# Power flow analysis with TCSC using Newton- Raphson Method

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**Abstract:- In this paper, Newton Raphson power flow algorithm in matlab incorporating TCSC is presented. Overview of the different static load models for distribution system has been covered and included in N-R power flow. This paper present effect of TCSC level on transmission system voltage profile for different types of static load types , in which active and reactive power vary with its terminal voltages with as in exponential form, variation of the load voltage for different sizes of TCSC are simulated with 5 bus. It has also been observed that the proposed algorithm can be applied to larger systems and does not suffer with computational difficulties**

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## 1. INTRODCTION:

When large power systems are interconnected by relatively weak tie lines, low frequency oscillations are observed. These oscillations may sustain and grow to cause system separation if no adequate damping is available .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 important members of FACTS family that is increasingly applied with long transmission lines by the utilities in modern power systems. It can have various roles in the operation and control of power systems, such as scheduling power flow; decreasing unsymmetrical components; reducing net loss; providing voltage support limiting short-circuit currents; mitigating sub-synchronous resonance (SSR); damping the power oscillation; and enhancing transient stability . The problem of FACTS controller parameter tuning is a complex exercise as uncoordinated local control of FACTS controller may cause destabilizing interactions . The demand of electrical power is ever increasing. However, the process of development of new infrastructure for power generation and dispatch is restricted due to mainly economic and partially environmental constraints. These result in the need for better utilization of the existing system. Flexible AC transmission system (FACTS) controllers are potent tools to achieve this goal. These devices help in pushing the system to their limits and thus to attain higher operational efficiency. The use of these controllers increases the flexibility of operation by providing more options to the power system operators.

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**2.TCSC ( Thyristor controlled series capacitor):**

The configuration of TCSC is shown in ***Figure 3.*** TCSC configuration uses the thysisitor –controlled reactors (TCR's) is parallel with a segment of a capacitor bank. This configuration allows the fundamental frequency capacitive reactance to be smoothly controlled over a wide range and switch to a condition where the bi-directional thyristor pairs conduct continuously and insert an inductive reactance in the line.
D1 and D2 are high power diode

L= Air cored inductor (few mH)

MOV = Metal oxide Varistor provided across the capacitor to prevent the over voltage across the capacitor.

Capacitor bank may have the reactance of 10-30 Ω/Ph and rated for continuous current 1500-3000 A rms. The capacitor bank for each phase mantled on a platform providing full insulation towards ground.

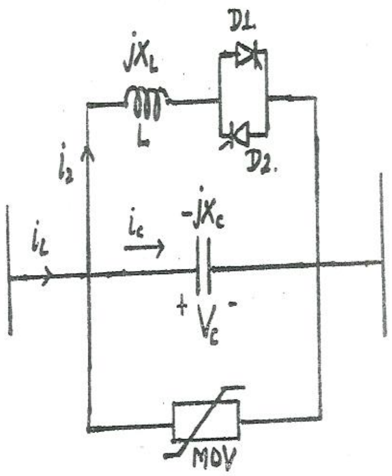


Figure 1.

Thyristor Controlled Series Capacitor

3.**POWER FLOW ANALYSIS WITH TCSC:**

Power flow or Load flow is the solution obtained for power system under the static condition of operations, the load flows studies are carried out to determine :-

i)line losses
ii) The bus voltages and the system voltage profiles
iii) The effect of the changes in the circuit configuration and incorporating new circuits on system loading
iv) The effect of temporary loss of transmission capacity and (or) generation on the system loading and accompanied factor
v) The effect of in phase and quadrature boost voltage on the system loading
vi) Economic operation system
vii) System transmission loss minimization
viii) Transfor for tap setting operation
ix) Possible improvement to the existing system by changing load configuration or system voltages
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## *4.Power Flow Problem*

Power flow studies are performed to calculate the magnitude of phase angles of voltages at the buses and also the active power and reactive VA flow for the given terminal or bus conditions. The following variables associate with each bus:-

i) Magnitude of voltage │Vi │

ii) Phase angle of voltages δi
iii) Active power Pi and
iv) Reactive VA Qi

There are three types of buses used in power flows studies. At each bus two variables are specified and two are to be determined. The bus classifications depend upon the specified variable. The buses are classified as

**TABLE - 1**
BUS CLASSIFICATION

| S. No. | Bus Type | Specified Variable | Unknown Variable | Remarks |
|---|---|---|---|---|
| 1 | Slack Bus | IViI δi | Pi Qi | First responds to a changing load conditions |
| 2 | Generator Bus | Pi IViI | δi Qi | Often upper and lower limits of Q are given. |
| 3 | Load Bus | Pi Qi | IViI δi | Buses with no generator but load is considered as load bus |

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## 5.PROBLEM FORMULATION AND RESULT:

Power Flow Analysis using TCSC has been undertaken for Five Bus System presented hereunder:

**CASE: FIVE BUS SYSTEM**

A 5 bus system as shown in Figure-9 below has been considered. The system parameters are given in Table - 4 and Load and Generation data are as presented in Table -5. The bus voltage at bus 2 is maintained at 1.05 p.u.. The maximum and minimum reactive power limits of generator bus 2 are 20 and 60 Mvar respectively. Bus 1 is taken as slack bus.

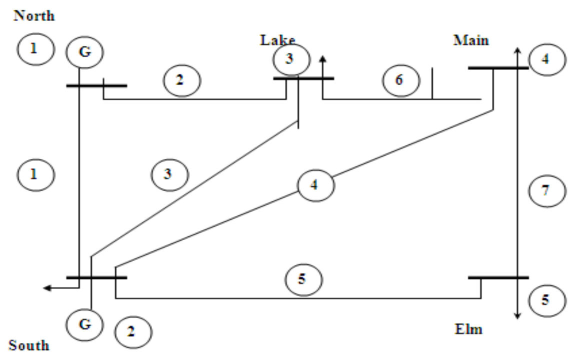


Fig-9 – Five Bus System

| Bus Code p | Line Admittance $Y_{pq}$ |
|---|---|
| 1-2 | 5.00000 – j15.00000 |
| 1-3 | 1.25000 – j3.750000 |
| 2-3 | 1.66667 – j5.00000 |
| 2-4 | 1.66667 – j5.00000 |
| 2-5 | 2.50000 - j7.50000 |
| 3-4 | 10.0000 – j30.0000 |
| 4-5 | 1.25000 – j3.75000 |

**TABLE-4**

FIVE BUS PARAMETERS

**TABLE –5**

Line admittances and line charging:

| Bus Code p-q | Impedance $z_{pq}$ | Line Charging $Y'_{pq}/2$ |
|---|---|---|
| 1-2 | 0.02 + j0.06 | 0.0 + j0.030 |
| 1-3 | 0.08 + j0.24 | 0.0 + j0.025 |
| 2-3 | 0.06 + j0.18 | 0.0 + j0.020 |
| 2-4 | 0.06 + j0.18 | 0.0 + j0.020 |
| 2-5 | 0.04 + j0.12 | 0.0 + j0.015 |
| 3-4 | 0.01 + j0.03 | 0.0 + j0.010 |
| 4-5 | 0.08 + j0.24 | 0.0 + 0.025 |

**Results**

For the TCSC parameter let the capacitance offers the **r**eactance of –0.12 p.u. In the thyristor arm let the firing angle alpha=150.0 degree which regulates the inductive reactance in this arm. To compute the reactance of inductance the load flow has done for getting optimal flow in compensated line. The result is given below when each line is compensated by same amount respectively. Let us want to compensate each and every line by amount of 0.04 p.u. capacitive reactance of TCSC,$X_{TCSC}$=-0.04pu

### Case 2.1

In this case TCSC is installed in line1(bus1-2)

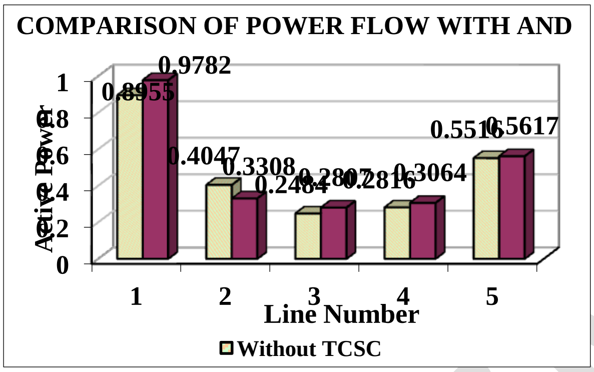


Fig-10

Above figure -10 shows the variation of power flow after TCSC has been installed on line1 (bus1-2)..Line 1 (1-2) power flow capability has been increased by 9.23% . Due to TCSC, power flow d capability of other lines also increased. Figure-11 shows the line losses of different lines after TCSC has been installed on line1(1-2)

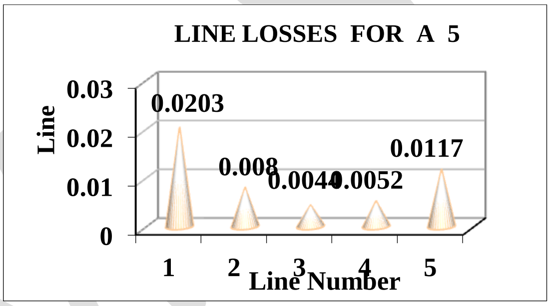


Fig-11

### Case-2.2

In this case TCSC is installed in line2(1-3)

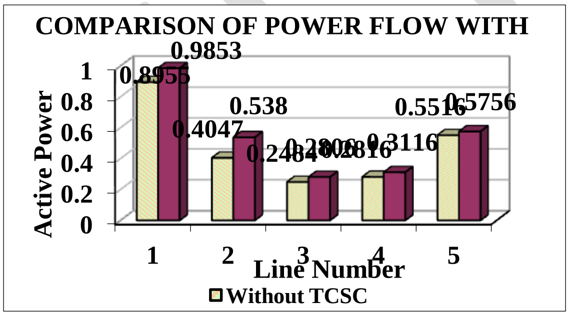


Fig-12

Above figure -12 shows the variation of power flow after TCSC has been installed on line2 (bus1-3)..Line 1 (1-2) power flow capability has been increased by 10.028%

.The maximum increase in power flow capability is in line2(1-3) Due to TCSC, power flow capability of other lines also increased. Figure-13 shows the line losses of different lines after TCSC has been installed on line2 (1-3).

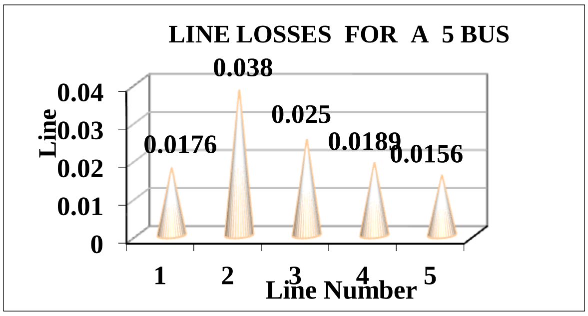


Fig-13

### Case 2.3

In this case TCSC is installed in line3 (2-3)

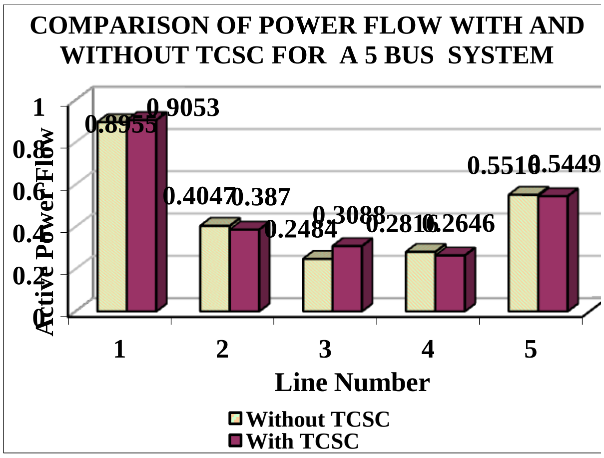


Fig-14

Above figure- 14 shows the variation of power flow after TCSC has been installed on line3 (bus2-3)..Line 3 (2-3) power flow capability has been increased by 24.31% .The maximum increase in power flow capability is in line3(2-3). But due to TCSC, power flow capability of other lines do not increased. Figure-15 shows the line losses of different lines after TCSC has been installed on line3(2-3)

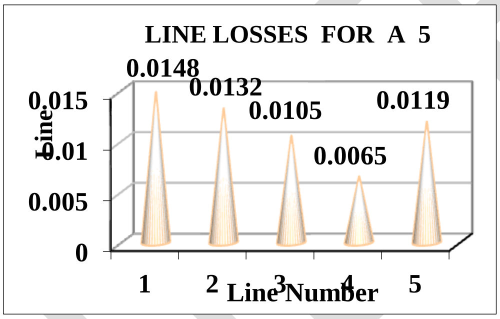


Fig-15

## Case 2.4

In this case TCSC is installed in line 4 (2-4)

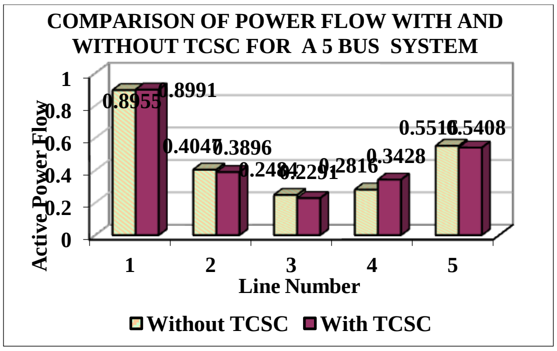


Fig-16

Above figure -16 shows the variation of power flow after TCSC has been installed on line4 (bus2-4)..Line4(2-4) power flow capability has been increased by 21.73% .The maximum increase in power flow capability is in line4(2-4). But due to TCSC, power flow capability of other lines do not increased.This has negate effect on other lines. Figure-17) shows the line losses of different lines after TCSC has been installed on line4(2-4)

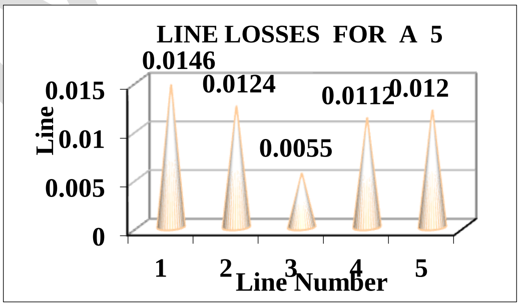


Fig-17

## Case-2.5

In this case TCSC is installed in line 7 (4-5)

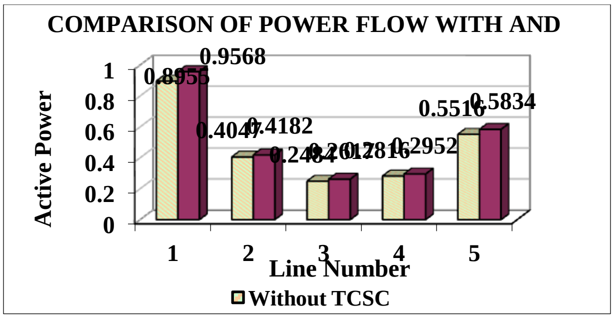


Fig-18

Above figure -18 shows the variation of power flow after TCSC has been installed on line4 (bus4-5)..Line7(4-5) power flow capability has been increased .The maximum increase in power flow capability is in most heavily loaded line1(1-2).Due to TCSC, power flow capability of other lines also increased. Figure-19 shows the line losses of different lines after TCSC has been installed on line7 (4-5)

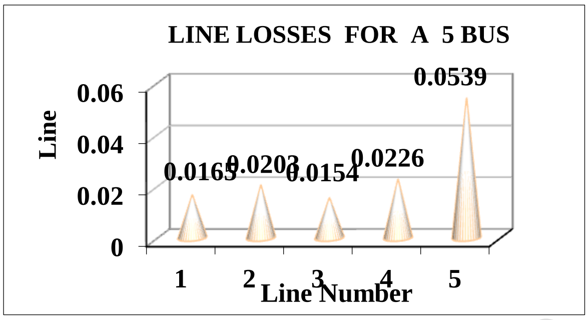


Fig-19

## Discussions and Conclusion

The motivation of this paperis to develop an algorithm in matlab to choose the location of FACTS devices – TCSC Thyristor Control Series Capacitor to maximize the power flow in a given power network based on load flow studies using Newton Raphson method. The main purpose of load flow a study is to analyze in which line TCSC should be installed so that the overall power flow capacity of transmission line is increased. This attempt has been made in Chapter 4 – "Power Flow Analysis with TCSC" in which power flow model with TCSC has been designed.

To validate this analysis two case studies have been taken up for 5 bus system

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