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Practical Implementation of Microprocessor Controlled FC-TCR Compensator for Voltage Regulation

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Abstract: The economic recession coupled with environmental and ecological pressures has compelled electric utilities all over world to serve the increasing load demand without corresponding increase in their transmission and generation facilities. However under these stressed conditions the utilities are now facing the problem of maintaining required voltage in some parts of power system network and increased probability of voltage collapse. This paper deals with controlling receiving end voltage of a long artificial transmission line by controlling the reactive power at the receiving end of the transmission line under various load conditions by pumping or absorbing reactive power using fixed capacitor-thyristor control reactor. A microprocessor based control scheme used for controlling the firing angle of the thyristors, based on the status of the receiving end voltage by means of ADC0809 and a look-up table.

Key words: Fixed Capacitor-Thyristor Control Reactor · Analog to Digital Converter

INTRODUCTION

Reactive power has been recognized as a significant factor in the design and operation of alternating current electric power system. Reactive power is consumed not only by most of the network elements but also by most of the consumer loads. There is a fundamental and important interrelation between active and reactive power transmission. Transmission of active power requires a phase displacement of voltages but the magnitudes of these voltages are equally important. Not only they are necessary for power transmission but also they must be high enough to support the loads and low enough to avoid equipment breakdown. Thus it is necessary to control and support or constrain the voltages of all the key points of the network.

Reactive power control [1] is an essential tool in maintaining the quality of supply. Certain types of industrial loads including electric furnaces, rolling mills, mine hoists and drag line excavators impose on the supply large and rapid variations in their demand for power and reactive and it is necessary to compensate for them with voltage stabilizer equipment in the form of static reactive power compensators. With recent advances in power electronics high power high speed electronic switches make it possible to realize real time control of compensating devices. As one of the potential option for flexible ac power transmission system devices [2] the thyristor controlled compensator has found application in improving power system damping stability. This provides an alternative to the conventional power system stabilizer. A TCR is one of the most important building blocks of thyristor-based SVCs. Although it used alone, it is more often employed in conjunction with fixed or thyristor-switched capacitors to provide rapid, continuous control of reactive power over the entire selected lagging-to-leading range.

Load Compensation: Load compensation is the management of reactive power to improve the quality of supply in A.C. power systems. No compensating equipment is usually installed on consumers own premises, near to load. References [3, 4, 5] present the principles of load compensation. In an ideal power system, the voltage and frequency at every supply point would be constant and free from harmonics. In such a system, each load could be designed for optimum performance at given supply voltage, rather than for merely adequate performance over an unpredictable range

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of voltage. Also there would be no interference between different loads as a result of variation in current taken by each one. The need for adjustable reactive power compensation is to maintain the stability of synchronous machines. The voltage control by reactive power compensation has a positive stabilizing influence on the system, during disturbances, which cause the rotor angles of synchronous machines to change rapidly. Both the transient stability and the dynamic stability of a system can be enhanced [6]. It is even possible with controlled compensators, to drive voltages deliberately out of their normal steady state bounds for several seconds, following a fault in other major disturbance to enhance the stabilizing influence still further. The need to control voltage within acceptable bounds about the desired steady state value to provide quality service to consumer loads. Following certain abrupt changes in the load, or in the network configuration as a result of switching actions, it may be necessary to make a voltage correction in as short a time as a few cycles of the power frequency. For other voltage disturbances, a correction with in a Few seconds will be sufficient. Uncorrected voltage deviations, may lead to an outage or damage to utility or consumer owned equipment. Even small variations, particularly those that cause flicker are objectionable. The need to regulate voltage profiles in the network to prevent unnecessary flows of reactive power on transmission lnes. Reactive power compensation used to maintain, transmission losses to a minimum [7].

Principle of Operation: The basic the thyristor controlled reactor (TCR) is shown in above Fig.1. The controlling element is the thyristor controller, shown in figure as two oppositely poled thyristors which conduct on alternate half-cycles of the supply frequency. If the thyristors are gated into conduction precisely at peaks of the supply voltage, full conduction results in the reactor and the current is same as though the thyristor controller were short circuited [8]. The current is essentially reactive lagging the voltage by nearly 90°.

Practical Implementation of FC-TCR Compensator: Fig. 2 shows the practical setup microprocessor controlled FC-TCR compensator for voltage regulation. Fig. 3 shows the control scheme block diagram. The main components of block diagram are: Transmission line model, Voltage Transformer, ADC 0809 (Analog to Digital Converter). 8085 Micro processor, 8253 (Interval Timer), 8255 Programmable Peripheral Interface, 555 IC (timer), Zero Crossing Detector, Optocouplers, Current Amplifiers, Back to Back Connected Thyristor [9].

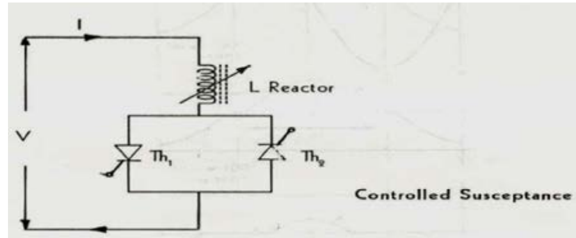

Fig. 1: Basic Thyristor Controlled Reactor

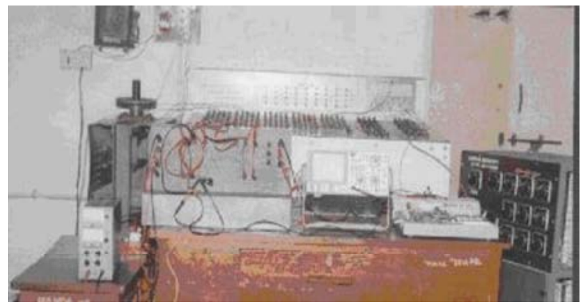

Fig. 2: Practical setup of microprocessor controlled FC-TCR compensator for voltage regulation.

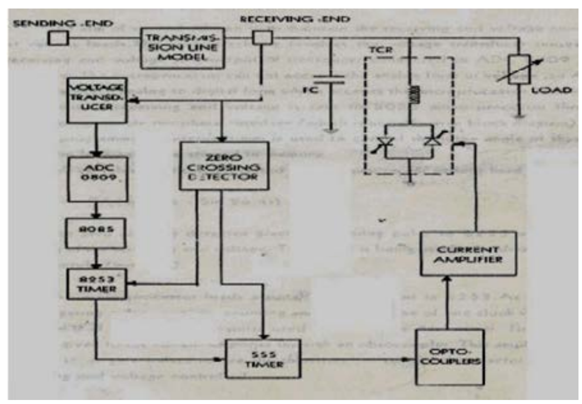

Fig. 3: Control scheme block diagram

The reactive power controlled by control lines the reactor current at receiving end of transmission line. The aim of control scheme is to maintain the receiving end voltage constant at various loads. The control scheme involves the voltage transducer senses the receiving end voltage, the output of transducer connected to ADC 0809 A/D converter. The microprocessor accepts the analog form of voltage, so ADC converts which analog to digital form which accepts the microprocessor. The digital equivalent of receiving end voltage is sent to 8085 micro-processor through 8255 programmable peripheral interface. The 8253 programmable interval timer used to

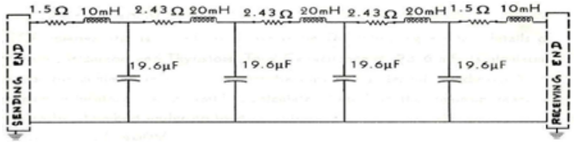

Fig. 4: Artificial Transmission line

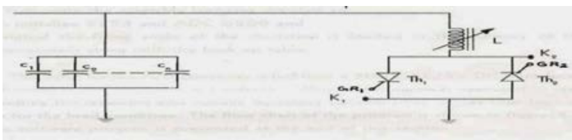

Fig. 5: FC-TCR unit

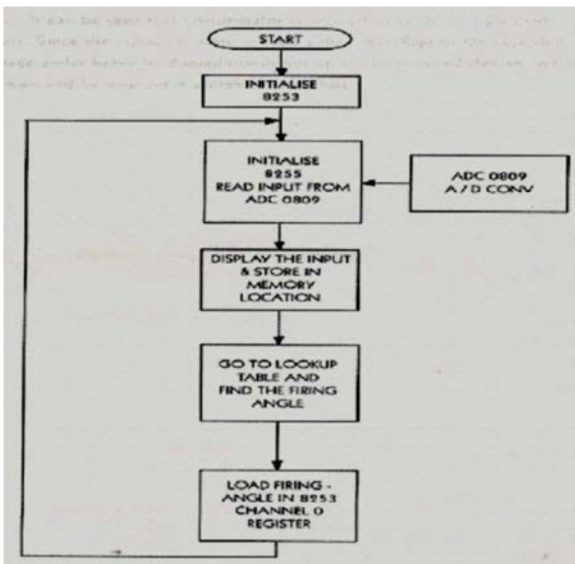

Fig. 6: Program flow

control the firing angle of thyristor based on look-up table stored in memory [10-11]. The look-up table is calculated based in the equation for various load conditions

Artificial Transmission Line: he transmission line model quarter wavelength 914 miles for 3 ph basis. The line is four sections of equivalent T representation The parameters of line 220KV, Series Impedance: 0.129+j 0.661 ohms/ph/mile Shunt admittance: 0. 428*10^{-6} mhos/ph/mile

For T-sections comprise of three middle coils two end coils and four sets of capacitors tapping are provided on each coil and each capacitor bank. The sending end voltage is 150V 50Hz. The model is rated at 5A.

FC-TCR Unit: FC-TCR compensator is fixed as shown in Fig. 5. Total Capacitance 93.6 mF; Maximum Inductance = 21.4mH; Thyristors = 10A, 400V. The program flow chart is shown in Fig. 6.

Table 1: Without SVC and FC

S.No	Load Current	Receiving end voltage (volts)
1	0.0	206
2	1.2	184
3	1.6	163
4	2.21	55
5	2.6	147
6	3.2	135
7	3.4	124
8	3.6	110
9	3.8	103
10	4.2	96
11	4.4	89

Table 2: Without SVC and with FC

S.No	I_c (amps)	I_L (amps)	V_L (volts)
1	2.12	0.9	260
2	1.8	1.2	230
3	1.6	2.0	204
4	1.56	2.5	182
5	1.34	3.0	165
6	1.2	3.4	152
7	1.0	3.7	132
8	0.93	4.0	118
9	0.96	4.2	109
10	0.85	4.5	99
11	0.78	4.5	94

Table 3: With fixed capacitor and SVC

S.No	I_i (amps)	I_c (amps)	I_L (amps)	V_L (volts)
1	2.2	1.6	0.36	182s
2	1.8	1.46	1.2	168
3	1.56	1.42	1.9	164
4	1.2	1.34	2.4	159
5	0.8	1.3	2.8	154
6	0.0	1.2	3.2	149
7	0.0	1.1	3.6	136
8	0.0	1.0	4.1	124
9	0.0	0.95	4.3	115
10	0.0	0.9	4.5	106
11	0.0	0.8	4.7	101

From Table 1 to Table 3 represent the various loading conditions of the system. Where I_i is the inductor current, I_L load current, I_c capacitor current and V_L receiving end voltage.

CONCLUSION

The microprocessor controlled FC-TCR compensator is working satisfactory in controlling the receiving end voltage of artificial transmission line and it was successfully tested on different load conditions. From the tables it is observed and it is remarking that switching capacitors improve the voltage profile, any desired voltage at receiving end using this compensator obtain by choosing specific L,C values and by changing Look-up table, Hence, this works as good automatic voltage regulator.

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