

**COMPARISON OF PI CONTROLLER AND FUZZY CONTROLLER IN  
SINGLE PHASE TRANSMISSION LINE IN THE PRESENCE OF SVC**

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**Abstract:**

This paper deals with the voltage and current comparison in single phase SVC compensated transmission line by using PI controller and FUZZY controller. The Static VAR Compensator (SVC) is one of the shunt connected FACTS device, which can be utilized for the purpose of reactive power compensation. FACTS is a technology, which is based on power electronic devices, used to enhance the existing transmission capabilities in order to make the transmission system flexible and independent operation. This paper attempted to design and simulated the Fuzzy logic control and PI control of firing angle for SVC in order to achieve better, smooth and adaptive control of reactive power. Transmission line is simulated using  $4\pi$  line segments by keeping the sending end voltage constant. The receiving end voltage and current fluctuations were observed for different loads. The complete design modeled and simulated in MATLAB using simulink and simpower system block set. The simulated results of receiving end voltage and current in transmission line compared. The comparison showed that the fuzzy control gives better performance than PI controller.

**Index Terms:** PI controller, Fuzzy Logic, FACTS and SVC.**I. INTRODUCTION**

The reactive power generation and absorption in power system is essential since the reactive power is very precious in keeping the voltage of power system stable. The main elements for generation and absorption of reactive power are transmission line, transformers and alternators. The transmission line distributed parameters through out the line, on light loads or at no loads become predominant and consequently the line supplies charging VAR (generates reactive power). In order to maintain the terminal voltage at the load bus adequate, reactive reserves are needed. FACTS devices like SVC can supply or absorb the reactive power at receiving end bus or at load end bus in transmission system, which helps in achieving better economy in power transfer.

In this paper Transmission line is simulated using  $4\pi$  line segments by keeping the sending end voltage constant. The receiving end voltage and current fluctuations were observed compared for different loads and different controllers (PI controller and FUZZY

controller). In order to maintain the receiving end voltage constant, shunt inductor and capacitor is added for different loading conditions. SVC is simulated by means of fixed capacitor and thyristor controlled reactor (FC-TCR) which is placed at the receiving end. The firing angle control circuit is designed and the firing angles are varied for various loading conditions to make the receiving end voltage equal to sending end voltage. PI controller and Fuzzy logic controller is designed to achieve the firing angles for SVC such that it maintains a flat voltage profile. All the results thus obtained, were verified and were utilized in framing of fuzzy rule base in order to achieve better reactive power compensation compare than PI controller for the Transmission line. Based on observed results for load voltage variations for different values of load resistance, inductance and capacitance a fuzzy controller is designed which controls the firing angle of SVC in order to automatically maintain the receiving end voltage constant.

## II. OPERATING PRINCIPLES AND MODELING OF SVC

An elementary single phase thyristor controlled reactor [1] (TCR) shown in Fig.1 consists of a fixed (usually air core) reactor of inductance  $L$  and a two anti parallel SCRs. The device brought into conduction by simultaneous application of gate pulses to SCRs of the same polarity. In addition, it will automatically block immediately after the ac current crosses zero, unless the gate signal is reapplied. The current in the reactor can be controlled from maximum (SCR closed) to zero (SCR open) by the method of firing delay angle control. That is, the SCR conduction delayed with respect to the peak of the applied voltage in each half-cycle, and thus the duration of the current conduction interval is controlled. This method of current control is illustrated separately for the positive and negative current cycles in Fig.2 where the applied voltage  $V$  and the reactor current  $I_L$  ( $\alpha$ ) at zero delay angle (switch fully closed) and at an arbitrary  $\alpha$  delay angle are shown. When  $\alpha = 0$ , the SCR closes at the crest of the applied voltage and evidently the resulting current in the reactor will be the same as that obtained in steady state with a permanently closed switch. When the gating of the SCR is delayed by an angle  $\alpha$  ( $0 \leq \alpha \leq \pi/2$ ) with respect to the crest of the voltage, the current in the reactor can be expressed [1] as follows

$$V(t) = V \cos \omega t \quad (1)$$

$$i_L = (1/L) \int_{\omega t - \alpha}^{\omega t} V(t) dt = (V/\omega L) (\sin \omega t - \sin \alpha) \quad (2)$$

Since the SCR, by definition, opens as the current reaches zero, is valid for the interval  $\alpha \leq \omega t \leq \pi - \alpha$ . For subsequent negative half-cycle intervals, the sign of the terms in equation (1) becomes opposite.

In the above equation (1) the term  $(V/\omega L) \sin \alpha = 0$  is offset which is shifted down for positive and up for negative current half-cycles obtained at  $\alpha = 0$ , as illustrated in Fig.2. Since the SCRs automatically turns off at the instant of current zero crossing of SCR this process actually controls the conduction intervals (or angle) of the SCR. That is, the delay angle  $\alpha$

Defines the prevailing conduction angle  $\sigma$  ( $\sigma = \pi - 2\alpha$ ). Thus, as the delay angle  $\alpha$  increases, the corresponding increasing offset results in the reduction of the conduction angle  $\sigma$  of the SCR, and the consequent reduction of the reactor current. At the maximum delay of  $\alpha = \pi/2$ , the offset also reaches its maximum of  $V/\omega L$ , at which both the conduction angle and the reactor current becomes zero. The two parameters, delay angle  $\alpha$  and conduction angle  $\sigma$  are equivalent and therefore TCR can be characterized by either of them; their use is simply a matter of preference. For this reason, expression related to the TCR can be found in the literature both in terms of  $\alpha$  and  $\sigma$  [1].

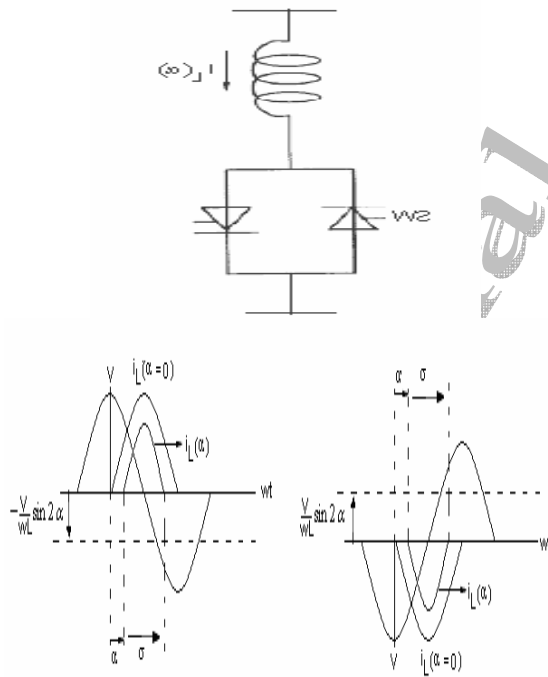


Fig. 1. Basic Thyristor Controlled Reactor firing delay angle

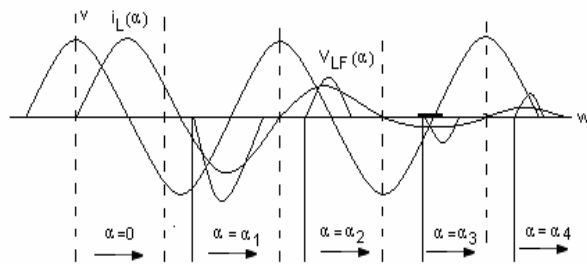


Fig. 3. Operating waveforms

It is evident that the magnitude of the current in the reactor varied continuously by delay angle control from maximum ( $\alpha=0$ ) to zero ( $\alpha=\pi/2$ ) shown in Fig.3, where the reactor current  $i_L(\alpha)$  together with its fundamental component  $i_{LF}(\alpha)$  are shown at various delay angles  $\alpha$  [1]. However the adjustment of the current in reactor can take place only once in each-half cycle, in the zero to  $\pi/2$  interval [1]. This restriction result in a delay of the attainable current control.

The worst-case delay, when changing the current from maximum to zero (or vice versa), is a half-cycle of the applied ac voltage. The amplitude  $I_{LF}(\alpha)$  of the fundamental reactor current  $i_{LF}(\alpha)$  can be expressed as a function of angle  $\alpha$  [1].

$$I_{LF}(\alpha) = V/\omega L (1 - (2/\pi) \alpha - (1/\pi) \sin (2\alpha)) \quad (3)$$

Where  $V$  is the amplitude of the applied voltage,  $L$  is the inductance of the thyristor-controlled reactor and  $\omega$  is the angular frequency of the applied voltage. The variation of the amplitude  $I_{LF}(\alpha)$ , normalized to the maximum current  $I_{LFmax}$ , ( $I_{LFmax} = V/\omega L$ ), is shown plotted against delay angle  $\alpha$  shown in Fig.4.

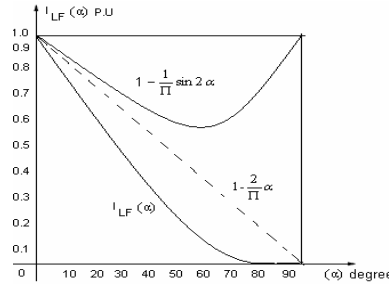


Fig.4. Amplitude variation of the fundamental TCR current with the delay angle ( $\alpha$ )

### III. FUZZY LOGIC CONTROLLER

Fuzzy logic is a new control approach with great potential for real time applications [2] [3]. Fig.5 shows the structure of the fuzzy logic controller (FIS-Fuzzy inference system) in MATLAB Fuzzy logic toolbox. [5][6]. Load voltage and load current taken as input to fuzzy system. For a closed loop control, error input can be selected as current, voltage or impedance, according to control type [7]. To get the linearity triangular membership function is taken with 50% overlap. The output of fuzzy controller taken as the control signal and the pulse generator provides synchronous firing pulses to thyristors as shown in fig.6. 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 [8] [9]. In fuzzy logic, the five linguistic variables expressed by fuzzy sets defined on their respective universes of discourse. Table-I shows the suggested membership function rules of FC-TCR controller. The rule of this table can be chosen based on practical experience and simulation results observed from the behavior of the system around its stable equilibrium points.

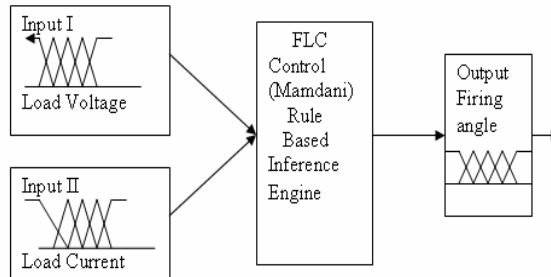


Fig.5. Structure of fuzzy logic controller

Table I. Membership function rules

		Load voltage				
Load current		NL	NM	P	PM	PB
	NL	PB	PB	NM	NM	NL
	NM	PB	PB	NM	P	NL
	P	P	PM	NM	NM	P
	PM	NM	P	NM	NM	PM
	PB	NL	NM	NM	NL	NL

In a fuzzy controller the data passes through a preprocessing block, a controller, and a post processing block. Preprocessing consists of a linear or non-linear scaling as well as a quantization in case the membership functions are discredited (vectors); if not, the membership of the input can just be looked up in an appropriate function. When designing the rule base, the designer needs to consider the number of term sets, their shape, and their Overlap. The rules themselves must be determined by the designer, unless more advanced means like self-organization or neural networks are available. There is a choice between multiplication and minimum in the activation. There is also a choice regarding defuzzification. Centre of gravity is probably most widely used. The post processing consists in a scaling of the output. In case the controller is incremental, post processing also includes integration. The following is a checklist of design choices that have to be made.

- A. *Rule based related choice:* Number of inputs and outputs, rules, universes, continuous / discrete, the number of membership functions, their overlap and width, singleton Output.
- B. *Inference engine related choice:* Connectives, modifiers, activation operation, aggregation operation, and accumulation operation.
- C. *Defuzzification method:* COG, COGS, BOA, MOM, LM, and RM.
- D. *Pre and post processing:* Scaling, gain factors, quantization, and sampling time. Some of these items must always be considered, others may not play a role in the particular design. The input-output mappings provide an intuitive insight which may not be relevant from a theoretical viewpoint, but in practice they are well worth using. The analysis represented by plots is limited, though, to three dimensions. Various input-output mappings can be obtained by changing the fuzzy membership functions, and the chapter shows how to obtain a linear mapping with only a few adjustments.

#### IV. PI CONTROLLER

The fig.6 shown, A PI Controller (proportional-integral controller) is a feedback controller which drives the plant to be controlled with a weighted sum of the error (difference between the output and desired set-point) and the integral of that value. It is a special case of the common PID controller in which the derivative (D) of the error is not used.

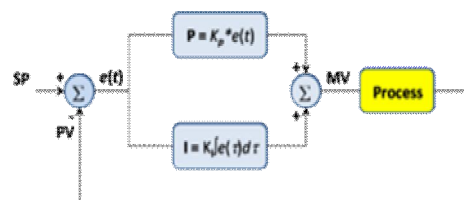


Fig. 6 basic block of PI controller

*A. PI Controller Model:*

The controller output is given by

$$K_P \Delta + K_I \int \Delta dt$$

Where  $\Delta$  is the error or deviation of actual measured value (*PV*) from the set-point (*SP*).  $\Delta = \text{SP} - \text{PV}$ .

A PI controller can be modeled easily in software such as Simulink using a "flow chart" box involving Laplace operators:

$$C = \frac{G(1 + \tau s)}{\tau s}$$

Where

$G = K_p =$  proportional gain

$G / \tau = K_i =$  integral gain

Setting a value for  $G$  is often a tradeoff between decreasing overshoot and increasing settling time.

*B. Finding a value for  $\tau$ :*

Finding a proper value for  $\tau$  is an iterative process.

- 1) Set a value for  $G$  from the optimal range.
- 2) View the Nichols plot for the open-loop response of the system. Observe where the response curve crosses the 0dB line. This frequency is known as the cross-over frequency  $f_c$ .
- 3) The value of  $\tau$  can be calculated as:  $\tau = 1 / f_c$
- 4) Decreasing  $\tau$  decreases the phase margin, however it eliminates the steady-state errors quicker.

*C. Advantages and disadvantages:*

- The integral term in a PI controller causes the steady-state error to reduce to zero, which is not the case for proportional-only control in general.
- The lack of derivative action may make the system more steady in the steady state in the case of noisy data. This is because derivative action is more sensitive to higher-frequency terms in the inputs.
- Without derivative action, a PI-controlled system is less responsive to real (non-noise) and relatively fast alterations in state and so the system will be slower to reach set point and slower to respond to Perturbations than a well-tuned PID system may be.

## V. SIMULATION STUDY

Here the fig.7 shows the simulation circuit of single phase compensated transmission line by using static var compensator (SVC) and comparison with PI and FUZZY controller. In this 750 km transmission line. The line inductance 0.1mH /km, capacitance 0.01 $\mu$ f/km and the line resistance 0.001 $\Omega$  were used. Each  $\pi$  section is of 187km, 187km, 188km and 188 km. Supply

voltage is 230V - 50 Hz having source internal resistance of  $1 \Omega$  connected to node A. Static load is connected at receiving end B. The load resistance was varied to obtain the voltage variations at the receiving end. A shunt branch consisting of inductor and capacitor is added to compensate the reactive power of transmission line. With the change of load and due to Ferranti effect, the variations in voltages are observed at receiving end B of transmission line [9]. And SVC connected near to the receiving end. The total electrical system was designed and simulated by using MATLAB.

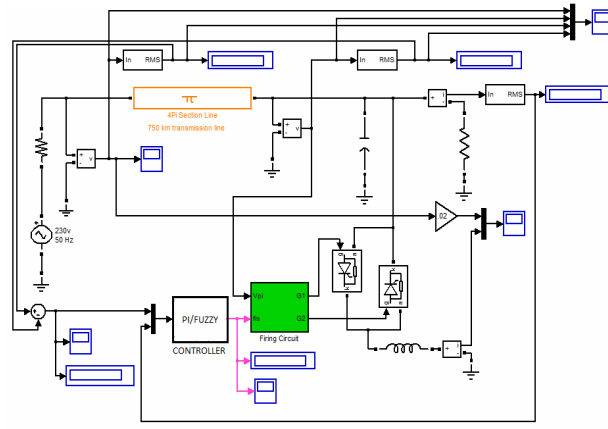


Fig.7. Single Phase equivalent circuit and PI/fuzzy logic control structure of SVC

A. Performance of PI and FUZZY controllers:

The PI controller have fixed gain values but FUZZY controller is not depends on gain values. In this sending end voltage and receiving end voltage difference is voltage error, these error value given to the PI controller input and the PI controller output and fixed frequency saw tooth out compared to generate the gating pulses of SVC for compensation of single phase transmission line. And same as used FUZZY controller also to given the pulses for SVC for line compensation. So in this way the FUZZY controller performance is better than the PI controller as shown in table.2 to give the gating signals. Here error voltage and receiving end current both are inputs to given the fuzzy controller.

VI. TEST RESULTS

The transmission line without any compensation was not satisfying the essential condition of maintaining the voltage within the reasonable limits. The effect of increasing load was to reduce the voltage level at the load end. At light loads, the load voltage is greater than the sending end voltage as the reactive power generated is greater than absorbed. At higher loads the load voltage drops, as the reactive power absorbed is greater than generated, as shown in fig.8 and fig.9. And after compensating wave forms are shown in fig .10 and fig.11.

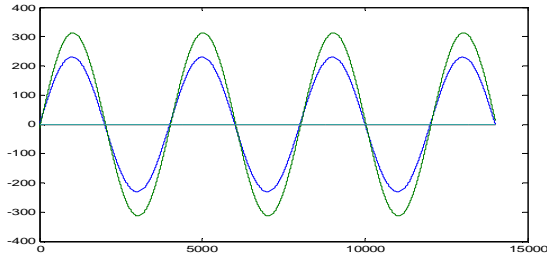
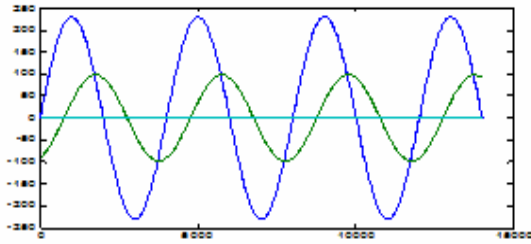


Fig.8. Uncompensated

voltages for heavy loads

Fig.9. Uncompensated voltage for light load

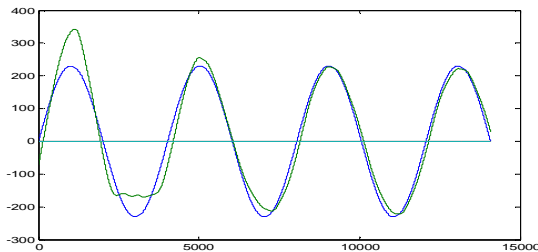
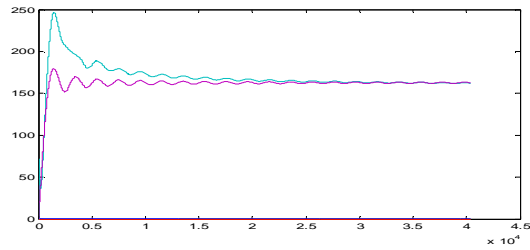


Fig.10. Compensated  $V_R = V_S$  (RMS voltage) for  $R=200\Omega$   
 Compensated  $V_R = V_S$  (instantaneous voltage) For  $R=200 \Omega$

Fig.11.

Table. 2. Comparison of PI and FUZZY controller

LOAD & SENDING VOLTAGE		With PI controller		With FUZZY controller	
R $\Omega$	$V_S$ (rms) Volts	$V_R$ (rms) Volts	$I_R$ rms Amp	$V_R$ (rms) Volts	$I_R$ (rms) Amp



<b>20</b> <b>8</b>	<b>161.8</b>	<b>159.4</b>	<b>0.767</b>	<b>161.</b> <b>3</b>	<b>0.77</b> <b>5</b>
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#### VII. CONCLUSION

Hence the rms voltage and current values are compared as shown in table 2, with PI controller and FUZZY of single phase SVC compensated transmission line. The SVC (FC-TCR) compensating device with the firing angle control is continuous, effective and it is a simplest way of controlling the reactive power of transmission line. It is observed that SVC device was able to compensate both over and under voltages. The use of fuzzy logic 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.

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