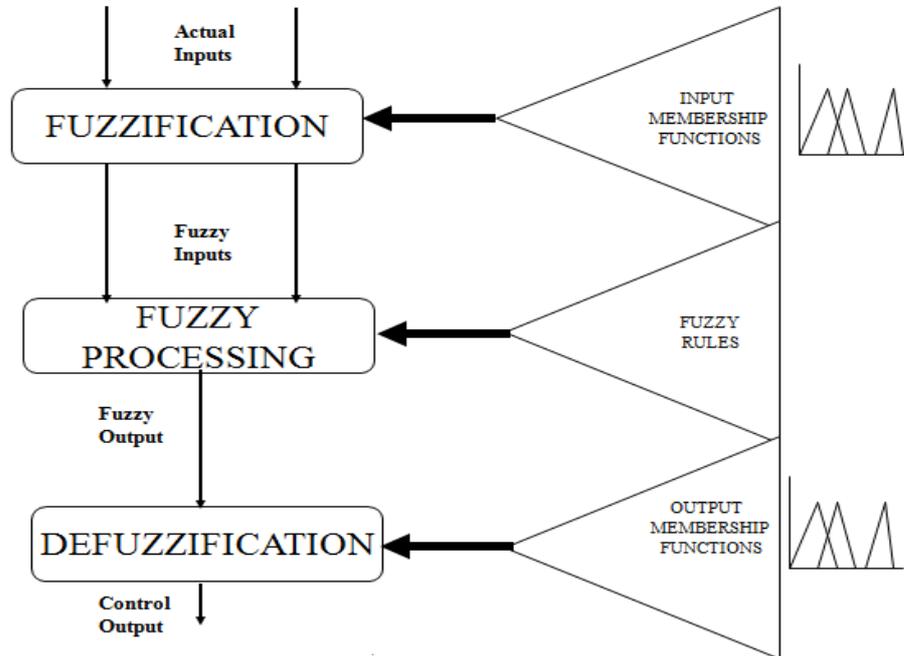


Fig. 2:Operation of FLC

In the first stage, the crisp variables are converted into fuzzy variables using the membership functions[9] as shown in Figure 3. The signals error and error rate are described as linguistic variables in the FLC such as large negative (LN), medium negative (MN), small negative (SN), very small (VS), small positive (SP), medium positive (MP) and large positive (LP).

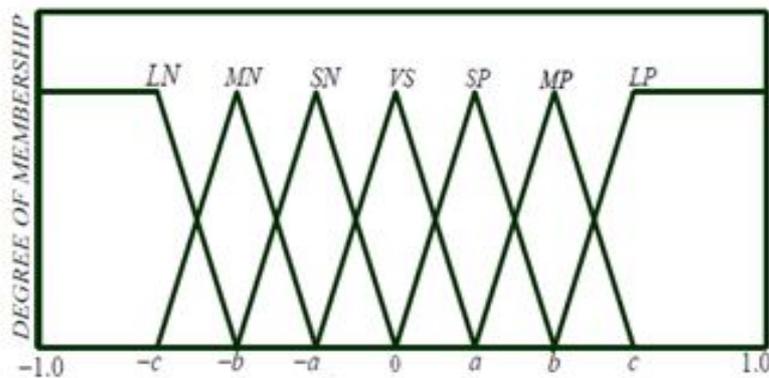


Fig.3:Membership function in an FLC

The membership functions determines the extent or the to which an element belongs to a fuzzy set. The most commonly used membership functions include piecewise linear (Triangular & Trapezoidal), Guassian, GBell shaped, Quadratic, Cubic and some special membership functions. Piecewise linear, Gaussian and GBell shaped

functions are more popular with the fuzzy logic theory, the reason being the simplicity of function, allowing for the prediction and calculation of an output of the fuzzy system[10].

4. System under Study

A power generation station along with an SVC connected to infinite bus and one load are taken as the system of study. A three-phase variable voltage source is taken and the response of SVC to the variations in voltage is studied. The operation of the generating station with SVC with conventional voltage regulator unit is studied, and compared with the performance of SVC with Fuzzy Based voltage regulator. The fuzzy controller designed for the voltage regulator unit of SVC is also further modified with four different membership functions of Trapezoidal, Triangular, Gaussian and GBell shaped. The effect of changing membership functions on the operation of fuzzy controller is also analysed.

5. Simulation Results

The system under study is simulated using SVC with conventional voltage regulator and fuzzy based regulator in MATLAB/Simulink. The simulation results of the system under study with conventional voltage regulator for SVC are as shown in Figure 4. The SVC with fuzzy based voltage regulator is simulated and the responses for various membership functions of Fuzzy Controller are depicted in Figures 5, 6, 7 & 8.

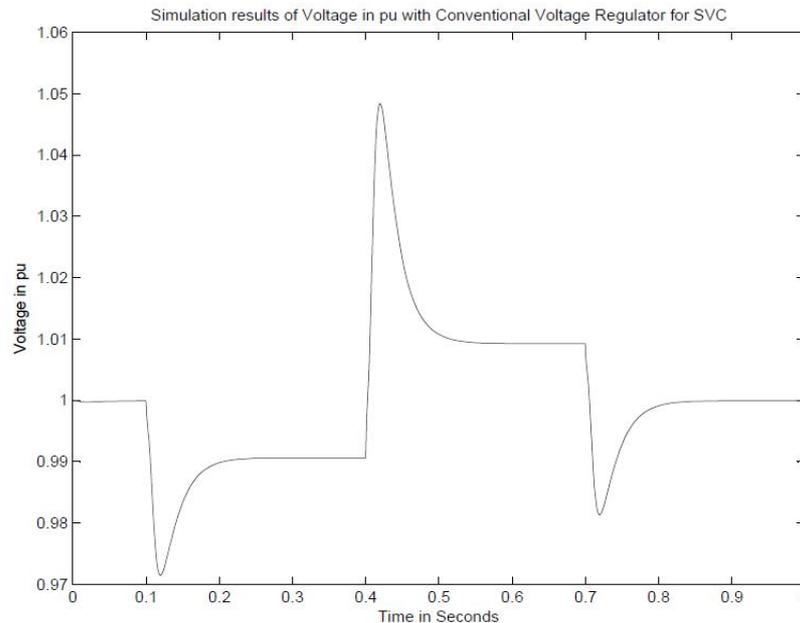


Fig. 4:Simulation results of Voltage in pu with Conventional Voltage Regulator for SVC

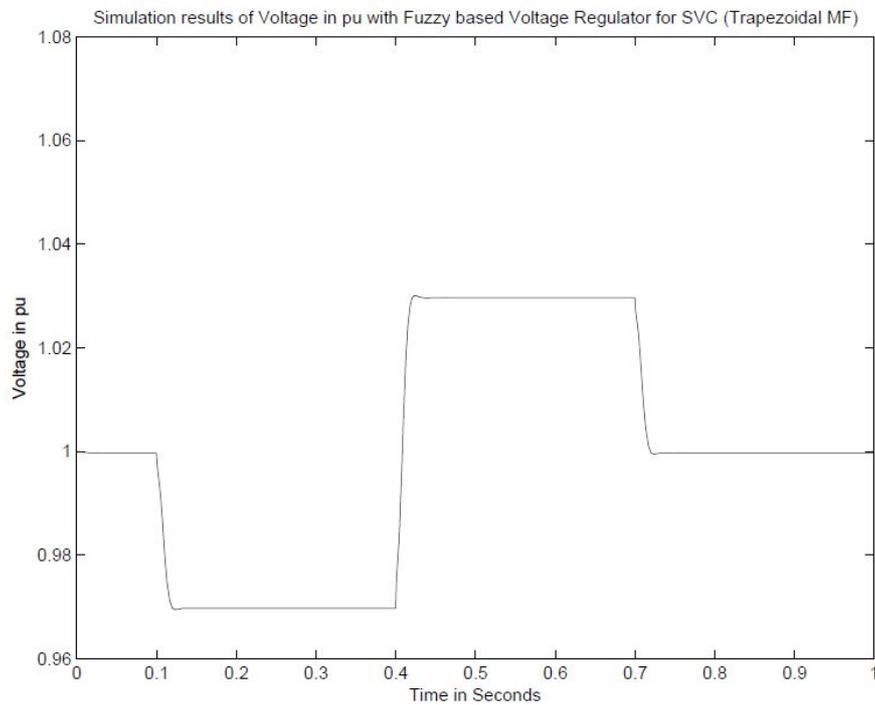


Fig.5: Simulation results of Voltage in pu with Fuzzy based Voltage Regulator for SVC (Trapezoidal MF)

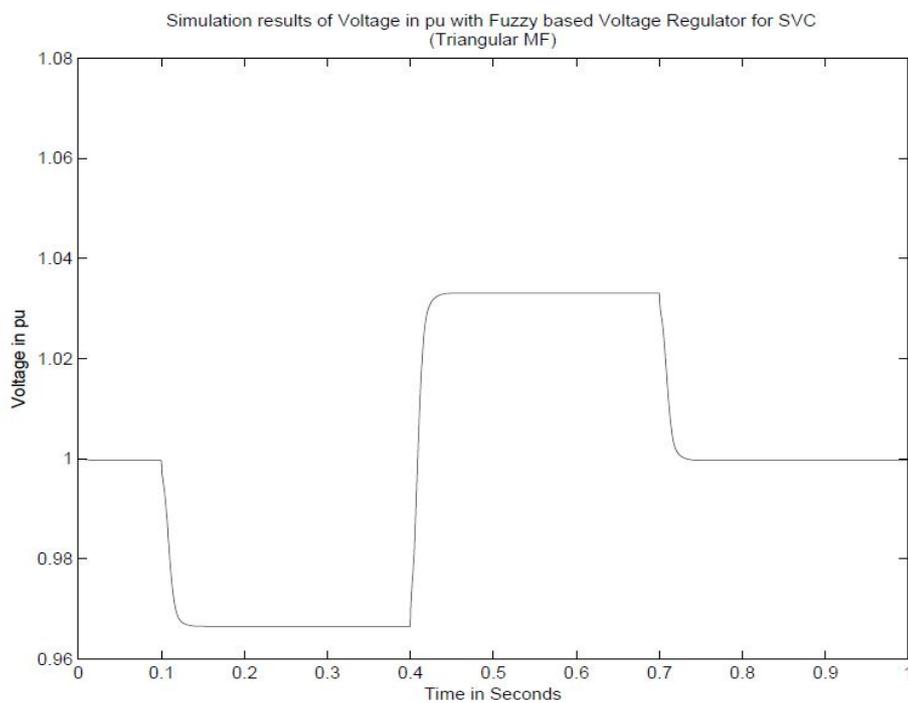


Fig.6: Simulation results of Voltage in pu with Fuzzy based Voltage Regulator for SVC (Triangular MF)

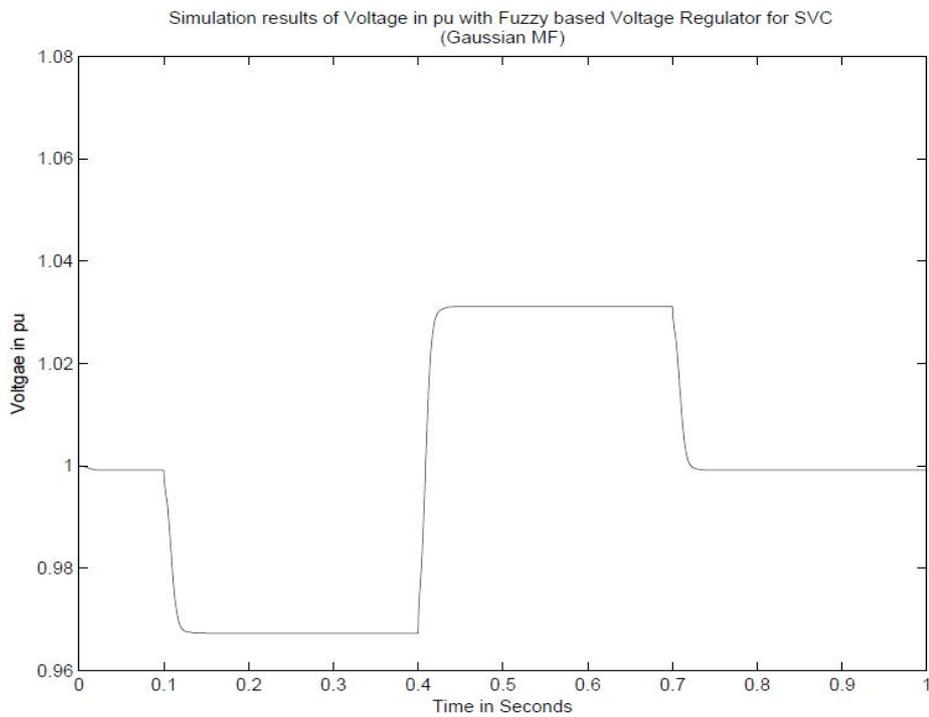


Fig.7: Simulation results of Voltage in pu with Fuzzy based Voltage Regulator for SVC (Gaussian MF)

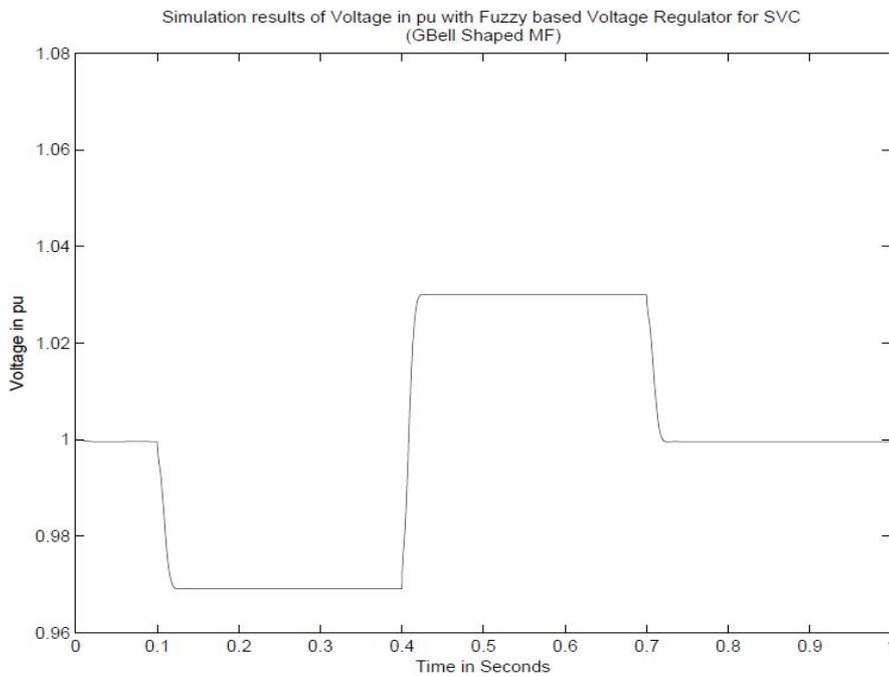


Fig.8: Simulation results of Voltage in pu with Fuzzy based Voltage Regulator for SVC (GBell Shaped MF)

Conclusions

To overcome the limitations of conventional PI based voltage regulators in conventional SVC, they are replaced with fuzzy controllers in this work. The conventional strategies are compared with fuzzy inference system counterparts, in terms of accuracy, simplicity, robustness and speed dynamics. The new control strategies, take advantages of its positive attributes to enhance the response of SVC.

The proposed fuzzy controller for SVC improves their performance, reducing the overshoots and settling times in power oscillations, when compared to the conventional designs, during the system operation with continuously varying voltage source. The comparison of the simulations results also infers that the GBell membership functions for the input and output variables in the fuzzy controller of SVC, further enhances its ability to damp out power oscillations, when compared to trapezoidal, triangular and gaussian membership function.

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