Implementation of TCSC for Enhancement of ATC

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***Abstract*-Power system engineers are currently facing challenges to increase the power transfer capabilities of existing transmission system. The Flexible AC Transmission Systems (FACTS) technology with relatively low investment, compared to new transmission or generation facilities, allows the industries to better utilize the existing transmission lines. FACTS controllers in the deregulated electricity market allow the system to be used in more flexible way with increase in various stability margins. The FACTS controllers clearly enhance power system performance, improve quality of supply and also provide an optimal utilization of the existing resources. Thyristor Controlled Series Compensator (TCSC) is a key FACTS controller and is widely recognized as an effective and economical means to enhance power transfer capability. In Deregulating power systems, Available transfer capability (ATC) determination and calculation are important for efficient and competitive utility operation.**

The thesis aims to present reliable method to meet the requirements by developing a Newton-Raphson based load flow calculation through which control settings of TCSC can be determined for the prespecified power flow between the lines. The proposed method keeps the NRLF algorithm intact and needs little modification in the jacobian matrix.

A MATLAB program has been developed to calculate the power flow and losses between the lines. Also the program for ATC Calculation has been developed. To find out the optimal location of TCSC a sensitivity index is calculated. The case studies have been performed on IEEE 6 bus and 39 bus system to show that the proposed method is effective.

The test results for IEEE 6 bus and 39 bus system are obtained which shows the losses between the lines, and the Available Transfer Capability of the lines without and with incorporation of TCSC.

It can be concluded that after the incorporating of TCSC the losses of the lines reduces. The Available Transfer Capability of the system can be enhanced by implementing the TCSC.

Keywords: Development of Power Systems – Power Electronics - FACTS and TCSC – System Stability - Transmission Efficiency- Available Transfer Cabality

I. INTRODUCTION

The power system is an interconnection of generating units to load center through high voltage electric transmission lines and in general is mechanically controlled. It can be divided into three subsystems: generation, transmission and distribution subsystems. Until recently all three subsystems were under supervision of one body within a certain geographical area providing poor at regulated rates. In order to provide cheaper electricity the deregulation of power system, which include separate generation, transmission and distribution companies is already being implemented. At the same time electric power demand continues to grow and also building of the new generating units and transmission circuits is becoming more difficult because of economic and environmental reasons. Therefore power utilities are forced to rely on utilization of existing generating units and to load existing transmission lines close to their thermal limits. However stability has to be maintained at all times. Hence, it is necessary to operate power system effectively, without reduction in the systems security and quality of supply even in the case of contingency conditions. The contingency may be such as loss of transmission lines and generating units, which occur frequently and will most probably occur at higher frequencies. So a new control strategies need to be implemented. To take care of such expected situations.

In the late 1980s the electric power research institute (EPRI) has introduced a new technology program known as flexible AC transmission system (FACTS). The main idea behind this program was to increase controllability and optimize the utilization of the existing power system capacities by replacing mechanical controllers by reliable and high speed power electronic devices.

Power electronic devices had a revolutionary impact on the electric power systems around the world. The availability and application of thyristors has resulted in a new breed of thyristor based fast operating device for control and switching operations. Flexible AC transmission system (FACTS) devices are new comings, which have found a wide spread application in the power industry for active and reactive power control.

II. LIMITATIONS OF LARGE AC SYSTEM

A. *Long Distance Transmission Systems*

1. Voltage Stability
2. Reactive Power Problems
3. Steady- state stability
4. Transient Stability
5. Sub synchronous Oscillations

B. Interconnected systems

1. Frequency control
2. Voltage Stability
3. Oscillation Stability
4. Load flow problems
5. Inter – Area oscillations
6. Physical interconnection between power Systems
7. Blackout Risk due to cascading effects

III. THYRISTOR CONTROLLED SERIES COMPENSATOR

It is obvious that power transfer between areas can be affected by adjusting the net series impedance. One such conventional and established method of increasing transmission line capability is to install a series capacitor, which reduces the net series impedance, thus allowing additional power to be transferred. Although this method is well known, slow switching times is the limitation of its use.

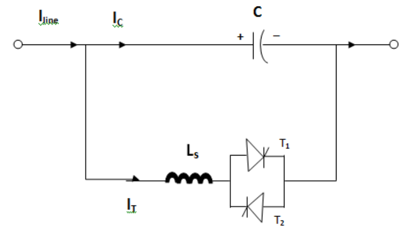
Thyristor controllers, on the other hand, are able to rapidly and continuously control the line compensation over a continuous range with resulting flexibility. Controller used for series compensation is the Thyristor Controlled Series Capcitor (TCSC).

A. Constructional Features

TCSC controllers use thyristor-controlled reactor (TCR) in parallel with capacitor segments of series capacitor bank (Figure 1). The combination of TCR and capacitor allow the capacitive reactance to be smoothly controlled over a wide range and switched upon command to a condition where the bi-directional thyristor pairs conduct continuously and insert an inductive reactance into the line.

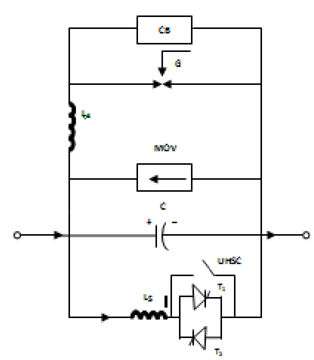
TCSC is an effective and economical means of solving problems of transient stability, dynamic stability, steady state stability and voltage stability in long transmission lines.TCSC, the first generation of FACTS, can control the line impedance through the introduction of a thyristor controlled capacitor in series with the transmission line.

A TCSC is a series controlled capacitive reactance that can provide continuous control of power on the ac line over a wide range. The functioning of TCSC can be comprehended by analyzing the behavior of a variable inductor connected in series with a fixed capacitor, as shown in Figure 1.



B. Practical Module

A practical TCSC module also includes protective equipment normally installed with series capacitors, as shown in Fig.2. A metal-oxide varistor (MOV), essentially a nonlinear resistor, is connected across the series capacitor to prevent the occurrence of high-capacitor over-voltages. Not only does the MOV limit the voltage across the capacitor, but it allows the capacitor to remain in circuit even during fault conditions and helps improve the transient stability. Also installed across the capacitor is a circuit breaker, CB, for controlling its insertion in the line. In addition, the CB bypasses the capacitor if severe fault or equipment-malfunction events occur. A current-limiting inductor, *Ld*, is incorporated in the circuit to restrict both the magnitude and the frequency of the capacitor current during the capacitor-bypass operation. If the TCSC valves are required to operate in the fully “on” mode for prolonged durations, the conduction losses are minimized by installing an ultra–high-speed contact (UHSC) across the valve. This metallic contact offers a virtually lossless feature similar to that of circuit breakers and is capable of handling many switching operations. The metallic contact is closed shortly after the thyristor valve is turned on, and it is opened shortly before the valve is turned off. During a sudden overload of the valve, and also during fault conditions, the metallic contact is closed to alleviate the stress on the valve. Fig.2.



IV. CASE STUDY AND RESULT ANALESYS

A. Case Study **-** An IEEE 6 bus network has been used to show how the TCSC performs. The original network is modified to include the TCSC. The TCSC is used to regulate the active and reactive power flow in the line, decreases the losses and increases the available transfer capability of the line. The load flow solution for the modified network is obtained by using Newton-Raphson method.

B. Analysis for IEEE 6 Bus System Case: 1

In Case-1, the standard data is taken into consideration for ATC calculation by direct method analysis without and with TCSC.

1) IEEE 6 Bus Network

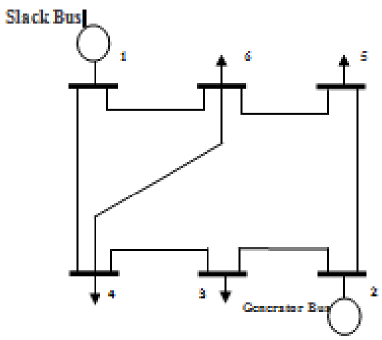


TABLE NO. 1

BUS DATA FOR IEEE 6 BUS SYSTEM (CASE – 1)

Bus No.	Bus Type	Pg	Qg	Pl	Ql	VM	VA
1	1	0	0	0	0	1.05	0
2	2	0.45	0.24	0	0	1.07	0
3	3	0	0	-0.275	-0.065	1	0
4	3	0	0	0	0	1	0
5	3	0	0	-0.15	-0.09	1	0
6	3	0	0	-0.25	-0.005	1	0

TABLE NO. 2

LINE DATA FOR IEEE 6 BUS SYSTEM

Line No.	Between Buses	R in p.u.	X in p.u.	Half-line charging susceptance in p.u.
1	1-6	0.123	0.518	0.03
2	1-4	0.08	0.37	0.01
3	2-3	0.0723	1.05	0.022
4	2-5	0.282	0.064	0.12
5	3-4	0	0.133	0.33
6	4-6	0.097	0.407	0.01
7	6-5	0	0.3	0.025

2) ATC Calculation of IEEE – 6 Bus System with Direct Method:

a) Calculation of ATC without using TCSC:

- No. of iteration (it) = 6
- S= TOTAL PQLOSS = **0.0361 - 0.5667i**
- Total load = 0.675 (Pload) 0.160 (Qload)
- Total Generation = 0.711 (Pgen) -0.407 (Qgen)
- Enter the Value of Real Power for TTC (active) -->3
- Enter the Value of Reactive Power for TTC (reactive) -->2
- Enter the Percentage of TRM (%) -->10
- Total Available Transfer Capability = **1.989 (active) 2.207 (reactive)**

b) Calculation of ATC with TCSC between Bus-2 and Bus-5:

- No. of iteration (it) = 6
- S= TOTAL PQLOSS **0.0028 -0.5350i**
- Total load = 0.675 (Pload) 0.160 (Qload)
- Total Generation = 0.678 (Pgen) -0.375 (Qgen)
- Enter the Value of Real Power for TTC (active) -->3
- Enter the Value of Reactive Power for TTC (reactive) -->2
- Enter the Percentage of TRM (%) -->10
- Total Available Transfer Capability = **2.022 (active) 2.175 (reactive)**

c) Summary:

TABLE NO. 3

SUMMARY FOR CASE – I OF IEEE 6 BUS SYSTEM

TCSC STATUS	TOTAL GENERATION		TOTAL LOAD		TOTAL LOSSES		ATC	
	Pgen	Qgen	Pload	Qload	Active	Reactive	Active	Reactive
WITHOUT TCSC	0.711	-0.407	0.675	0.160	0.0361	-0.5667	1.989	2.207
WITH TCSC (1 - 6)	0.693	-0.383	0.675	0.160	0.0182	-0.5430	2.007	2.183
WITH TCSC (1 - 4)	0.693	-0.386	0.675	0.160	0.0179	-0.5459	2.007	2.186
WITH TCSC (2 - 3)	0.694	-0.383	0.675	0.160	0.0190	-0.5430	2.006	2.183
WITH TCSC (2 - 5)	0.678	-0.375	0.675	0.160	0.0028	-0.5350	2.022	2.175
WITH TCSC (3 - 4)	0.694	-0.380	0.675	0.160	0.0193	-0.5399	2.006	2.180
WITH TCSC (4 - 6)	0.694	-0.380	0.675	0.160	0.0193	-0.5399	2.006	2.180
WITH TCSC (6 - 5)	0.694	-0.380	0.675	0.160	0.0193	-0.5399	2.006	2.180

CONCLUSION

Thyristor Controlled Series Capacitor (TCSC) is a variable impedance type series compensator and is connected in series with the transmission line to increase the power transfer capability, improve transient stability, reduce transmission losses and dampen power system oscillations.

In this thesis an IEEE 6 bus system is taken into consideration to observe the effects of TCSC for enhancement of Available Transfer Capability. Load flow studies were conducted on given system to find the power flow and system losses. The MATLAB program is run with and without incorporation of TCSC. The TCSC is connected in series with the line to improve the Available Transfer Capability of the line. From the result it has been observed that the line losses are reduced and Available Transfer Capability is improved. Also the location of TCSC is an important factor. By placing the TCSC on a sensitive line we can get better improvement in the result compared to other lines. So, it can be concluded that after incorporation of TCSC the line losses are reduced and Available Transfer Capability of the line is improved. Sensitivity analysis is one of the best methods to find out the optimal location of TCSC.

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