

SENSITIVITY BASED OPTIMAL LOCATION OF TCSC FOR IMPROVEMENT OF POWER SYSTEM SECURITY

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Abstract

Over the last two decades, instability problem in power systems have become one of the most important concerns in the power industry which lead to blackouts. So, it is very important to have high efficiency, maximum reliability, and security in design and operation of power system. Recent development of power electronics introduces the use of flexible ac transmission system (FACTS) controllers in power systems. FACTS controllers are capable of controlling the network condition in a very fast manner and this feature of FACTS can be exploited to improve the stability of a power system. Thyristor controlled series compensator (TCSC) is one of the FACTS devices used for maintaining and enhancing the power system security. This paper gives a review about different methods used for enhancement of power system security.

Keywords: TCSC (thyristor controlled series compensator), FACTS, Sensitivity index.

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1. INTRODUCTION

Now days, the load on the power system is increasing day by day with increasing population. As load on the power system is increasing, the transmission networks are working near to its thermal and voltage limits, leading threat to the power system security. Under severe conditions of overloading, the whole system can lead to blackout. It is very important for power system security and reliability that transmission network should work within its safe limits. But with increasing load demands it is also necessary to utilize the maximum capacity of transmission network within safe limits, as there are many difficulties in constructing new lines [2].

Flexible alternating currents transmission system (FACTS) devices such as thyristor controlled series compensator (TCSC), Static Var Compensator (SVC), can provide benefits in increasing system transmission capacity and power flow control flexibility [2]. FACTS devices are used as modern active and reactive power compensators. The available capacities of transmission lines can better be utilized by allocation of FACTS devices. These devices are used to control the power flow in the network, also are helpful to reduce the power flows in the heavily loaded lines, resulting in an increased loadability, low system loss, improved stability of the network.

Thyristor controlled series compensator is used in series with the transmission line to compensate the line reactance and improve its transmission capability.[4]

2. THYRISTOR CONTROLLED SERIES COMPENSATOR (TCSC)

In electrical power system series compensation is utilized successfully from several years. The transfer capability of existing transmission network can be increased by using series compensation at lower investment cost. TCSC is one of series compensator with fast controlling action. TCSC is one of the series device used to control the reactance of the transmission line, so as to provide the sufficient load compensation.

TCSC is composed of thyristor controlled reactor in parallel with the capacitor, this combination provides the smoothly variable reactance over a wide range. TCSC can act as an inductive or capacitive compensator by modifying the reactance of transmission lines. Fig. 1 below shows the diagram for TCSC. Some of the advantages of TCSC include:

- It eliminates risk of subsynchronous resonance.
- Active power oscillations are damped.
- Improves post-contingency stability.
- Controls dynamic power flow control .

Using TCSC, the power flows can be control so as to achieve a number of goals:

- It minimizes system loss
- Lie overloads can be eliminated.
- Load sharing between parallel lines can be optimized.
- Power flows can be directed along contractual paths.

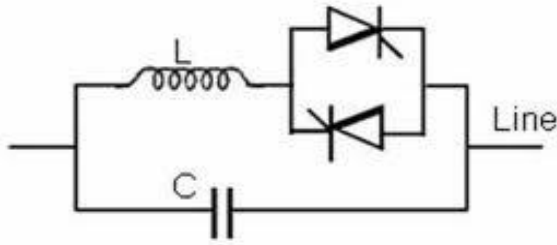


Fig 1:- Diagram for Thyristor controlled series compensator (TCSC).

The impedance characteristics curve of a TCSC device shows that by varying its firing angle (α) or by varying its reactance it can work in both the regions inductive as well as capacitive [1].

3. OPTIMAL LOCATION OF TCSC

For optimal location of TCSC, the sensitivity index method has been used. The severity of system loading under normal conditions can be described by a real power line flow performance index as given below.

$$PI = \sum_{m=1}^{NL} \frac{W_m}{2^n} \left(\frac{P_{LM}}{P_{LM}^{max}} \right)^{2n}$$

Where

P_{LM} is the real power flow in a line.

P_{LM}^{max} is the rated capacity of line m.

NL is the number of lines.

n is the exponent

W_m is a real non- negative weighting coefficient which may be used to reflect the importance of lines.

Performance index (PI) will have small value when lines are within their limits and have high values when lines are overloaded. Thus, it provides a good method to measure the severity of the line overloaded for the given state of power system.

The sensitivity of PI with respect to TCSC parameter connected between bus-i and bus-j can be written as:

$$\frac{\partial PI}{\partial x_{ck}} = \sum_{m=1}^{NL} W_m P_m^3 \left(\frac{1}{P_{lm}^{max}} \right)^4 \frac{\partial P_{lm}}{\partial x_{ck}}$$

The real power flow in a line m can be represented in terms of real power injections using DC power flow equations where s is the slack bus.

$$P_{lm} = \begin{cases} \sum_{\substack{n=1 \\ n \neq s}}^N S_{mn} P_n \\ \sum_{\substack{n=1 \\ n \neq s}}^N S_{mn} P_n + P_j \end{cases}$$

$$\frac{\partial P_{Lm}}{\partial x_{ck}} = \begin{cases} \left(S_{mi} \frac{\partial P_i}{\partial x_{ck}} + S_{mj} \frac{\partial P_j}{\partial x_{ck}} \right) \\ \left(S_{mi} \frac{\partial P_i}{\partial x_{ck}} + S_{mj} \frac{\partial P_j}{\partial x_{ck}} \right) + \frac{\partial P_j}{\partial x_{ck}} \end{cases}$$

Where the terms

$$\left. \frac{\partial P_i}{\partial x_{ck}} \right|_{x_{ck}=0} \text{ and } \left. \frac{\partial P_j}{\partial x_{ck}} \right|_{x_{ck}=0} \text{ can be given by}$$

$$\left. \frac{\partial P_i}{\partial x_{ck}} \right|_{x_{ck}=0} = (V_i^2 - V_i V_j \cos \delta_{ij}) * 2 * B_{ij} * G_{ij} - V_i V_j \sin \delta_{ij} (B_{ij}^2 - G_{ij}^2)$$

And

$$\left. \frac{\partial P_j}{\partial x_{ck}} \right|_{x_{ck}=0} = (V_j^2 - V_i V_j \cos \delta_{ij}) * 2 * B_{ij} * G_{ij} + V_i V_j \sin \delta_{ij} (B_{ij}^2 - G_{ij}^2)$$

The real power flow sensitivity index has been calculated for different lines using the above equations.

For the best suitable location, TCSC should be placed on the line having least sensitivity. The sensitivity index calculated for the different lines are shown in table below [3].

4. SIMULATION AND RESULTS

The optimal location of TCSC has been found by implementing analysis over 14 bus systems. 14-bus system is as shown in fig below.

Power flow for system has been found by using MATLAB programming. The result for power flow is as shown in table 1, it also shows the limits for different transmission lines.

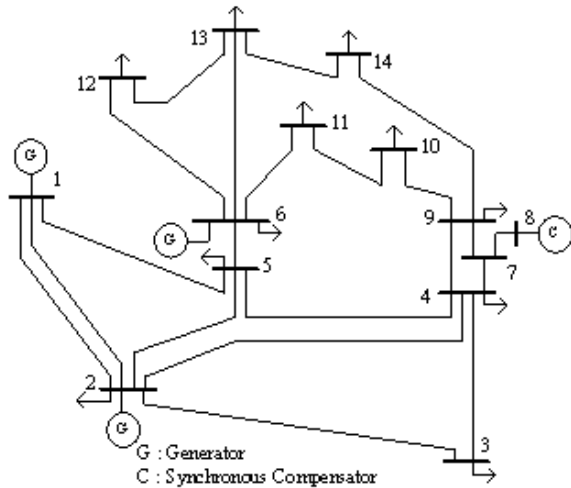


Fig 2: 14 bus system

Table 1: Power flow in different transmission lines

Branch	From Bus	To Bus	Real power flow	Limit
1	1	2	1.5688	1.5
2	1	5	0.7551	1
3	2	3	0.7324	1
4	2	4	0.5613	1
5	2	5	0.4152	1
6	3	4	-0.2329	1
7	4	5	-0.6116	1
8	4	7	0.2807	1
9	4	9	0.1608	1
10	5	6	0.4409	1
11	6	11	0.0735	1
12	6	12	0.079	1
13	6	13	0.1775	1
14	7	8	0	1
15	7	9	0.2807	1
16	9	10	0.0523	1
17	9	14	0.0943	1
18	10	11	-0.0379	1
19	12	13	0.0161	1
20	13	14	0.0564	1

From the power flow results it was found that the branch 1 is operating above its limits. So to maintain the system security it was necessary to operate this line within its safe limits. This can be achieved by proper allocation of TCSC device in transmission line.

Table 2 shows the location of TCSC device in different branches and power flow before and after placing TCSC in

branch 2. The TCSC device was placed in some branches and it was found that with TCSC in line 1-5, the power flow of branch 2 is under its limits and no other line is violating its limits. The compensation provided is 37%. The TCSC reactances for different cases are also in table 2 below.

Table 2: TCSC location and compensation for different lines

S. No.	TCS C Location	TCSC Reactance	Compensation	Power flow Before TCSC in line1-2	Power flow After TCSC in line1-2
1	1-5	-0.0825	0.37	156.88	136.43
2	2-5	0.0643	0.37	156.88	154.01
3	4-5	-0.0155	0.37	156.88	155.57
4	3-4	-0.063	0.37	156.88	156.24

Table 3: Sensitivity index for transmission lines

S. No.	Line	Sensitivity Factor
1	1-5	8.7510
2	2-5	13.2196
3	4-5	14.2005
4	3-4	15.1932

The real power flow performance index for the same lines have been calculated and again it was found that branch 1-5 has least value of real power sensitivity index and it is most suitable for the placement of TCSC device.

5. CONCLUSIONS

Power system security is the major concern of the transmission network operators. FACTS devices such as TCSC can be helpful in improving the transmission network loadability by increasing or decreasing the transmission line reactance. For the best results it is very necessary to find the optimal location of TCSC device.

In this paper real power sensitivity based method has been used to find the optimal location of TCSC device and it was found that by placing TCSC device at proper location the overloaded lines can share its load with different lines for safe and secure operation of power system.

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