ISSN No:-2456-2165

Power Quality Improvement by Thyristor Controlled Series Capacitor

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Abstract:- Nonlinear loads connected to electrical distribution networks are a source of harmonic pollution. These loads draw currents that contain varying levels of harmonic content, which do not contribute to useful active power because their frequencies do not match the grid voltage. To address the issue of harmonic current injection, one effective solution is the installation of series controllers in transmission lines. The Thyristor Controlled Series Capacitor (TCSC) represents a significant advancement in the management and optimization of power flow in electrical transmission networks. By integrating TCSCs into the grid, utilities can enhance the stability, capacity, and flexibility of power transmission systems. The core component of a TCSC is a series capacitor, which is partially bypassed by a thyristor-controlled reactor. This configuration allows for the dynamic adjustment of the capacitor's apparent reactance, thereby controlling the power flow through the transmission line with high precision and speed.

***Keywords**:- FACTS Controller, Power Quality, TCSC, MATLAB.*

I. INTRODUCTION

Power quality refers to the characteristics of the electrical power supplied to consumers and how closely it adheres to certain standards that ensure electrical equipment operates effectively without suffering degradation or increased risk of failure. The concept encompasses various aspects of the electricity supply, including voltage, frequency, and waveform purity. A high-quality power supply maintains steady voltage levels, consistent frequency, and clean sinusoidal waveforms without significant distortion.

Improving power quality is crucial for the reliability and efficiency of electrical systems, especially in environments with sensitive electronic equipment such as data centers, hospitals, and industrial plants. It involves a combination of proper system design, regular monitoring, and the use of corrective devices to ensure that power delivery meets the required standards.

Flexible AC Transmission Systems (FACTS) devices play a pivotal role in enhancing power quality and ensuring the efficient operation of electrical power systems. FACTS technologies provide dynamic control over electrical power networks, improving their reliability, capacity, and flexibility. FACTS devices, can rapidly adjust the reactive power flow in the system. This capability is crucial for maintaining stable voltage levels, especially under varying load conditions, thereby improving the overall power quality and reducing the risk of voltage sags, swells, and flicker.

Certain FACTS devices, equipped with filtering capabilities, can mitigate harmonic distortion in the power system. By reducing harmonics, these devices prevent the associated problems such as overheating of equipment, malfunctions in sensitive electronics, and inefficiencies in power delivery. FACTS devices contribute to the damping of oscillations in the power system, which can be triggered by sudden changes in load or generation. This stabilizing effect is essential for preventing the propagation of disturbances that can lead to widespread power outages and for ensuring the continuous delivery of high-quality power.

By optimizing the flow of power and reducing losses, FACTS devices enable existing transmission lines to carry more power. This not only defers the need for building new infrastructure but also ensures that the power delivered is of high quality by minimizing the effects of overloading and reducing the likelihood of voltage instability.

With the increasing integration of variable renewable energy sources like wind and solar, FACTS devices are becoming increasingly important for managing the intermittent nature of these sources. They help in smoothing out the power supply, ensuring that the power quality remains within acceptable standards despite the variability in generation. FACTS devices offer a versatile set of tools for addressing a wide range of power quality issues. Their ability to provide dynamic, real-time control over the electrical power system makes them indispensable for modern power networks, ensuring that both utilities and consumers benefit from a stable, efficient, and high-quality power supply.

By dynamically controlling the impedance of transmission lines, FACTS devices like the Thyristor-Controlled Series Capacitor (TCSC) can direct power flows along predetermined paths. This not only enhances the utilization of existing transmission assets but also alleviates congestion, leading to a more stable and reliable power supply.

II. PROPOSED TECHNIQUE

The term "TCSC" typically refers to "Thyristor Controlled Series Capacitor," a type of Flexible AC Transmission System (FACTS) device used in electrical power transmission systems. The ability of a TCSC to quickly change the line reactance makes it an invaluable tool for several key applications within the power system. These include mitigating subsynchronous resonance (SSR), damping power system oscillations, increasing transmission line capacity by managing power flow, and improving system stability during disturbances. By providing a means to control the power flow dynamically, TCSCs help in maintaining the reliability of the power system, reducing the risk of blackouts, and enabling the efficient integration of renewable energy sources.

A. Basic construction and principle operation

TCSC technology contributes to the deferral of costly transmission line upgrades and the optimization of existing infrastructure. Its deployment can lead to significant economic benefits for utilities and consumers alike by ensuring more efficient and reliable power delivery. As the demand for electricity grows and the grid becomes increasingly complex with the integration of renewable energy sources, the role of TCSCs in ensuring the stability and efficiency of the power system is expected to become even more critical.

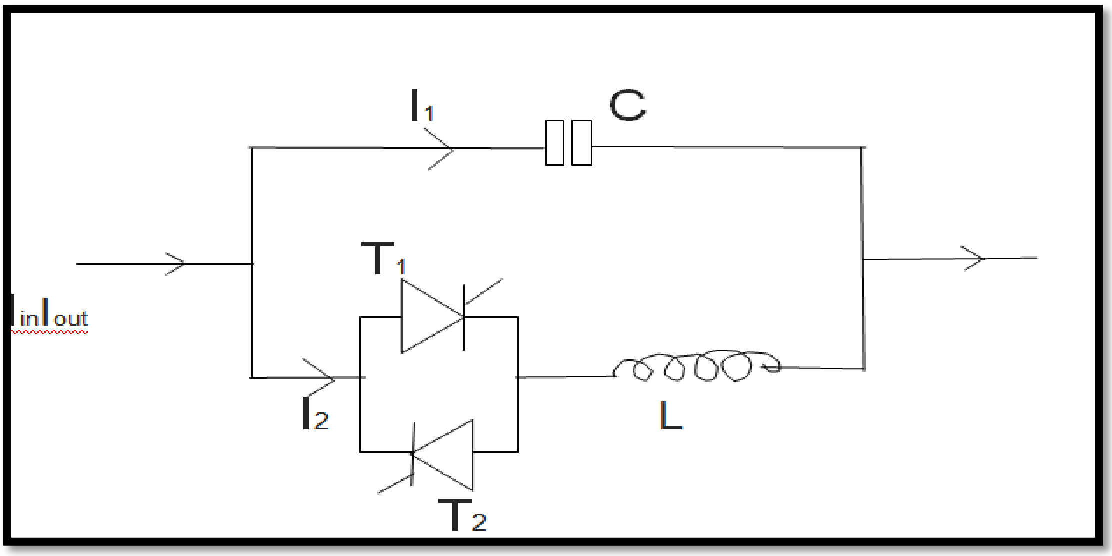

Fig 1. Basic configuration of TCSC

B. Basic Components

- **Series Capacitor:** It is intended to decrease the overall impedance of the transmission line, thereby allowing more power to flow through the line.
- **Thyristor-Controlled Reactor (TCR):** A reactor whose impedance can be dynamically adjusted by controlling the firing angle of thyristors connected in series with the reactor. The reactor effectively works as a variable inductor.

C. Operation Mechanism

- **Impedance Control:** The TCSC varies the net impedance of the transmission line by adjusting the reactance of the thyristor-controlled reactor. By controlling the firing angle of the thyristors, the TCSC can change the amount of current flowing through the reactor, thus varying the total reactance in the circuit.
- **Power Flow Control:** By varying the line impedance, the TCSC can control the power flow along the transmission line. Reducing the impedance allows more power to flow, whereas increasing the impedance reduces the power flow. This dynamic control is crucial

ISSN No:-2456-2165

for optimizing the use of transmission assets and for responding to changing system conditions.

- **Stabilization and Damping**: The TCSC can also contribute to the damping of power system oscillations, which enhances the stability of the network. By rapidly adjusting the impedance, the TCSC can counteract oscillations that might occur due to sudden changes in load or generation, preventing the propagation of disturbances.

D. Modes of Operation

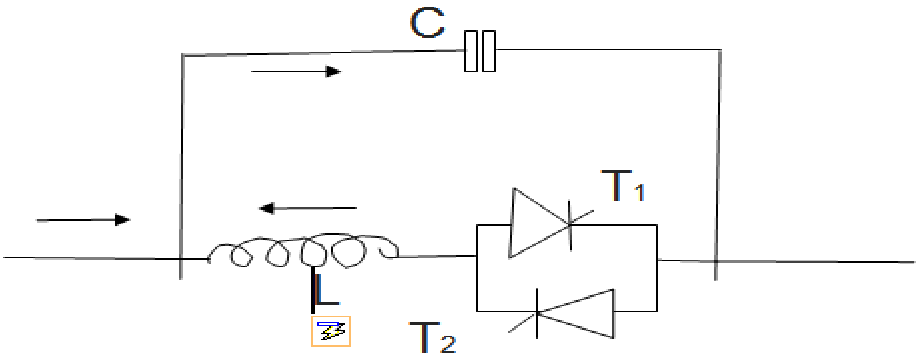

Fig 2. Basic diagram capacitive mode operation of TCSC

- **Capacitive Boost Mode:** In this mode, the TCSC decreases the overall impedance of the line by allowing the series capacitor to dominate. This mode is used to increase the power flow through the line.

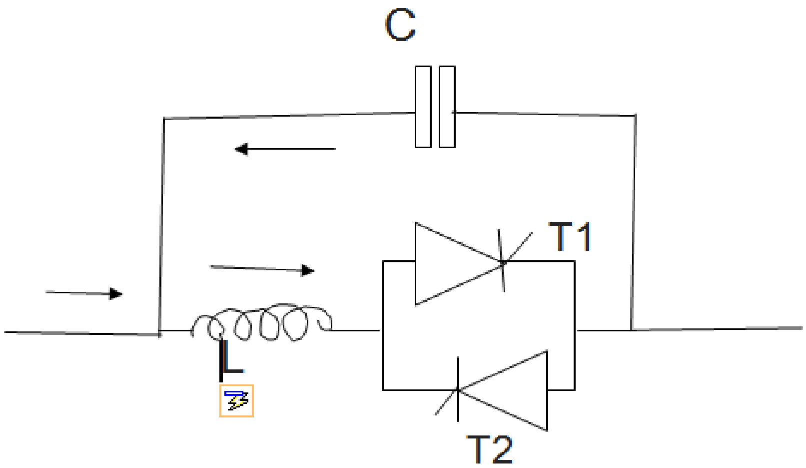

Fig 3. Basic diagram Inductive mode operation of TCSC

- **Inductive Boost Mode**: The TCSC increases the overall impedance of the line by increasing the reactance of the thyristor-controlled reactor, which is used to decrease the power flow or to remove excess power from the line.

III. APPLICATIONS

The TCSC finds applications in several areas of power system management, including:

- **Load Balancing:** Dynamically balancing power flow across multiple transmission paths.
- Increasing Transfer Capacity: Allowing more power to be transferred over existing transmission lines.
- **Stability Improvement:** Enhancing the damping of system oscillations to improve the overall stability of the power grid.
- **Voltage Regulation:** Assisting in maintaining the desired voltage levels along transmission lines.

The TCSC's ability to provide fast, controllable adjustments to the transmission line impedance makes it a valuable tool for modern power systems, addressing challenges related to power flow management, system stability, and the integration of renewable energy sources.

IV. RESULTS

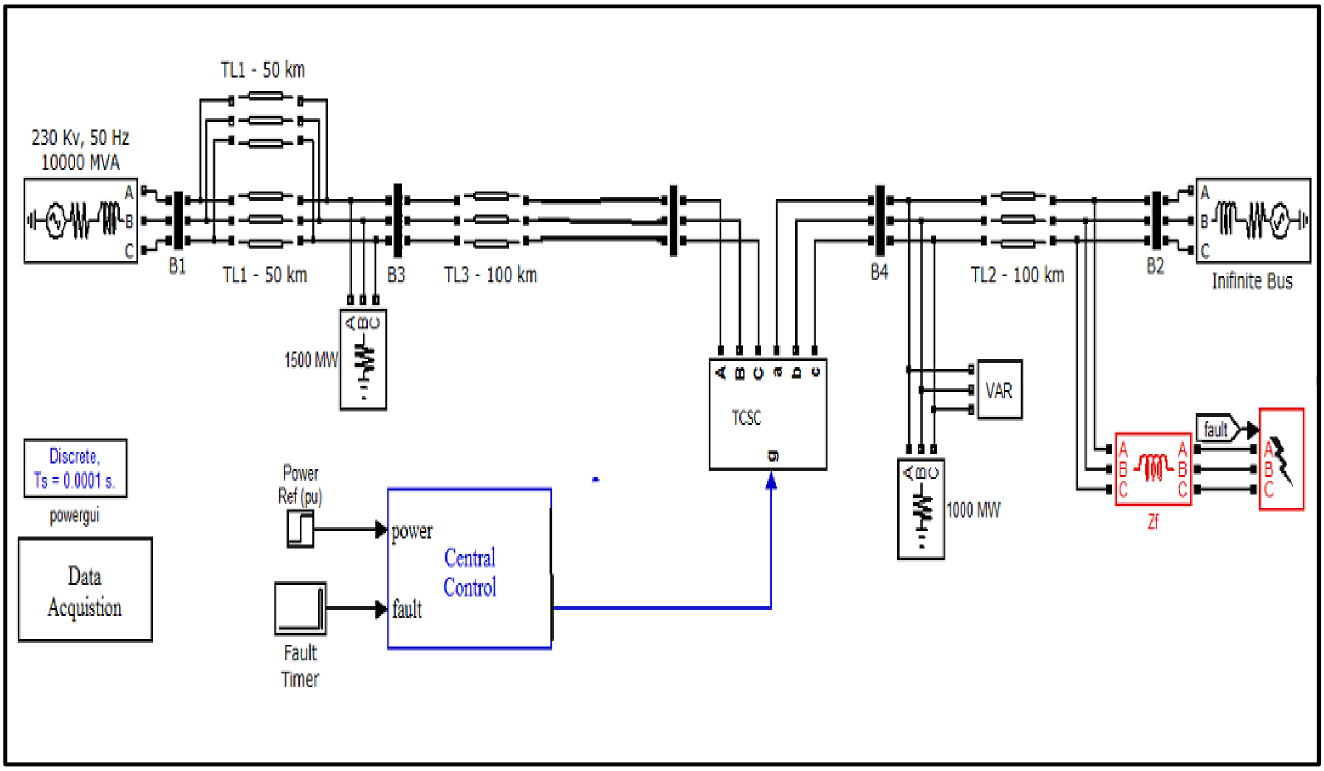

Fig 4 .Representation of simulation circuit

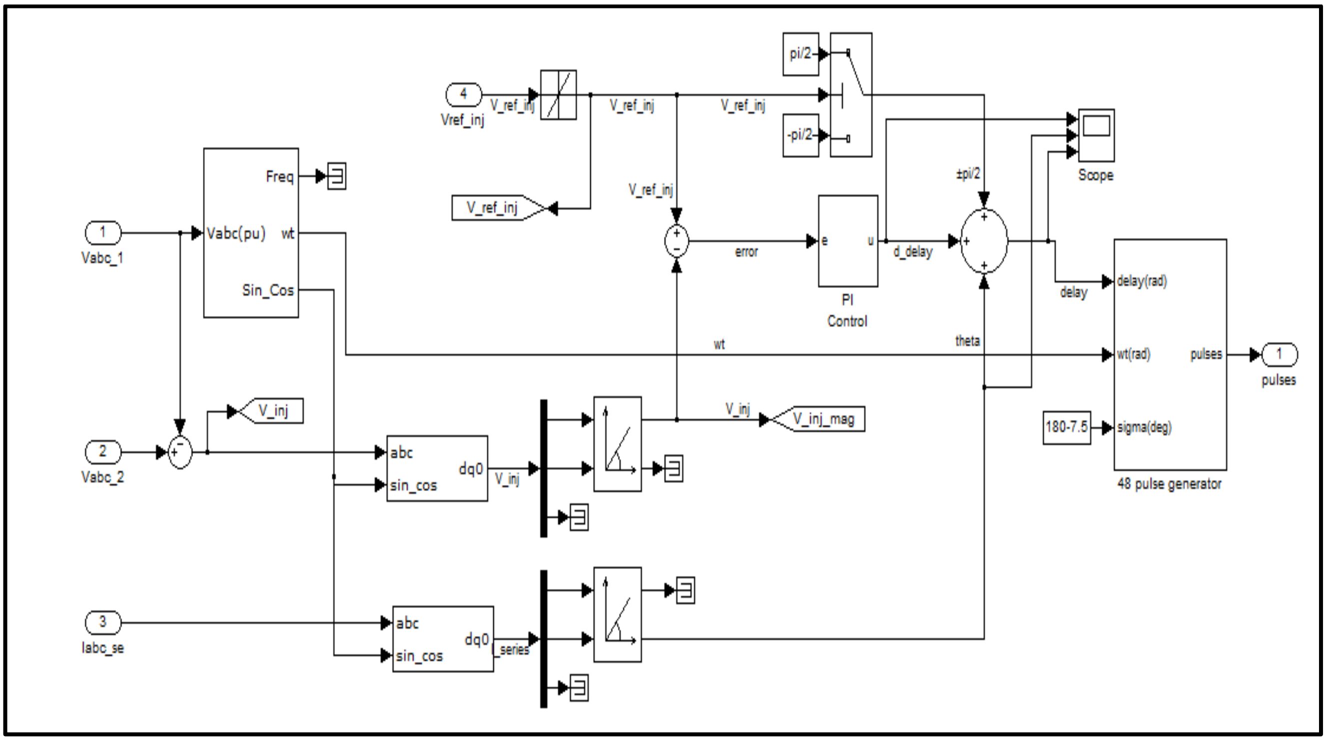

Fig 5 .Representation of control circuit

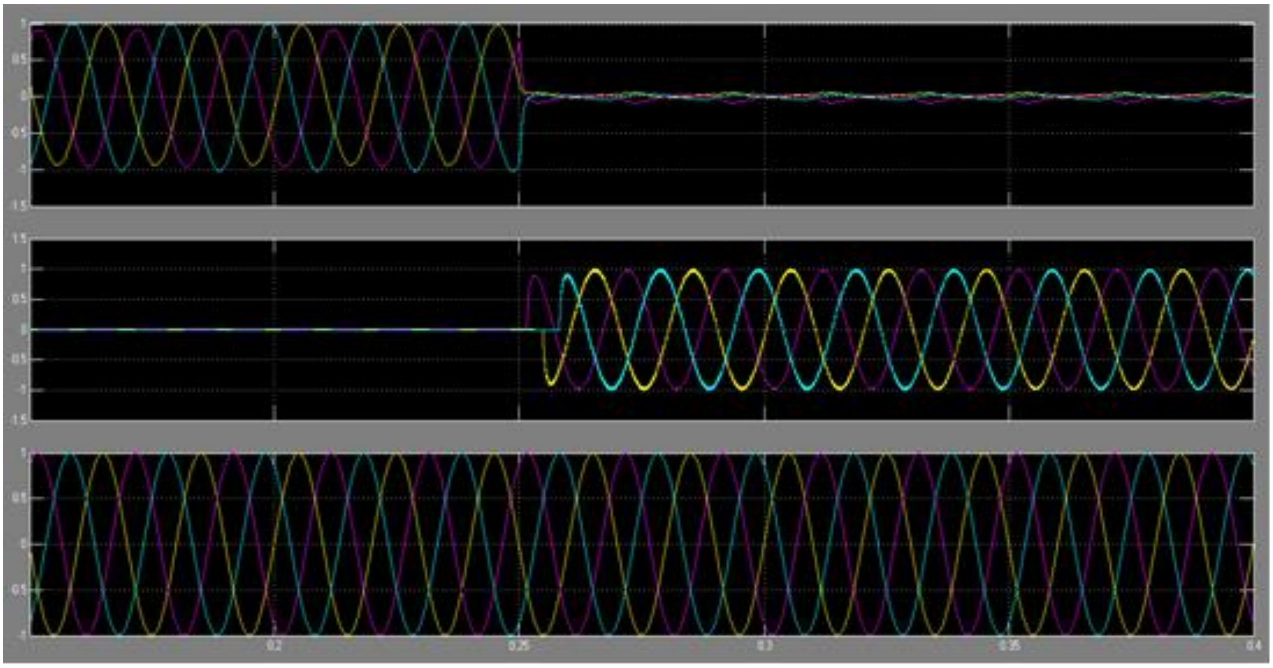

Fig 6 Output Waveforms

V. CONCLUSION

The suggested setup offers significant benefits for contemporary load centers that demand precise voltage regulation. It is capable of functioning in various modes depending on the state of the grid. Through extensive simulation studies and experimental validation, the efficacy and practical viability of this setup to adapt and perform across diverse operating scenarios have been clearly demonstrated. TCSC technology contributes to the deferral of costly transmission line upgrades and the optimization of existing infrastructure. Its deployment can lead to significant economic benefits for utilities and consumers alike by ensuring more efficient and reliable power delivery. As the demand for electricity grows and the grid becomes increasingly complex with the integration of renewable energy sources, the role of TCSCs in ensuring the stability and efficiency of the power system is expected to become even more critical.

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