Maintaining Voltage Stability using FC-TCR with Fuzzy Logic Controller

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***Abstract*— In order to increase the transmission ability and maintain the transmission operational flexibility we use FACTS technique which is totally based on power electronic devices. Fixed Capacitor Thyristor Control Reactor compensating technique is a shunt type FACTS control technique which is used in power system primarily for the purpose of maintaining steady state voltage stability in the power system network. This paper consist of a fuzzy logic based supplementary controller for Fixed Capacitor Thyristor Control Reactor (FC-TCR) which is used to improve the voltage stability, generation, transmission and distribution side of power system network. The loading ability of transmission line can also be enhanced closer to the thermal limits without affecting the voltage stability. The designing and simulation of the Fuzzy logic control of triggering angle for FC-TCR is done in order to achieve better and smooth voltage. The modeling and simulations are brought out for long transmission line and the compensation is placed at the load end.**

Keywords*— *Fuzzy Logic, FACTS and FC-TCR

1. INTRODUCTION

Power quality is a matter of great importance to electricity consumers at all levels of usage. Sensitive instruments and non-linear loads are common for both the domestic and the industrial environment. As the reactive power is very precious for maintaining the voltage of power system hence generation and absorption in power system is essential. The basic elements for generation and absorption of active and reactive power are alternator, transmission line and transformers. The transmission system distributed parameters throughout the line, on low loads or at no loads becomes most important and consequently the line provides charging VAR (generates reactive power). To maintain the terminal voltage at the load bus adequate, reactive reserves are required. FACTS devices like SVC type FC-TCR may supply or absorb the reactive power at load end bus in transmission line, which supports in acquiring better economy in power transfer [1].

In this paper long transmission line is simulated using π line segment by keeping the supplying end voltage constant. The load end voltage fluctuations were observed for various loads. In order to sustain the load end voltage constant, shunt inductor and shunt capacitor is added for various loading conditions. Fixed capacitor along with Thyristor Controlled Reactor (FC-TCR) is placed at the load end. The triggering angle control circuit is designed and the triggering angles are varied for different loading conditions to make the load end voltage equal to supply end voltage. Fuzzy logic controller is designed to acquire the triggering angles for FC-TCR such that it maintains a flat steady state voltage profile [2]. The results obtained, were confirmed and were used in designing of fuzzy rule base in order to achieve better voltage and reactive power compensation for the long transmission line. Depending upon observed results for load voltage variations for different values of load resistance, capacitance and inductance a fuzzy controller is designed which controls the triggering angle of FC-TCR in order to automatically maintain the load end voltage constant[3].

2. OPERATING PRINCIPLE OF TCR AND FC-TCR

This thesis will attempts with an overview of the problems encountered with Shunt compensator (FC-TCR). Fixed Capacitor Thyristor Controlled Reactor is a shunt type FACTS device which is used to improve the quality of power for the purpose of voltage and reactive power control. A basic diagram of single phase Thyristor controlled reactor (TCR) is shown in Fig.1 which consists of a fixed reactor of inductance L and a two anti parallel Thyristors. The system carried out into conduction and simultaneous application of gate pulses to Thyristors of the similar polarity. Additionally, it may automatically block instantly after the alternating current crosses zero, until the gate pulses is applied again. The current in the reactor can be controlled from maximum (Thyristor closed) to zero (Thyristor open) by the phenomenon of triggering delay angle control [4].

The Thyristor conduction delays with respect to the peak of the supplied voltage in each half-cycle, and hence the time interval of the current conduction duration is controlled. This phenomenon of current control is illustrated individually for the positive and negative current cycles in Fig.2 where the reactor current $i_L(\alpha)$ at zero delay angle (valve fully closed) and at an α delay angle are shown.

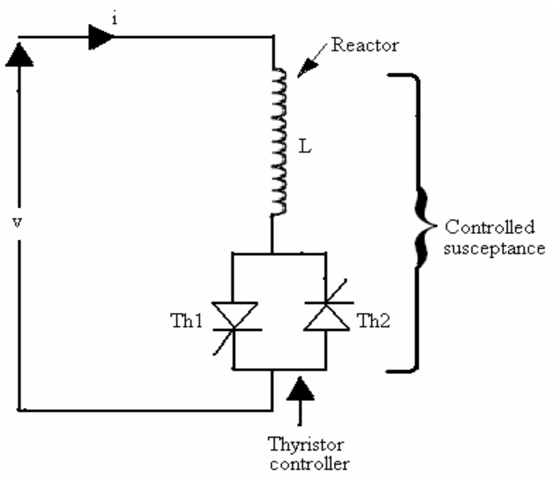

Fig.1. Thyristor Controlled Reactor

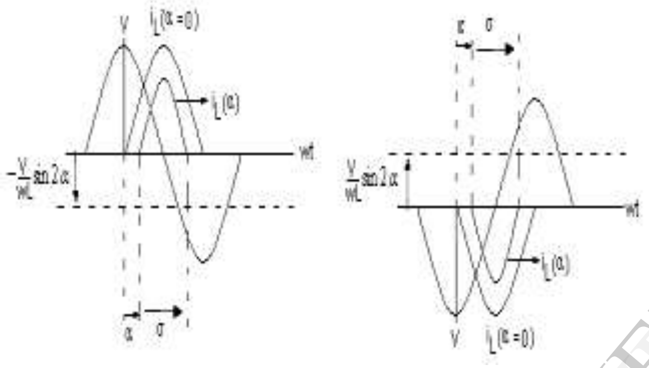

Fig.2. Firing Delay Angle

When α=0 the valve closes at crest of the supplied voltage and clearly the resulting current in the reactor will be the same. When the gating of the switch is delayed by an angle α $(0 \leq \alpha \leq \pi/2)$ with respect to the crest of the voltage, the current can be expressed as:

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

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

Thyristor valve opens as the current reaches zero expression (2) and is applicable for duration $\alpha \leq \omega t \leq \pi-\alpha$. For subsequent half cycle intervals the same expression remains justifiable but for negative half cycle intervals the sign of the terms in expression (1) becomes opposite.

In above expression (1) term $(V/\omega L) \sin \alpha = 0$ is basically α based which shifts down for positive and up for negative half cycles. Figure 2 shows that the valve automatically turns off at the moment of current zero crossing. This process usually controls the conduction interval of the thyristor valve [4].

The delay angle α defines the prevailing conduction angle σ: $(\sigma = \pi-2\alpha)$. So when the delay angle α rises there is a decrease in the conduction angle α of the valve and the reduction of the reactor current .At the maximum of v/ωL, at which both the conduction angle and the reactor current becomes zero.

It is clear that the value of the current in the reactor can be changed continuously by this method of delay angle control from maximum (α=0) to (α=π/2) where reactor current, together with its fundamental component are shown in fig.3 at different delay angles.

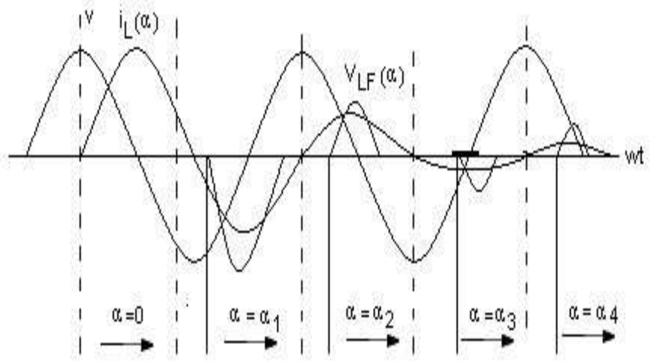

Fig.3. Operating waveforms of TCR

Typical arrangement using a fixed capacitor along with Thyristor Controlled Reactor is shown in Figure.4. Controlled reactor may be considered necessarily to consist a variable reactor which is regulated by delay angle α and fixed capacitor.

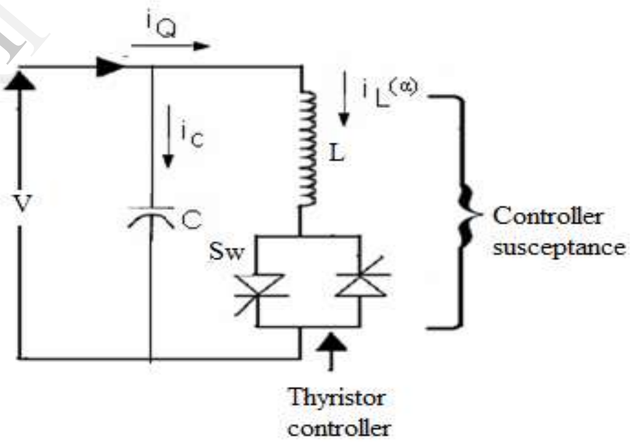

Fig.4. Typical diagram of FC-TCR

Fig.5 shows the plot between VAR demand and VAR output In the fixed capacitive VAR generator (Qc) of fixed is opposed by the variable VAR absorption (Qc) of TCR, to yield the total VAR output Q is needed. At maximum capacitive VAR output thyristor controlled reactor is switched off (α=90). To reduce the capacitive output, the current in the reactor is improved by decreasing delay angle α. At zero VAR output, the inductive and capacitive currents become equal and thus inductive and capacitive VARs cancel out with further decreases of angle α, the inductive current becomes greater than the capacitive current. At zero delay angle the TCR conducts current over the full 180^o duration, resulting in maximum inductive VAR output which is equal to the difference between the VARs generated by the capacitor and those absorbed by the reactor which is fully conducting in nature.

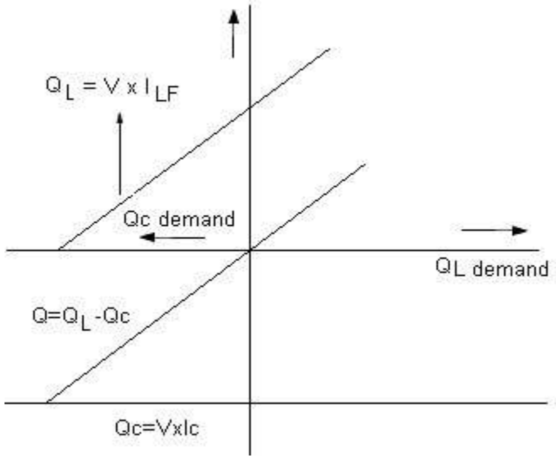

Fig.5. Plot between VAR demand and VAR output

In Fig.6 voltage defines the V-I operating area of the FC-TCR VAR generator and is defined by the maximum sustainable capacitive and inductive admittance and by the voltage and current ratings of the major power element (capacitor, reactor and thyristor valve) as illustrated in Fig.6 the ratings of the power element are derived from application requirements.

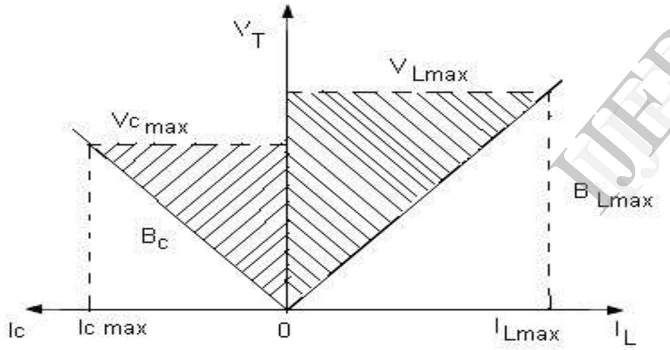

Fig.6. V-I characterstics of the FC-TCR

3. FUZZY LOGIC CONTROLLER

Fuzzy logic was initiated in 1965 by Dr. Lolfi A. Zadeh professor of computer science at the University of California in Berkley. Fuzzy logic is a mathematical tool used for dealing with uncertainty. It is best utilized in complex ill defined process that can be controlled by a skilled operator without much knowledge of their underlying dynamics. It provides a technique to deal with imprecision and information granularity [5]. Basically, fuzzy logic is a multi-valued logic that provides intermediate values between typical evaluations like true /false, yes /no, high/low etc. Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth that is true values (between completely true and completely false). Fuzzy logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous and missing input information. Fig.7 shows basic configuration of fuzzy logic controller.

Fuzzy logic controller is designed in following four stages.

- Fuzzification
- Rule base
- Inference mechanism
- Defuzzification

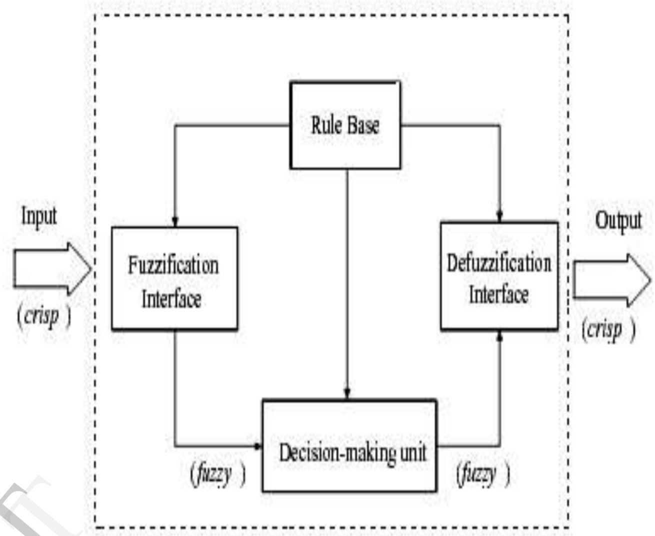

Fig.7. Basic configuration of Fuzzy Logic Controller

A. Fuzzification
It is the process of defining the degree of membership of a crisp value for each fuzzy set means. It is the process of making crisp quantity fuzzy, if it is assumed that the input data are vague or perturbed by noise they should be converted in to a fuzzy number and if data do not contain noise of vagueness a fuzzy single ton can be used.

B. Rule base
These rules depend on the operator knowledge and experience. Knowledge base comprises of the definition of fuzzy and MFS for the input and output variable and some necessary control rules which specify the control action.

C. Inference mechanism
A fuzzy inference system FIS is a way of mapping an input space to an output space using fuzzy logic. It uses a collection of fuzzy membership functions and rules instead of Boolean logic to reason about data mapping logic which plays an essential role and contains set of fuzzy if-then-rules [5].

D. Defuzzification
The last step in the fuzzy inference process is defuzzyfication. It converts the fuzzy value obtained from composition in to a crisp value. Fuzziness helps us to evaluate the rules but the final output of fuzzy system has to be crisp number. The input for the defuzzification process is the aggregate output fuzzy set whose output is a single

number. There are several defuzzificatin methods but probably the most popular one is the centriod technique as it finds the point where vertical line would slice the aggregate set in to two equal masses [6].

3.1 Proposed Fuzzy Logic Controller

Fig.8 shows the basic structure of the fuzzy logic inference system in MATLAB Fuzzy logic toolbox. For a closed loop, control input may be elected as voltage current or resistance, according to type of control. To obtain the linear triangular membership the function is taken with fifty percent overlapping. The output of fuzzy system is taken as pulse generator that generates and provides synchronous triggering pulses to SCRs as shown in fig.10. The Fuzzy Logic controller is a rule based controller, here a set of rules represents a control decision mechanism to correct the effect of certain causes coming from power system [6]. In fuzzy logic controller, seven linguistic variables exhibited by fuzzy sets described on their appropriate universes of discourse. The rule of this table can be chosen by the experienced engineers and simulation results observed from the performance of the system about its stable equilibrium points [7].

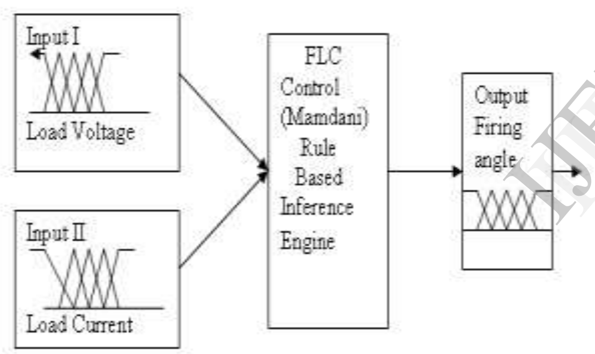

Fig.8. Fuzzy Logic Controller

4. HARDWARE IMLEMENTAION AND TRIGGERING CIRCUIT

An available simple two-bus transmission line distribution parameter were used and the voltage supply 230V – 50Hz having source internal resistance is connected to node A. Load is connected at receiving end side B. The shunt branch component that is inductor and capacitor is added to compensate the reactive power in transmission system.
The firing circuit for SCR is s switch that is used in ac circuit to control the amount of power supplies to the load. It can be controlled by turning on an electric pulse applied to the gate terminal of the Thyristor.

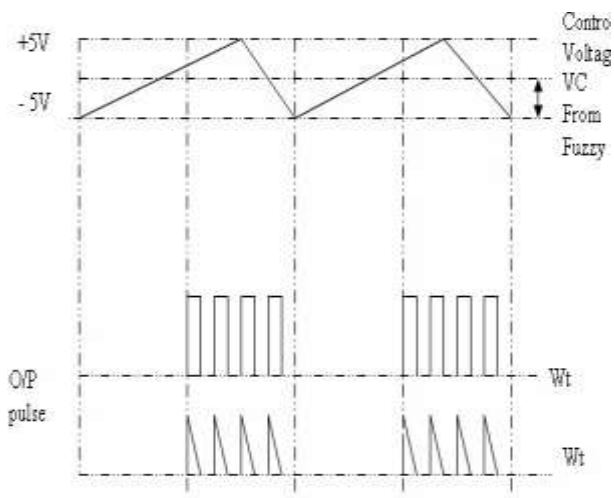

Fig.9. Wave-forms generation

5. CONTROL STRUCTURE FOR FC-TCR

The control structure consists of

- Measurement system which measures both the positive-sequence voltage as well as negative sequence voltage.
- A voltage regulator in the system that requires the voltage error (i.e. difference between the measured voltage and the reference voltage).
- A distribution unit that determines the FC-TCR that must be switched in and out, and computes the triggering angle of TCRs.
- Fuzzy logic is a computing based or rule based controller with set of rules which represents control decision mechanism to correct the effect of certain cause coming from power system
- A synchronizing system is synchronized on the secondary voltages and a pulse generator that send appropriate pulses to the Thyristors.

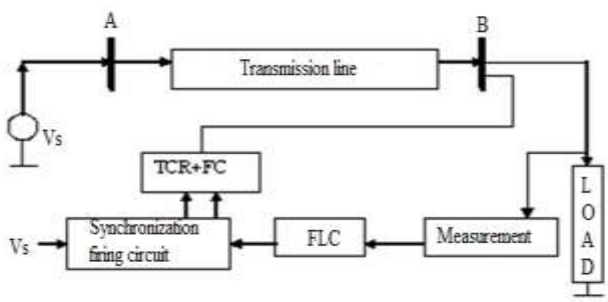

Fig.10. Single phase equivalent circuit with fuzzy control technique of FC-TCR

6. RESULT

The transmission system without any compensation was not fulfilling the required condition of maintaining the voltage within the reasonable limits. At low loads, the receiving end voltage is greater than the sending end voltage as the reactive power produced is greater than absorbed. Fig. 11 shows the instantaneous voltage without any compensation at load 300Ω and fig.12 shows instantaneous voltage after compensation at load 300Ω.

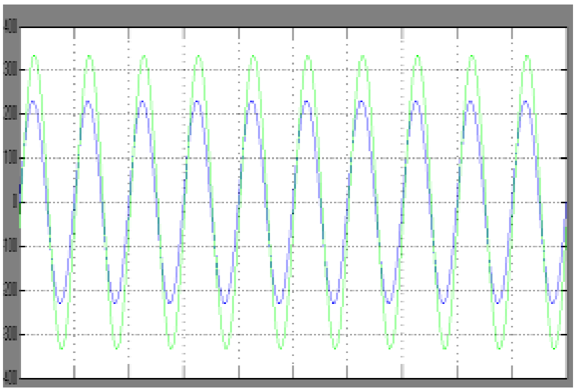

Fig.11. Instantaneous voltage without any compensation at load 300Ω

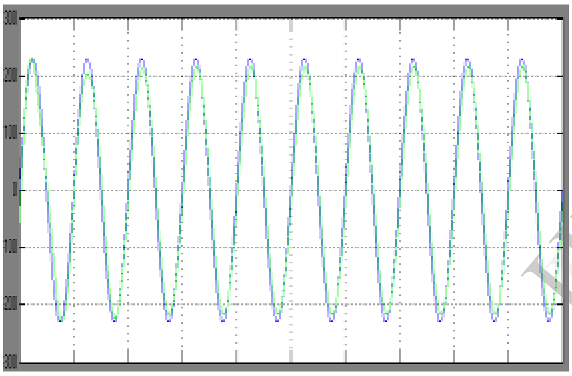

Fig.12. Instantaneous voltage after compensation at load 300Ω

7. CONCLUSION

This paper presents a “Fuzzy control scheme for FC-TCR” and it can be concluded that the use of fuzzy controlled FC-TCR compensating devices with the triggering angle control is continuous, effective and it is an easiest way of controlling the reactive power of transmission system. It is observed that FC-TCR devices were able to compensate over voltages. The basic use of fuzzy logic has provided the closed loop control of system, by designing a set of rules, which sets the firing angle given to FC-TCR to attain the required voltage.

8. REFRENCE

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