IJournals International Journal of Software & Hardware Research in Engineering
ISSN No: 2347-4890 Volume 2 Issue 12, December-

Voltage Profile Improvement of Transmission Lines using ANFIS Based Static VAR Compensator

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ABSTRACT
In this paper we investigate the effect of SVC with ANFIS system to the improvement of voltage profile of transmission lines. Now days we see that the technology has advanced day by day, this requires precise and regulated electricity requirement continuously. Hence we need a device which can control the random fluctuations comes in the transmission line due to fault or other abnormal condition in the system and also clear efficiently the high transients occurs after the clearing the fault which affects the performance of the connected applications. SVC is a power electronics based FACTS device used to enhance the transmission capability near thermal limit without affecting the stability. But the situations in transmission systems are very much vague or imprecise; it is not possible to handle it properly with the help of simple SVC. So for in this paper proposed a novel technique called ANFIS (Adaptive Neuro Fuzzy Inference System) system with Static VAR Compensator to handle this uncertain situation. The conventional PI controller and droop gain block in SVC voltage regulator is replaced by ANFIS based voltage regulator. This system is implemented in MATLAB Simulink Software. The ANFIS system increased the performance characteristics of static VAR compensator and has very less overshoot, very small settling time, wide range of control and effective voltage regulation.

Keywords:
Static-VAR Compensator (SVC), ANFIS, Voltage Stability, MATLAB Simulink.

1. INTRODUCTION
Static VAR Compensators can be very effective in controlling voltage fluctuations at rapidly varying loads. Unfortunately, the price for such flexibility is high. Nevertheless, they are often the only cost-effective solution for many loads located in remote areas where the power system is weak [2]. In the present scenario the demand for electrical energy has very much intense. This has led to the facing of power transmission limitation crisis by energy transmission systems. The limitations occur due to maintaining a balance between supplying the allowed level of voltage and maintaining stability of the system. Voltage stability is severe problem, which steadily reach operating limits imposed by economic and environment conditions. Whenever there is change in load or fault the system voltage level changes. With the drop in voltage level, the reactive power demand increases. If the reactive powers demand is not met, then it leads to furtherer decline in bus voltage resulting in the cascading effect on neighboring regions.

Hence there is a requirement of devices which can control the random fluctuations comes in the transmission line voltage during transmission. It is necessary that system has very less overshoot and very less settling time for retain of voltage in steady level. The shunt connected, fixed or mechanically switched reactors are applied to minimize the line overvoltage under light load condition, and shunt connected, fixed or mechanically switched capacitors are applied to maintain voltage levels under the heavy load conditions [1]. Flexible AC Transmission Systems (FACTS) devices with a suitable control strategy have the potential to increase the system stability margin [2, 3]. Shunt FACTS devices play an important role in reactive power flow in the power network. In large power systems, low frequency electro-mechanical oscillations often follow the electrical disturbances. Generally, power system stabilizers (PSS) are used in conjunction with Automatic Voltage Regulators (AVR) to damp out the oscillations [3]. However, during some operating conditions this device may not produce adequate damping and other effective alterations are needed in addition to PSS [11].

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Another means to achieve damping is to use the same shunt FACTS device Static VAR Compensator (SVC) designed with auxiliary controllers [6]. Therefore SVC is more effective and if accommodated with supplementary controller, by adjusting the equivalent shunt capacitance, SVC will damp out the oscillations and improves the overall system stability [7]. The system operating conditions change considerably during disturbances. Various approaches are available for designing auxiliary controllers in SVC. In [8] a proportional integral derivative (PID) was used in SVC. It was found that significant improvements in system damping can be achieved by the PID based SVC. Although PID controllers are simple and easy to design, their performances deteriorate when the system operating conditions vary widely and large disturbances occur. ANFIS approach is an emerging tool for solving complex problems whose system behavior is complex in nature. An attractive feature of ANFIS is its robustness in system parameters and operating conditions changes [9, 10]. ANFIS controllers are capable of tolerating uncertainty and imprecision to a greater extent [11]. This paper deals with a method based on ANFIS controller for SVC controller which damp out the oscillations at a faster rate and reduce the settling time so as to efficiently operation of connected applications are done.

2. MODELING AND CONTROL OF SVC

The Static VAR Compensator is basically a shunt connected variable VAR generator whose output is adjusted to exchange capacitive or inductive current to the system. One of the most widely used configurations of the SVC is the FC- TCR type in which a Fixed Capacitor (FC) is connected in parallel with Thyristor Controlled Reactor (TCR). The magnitude of the SVC is inductive admittance $B_L(\alpha)$ is a function of the firing angle α and is given by:

$$B_{TCR}(\alpha) = B_L\left(\frac{2\pi-2\alpha-\sin 2\alpha}{\pi\, X(S)}\right) \quad ...1$$

$$\text{For } \frac{\pi}{2} \le \alpha \le \pi$$

Where, $Xs = \frac{V_s^2}{Q_L}$ and V_s = SVC bus bar voltage

Q_L = MVA rating of reactor. As the SVC uses a fixed capacitor and variable reactor combination (TCR-FC). The effective shunt admittance is:

$$B_s = \frac{1}{X_c} - B_L(\alpha) \quad ...2$$

Where $X_{c(S)}$ = capacitive reactance

A rapidly operating Static VAR Compensator (SVC) can regularly provide the reactive power necessary to control dynamic voltage swings under different system conditions and thereby improve the power system transmission and distribution performance. Installing an SVC at one or more appropriate points in the network will enhance transfer capability through improved voltage stability, while maintaining a smooth voltage profile under different network conditions. In addition, an SVC can diminish active power oscillations through voltage amplitude modulation [3].

3. METHODOLOGY

The Static VAR Compensator is basically a shunt connected variable VAR generator whose output is adjusted to exchange capacitive or inductive current to the system. In this paper, the suggested ANFIS controller uses Sugeno-type Fuzzy Inference System (FIS) controller, with the parameters inside the FIS determined by the neural-network back propagation technique. The ANFIS controller is determined by taking difference of two voltages as a input for controller and firing angle α as the function of Bsvc as a output. The output stabilizing signal, i.e., is calculated utilizing the fuzzy membership functions depending on the input variables. The modeling and simulation of the SVC controller is done in the Simulink platform of MATLAB effectively.

3.1 Voltage Regulation of transmission lines using ANFIS based Static VAR compensator

The Static VAR Compensator (SVC) is a shunt device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids [1]. The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the SVC generates reactive power (SVC capacitive). When system voltage is high, it absorbs reactive power (SVC inductive). The variation of reactive power is performed by switching three-phase capacitor banks and inductor banks connected on the secondary side of a coupling transformer. Each

Capacitor bank is switched on and off by three thyristor switches (Thyristor Switched Capacitor or TSC). Reactors are either switched on-off (Thyristor Switched Reactor or TSR) or phase-controlled (Thyristor Controlled Reactor or TCR). Fig 1 shows a single-line diagram of a static VAR compensator control system. The control system consists of:

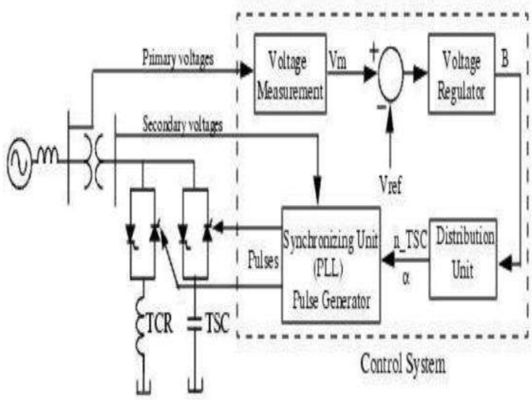

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Fig1: Single line Diagram of a Static VAR Compensator [3]

The model shown in fig 1 can be used in three-phase power systems together with synchronous generators, motors, and dynamic loads to perform transient stability studies and observe impact of the SVC on electromechanical oscillations and transmission capacity. The distribution unit computes the firing angle α so as to give a control signal to the TCR to conduct. The calculation of proper firing angle

$$B_{TCR} = \frac{2(\pi-\alpha)+\sin(2\alpha)}{\pi} \quad ...3$$

Where BTCR is the TCR susceptance in pu of rated TCR reactive power (109 Mvar).

But it is observe that in this conventional method gives the input voltage has large transients after clearing fault or abnormal condition and take more time to settle down to its final steady value. This may affect the performance characteristics of applications.

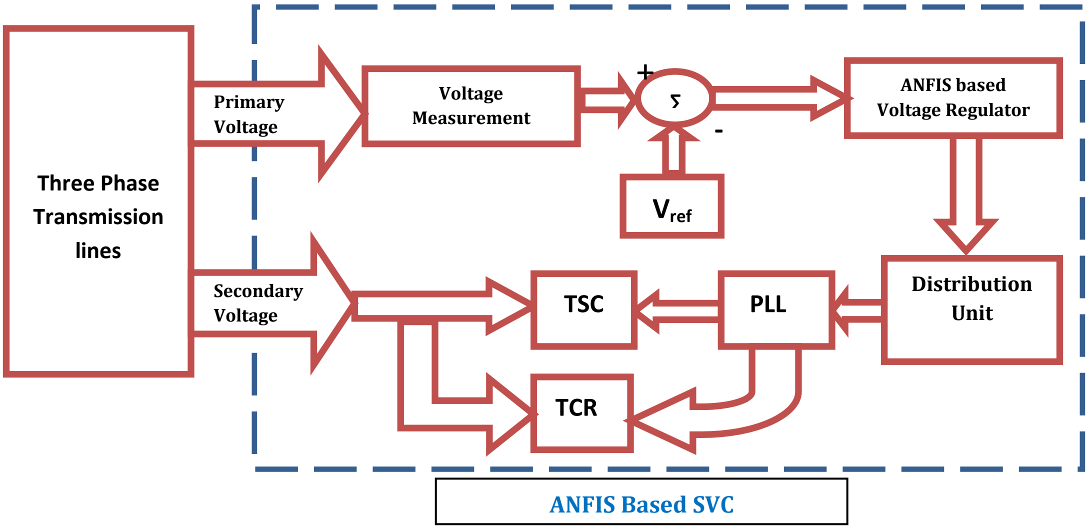

Fig2: Block diagram representation of Project work.

α depends on the Bsvc that would be calculating with the help of voltage regulator. So for the better control of input voltage it is necessary to regulate efficiently the voltage regulator. In this project work we use a novel technique called ANFIS system to control the voltage regulator. The methodology of the project work is shown in the fig 2 with the help of block diagram representation.

i. Measurement System measures the positive-sequence primary voltage. This system uses discrete Fourier computation technique to evaluate fundamental voltage over a one-cycle running average window. The voltage measurement unit is driven by a phase-locked loop (PLL) to take into account variations of system frequency.

ii. Conventional Voltage Regulator uses a PI controller to regulate primary voltage at the reference voltage (1.0 pu specified in the SVC Controller block menu). A voltage droop is incorporated in the voltage regulation to obtain a V-I characteristic with a slope (0.01 pu /100 MVA). Therefore, when the SVC operating point changes from fully capacitive (+300 Mvar) to fully inductive (-100 Mvar) the SVC voltage varies between 1-0.03=0.97 pu and 1+0.01=1.01 pu. The voltage regulator uses PI controller for calculation of TCR susceptance Bsvc and so for calculation of firing angle α to maintain input voltage constant.

So for in this project work we replace the conventional PI controller and droop gain block and introduce a novel technique called ANFIS (Adaptive Neuro Fuzzy Inference System) based voltage regulator block.

iii. The Distribution Unit uses the primary susceptance Bsvc computed by the voltage regulator to determine the TCR firing angle α and the status (on/off) of the three TSC branches. The firing angle α as a function of the TCR susceptance B_{TCR} is implemented by a look-up table.

iv. Firing Unit consists of three independent subsystems, one for each phase (AB, BC and CA). Each subsystem consists of a PLL synchronized on line-to-line secondary voltage and a pulse generator for each of the TCR and TSC branches. The pulse generator uses the firing angle α and the TSC status coming from the Distribution Unit to generate pulses. The firing of TSC branches can be synchronized (one pulse is sent at positive and negative thyristors at every cycle) or continuous. The synchronized firing mode is usually the preferred method because it reduces harmonics faster.

3.2. Development of ANFIS Based Voltage Regulator Block

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The normal voltage regulator block deals with the calculation of firing angle α with the help of look up table based on the equation

$$B_{TCR} = \frac{2(\pi-\alpha)+\sin(2\alpha)}{\pi} \qquad ...3$$

This method of calculation of firing angle lacking with the handling of imprecise fluctuations in line voltage and also could not able to provide the damping to the system. Hence not able to provide efficient voltage regulation. Hence for handling of such type imprecise situation ANFIS (Adaptive Neuro-Fuzzy Inference System) has been used. Figure 3 show the developed ANFIS based Voltage Regulator unit simulation diagram.

The calculation of the firing angle α for the voltage regulator block is based on the susceptance generated by the voltage regulator which controlled by ANFIS based system.

VOLTAGE PROFILE IMPROVEMENT USING ANFIS BASED STATIC VAR COMPENSATOR

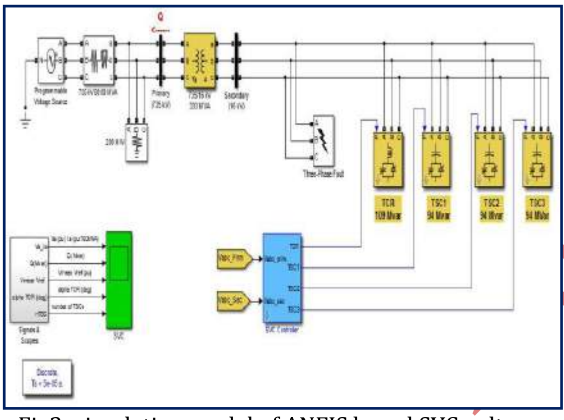

Fig3: simulation model of ANFIS based SVC voltage regulator

3.2.1 ANFIS Based Voltage Regulator Block

ANFIS based Voltage Regulator unit is based on the control mechanism of developed with the help if ANFIS based controller. Block diagram is shown figure 4. Figure 5 shows the member ship functions for single input and single output to handle imprecise situations. Also figure shows the layout and basic structure of developed ANFIS Structure. The rule base developed for ANFIS controller is as follows:

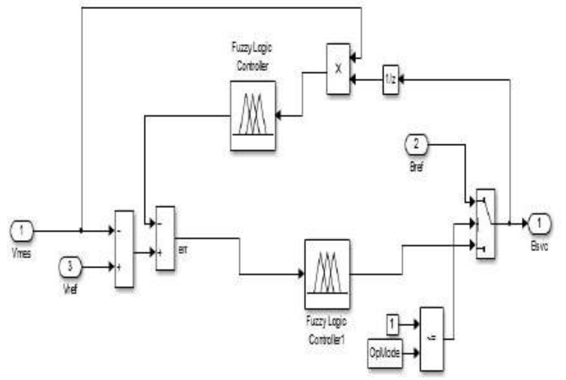

Fig4: ANFIS Based Voltage Regulator Block Diagram

1. If (input1 is in1mf1) then (output is out1mf1) (1)

2. If (input1 is in1mf2) then (output is out1mf2) (1)

3. If (input1 is in1mf3) then (output is out1mf3) (1)

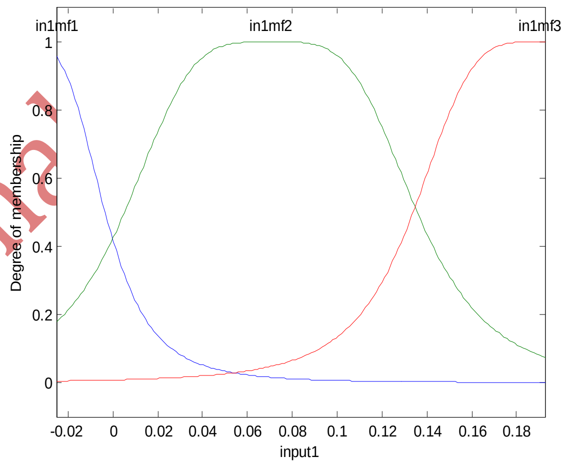

Fig 5: input membership function for developed ANFIS system

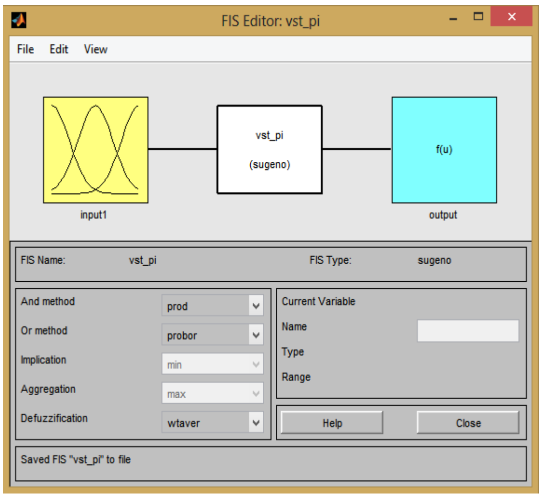

Fig 6: Basic layout of developed ANFIS

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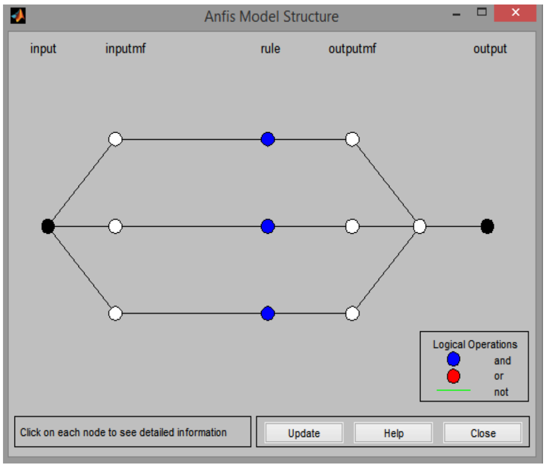

Fig7: Basic structure of developed ANFIS model

4. RESULTS AND DISCUSSIONS

The voltage profile improvement through the ANFIS based static VAR compensator has been successfully implemented in the Simulink. In this section shows the results obtained and steady state and dynamic performance analysis of results obtained and also theability to provide damping by the system so as to achieve the steady state value quickly. For the efficient Voltage regulation the reference voltage is taken as 1.0 pu. Waveforms of Figure (8) illustrates, SVC voltage regulator Dynamic Response to System Voltage variations.

instant. The SVC reacts by generating 256 Mvar of reactive power, thus increasing the voltage to 0.974 pu. At this point the three TSCs are in service and the TCR absorbs approximately 40% of its nominal reactive power. Observe on the last trace of the scope how the TSCs are sequentially switched on and off. Each time a TSC is switched on the TCR α angle changes from no conduction to partially or fully conduction depending on the requirement. Finally, at t=0.63s the voltage is increased to 1.0 pu and the SVC reactive power is reduced to zero. The TCR voltage and current in branch AB as well as thyristors pulses are displayed in on the TCR AB scope.

In the fig 10 it is clear that for the time 0.6s, ANFIS based system take very less time settle down and damped quickly to its final steady value as compare to the normal SVC system. This shows that ANFIS based system has clear such oscillations which hazards for the system to be connected.

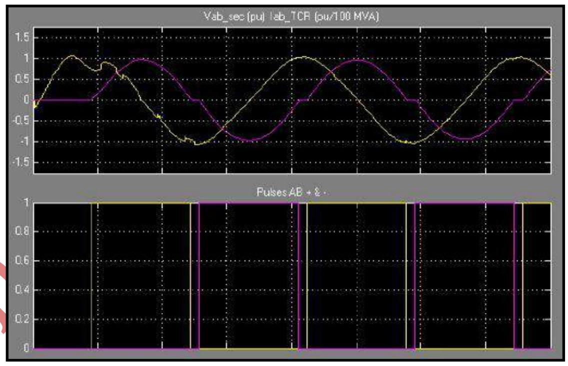

Fig 8: Simulation Result of ANFIS Based Static VAR

At t=0.4 s the source voltage is suddenly lowered to 0.93 pu due to the fault generator applied on that

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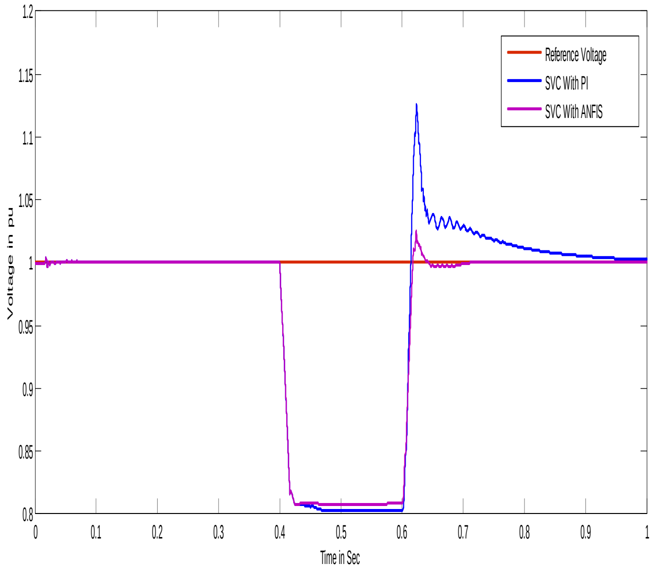

Fig 10: Comparison of ANFIS Based and Without ANFIS Based SVC System

5. CONCLUSIONS

From the result concluded that the use of ANFIS based SVC compensating device with the firing angle control is continuous, effective and it is a simplest way of controlling of voltage fluctuations and take very less time to settle in the final steady value. The use of ANFIS system has facilitated the closed loop control of system, by designing a set of rules, which decides the firing angle given to SVC to attain the required voltage. With MATLAB simulations it is observed that SVC provides effective voltage regulation irrespective of load variation and also provide voltage stability during abnormal operating conditions.

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