An Innovative SSSC Device for Power Quality Enhancement

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Abstract:- Recent developments in technology have resulted in increased power consumption from a larger number of nonlinear loads, consequently impacting the overall quality of power transmission. It is crucial for the power transmitted in a line to be of top-notch quality. The power flow is determined by factors such as line impedance and the magnitudes of voltage at thesending and receiving ends. Nonlinear loads can lead to the generation of harmonic currents, resulting in system resonance, capacitor overloading, decreased efficiency, and changes in voltage magnitude. The simulation results demonstrate the enhanced system stability achieved through the utilisation of FACTS devices. Additionally, the SSSC-based stabiliser provesto be highly effective in dampening power system oscillations.

Keywords:- *Reactive Power, SSSC, MATLAB2018b*

I. INTRODUCTION

Reactive power is an essential component in alternating current (AC) electrical systems, alongside active power. While active power (measured in watts) represents the actual energy used to perform work, reactive power (measured in volt-amperes reactive or VAR) is associated with theexchange of electric fields in the system without performing any real work. Reactive power is the power associated with the establishment of magneticand electric fields in AC circuits. It does not performany useful work directly but is crucial for maintaining voltage levels and supporting the flow of active power.

The power factor is a critical parameter associated with reactive power, representing the ratio of real power (active power) to apparent power (the sum of active and reactive power). It is quantified as a valueranging from 0 to 1, with a higher power factor signifying a more efficient utilization of electrical power.

- A power factor of 1 (or 100%) indicates that all the power is active power, meaningthe system is purely resistive.
- A power factor less than 1 indicates the presence of reactive power, which istypical in systems with inductive or capacitive loads.

A. *Importance of Reactive Power:-*

- Voltage Stability: Reactive power is essential for maintaining voltage levels within acceptable limits. A lack of reactivepower can lead to voltage drops, affecting the performance and reliability of electricalequipment.
- Transmission and Distribution Efficiency: Adequate reactive power support helps in reducing power losses and enhancing the efficiency of electrical transmission and distribution systems.
- Motor and Equipment Operation: Inductiveloads, such as electric motors, require reactive power for their operation. Providing the necessary reactive power ensures the proper functioning of these devices.

B. *Sources of Reactive Power:-*

- Capacitors: These devices can supplyreactive power and are often used to improve power factor and voltage regulation.
- Inductors: While inductive loads consume reactive power, inductors themselves can also be a source of reactive power when appropriately controlled.

Understanding and managing reactive power arecrucial for ensuring the reliability and efficiency of electrical power systems. Utilities and industriesemploy various methods and devices to control andoptimize reactive power flow to meet operational requirements.

II. METHODOLOGY

The Static Synchronous Series Compensator (SSSC) is an important device in power systems and has several key functions that contribute to the stability and efficiency of the electrical grid. SSSC allows for precise and rapid control of power flow in transmission lines. Byadjusting the impedance of the line in a controlled manner, it enables operators to optimize the usage ofexisting transmission infrastructure and manage power flows more efficiently. SSSC can help in enhancing voltage stability in the power system. By dynamically adjusting the line impedance, it can mitigate voltage fluctuations and maintain voltage levels within acceptable limits, especially during transient conditions. SSSC provides a means to dampen power oscillations in the transmission network. This is particularly important for maintaining system stability and preventing the occurrence of voltage instability or large-scale blackouts.

As more renewable energy sources are integrated into the grid, the variability of power generation increases. SSSC can help manage the challenges associated with integrating renewable energy by providing dynamic control over transmission parameters. The Static Synchronous Series Compensator plays a crucial role in enhancing the overall performance, stability, and reliability of power systems, making it an importantcomponent in modern electrical grids.

The Static Synchronous Series Compensator (SSSC), belonging to the FACTS (Flexible Alternating Current Transmission System) family, is integrated in series with a power system. Comprising a solid-state voltage source converter generating a controlled alternating current voltage atthe fundamental frequency, the SSSC achieves a 90-degree phase difference between the injected voltage and the line current, simulating either inductive or capacitive reactance. This simulation capability facilitates the manipulation of power flow within thetransmission line. Primarily, the SSSC serves toregulate power flow during steady-state conditions in a power system, while also possessing the capability to improve transient stability.

The SSSC controller adeptly alleviates power system oscillations, markedly improving thesystem's voltage profile. This proposed SSSC controller effectively mitigates power system oscillations in both inter-area and local modes. These recommended stabilizers have been applied and assessed in power systems under severedisturbances and diverse loading conditions.Grounded in FACTS (Flexible AC Transmission Systems), the stabilizer exhibits outstanding damping characteristics, notably enhancing system stability in comparison to standalone systems.

A. Working and Operation:-

The Static Synchronous Series Compensator (SSSC)is a modern Flexible AC Transmission System (FACTS) device that utilizes a voltage source converter connected in series to a transmission line through a transformer. Operating akin to a controlled series capacitor or series inductor, the key differentiation lies in the independently controlled injected voltage. This distinctive feature allows the SSSC to function effectively under diverse loadconditions, including both high and low demand scenarios

The SSSC has three main components:-

- The primary component is the Voltage Source Converter (VSC).
- The Transformer connects the SSSC to the transmission line.
- The Energy Source supplies voltage to theDC capacitor and compensates for device losses.

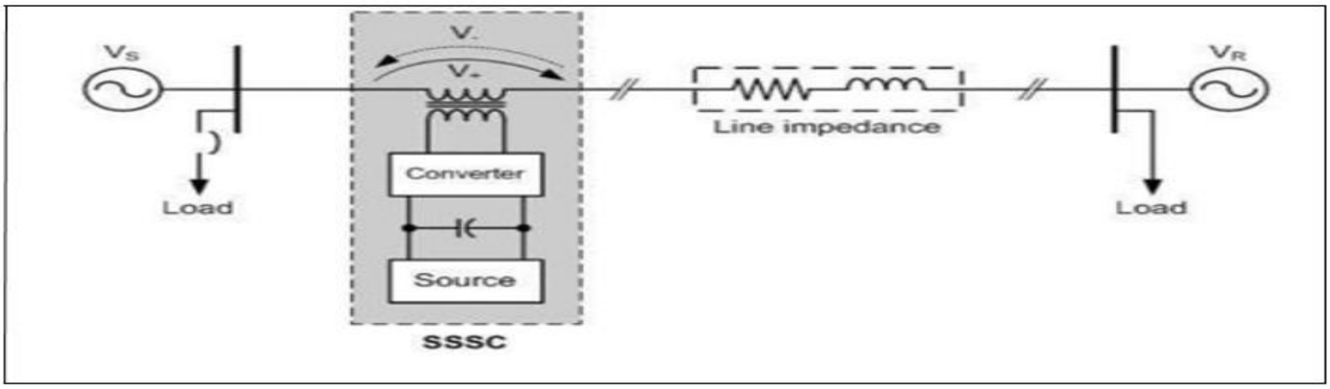

Fig. 1 Basic Structure of SSSC

The Static Synchronous Series Compensator functions in a manner akin to the STATCOM, differing in that it is connected in series rather than in parallel. This system possesses the ability to transmit both active and reactive power, enabling itto counteract resistive voltage drops and uphold a consistently high effective X/R ratio unaffected by the extent of series compensation.

However, thedrawback lies in substantial costs associated with therequirement for a sizable energy supply.

B. Modes of Operations:-

Typically, the line reactance remains consistent, yetits overall influence can be altered through the injection of voltage. As the level of inductive reactance compensation increases from 0% to 100%, the line current decreases. Conversely, the line current ascends as the level of capacitive reactance compensation rises from 0% to 33%.

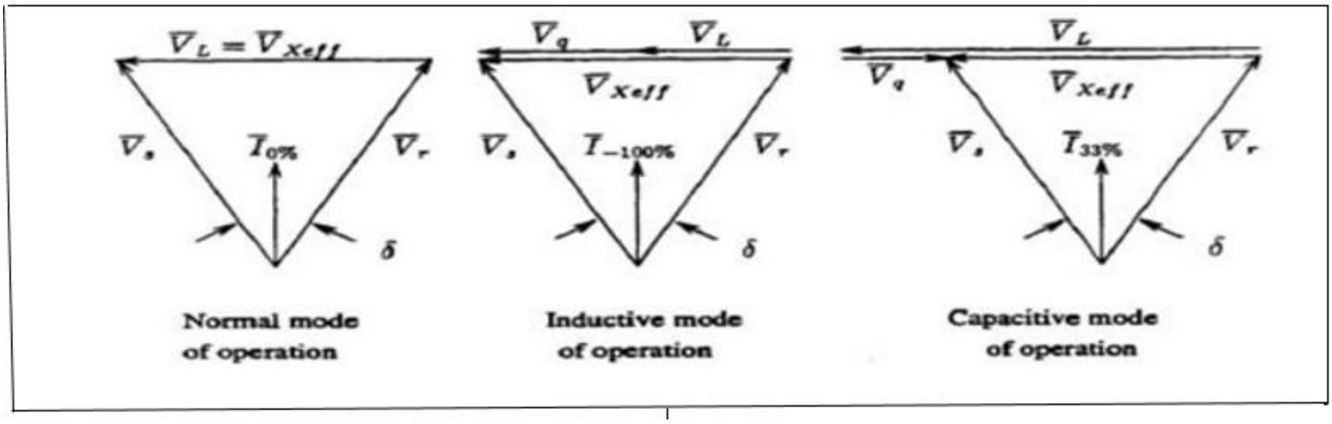

Fig 2 Modes of Operation of Proposed Method

The static synchronous series compensate or has the ability to both raise and reduce the transferable power. This may be achieved by reversing the polarity of the injected voltage. The reversed polarity voltage is immediately applied to the line voltage drop, simulating an increase in line resistance. The effect of reactance compensation on normalized power flow in the transmission line can be encapsulated as follows:

- When the emulated reactance is capacitive, increasing reactance compensation in the positive direction leads to an increase in both active and reactive power flow, while decreasing the effective reactance.
- Conversely, when the emulated reactance is inductive, increasing reactance compensation in the negative direction results in a decrease in both active andreactive power flow.

III. APPLICATIONS

The Static Synchronous Series Compensator (SSSC) finds applications in various aspects of power systems where precise control of transmission line parameters and improved stability are required. Some of the key applications of SSSC include:

- *Power Flow Control:-* SSSC is used to control power flow on transmission lines. By dynamically adjusting the impedance, it allows grid operators to optimize power flow, relieving congestion in the network and preventing overloads on specific lines.
- *Voltage Stability Enhancement:-* SSSC helps enhance voltage stability by regulating voltage levels within acceptable limits during both steady- state and transient conditions. This is crucial for maintaining the reliability of the power system.
- *Damping Power Oscillations:-* SSSC is employed to dampen power oscillations that can occur in the transmission network. This improves the overallstability of the power grid and prevents the amplification of oscillations that could lead to instability.
- *Flexible AC Transmission System (FACTS) Devices:-* SSSC is part of the family of Flexible AC Transmission System devices. These devices, including SSSC, provide dynamic control of power system parameters to enhance grid performance,stability, and reliability.
- *Grid Expansion and Reinforcement:-* Instead of or in addition to traditional methods of grid expansion,SSSC can be utilized to increase the transmission capacity of existing lines. This can defer the need forbuilding new transmission infrastructure, saving costs and time.
- *Mitigating Subsynchronous Resonance (SSR):-* SSSC can be used to mitigate subsynchronous resonance, a phenomenon that can occur in powersystems with series-compensated transmission lines.The device helps control system dynamics and prevent detrimental effects on equipment.
- *Integration of Renewable Energy:-* SSSC aids in integrating renewable energy sources into the grid by providing dynamic control over transmission parameters. This is particularly important as renewable energy generation often introduces variability and uncertainty into the power system.
- *Preventing Voltage Collapse:-* SSSC helps preventvoltage collapse by maintaining suitable voltage levels in the system. It contributes to grid stability during contingencies and disturbances, reducing therisk of widespread outages.
- *Contingency Management:-* SSSC assists in managing contingencies by providing a rapidresponse to changing grid conditions. It helps stabilize the system during events such as sudden load changes, line outages, or other disturbances

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IV. RESULTS

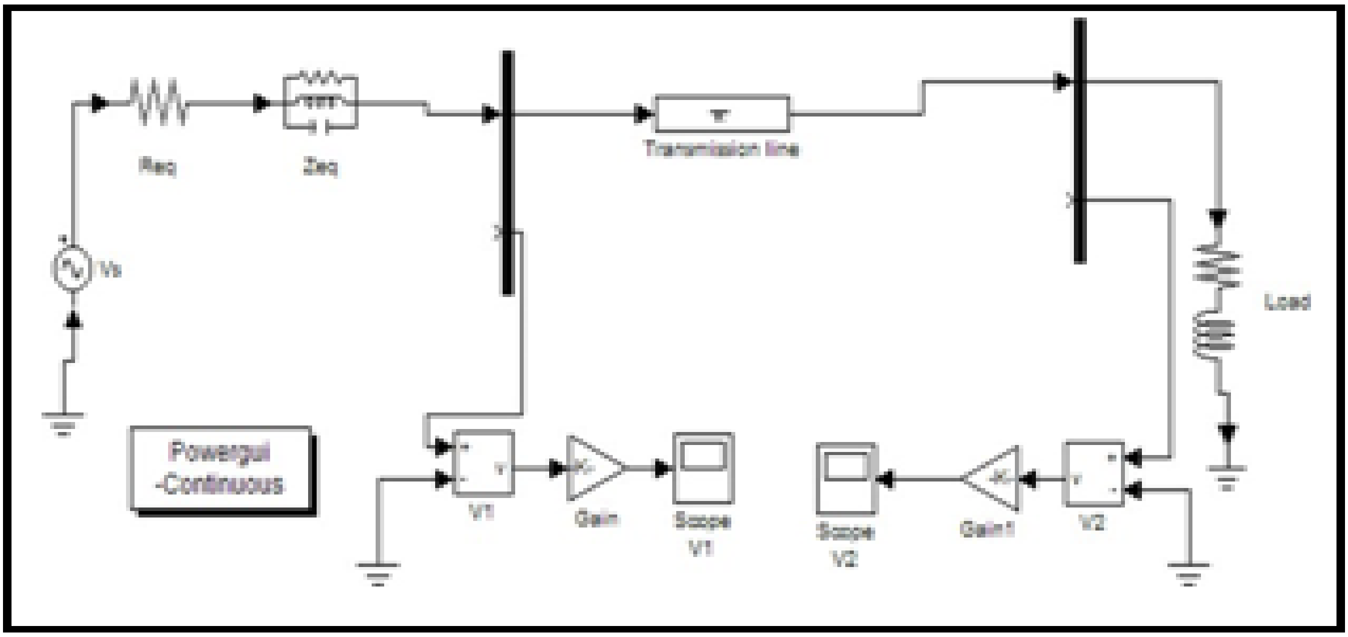

Fig 3 Single Line Diagram

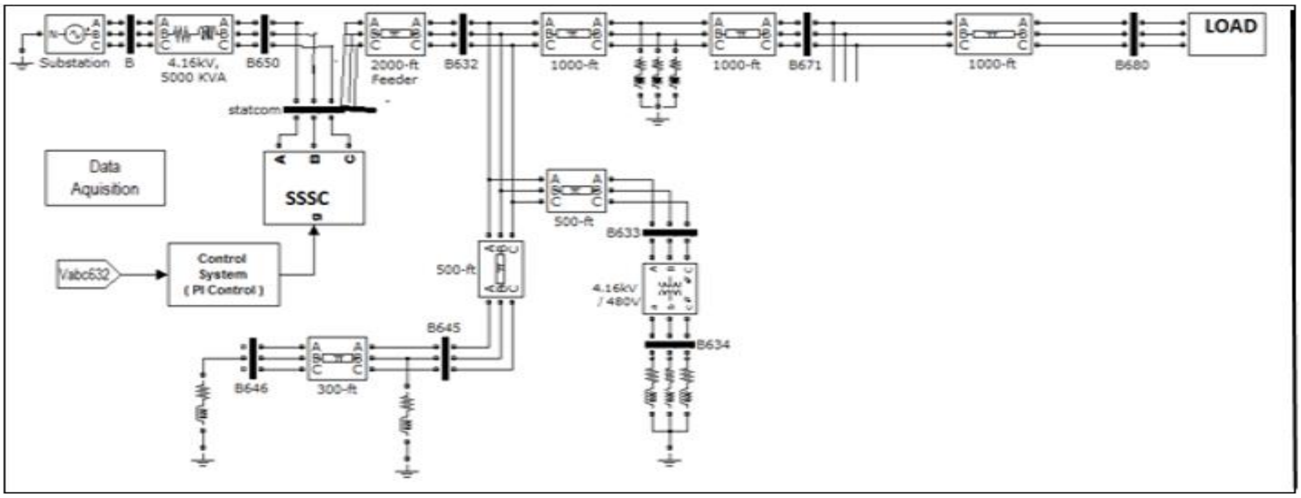

Fig 4 Simulation Diagram

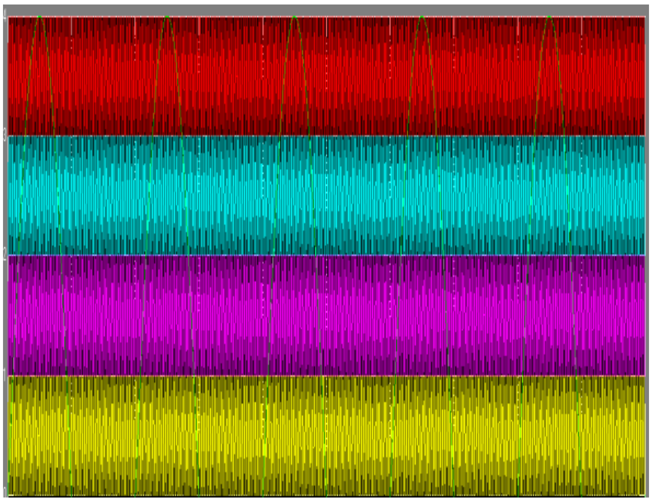

Fig 5 Three Phase Voltages

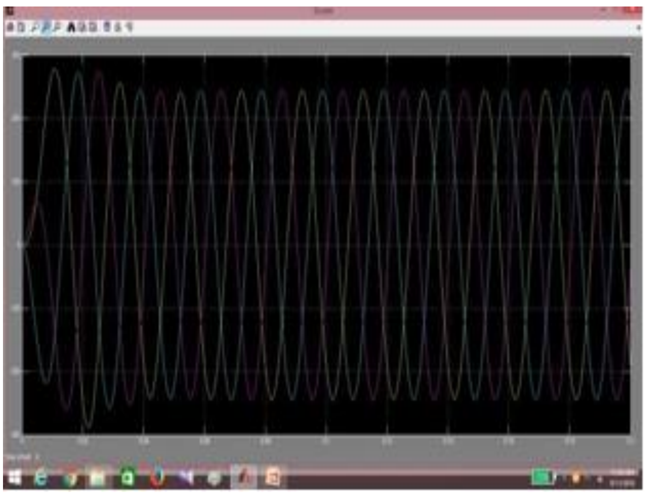

Fig 6 Three Phase Source Voltages

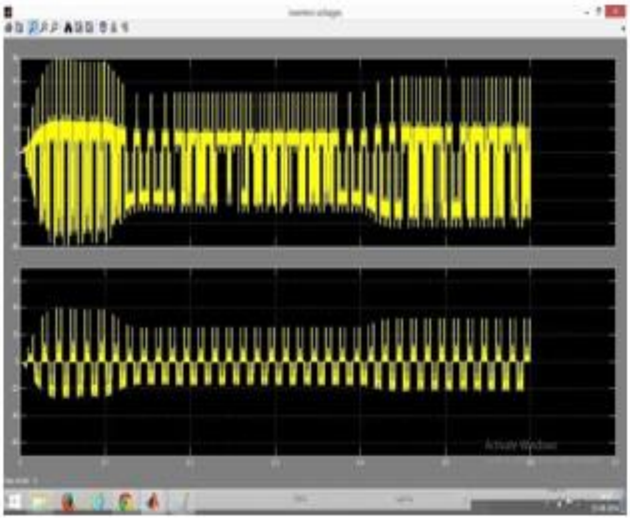

Fig 7 Inverter Voltages

V. CONCLUSION

The Static Synchronous Series Compensator (SSSC) stands as a significant and sophisticated Flexible AC Transmission System (FACTS) device that plays a crucial role in enhancing the stability, control, and overall performance of power systems. By operating on power electronic principles, the SSSC provides adynamic and real-time solution to address challenges associated with power transmission and distribution. The Static Synchronous Series Compensator represents a significant advancement in power system control and stability, offering a versatile and effective solution for addressing challenges associated with reactive power control, voltage stability, and power flow management in modern electrical grids.

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