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Enhancing Power Quality in Transmission System Using Fc-Tcr

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Abstract*: FACTS methodology is totally based on power electronics devices which are used to increase the transmission capability. To make the power system flexible, FACTS technology is used to attain entire control of power system i.e. transmission, distribution and generation. This paper is mainly concerned about the significance of Fixed Capacitor Thyristor Control Reactor (FC-TCR) acquiring automatic power and steady state voltage stability with the help of fuzzy logic controller. In transmission systems, the fuzzy rules are set to generate the required firing angle of FC-TCR to maintain a flat profile of steady state voltage and stability. The fundamental model is simulated in MATLAB along with the fuzzy logic control strategy. The results obtained are trust worthy and it can be used for controlling the voltage and reactive power in any electrical transmission system.*
Keywords*: Facts, Fc-Tcr, Flc.*

I. Introduction

Electrical energy is the superior form of energy out of all energy forms in the world. It is easily controllable and transformable into various others forms (light, heat etc.) of energy. The basic control objectives of a power system are system voltage control, frequency control and protection. A power system is said to be well designed if it provides improve quality of reliable supply. It is said to be of good quality when the voltage levels are maintained within the reasonable limits [1].

In this thesis the first generation FACTS controller SVC type FC-TCR is considered with the fuzzy controller. The transmission line distributed parameters throughout the line, on at no loads or at no load become predominant and consequently the line applied charging VAR. In order to sustain the both side terminal voltage at the load bus bar adequate, reactive reserves are needed. FACTS devices like SVC can maintain voltage or absorb the reactive power at load end bus or at load end bus in transmission line, which helps in attaining economy in power transfer and distribution. The fuzzy control strategy has emerged as one of the most active and fruitful areas for research in the applications of fuzzy set theory [1].

Fuzzy control is based on fuzzy logic and is a logical system which is much closer in spirit to human thinking and nature language than traditional logical system. The fuzzy logic controller (FLC) provides a means for converting a linguistic control strategy based on an expert knowledge into an automatic control strategy. Based on observed results for receiving side voltage variations for various values of load inductance, resistance and capacitance a fuzzy logic controller is designed which controls the triggering angle of FC-TCR in order to automatically maintain the receiving end voltage constant [4].

II. Operating Principle Of FC-TCR

A basic type VAR generator arrangement using a fixed (permanently connected) capacitor with a Thruster-controlled reactor (FC-TCR) is shown in fig 1.

The current in reactor is varied by firing delay angle control. The fixed capacitor in practice is generally substituted, wholly or partially, by a filter network that has the necessary capacitive impedance at the fundamental frequency to provide the reactive power required, but it generates low impedance at selected frequencies to shunt the dominant harmonics [1].

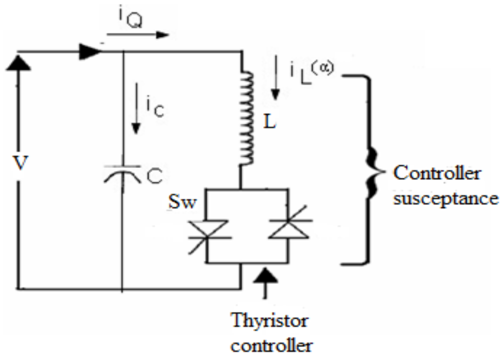

Fig.1 FC-TCR type VAR generator

The FC-TCR type VAR generator may be considered essentially to consist of a variable reactor and a fixed capacitor, with characteristics of overall VAR demand versus VAR output shown in fig 2.

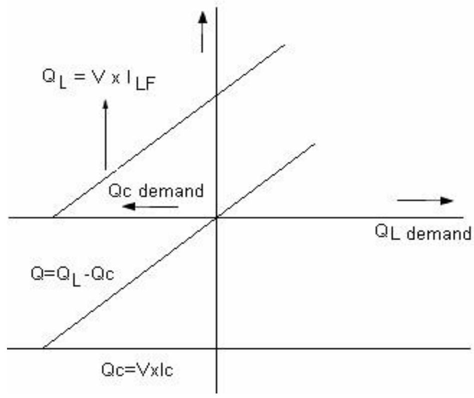

Fig.2 VAR demand versus VAR output characteristics

As seen the capacitive VAR generation of the fixed capacitor is opposed by the variable VAR absorption of the Thruster controlled reactor, to provide the entire VAR output required. At capacitive VAR output, when (α=90) the Thruster Controlled Reactor is off. To reduce the capacitive output, the current in the reactor is raised by decreasing delay angle α. When VAR output is zero, the capacitive and inductive currents become equal and thus capacitive and inductive current cancel out. With a further decrease of angle (assuming that the rating of the capacitor is lesser than that of reactor), the capacitive current becomes lower than the inductive current, resulting in a net inductive VAR output. At (zero) delay angle, the Thruster Controlled Reactor conducts current over the full180° time duration, resulting in maximum inductive VAR output that is equal to the difference between the VARs generated by capacitance and those absorbed by the fully conducting reactor. The control of Thruster controlled reactor in the FC-TCR Type VAR generator needs to provide following basic functions [3].

- Synchronous timing
- Reactive current to triggering angle converter
- Computation of required fundamental reactor current
- Thruster firing pulse generation

The first function is synchronous timing which is generally provided by a phase locked loop circuit that runs in synchronism with the ac system voltage and generates appropriate pulses with respect to the peak of that voltage.

The second function is the reactive current to firing angle conversion. This can be a real time circuit implementation of the mathematical relationship between the amplitude of the fundamental TCR current versus delay angle alpha relationship. The another is a digital "look up table" for the normalized fundamental TCR current versus alpha function which is read at t regular intervals starting from α=0 until the requested value is found, at which instant a firing angle the delay angle corresponding to the required fundamental TCR current. The actual firing instant is then determined by a timing circuit 'measuring' alpha from the peak of the voltage. The current in the reactor is varied by the method of triggering delay angle control.

A filter network that has the mandatory capacitive impedance at the frequency to generate the reactive power required generally substitutes the fixed capacitor in practice, wholly or partially, but it generates low impedance at selected frequencies to shunt the dominant harmonics produced by the TCR [7].

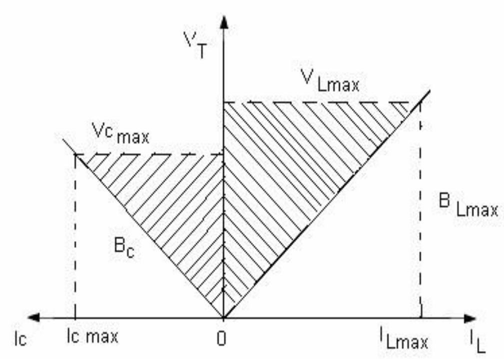

Fig.3 V-I characteristics

In Fig 3 the voltage defines the V-I operating area of the FC-TCR VAR and current rating of the major power components. In the dynamic V-I Characteristics of FC-TCR along with the Load lines showed in the Fig.4. The load characteristics are assumed to be straight lines for Dynamic studies as easily seen that the voltage is improved with compensation when compared without compensation.

III. Proposed Fuzzy Logic Controller

Fuzzy logic is an advanced control approach with great potential for real time applications and fuzzy inference system in MATLAB Fuzzy logic toolbox. Load voltage and load current are taken as input to fuzzy system. For a closed loop control, error and change in error input can be selected as current or voltage according to control type. To acquire the linearity triangular membership function is taken with fifty percent overlap [2]. The output of fuzzy controller taken as the control signal and the pulse generator provides synchronous firing pulses to thrusters as shown in fig 5.

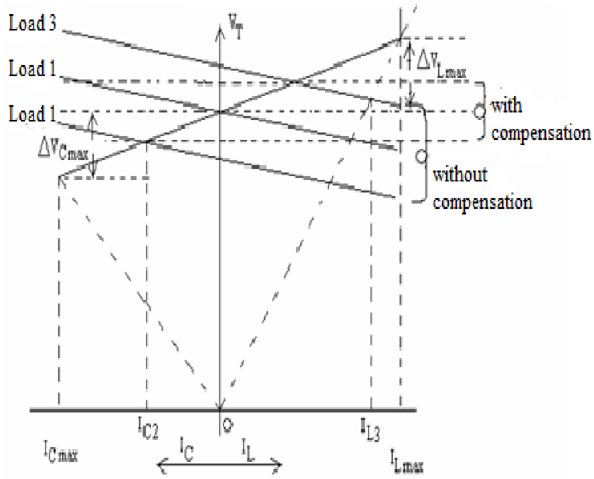

Fig.4 Dynamic V-I characteristics

The Fuzzy Logic control technique is a rule based technique, where a set of rules presents a control decision mechanism to correct the effect of definite causes coming from power system. In fuzzy logic, the seven linguistic variables expressed by fuzzy sets defined on their respective universes of discourse. Table-I shows the proposed membership function rules of FC-TCR controller. The rules chosen for this table are totally based on practical experience of experts and engineers and MATLAB simulation results observed from the behavior of the system around its stable equilibrium points [4].

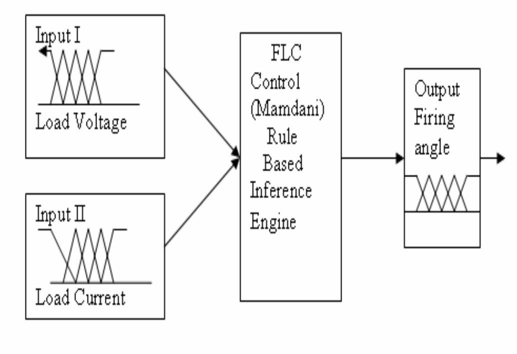

Fig.5 Proposed Fuzzy Logic Controller

TABLE I. Rules for the fuzzy logic controller

		LOAD VOLTAGE						
	ce \ e	NL	NM	NS	Z	PS	PM	PL
LOAD CURRENT	NL	NB	NB	NB	NB	NM	NS	Z
	NM	NB	NB	NB	NM	NS	Z	PS
	NS	NB	NB	NM	NS	Z	PS	PM
	Z	NB	NM	NS	PM	PS	PM	PB
	PS	NM	NS	Z	PS	PM	PB	PB
	PM	NS	Z	PS	PM	PB	PB	PB
	PL	Z	PS	PM	PB	PB	PB	PB

IV. FIRING ANGLE GENERATION

The control circuits discussed so far were discrete in nature. But present days specially develop ICs like IC TCA 785 can replace all the discrete circuitry. This IC can be used for triggering the SCR as well as TRIAC in different applications. It can be used in applications such as single phase semiconductor or full converters etc. That facilities like multiple pulse triggering, pulse width adjustment, variation in the firing angle etc. The same IC can be used for triggering the three 2 phase line commutated converter as well and for this three IC's are used. Fig.6 shows the fundamental diagram of firing scheme for Thruster with TCA785. The synchronizing signals should be generated by using step down transformers. Fig 6 shows Firing Scheme with TCA 785 IC for SCRs. This IC 785 having output current of 250 mA and a fuzzy logic trainer kit with two input variables and having seven linguistic sets is used. This can generate 7 X 7 rules.

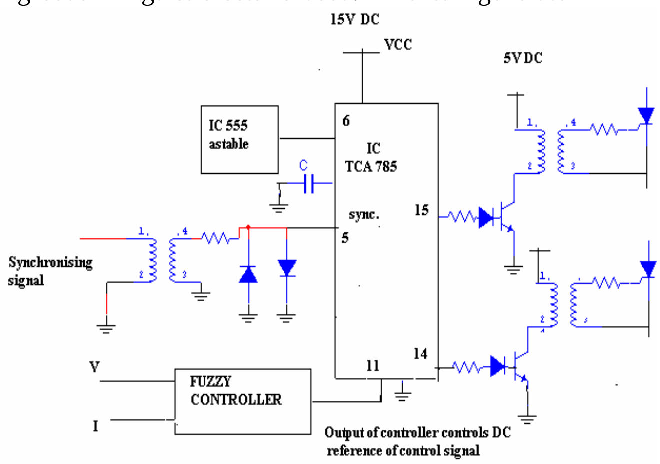

Fig.6 Fundamental diagram of firing scheme for Thruster with TCA785

V. CONTROL STRUCTURE FOR FC-TCR

The control system consists of:

- A measurement system measuring the positive-sequence and negative sequence voltage control.
- A voltage regulator that manipulates the voltage error (difference between the reference voltage and the measured voltage) to determine the FC-TCR susceptance needed to maintain the system voltage constant.
- 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 [5].
- A distribution unit that regulate eventually FC-TCR must be switched in and out, and calculate the firing angle of TCRs.
- A synchronizing system synchronizes the secondary voltages and a pulse generator that send appropriate pulses to the thruster [5].

VI. HARDWARE IMPLEMENTATION

The TCR (Thruster Controlled Reactor) block consists of two thrusters in an anti-parallel connection. This setup is connected to a reactor of a fixed value. By changing the firing angles the effective value of inductance is also changed, thus the reactive power absorbed by the reactor is changed which leads to a change in the receiving end voltage. The transmission line used in the network is λ/8 transmission line. A π model is used for representing the transmission line. There are four π sections for long transmission line. Fig.8 shows the long transmission line representation. The firing pulses are generated by the block "firing circuit" which gives the firing angle α for one cycle and 180 – α during the negative cycle. The inputs to this block are the receiving end voltage of the line and a control value (firing angle). The fuzzy toolbox in the MATLAB is used to design the fuzzy controller. The designing of the fuzzy controller is done on the basis of the rules given before. The load current is taken as an input for the fuzzy controller. The firing angle is obtained as the output [7].

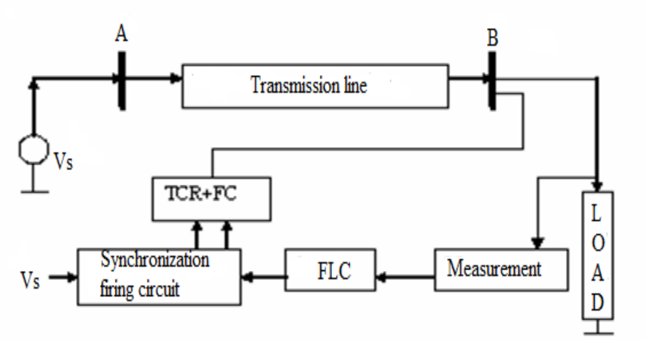

Fig.7 Single phase equivalent circuit with fuzzy control structure of FC-TCR

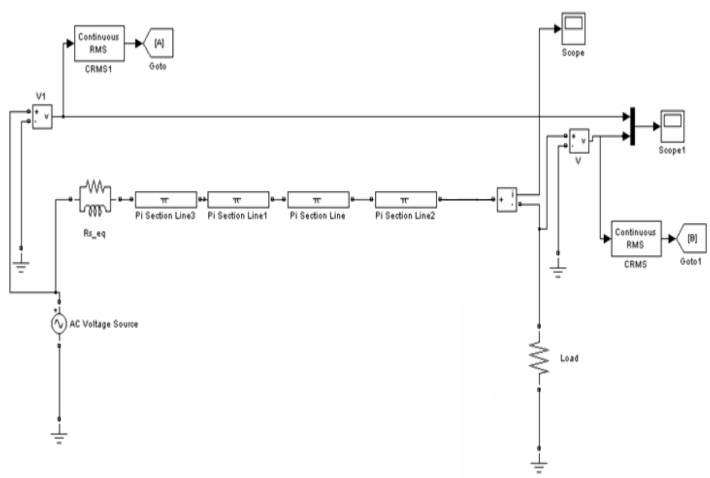

Fig.8 Transmission line representation

VII. RESULTS

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. 9 shows the voltage before compensation at load 400Ω and fig.10 shows instantaneous voltage after compensation at load 400Ω. Fig11 and 12 shows the RMS voltage before and after compensation at load 400Ω.

VIII. CONCLUSION

This paper deals with a "fuzzy control scheme for FC-TCR" and it can be concluded that the use of fuzzy controlled FC-TCR compensating device with firing angle control is effective, continuous and it is a simplest way of controlling the power and voltage of transmission line. It is observed that FC-TCR device was able to compensate both over and under voltages. Compensating voltages are shown in wave forms. 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 FC-TCR to attain the required voltage. With MATLAB simulations and actual testing it is observed that SVC type FC-TCR provides an effective reactive power control irrespective of load variation

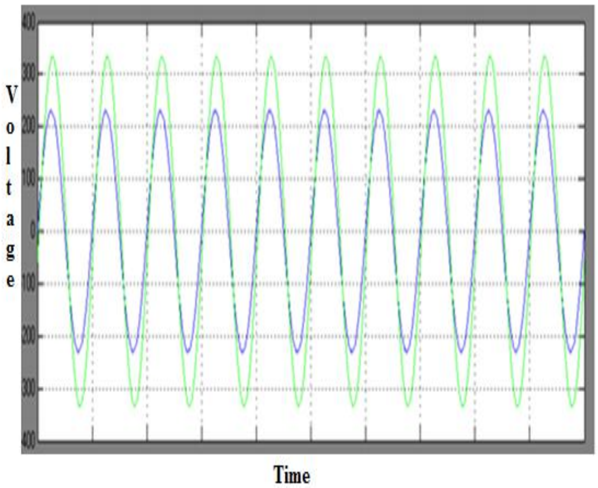

Fig. 9 Voltage waveforms before compensation at load R= 400Ω

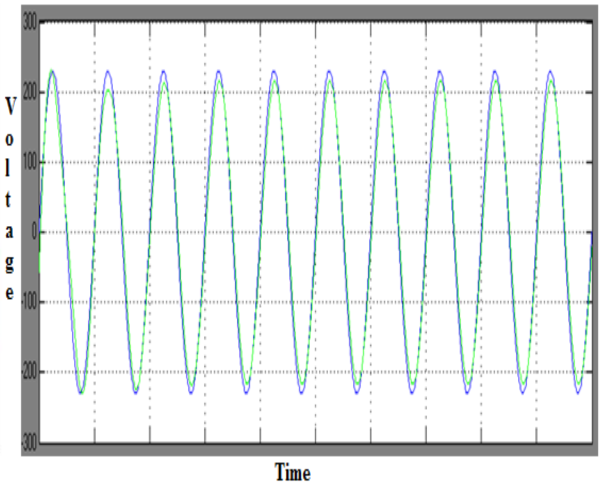

Fig. 10 Voltage waveforms after compensation at load R= 400Ω

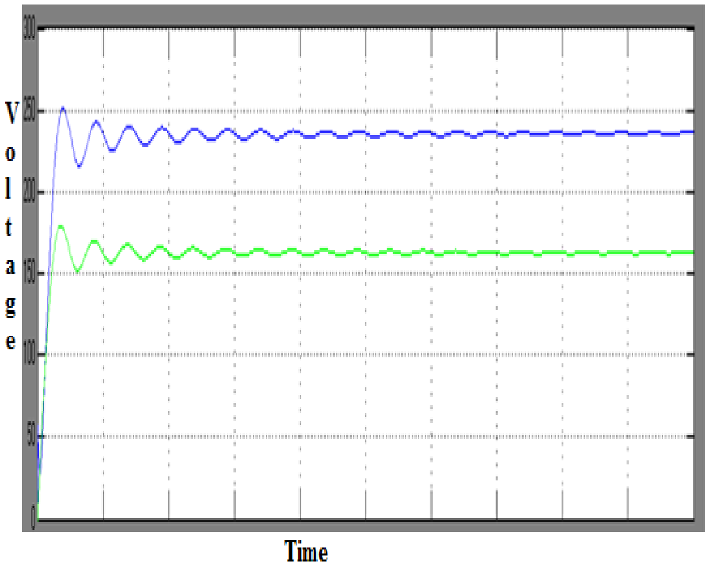

Fig. 11 Voltage waveforms before compensation at load R= 400Ω

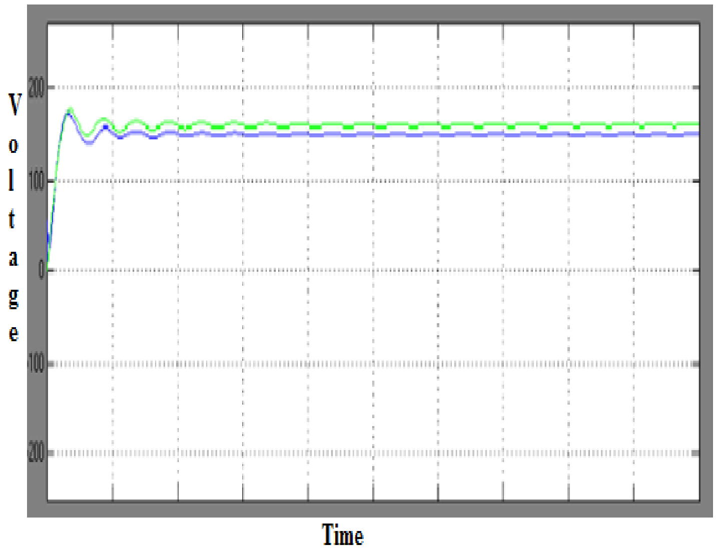

Fig. 12 RMS Voltage waveforms before compensation at load R= 400Ω

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