Journal of Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7735500

REACTIVE POWER COMPENSATION IN IEEE 9 BUS SYSTEM USING TCSC

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ABSTRACT:

It is a major concern for utility companies, power engineers, and consumers everywhere that power outages, voltage fluctuations, and power system breakdowns may occur. The voltage profile and power quality of the system as a whole will benefit from a more refined reactive power adjustment. This study investigates the use of a series capacitor controlled by a thyristor to achieve reactive power balance in an IEEE-9 bus system. For these purposes, we use the simulation and analytical tool Mipower (version 6.1). The load flow problem has been solved using the Newton Raphson technique. At first, we checked out the IEEE-9 bus architecture with a series capacitor managed by a thyristor. The system study evaluates TCSC and traditional systems, contrasting their reactive power compensation, voltage profiles, and line losses. Results from the two scenarios show that TCSC boosts system performance.

Keywords: TCSC, Reactive power compensation, line losses, voltage profile, Mipower

1.INTRODUCTION:

Because of our training as power system engineers, we are constantly on the lookout for new ways to enhance the power grid's reliability beyond the capabilities of current methods and tools. The typical devices' principal flaws are their brittleness and slow response time. With the advent of the thyristor switch, a new class of power electrical devices known as FACTS controllers became practical[1] (a semi-conductive device). A tool that fits under FACT is the TCSC [2]. Reactive power compensation is essential for maintaining a consistent voltage throughout the power grid's individual busses[3]. Kilowatts (kw) or megawatts (MW) are the standard units of measurement for active power (mw). To provide this "active power," a power plant is necessary. Our nation's electrical power grid has been designed and is constantly maintained with this requirement in mind. KVAR and MVAR are common units of measure for reactive power. Reactive power is generally needed when inductive loads are connected to a system. Reactive power correction is necessary to maintain a 1:1 ratio between the real power used by the load and the real power produced by the source. If not, the ratio of electrical power factor would drastically decrease. Hence, there will be an increase in the total amount of current drawn from the power system.

As transmission losses increase, the creation of reactive power has an impact on the overall cost of generating. Losses in the I^2R conversion and other issues are made worse by the increased transmission losses. Reactive power can be adjusted to decrease transmission loss[4]. These are the energy consumers, or reactive components, of the circuit or transmission line. Furthermore, inadequate reactive power assistance from generators and transmission lines is a major source of voltage instability[5] or voltage collapse, which has led to a number of significant system failures around the world. "A power electronic fundamental system called FACTS and other pieces of state equipment improve the AC transmission system's controllability. Energy transmission capacities

The TCSC setup consists of a bank of capacitors and a controlled reactor connected in parallel. By setting up a reactor and capacitor in parallel, fundamental frequency may be easily modified. A metal oxide varistor (MOV) [6] is wired across the capacitor to regulate the voltage. Some significant advantages of series compensation are highlighted by TCSC.

1) The reduction of sub-synchronous resonance risks
2) Damping of real power oscillation
3) Enhancement of post-event stability
4) Enhanced electricity flow across the lines

The transmission lines' impedance determines the precise path taken by electricity between nodes in a network. Using TCSC [7], we can improve energy transfer between the interconnected areas. When there is a high volume of power transmission between two locations, active power oscillation may emerge due to insufficient damping of the interconnection. The electricity transmission capability of the lines is thereby diminished [8]. The TCSC is a less expensive alternative to other FACT devices that can boost the total power flow[9].

2.THYRISTOR CONTROLLED SERIES CAPACITOR:

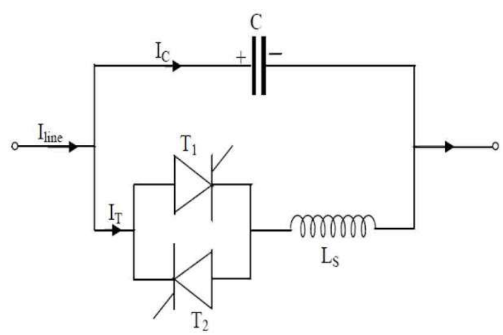

Fig 1: TCSC Circuit

In order to generate a variable series capacitive reactance, the thyristorcontrolled series capacitor (TCSC) uses a series-connected bank of capacitors and a thyristor-controlled reactor. To expand the capabilities of a one-port circuit, a transmission line is linked in series with it. In Fig. 1 we see a typical TCSC circuit. It functions similarly to a fixed-series salary structure. Yet, it is unique in that the amount of reactance absorbed by the capacitor may be adjusted on a sliding scale. Depending on when the thyristor in the inductive circuit turns on. The TCSC can be used in a variety of ways. A TCSC can function in a number of different ways, such as a blocking device and a capacitive boost device. The TCSC outperforms competing FACT devices [10] because it can switch between several modes of operation according on the requirements of the system.

As seen in Fig.2, the TCSC is wired to the line carrying traffic between buses I and j. For this purpose, we can substitute the pi model of the transmission line. When compared to a -jXc astatic reactance, the TCSC looks like it would behave similarly. The power flow equation is directly modified by using the controlled reactance Xc as an implicit control variable to represent TCSC.

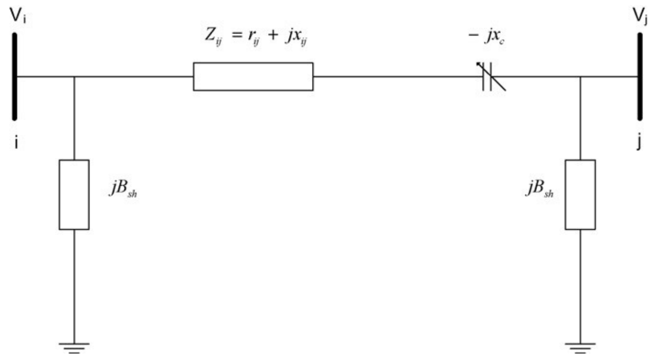

Fig 2: Transmission line with TCSC

From I and j, the complex power [12] is calculated by considering the impedance of the series reactive line, where k is the degree of series compensation.

$$S_{ij}^{\ *} = P(i.j) - Q(i,j) = V(i) * I(i,j)$$

$$S_{ij}^{\ *} = V(i) * [V(i) - V(j)Y(i,j) + V(jB)]$$

$$S_{ij}^{\ *} = V(i) * V(j)[(G(i,j) + jB(i,j)]$$

$$S_{ij}^{\ *} = G(i,j) + B(i,j)$$

$$S_{ij}^{\ *} = \frac{1}{R_L + jX_L - jX_C} \ldots(i)$$

Vi and Vj stand for the voltages on bus I and bus j, respectively. The current flowing from bus i to bus j is represented by the symbol It j along the transmission wires. Sij is the apparent power transfer between buses i and j. By lowering the overall impedance of the circuit, putting the TCSC between bus i and bus j increases the active power flow from bus i to bus j, as shown in equation i.

3. METHODOLOGY:

I. OBJECTIVE OF LOAD FLOW STUDY:

Planning decisions, such as adding generation sites to meet rising load demand and selecting new transmission sites, are significantly reliant on power flow analyses for new or extended networks.

In addition to providing voltages and phase angles at each node, the load flow solution also provides power injection at each bus and power flows across interconnected power channels. With this information, the proposed power plant, substation, and extension lines may be located in the best possible spot. The ideal bus voltage and capacity are calculated by it. Certain buses' voltage levels must be maintained within a narrow range. Full electrical demand is met despite the high cost of fuel, and system transmission losses are minimised. The line's inner workings can be discovered. Avoid damaging the line by exceeding its operating temperature or stability parameters.

A BRIEF INTRODUCTION TO LOAD FLOW STUDY:

There are four quantities of interest associated with each bus:

- Real Power, P

- Reactive Power, Q
- Voltage Magnitude, V
- Voltage Angle, δ

Two of these four parameters will be stated at each node of the system, leaving the other two as unknowns. Depending on which of the two amounts is specified each system bus can be classified[4] as slack bus, load bus(PQ) ,voltage controlled bus(PV).

A.SLACK BUS:

The system has a single bus designated as the slack bus, for which the voltage magnitude and angle are given. Unknown are the true and reactive powers. The bus chosen as the slack bus needs to have a real and reactive power supply.

B. LOAD BUS (PQ BUS):

In this context, "load bus" refers to any bus in the system for which both actual and reactive power are known. However, any bus with a known amount of injected complicated power is more commonly referred to as a load bus. It is possible to install generators on load buses with predetermined reactive and actual power outputs.

C. VOLTAGE CONTROLLED BUS (PV BUS):

The term "voltage regulated" (or "PV")bus is used to describe any bus that has a set voltage magnitude and actual power injection. The injected reactive power is a factor in the power flow analysis (with defined upper and lower boundaries)

II.SOLUTION METHODS:

Even the simplest power systems use iterative methods for solving simultaneous nonlinear power flow equations.

- Gauss-siedel method
- Newton Raphson method
- Fast decoupled method

III. NEWTON RAPHSON METHOD:

A set of nonlinear equations with the same number of unknowns is solved using the iterative newton Raphson method. The load flow problem can be addressed in a couple of different ways using the newton Raphson method. The variables in the first technique are represented by rectangular co=ordinates, while in the second method they are represented by polar coordinates. Of these two methods, polar co-ordinates is the one more usually employed.

Let us understand this method with the help of the equations:

$$S_i = P_i + jQ_i = V_i \sum_{k=1}^{n} V_{ik} V_k \; ....(1)$$

$$S_i = \sum_{k=1}^{n} (V_i \, V_k \, Y_{ik}) \Big/ (\delta_i - \delta_k - \theta_{ik}) \; ... . (2)$$

$$P_i = \sum_{k=1}^{n} (V_i \, V_k \, Y_{ik}) \cos(\delta_i - \delta_k - \theta_{ik}) \; ... . (3)$$

$$Q_i = \sum_{k=1}^{n} (V_i \, V_k \, Y_{ik}) \sin(\delta_i - \delta_k - \theta_{ik}) \; ... . (4)$$

The above equation (3) and (4) can also be written as shown below.

$$P_i = V_i V_i Y_{ii} \cos\theta_{ii} + \sum_{\substack{k=1 \\ k \neq 1}}^{n} (V_i \, V_k \, Y_{ik}) \cos(\delta_i - \delta_k - \theta_{ik}) \; ... . (5)$$

$$Q_i = -V_i V_i Y_{ii} \cos\theta_{ii} + \sum_{\substack{k=1 \\ k \neq 1}}^{n} (V_i \, V_k \, Y_{ik}) \sin(\delta_i - \delta_k - \theta_{ik}) \; ... . (6)$$

If $\Delta P_i = P_{i\,(sp)} - P_{i\,(cal)} \; ..... (7)$

$$\Delta Q_i = Q_{i\,(sp)} - Q_{i\,(cal)}$$

We have $\Delta f = J \, \Delta X$

Then I=1,2,…..n, I≠ slack, and if

Then I = 1,2,….n, I ≠slack, I ≠PV bus

Where the subscripts sp and cal denote the specified and calculated values, respectively, then the equation (7) can be written as shown below.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & N \\ M & L \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta V \end{bmatrix} \; ... ... (8)$$

$$\Delta P_i^{(r)} < \varepsilon, \qquad \Delta Q_i^{(r)} < \varepsilon$$

The off diagonal and diagonal elements of the sub matrices H,N,M and L are determined by differentiating (3) and (4) with respect to δ and |V|.

4. SIMULATION AND RESULT:

A simulation model of the IEEE 9 bus system is developed [2] based on the results of the tests. The simulation model is developed with Mipower, a simulation platform. To address the many facets of today's power grids, experts turn to load flow analysis using the Newton-Raphson method.

A. ***SIMULATION MODEL OF IEEE 9 BUS SYSTEM WITHOUT TCSC***:

Fig 3 shows a IEEE 9 bus system of without TCSC using Mipower software (version 6.1)

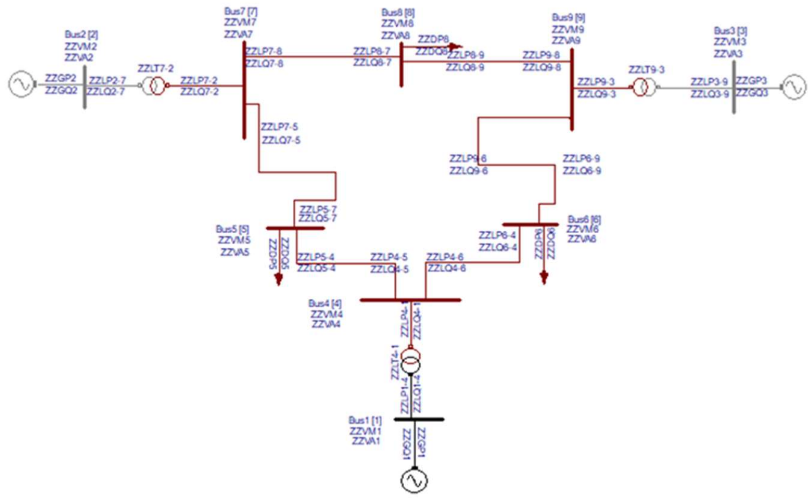

Fig 3: IEEE 9 Bus system without TCSC

B.SIMULATION MODEL OF IEEE 9 BUS SYSTEM USING TCSC

According to the test data in this instance, TCSC has been implemented between buses 6 and 9, The IEEE 9 bus system with TCSC is shown in fig 4

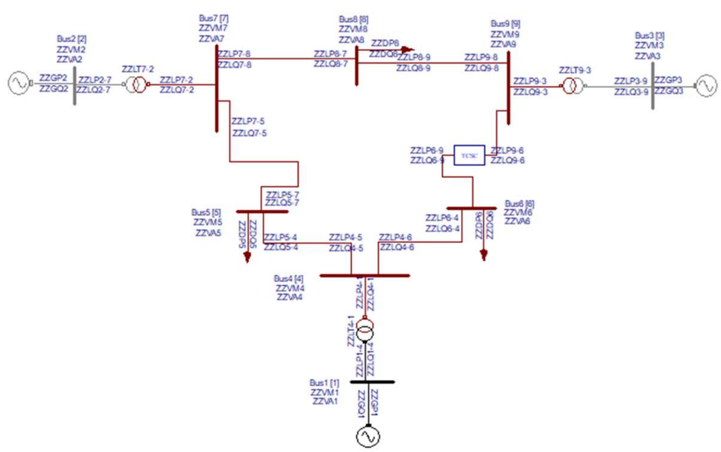

Fig.4 IEEE 9 Bus system using TCSC

i. Comparison of reactive power:

The reactive power results from the various buses have been compared and analysed. In the first scenario the system is devoid of TCSC. A TCSC has been incorporated into the system for the second half. The TCSC is situated between buses 6 and 9.(in general any two buses in the system can be considered). The findings under the aforementioned conditions are shown in table 1

Table 1: Comparison of reactive power

BUS NO	Reactive power (MVAR) without TCSC	Reactive power (MVAR) with TCSC
1	0	0
2	0	0
3	0	0
4	0	0
5	30.067	5.118
6	45.188	28.034
7	41.406	26.476
8	0.0	0.0
9	0.0	0.0

The table 1 shows that when TCSC is incorporated into the system, reactive power is significantly reduced.
The maximum value of reactive power (MVAR) in a system without a TCSC is 215.905228.
TCSC, however causes the maximum value (MVAR) to decrease to 145.683098.

ii. Comparison of voltage magnitude (pu)

A number of buses' voltage magnitudes have been studied and analysed both with and without TCSC. As a result of implementing TCSC, the system's voltage profile as a whole has seen an improvement.

Take any two buses as an example here. The A 12.76 percent increase in voltage is seen at bus 6 after TCSC is installed. The second scenario would lead to a 6.46 percent increase in voltage on bus nine, raising and maintaining the system voltage.

Table 2: Comparison of voltage magnitude

BUS NO	WITHOUT TCSC VOLTAGE (pu)	WITH TCSC VOLTAGE (pu)
1	1	1

2	1	1
3	1	1
4	0.9387	0.9817
5	0.9482	0.9957
6	0.8712	0.9973
7	0.8928	0.9858
8	0.9232	0.9887
9	0.9258	0.9908

The voltage magnitude of different buses have been studied and assessed with and without TCSC was put into use, the voltages profile of the entire system has improved.

iii. Comparison of line losses

Engineers and designers of power systems have the challenge of overcoming transmission line loss as one of their primary constraints. With the introduction of TCSC into the electrical grid. The rate at which these losses occur has dropped dramatically. This is what the comparison study found. If transmission losses can be decreased, the overall capacity of the power grid can be increased. Loss distribution in the absence of TCSC. The line loss is 28.793110 MVAR, which is the highest, on the transmission line linking the buses at 6 and 9. In the case where TCSC shows a significant reduction in line losses, the loss value for the same transmission line linking the same buses drops to 17.784305 MVAR.

5. Result:

Summary of results with TCSC:

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Summary of results
TOTAL REAL POWER GENERATION   :     743.737 MW
TOTAL REACT. POWER GENERATION :     366.604 MVAR
GENERATION pf                 :      0.87

TOTAL SHUNT CAPACIT.INJECTION :     -0.000 MW
TOTAL SHUNT CAPACIT.INJECTION :      188.074 MVAR

TOTAL REAL POWER LOAD         :      723.830 MW
TOTAL REAL POWER INJECT,-ve L :      0.000 MW
TOTAL REACTIVE POWER LOAD     :      399.76 MVAR
LOAD pf                       :      0.850

TOTAL REAL POWER LOSS (AC+DC) :  17.784305 MVAR ( 17.784305+  0.000000)
PERCENTAGE REAL  LOSS (AC+DC) :    2.158
TOTAL REACTIVE POWER  LOSS    :  145.683098 MVAR

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Summary of results without TCSC:

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Summary of results
TOTAL REAL POWER GENERATION   :    750.360 MW
TOTAL REACT. POWER GENERATION :    613.632 MVAR
GENERATION pf                 :      0.976

TOTAL SHUNT CAPACIT.INJECTION :     -0.000 MW
TOTAL SHUNT CAPACIT.INJECTION :     -0.000 MVAR

TOTAL REAL POWER LOAD         :     723.480 MW
TOTAL REAL POWER INJECT,-ve L :      0.000 MW
TOTAL REACTIVE POWER LOAD     :     399.544 MVAR
LOAD pf                       :      0.995

TOTAL REAL POWER LOSS (AC+DC) :  28.793110 MVAR (28.793110+  0.000000)
PERCENTAGE REAL  LOSS (AC+DC) :     3.244
TOTAL REACTIVE POWER  LOSS    :  215.905228 MVAR

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6. CONCLUSION:

The newton Raphson method of load flow analysis in Mipower has been used to compare reactive power compensation for an IEEE 9 bus system". In the scenario where TCSC has been applied, the comparative study has revealed an improvement in the voltage profile of the system, the magnitude of line losses has also decreased. Reactive power losses and poor power quality can be overcome by using TCSC in real world power difficulties between any buses

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