Flexible AC Transmission System using TCR

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***Abstract*— Modern electrical power systems are being expanded continuously and are upgraded to cater the want of ever growing electrical power demand. However in recent years, electrical energy developers have faced both the financial difficulties as well as the environmental difficulties in expanding the power generation and transmission. These situations have forced power designers to look for advanced techniques system to enhance controllability, stability, and power transfer capability of ac transmission systems which are FACTS devices used to control power flow in the transmission grid to relieve congestion and limit loop flows. FACTS using Thyristor Controlled Reactance is thus used either when charging the transmission line or when there is very low load at the receiving end.**

***Keywords*—Electricity Markets, FACTS, FACTS Controllers, Power Flow Control, Power Transmission, Statcom, SVC, Thyristor-Controlled Reactor**.

I. INTRODUCTION

The electricity power system industry is undergoing a phenomenon transformation throughout the globe. Scarcer natural resources and an ever-increasing continuous demand for electric supply are some of the causes responsible for such adverse change. The ability of the long transmission system to transmit electric power becomes impaired by one or more of the following limitations: (a) voltage magnitude, (b) angular stability, (c) transient stability, (d) dynamic stability, and (e) thermal limits [1]. These limits the maximum electrical power to be transmitted from the generating source to the consuming load without causing much damage to transmission lines and electrical equipment connected between them. In principle, limitations on power transfer can always be reduced by the addition of few new transmission lines or upgrading the existing transmission line and generation facilities [2]. However that being a high capital investment, alternatively, flexible alternating current transmission system (FACTS) controllers can be used which enables the same objectives without causing any changes in the power system layout. FACTS are AC transmission systems which are totally incorporating power electronic-based and other few static controllers to enhance the controllability of the system and to increase power transfer capability of the system. The FACTS concept is basically based on the incorporation of power electronic devices and its methods into the high-voltage side of the network to make it fully controllable based on the electronic logic provided during both steady state condition and transient conditions. The concept of FACTS was introduced in 1988 by Dr. N. Hingorani. Based on the economical and technical benefits, FACTS then received the support from many electrical equipment manufacturers, electrical utilities, and research organizations all around the globe. This keen interest has led to the continuous significant technological developments of FACTS controllers over the last decade [3]. Several different kinds of FACTS controllers have been developed in various parts of the world. Few of the most popular are: phase-angle regulators, thyristor controlled series compensators, load tap changers, static VAR compensators, unified power flow controllers, interphase power controllers and static compensators In this paper, the development of FACTS controllers is presented [4]. The paper presents the objectives of FACTS, the types of FACTS controllers, and the benefits of FACTS controllers have been presented.

II. NEED OF FACT CONTROLLERS

Due to very low or no load, extremely low current flows through the long transmission line and shunt capacitance in the transmission line becomes considerable. This results in the voltage amplification which is also called as Ferranti Effect in which the receiving end voltage gets higher than the sending end voltage and sometimes even get double than the sending end voltage which happens generally in the case of very long transmission lines [5]. To compensate this Ferranti Effect, shunt inductors are automatically connected across the transmission line whenever this phenomenon is likely to occur. In this proposed plan, the lead time between the zero current pulse and zero voltage pulse which is duly generated by suitable operational amplifier are actually fed to two different interrupt pins of the microcontroller of 8051 family and then the program takes over to bring the shunt reactors to the circuit to get the voltage duly compensated and to maintain the healthy operation of the system. Back to back SCRs are duly interfaced through optical isolation which is obtained from the programmed microcontroller are then connected in series for switching the Inductive reactor (in our case a choke is used) [6]. In a conventional AC long transmission system, the ability of the system to transfer AC power from source to load is limited by several factors which are transient stability limit, thermal limits, short circuit current limit, voltage limit and introduction of variable impedance devices like capacitors and inductors due to which complete power from the source is not transferred to the load, but a part is stored in these devices [7]. Theselimits the maximum electric power which can be efficiently transmitted through the transmission line without causing much damage to the connected electrical equipments to the system and the transmission lines. This can be normally achieved by bringing respective changes in the power system layout.

However this is not that feasible and an another way of achieving maximum power transfer capability without causing any changes in the power system layout which is done using FACTS controllers. This is where the need of the FACTS controllers comes.

III. OBJETIVES OF FACT CONTROLLERS

The main objectives of FACTS controllers are described as follows
1. Damping of oscillations that threaten the security or limit the usable power capacity.
2. Securing the loading of long transmission lines closer to their thermal limits.
3. Reduces the line voltage drops and the transmission power angle.
4. To mitigate sub synchronous resonance and improve system stability [8].
5. To minimize short circuit currents and to limit load-dependent voltage drops.
6. Prevention of cascading outages by contributing to the emergency control.
7. Regulation of electric power flows in well defined transmission routes.
8. To improve terminal performance of connected HVDC converter [9].

IV. TYPES OF FACT CONTROLLERS

The different FACTS controllers are as follows
1. Series Controllers: Series Controllers consists of multiple capacitors or reactors or both which introduces the voltage in series with the transmission line. They are variable impedance devices basically. However their major task is just to reduce the inductivity present in the transmission line. As long as the voltage is in phase quadrature with the line current, the series controller only supplies or consumes variable reactive power [10]. Examples of series controllers are SSSC, TCSC, TSSC etc

2. Shunt Controllers: Shunt controllers consist of multiple variable impedance devices like capacitors or reactors which thus introduce current which is in series with the transmission line [10]. Their main task is to reduce the power capacity of the transmission line. They inject the current which is in phase with the transmission line voltage. Examples of shunt controllers are STATCOM, TSR, TSC, SVC.

3. Shunt-Series Controllers: This type of controller introduces the current in series of the transmission line using the series controllers and voltage in shunt of the transmission line using the shunt controllers. Example of the Shunt-Series controllers is UPFC.

4. Series-Series Controllers: These controllers basically consist of the combination of series controllers which are controlled in a coordinated manner in a multiline transmission system where each controller is providing series compensation to the system and also transfers real power along the transmission line [11]. Example of the Series-Series controller is IPFC which , makes it possible to balance both real and reactive power flow in the lines and thereby maximize the utilization of the transmission system

The Series Controllers are classified as

1. Thyristor controlled series capacitor (TCSC): Thyristor controlled series capacitor (TCSC) uses few silicon controlled rectifiers to manage the capacitor bank which is connected in series with the transmission line. This thus allows the utility companies for transferring more and more power on a specified well defined transmisson line. It generally consists of the multiple thyristors which are connected in series with the inductor (Inductive reactance) and connected across a capacitor (Capacitive Reactace). It can operate in the blocking mode where no pulse is given to the thyristor and current passes through the capacitor only in that case [12]. It can work in the bypass mode aswell where the current is bypassed to the thyristor connected and as a result the whole system behaves as a shunt impedance power network

2. Static Series Synchronous Compensators: The Static Series Synchronous Compensators abbreviated as SSSC is simply a series version of STATCOM. These are usually not used in commercial and industrial applications as independent controllers. It consists of synchronous voltage source which is in series with the transmission line such that it introduces a compensating voltage which is in series with the transmission line. They can increase or decrease the voltage drop across the transmission line.

Types of Static VAR Compensator (SVC) are
1. Thyristor Switched Reactor: It basically consists of a shunt connected inductor whose impedance is controlled using the Thyristor switch in a gradual manner. The Thyristor is only fired at angles of 90 and 180 degrees respectively.

2. Thyristor Switched Capacitor: It consists of the capacitor which is connected in shunt whose impedance is controlled using a Thyristor in a step wise manner. The controlling phenomenon is same as that of Thyristor Switched Reactor

3. Thyristor Controlled Reactor: It consists of the inductor which is connected in shunt whose impedance is controlled using firing angle delay method of SCR where the firing of the Thyristor is controlled which causes the variation in the current through the inductor connected.

V. BLOCK DIAGRAM

The block diagram of the FACTS using Thyristor Controlled Reactance is as shown in fig (1)

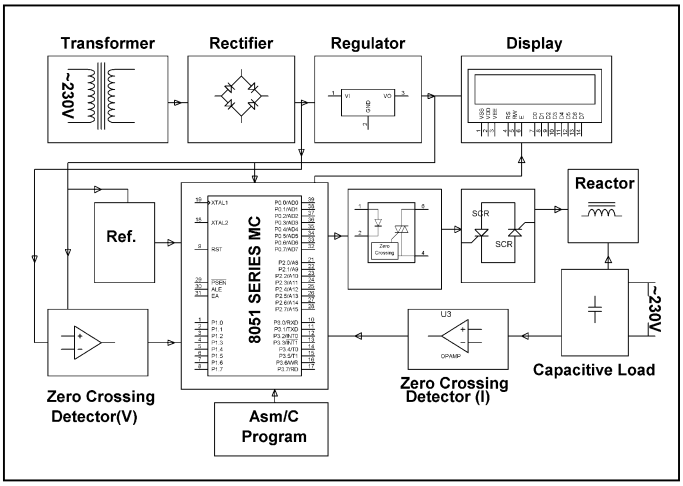

Fig (1) Block Diagram of FACTS using TCR

VI. POWER SUPPLY

The power supply required for the Thyristor Controlled Reactance is as shown in fig (2).

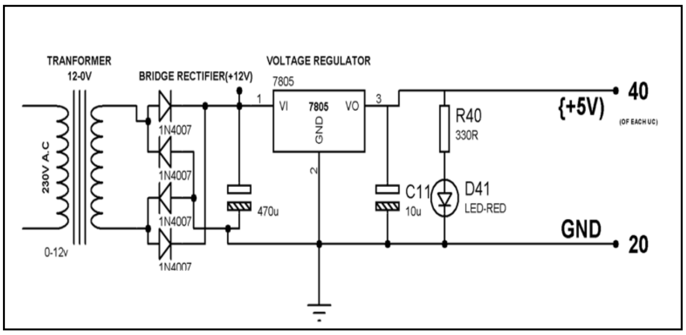

Fig (2) Power supply required for Thyristor Controlled Reactance

VII. ADVANTAGES

1. Control of electric power flow to follow a well defined contract, meet the utilities requirements, ensure optimum power flow through the system and minimize the emergency conditions occurring in the system
2. Environmental impact: In order to provide new transmission line routes to supply the continuous increasing worldwide demand of electrical power, it is extremely necessary to acquire the right to convey electrical energy over a given transmission route. It is thus common for environmental opposition to throw out frustrate attempts to establish new transmission routes. FACTS technology, however, allows greater throughput over existing transmission routes, thus meeting the instantaneous consumer demand without the construction of new transmission lines or upgrading the length of existing transmission lines [13].
3. Cost: Due to high capital cost of transmission system, cost considerations frequently overweigh all other respective considerations. Compared to alternative methods of solving transmission loading issues, FACTS technology is often the most economic option to choose to transmit the maximum electric power with minimum additional cost.
4. It contribute to the optimal system operation by reducing the various power losses and improving voltage stability profile
5. Convenience: All FACTS controllers can be retrofitted to existing ac transmission plant with varying degrees of ease Compared to HVDC or six-phase AC transmission schemes, solutions can be provided within a reasonable timescale.
6. Increase the loading capability of the transmission lines to their thermal capabilities
7. Overcome the problem of voltage fluctuations
8. Reduce the loop flows and to increase utilization of least cost generation
9. Provide greater flexibility in sitting new generation system
10. Provide secure tie line connections to the neighboring utilities and regions thereby decreasing overall generation reserve requirements on both sides of the transmission lines
11. Reduce reactive electric power flows, thus allowing the lines to carry more active power throughout the system.
12. Increase the security of the system by raising the limit of transient stability, limiting the short-circuit currents and overload current, managing the cascading blackouts and damping the electromechanical oscillations of power systems and machines connected [14].

VIII. CONCLUSION

It is envisaged that in the near future, The FACTS controllers could be installed on wide scale by electrical utilities companies as an attempt to control the electric power flows through the controlled well defined networks. Concern has however been expressed that such wide scale application of FACTS controllers could result in conflict between the various control systems of the different devices thus connected. By using the advanced solid state technology, FACTS controllers offer flexibility and enhance the controllability of the system operation fast and reliable control. FACTS controllers ensure better quality in modern power systems. Their main capabilities are reactive power compensation, power flow control and voltage control. Due to their controllable power electronics, FACTS controllers always provide faster control actions in comparison to the existing conventional devices

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