Static Var Compensator for Reactive Power Control

Namburi Nireekshana[1]; K.Pulla Reddy[2];
[1,2]Assistant Professor, EEED
Methodist College of Engineering & Technology

Reyya Bose Babu
160720734009
BE, EEED
Methodist College of Engineering & Technology

Bonda Sunder
160720734003
BE, EEED
Methodist College of Engineering & Technology

G.Sumanth Kumar
160720734004
BE, EEED
Methodist College of Engineering & Technology

P.Vivekananda Raj
160720734012
BE, EEED
Methodist College of Engineering & Technology

Abstract:- Static VAR Compensators play a crucial role in modern power systems, offering a dynamic solution for managing reactive power and voltage. Their ability to rapidly respond to system changes makes them invaluable for maintaining system stability, improving power quality, and enhancing the overall efficiency of power transmission and distribution networks.A Static VAR Compensator (SVC) is a sophisticated electrical device used in power systems for controlling and regulating voltage and reactive power flow. It is part of the Flexible AC Transmission Systems (FACTS) family, which enhances the controllability and increases the power transfer capability of the network.

Keywords:- *FACTS, Reactive Power SVC, MATLAB.*

I. INTRODUCTION

Reactive power control plays a crucial role in power systems to ensure the stable and efficient operation of the electrical grid. It is an essential aspect of maintaining the voltage levels within acceptable limits and optimizing the overall performance of the power system.Reactive power control helps regulate and maintain voltage levels within specified limits. Voltage stability is essential to ensure that electrical devices and equipment connected to the grid operate reliably. Excessive or insufficient voltage can damage equipment and disrupt the grid's operation.Reactive power control is used to improve the power factor of the system. Power factor is a measure of how effectively electrical power is converted into useful work. Low power factor can result in increased losses and reduced efficiency in the power distribution system. By injecting or absorbing reactive power as needed, power factor correction devices like capacitors and inductors can raise the power factor, reducing system losses and improving efficiency.

Proper control of reactive power can reduce the resistive losses in transmission and distribution lines. High-voltage transmission lines, in particular, can experience significant losses due to the flow of reactive power. By maintaining appropriate voltage levels and power factor, these losses can be minimized.Reactive power control is crucial for maintaining the stability of the power system. Sudden changes in load or generation can lead to voltage fluctuations and instability. Reactive power sources, such as synchronous condensers or static VAR compensators (SVCs), can provide or absorb reactive power to stabilize voltage levels and prevent voltage collapse.

Managing reactive power flow can increase the capacity of transmission lines and transformers by ensuring that they operate closer to their rated voltage levels. This allows for the efficient transmission of electricity over longer distances without significant losses.As more renewable energy sources like wind and solar are integrated into the grid, reactive power control becomes even more critical. These sources often have variable and intermittent power output, which can affect the grid's stability

Reactive power control can reduce voltage flicker, which can be a nuisance for consumers. Voltage flicker is caused by rapid variations in voltage levels and can affect sensitive equipment like lighting systems and manufacturing processes. Proper control of reactive power can minimize these fluctuations.Reactive power control is essential for maintaining voltage stability, power factor correction, grid reliability, and overall efficiency in power systems. It ensures that electricity is delivered reliably to consumers while minimizing losses and optimizing the operation of the electrical grid.

II. PROPOSED TOPOLOGY

A Static VAR Compensator (SVC) is a device used in power systems to control and manage reactive power to maintain voltage stability and improve power quality. SVCs are solid-state devices that can rapidly inject or absorb reactive power into the grid as needed.

A Static VAR Compensator works as follows:

- **Voltage Measurement:** The SVC continuously monitors the voltage at a specific point in the electrical grid, typically at the location where it is installed. This voltage measurement is used as feedback for the control system.

- **Control System:** The heart of the SVC is its control system, which includes a microprocessor-based controller. The control system calculates the required amount of reactive power injection or absorption based on the measured voltage and a set of predefined control parameters.
- **Thyristor-controlled Reactors (TCRs):** SVCs use thyristor-controlled reactors (TCRs) as one of their key components. TCRs are essentially variable reactors that can control the flow of reactive power by adjusting the impedance in the circuit. The control system adjusts the firing angle of the thyristors to vary the impedance of the TCRs.
- **Thyristor-switched Capacitors (TSCs):** In addition to TCRs, SVCs also use thyristor-switched capacitors (TSCs). These capacitors are switched on and off by thyristors to provide or absorb reactive power rapidly. Capacitors are used to inject reactive power into the system, while TCRs are used to absorb it.
- **Reactive Power Management:** The SVC modulates its components – thyristor-controlled reactors and thyristor-switched capacitors – in response to the control system's directives based on grid voltage levels. When the monitored voltage dips below the desired threshold, the SVC compensates by injecting reactive power into the grid. This is achieved by decreasing the impedance of the TCRs and/or activating the TSCs. On the other hand, to counteract an excessive voltage scenario, the SVC absorbs reactive power. This is done by elevating the impedance of the TCRs and/or deactivating the TSCs.
- **Rapid Response**: SVCs are known for their ability to respond rapidly to changes in voltage or load conditions. They can inject or absorb reactive power within milliseconds, making them valuable for maintaining voltage stability during sudden changes in the grid, such as switching operations or faults.
- **Voltage Support and Power Quality Improvement:** By dynamically controlling reactive power, SVCs help stabilize voltage levels, reduce voltage fluctuations, and improve power quality in the grid. This, in turn, enhances the reliability of the electrical supply and minimizes disruptions to sensitive equipment.

Static VAR Compensators are a vital part of modern power systems, especially in situations where the grid experiences varying loads or the integration of renewable energy sources, which can lead to fluctuations in voltage and reactive power requirements. SVCs play a crucial role in ensuring that the electrical grid operates within acceptable voltage limits and maintains stable and reliable power delivery to consumers.

A. Principle operation of SVC

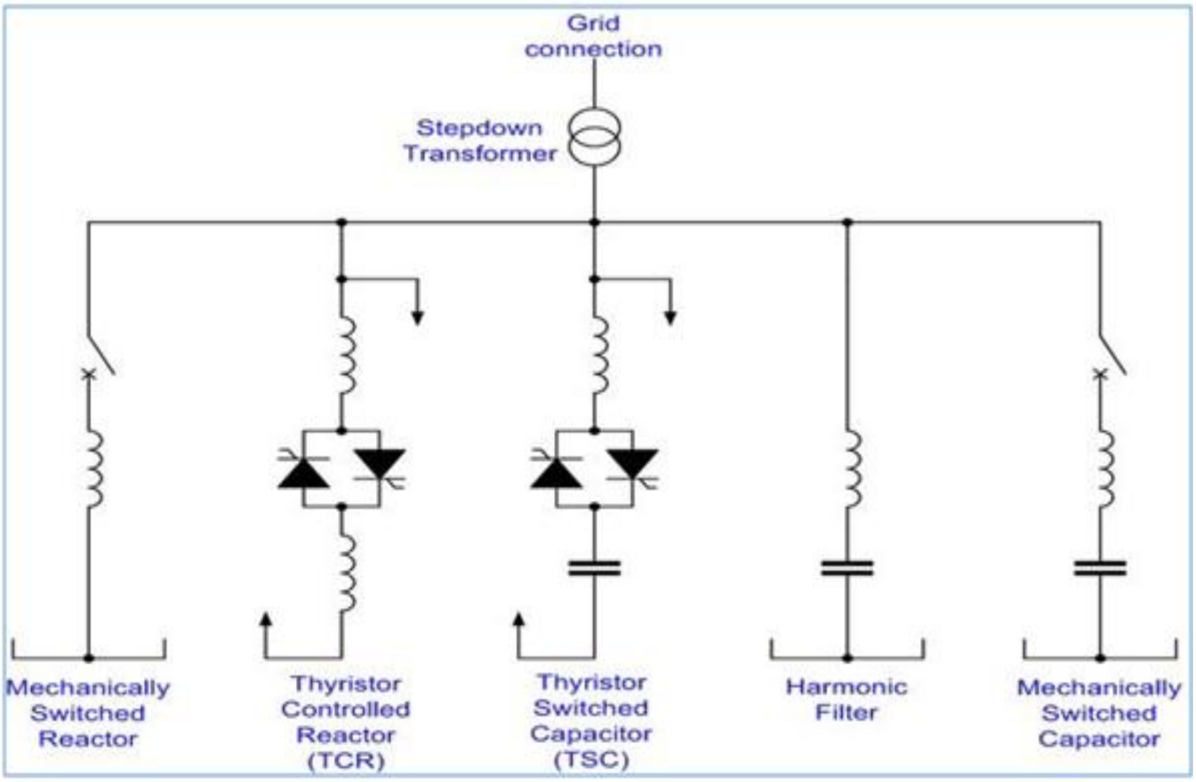

Fig. 1: Static Var compensator configuration

A Static Var Compensator (SVC) is a specialized electrical device designed to offer rapid reactive power compensation in high-voltage power transmission networks. As a key component of Flexible AC Transmission Systems (FACTS), SVCs play a crucial role in managing voltage levels and enhancing both the quality and efficiency of power flow within the network. The main function of an SVC is to stabilize the voltage of the grid it serves. It accomplishes this by modulating the flow of reactive power, which is critical for sustaining the appropriate voltage levels needed to transmit active (usable) power through the transmission lines.

A Static Var Compensator (SVC) is generally composed of components such as thyristor-controlled reactors (TCRs), thyristor-switched capacitors (TSCs), and in some instances, thyristor-switched reactors (TSRs). These elements collaboratively function to either produce or absorb reactive power, depending on the requirement. In situations where the system voltage falls below the desired level, the SVC steps in to generate reactive power, functioning similarly to a capacitor. This generation of reactive power is primarily facilitated by the TSCs, which contribute capacitive reactance to the system. Conversely, when the system experiences a high voltage, the SVC shifts to absorb reactive power, akin to a reactor's operation. Here, the TCRs come into play, introducing inductive reactance into the system to achieve the desired balance.

B. Operation Mechanism

- **Thyristor-Controlled Reactors (TCRs):** They are inductors whose effective inductance is varied using thyristors. By changing the firing angle of the thyristors, the SVC can control the amount of reactive power absorbed from the grid.
- **Thyristor-Switched Capacitors (TSCs):**Thyristor-Switched Capacitors (TSCs) function by being intermittently connected to, and disconnected from, the power grid through the use of thyristors. This process allows for a gradual, step-by-step modulation of capacitive reactive power, which is instrumental in enhancing and stabilizing the voltage levels within the grid.

C. Applications

SVCs are used in a variety of applications, including:

- Enhancing the power transfer capability of transmission lines.
- Improving voltage stability.
- Reducing the risk of voltage collapse.
- Damping power oscillations.

III. RESULTS AND SIMULATION

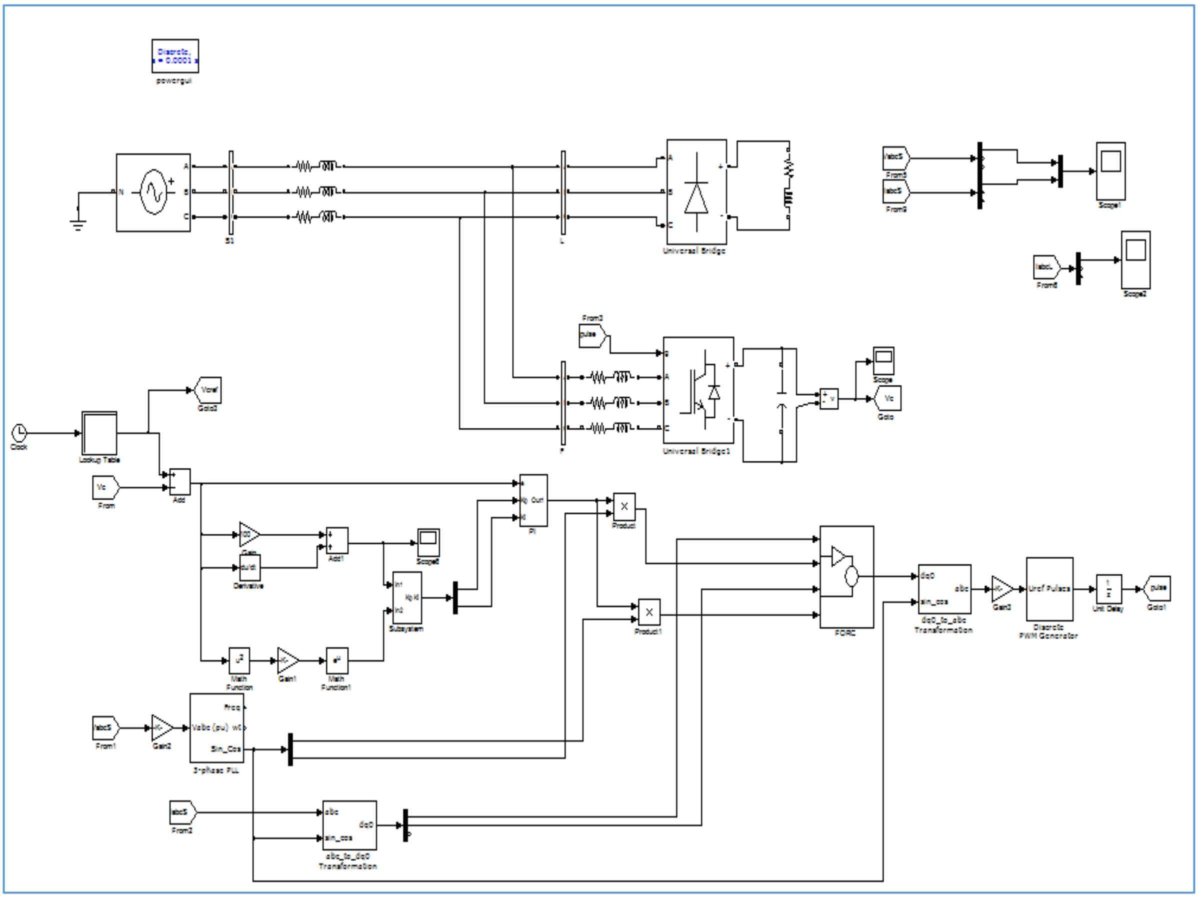

Fig. 2: Simulation Design of the Proposed System

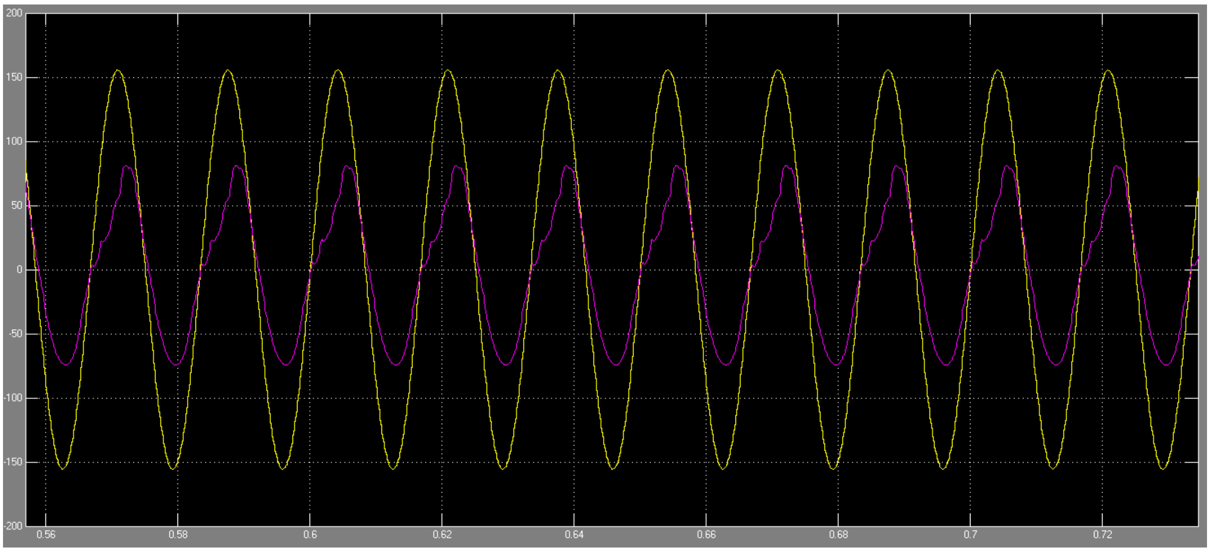

Fig. 3: Voltage and current waveforms of grid side

IV. CONCLUSION

SVCs play a crucial role in modern electrical grids, where the demand and supply of electricity can vary significantly and rapidly, requiring quick and efficient ways to manage voltage levels for reliable and stable power delivery.SVCs play a pivotal role in modern electrical networks, addressing key challenges related to voltage stability, power quality, and grid efficiency. Their ability to provide fast, flexible, and efficient reactive power compensation makes them invaluable in the evolving landscape of power generation and distribution, particularly with the increasing emphasis on renewable energy and the need for more resilient and adaptable power systems.

V. FUTURE RESEARCH SCOPE

The future research scope of Static Var Compensators (SVCs) is broad and promising, particularly as the world's energy systems continue to evolve towards more sustainable and efficient models. Here are some potential areas of future research and development in the field of SVCs:

- **Integration with Renewable Energy Sources**: With the increasing use of renewable energy sources like wind and solar, which are inherently intermittent and variable, research into how SVCs can better support grid stability and integration of these energy sources is vital.

- **Advanced Control Strategies:** Developing more sophisticated control algorithms for SVCs can enhance their performance. This includes the use of artificial intelligence and machine learning techniques for predictive control and better response to grid dynamics

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