NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 2, ISSUE 4APR.-2015

ENHANCEMENT OF ACTIVE POWER FLOW CAPACITY OF A TRANSMISSION LINE USING MSC-TCR SCHEME

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ABSTRACT

This paper represents the MSC-TCR scheme of shunt compensation used in FACTS. The laboratory setup of the SVC circuit using a Thyristor controlled reactor in parallel with mechanically switched capacitor will discussed in this paper. Results from the lab setup to exhibit firing angle adjustment to inject or absorb VAr into the system will also be described. During the process, losses happened are also discussed.

KEYWORDS*:* Static VAr Compensator, MSC-TCR, Reactive Power Compensation.

INTRODUCTION

This paper reports the development of a microcontroller controlled static VAr compensator (SVC) in the power systems laboratory of the Electrical Engineering Department of SETI, Kolhapur. To make the SVC understandable to students of undergraduate level, the hardware and software have been kept as simple as possible though provision is there to implement more complex software for control strategies within the same hardware facilities [2].

There are several ways to compensate for reactive power using power electronics, but one that will be the focus of this paper is the one that is called the Static VAR Compensator or SVC for short. SVC has been used by many utilities in the world, and its use will continue to grow. Because of the important role SVC plays in future power systems, it is therefore crucial for future power engineers/students to gain full understanding of how SVC operates. While covering the topic of SVC may seem ample for students to learn the basic theory of SVC, a lab experiment will be more beneficial for the students to grasp the practical issues associated with SVC. This paper describes a project that deals with the development of a small-scale SVC lab experiment suitable for university environment.

TRANSMISSION LINE

A Lab Model of a 300Km long transmission line is created by using the reference values of IEEE paper [1]. The model represents each 100Km section of the line by a π-model. The distributed values of transmission line resistance, inductance and there for internal resistance of Inductor is taken into consideration instead of separate resistance,capacitance in lumped form. The resistance is low

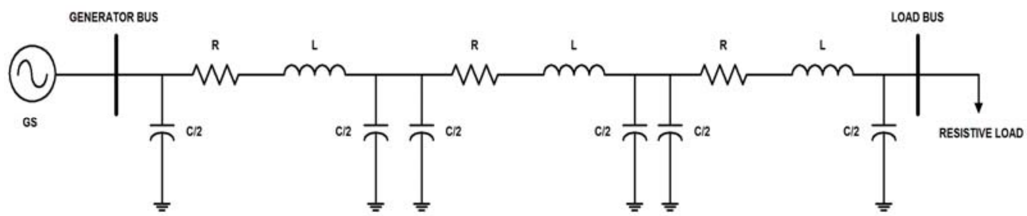

Fig. 1 Transmission Line Model

This model is also useful in practicing the different effects on the transmission line like Ferranti Effect etc. Also various power system experiments can be carried out like power factor improvement and FACTS practical.

STATIC VAR COMPENSATOR

A Static VAR Compensator consists of a Thyristor-controlled Reactor (TCR) which is an inductance in series with a bidirectional Thyristor switch as shown in Figure 2. The reactor is in parallel with a corrective no. of capacitor controlled by relay switch to adjust for injecting or absorbing reactive power. The main function of a SVC is to absorb or supply reactive power based on the changing VAR requirement of the load [3].

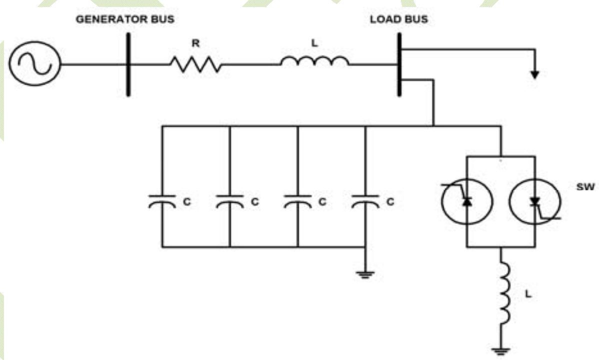

Fig. 2MSC-TCR Scheme

The Mechanically- Switched Capacitor Thyristor-controlled reactor (MSC-TCR) type compensator was developed primarily for dynamic compensation of power transmission systems with the intention of minimizing standby losses and providing increased operating flexibility. A basic single-phase MSC-TCR arrangement is shown in Figure. For a given capacitive output range, it typically consists of n MSC branches and one TCR. The number of branches, n, is determined by practical considerations that include the operating voltage level, maximum VAr output, current rating of the Thyristor valves, bus work and installation cost, etc. Of course, the inductive range also can be expanded to any maximum rating by employing additional TCR branches.

The total capacitive output range is divided into n intervals. In the first interval, the output of the VAr generator is controllable in the zero to $Q_{CMAX/n}$range, where $Q_{CMAX}$is the total rating provided by all MSC branches. In this interval, one capacitor bank is switched in firing, and, simultaneously, the current in the TCR is set by the appropriate firing delay angle so that the sum of the VAr output of the MSC (negative) and that of the TCR (positive) equals the capacitive output required. By being able to switch the capacitor banks in and out within one cycle of the applied ac voltage, the maximum surplus capacitive VAr in the total output range can be restricted to that produced by one capacitor bank, and thus, theoretically, the TCR should have the same VAr rating as the MSC. However, to ensure that the switching conditions at the endpoints of the intervals are not indeterminate, the VAr rating of the TCR has to be somewhat larger in practice than that of one MSC in order to provide enough overlap between the "switching in" and "switching out" VAr levels.

DESIGN REQUIREMENTS

A. Test Performed:

The transmission line is then tested on behalf of different loading conditions. The Lamp Load is taken as the resistive load. As the load increases, various effects on transmission line parameters are observed and taken into calculations. The Ferranti Effect is observed on No Load and Lightly Loaded condition. Whether decrease in R.E Voltage is observed on heavily loaded conditions. The values are then plotted on a graph as shown in fig. 3.

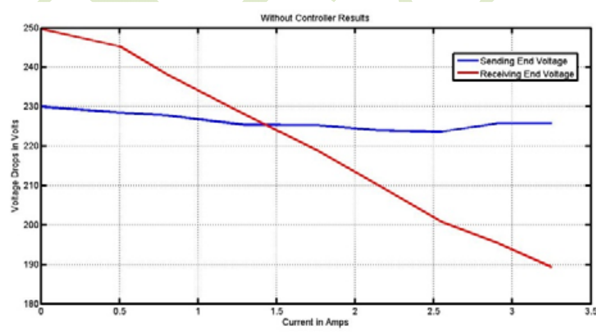

Fig. 3 without Controller Graph

B. Calculation of ABCD Parameters:

By doing both analytical and MATLAB program, the following results have been obtained,

These values are then used further in the calculation of Reactive VAr requirement on different loading conditions. The conventional Receiving End Power Circle Diagram method is used for this purpose [4].

C. Calculation of Required Reactive VAr:

By drawing the Receiving End Power Circle Diagram, the required reactive VAr's for compensation at different loading condition are obtained as shown in fig. 4

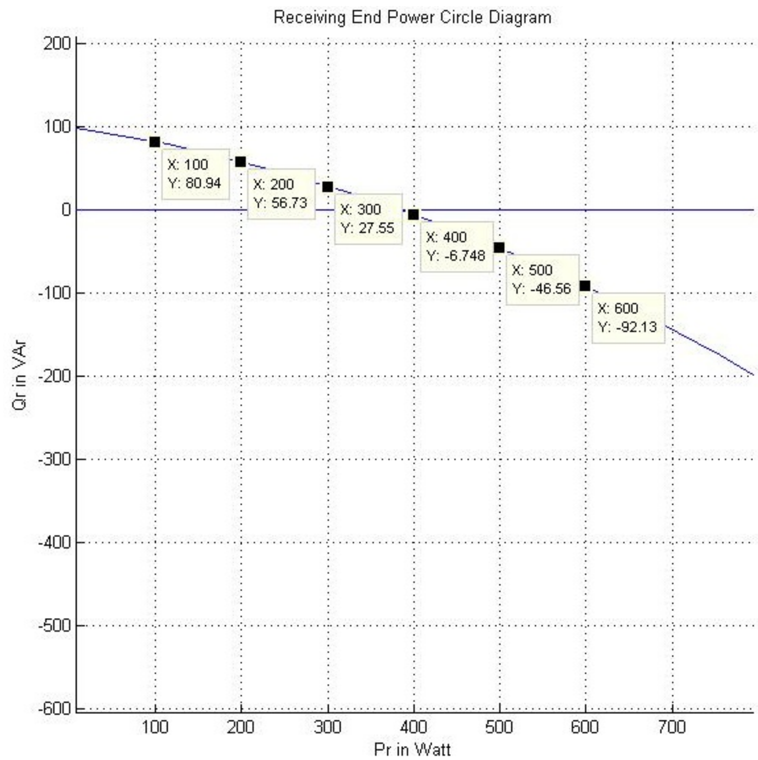

Fig. 4 Receiving End Power Circle Diagram

D. Selection of Dynamic range of SVC:

The dynamic range of an SVC is determined on the basis of the reactive power requirement at the load bus or SVC bus to control the voltage under steady state conditions. Here previous steady state load test reading data is used to obtain the required SVC rating.

TABLE I

SUMMARY OF STATIC LOAD AND REQUIRED COMPENSATION POWER

Sr. No.	**Static load**	**Required compensation power obtained by circle diagram**		**Voltage level**
	Maximum load	**Capacitive**	**Inductive**	
1	Incandescent lamp 600 Watt	244.404 VAr	100.945VAr	230 V

ISSN: 2394-3696
VOLUME 2, ISSUE 4APR.-2015

The dynamic range of an SVC is determined on the basis of the reactive power requirement at the SVC bus to control the voltage under steady state conditions. From above table we have to select 244.404 VAr capacitive and 100.945 Var inductive. Instead of choosing accurate value of compensation power we select round up value as, 300 VAr capacitive and 110 VAr inductive.

So range of SVC is:

+ 110 / - 300 VAr, 230 volts, 50 Hz.

Specifications of shunt capacitor:

1. Rated KVAR = 0.300 KVAR
2. Rated voltage = 230 volts
3. Rated frequency = 50 Hz
4. No of phase = 1

Specifications of Shunt Inductor:

1. Rated KVAR = 0.410 KVAR
2. Rated voltage = 230 volts
3. Rated frequency = 50 Hz
4. No of phase = 1

RESULT OBTAINED

TABLE II

COMPENSATION RESULTS OF LOADED TRANSMISSION LINE

SR. NO.	Load (Watts)	R.E Voltage Without Compensation (Volts)	R.E Voltage With Compensation (Volts)	Compensation Capacitor (MFD)
1	600	216	228.3	9.45
2	500	217.9	233	6.3
3	400	225	234	3.15

TABLE III

CALCULATED POWER TRANSFERRED TO LOAD

SR. NO.	Load (Watts)	Power Transferred without Compensation (Watts)	Power Transferred with Compensation (Watts)
1	600	540	634
2	500	458	536
3	400	338	398

TABLE IIII

CONTROLLER COMPENSATION TEST OF MSC-TCR WITH CONSTANT S.E VOLTAGE

Sr. No.	Load in watts	Sending end voltage in volts	Receiving end voltage in volts	Calculated power in watts
1	0	240	216	0
2	100	240	233	69.9
3	200	240	230	230
4	300	240	215	344
5	400	240	223	490.6
6	500	240	225.2	608.04
7	600	240	222.5	734.25

Above results have been taken down by using the Step Compensation (Static Capacitors). By doing the Dynamic Compensation (Microcontroller Controlled) we can get even more precise results than this.

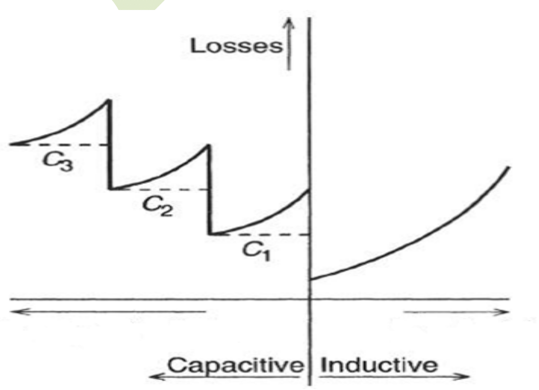

Fig. 5 Expected Graph of Loss VS VAr Output

CONCLUSION

The Static VAR Compensator showed that it is capable of enhancing the active power flow capacity of a transmission line, thus allowing the use of transmission line to its maximum power transfer capacity. Also the voltage stability is maintained. As only a purely resistive load was tested, the SVC is still can be configured for the various loads like varying inductive loads.

AKNOWLEDGEMENT

We wish to acknowledge, Sanjeevan Engineering and Technology Institue, Panhala, Kolhapur, Maharashtra for their support and provision of required Lab Accessories and also to Mr. Abhijeet P. Redekar for their guidance and support.

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