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Power Quality Improvement using Distribution STATCOM (D-STATCOM)

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ABSTRACT: D-STATCOM (static synchronous compensator) as a shunt-link flexible AC transmission system(FACTS) controller has shown extensive feasibility in terms of cost-effectiveness in a wide range of problem solving abilities from transmission to distribution levels. Advances in power electronic technologies such as Voltage Source Converter (VSC) improves the reliability and functionality of power electronic based controllers hence resulting in increased applications of STATCOM. In this paper, design and implementation of a Distribution type, Voltage Source Converter (VSC) based static synchronous compensator (D-STATCOM) has been carried out. It presents the enhancement of power quality problems, such as voltage sag and swell using Distribution Static Compensator (D-STATCOM) in distribution system. The model is based on Sinusoidal Pulse Width Modulation (SPWM) technique. The control of the Voltage Source Converter (VSC) is done with the help of SPWM. The main focus of this paper is to compensate voltage sag and swell in a distribution system. To solve this problem custom power devices are used such as Fixed Compensators (FC, FR), Synchronous Condenser, SVC, SSSC, STATCOM etc. Among these devices Distribution STATCOM (D-STATCOM) is the most efficient and effective modern custom power device used in power distribution networks. D-STATCOM injects a current into the system to mitigate the voltage sag and swell. The work had been carried out in MATLAB environment using Simulink and SIM power system tool boxes. The proposed D-STATCOM model is very effective to enhance the power quality of an isolated distribution system feeding power to crucial equipment in remote areas. The simulations were performed and results were found to be satisfactory using MATLAB/SIMULINK.

KEY WORDS: D-STATCOM, Voltage sag, Voltage swell, power Quality, Harmonics

I. INTRODUCTION

An increasing demand for high quality, reliable electrical power and increasing number of distorting loads may leads to an increased awareness of power quality both by customers and utilities. The most common power quality problems today are voltage sags, harmonic distortion and low power factor. Voltage sags is a short time (10 ms to 1 minute) event during which a reduction in rms voltage magnitude occurs. It is often set only by two parameters, depth/ magnitude and duration. The voltage sags magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min. Voltage sags is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing .Voltage sags are one of the most occurring power quality problems. For an industry voltage sags occur more often and cause severe problems and economical losses.

Utilities often focus on disturbances from end-user equipment as the main power quality problems. Harmonic currents in distribution system can cause harmonic distortion, low power factor and additional losses as well as heating in the electrical equipment. It also can cause vibration and noise in machines and malfunction of the sensitive equipment. The development of power electronics devices such as Flexible AC Transmission System(FACTS) and customs power devices have introduced and emerging branch of technology providing the power system with versatile new control capabilities. There are different ways to enhance power quality problems in transmission and distribution systems. Among these, the D-STATCOM is one of the most effective devices. A new PWM-based control scheme has been implemented to control the electronic valves in the DSTATCOM [01-04]. The D-STATCOM has additional capability to sustain reactive current at low voltage, and can be developed as a voltage and frequency support by replacing capacitors with batteries as energy storage.

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Power quality is the set of limits of electrical properties that allows electrical systems to function in their intended manner without significant loss of performance or life. The term is used to describe electric power that drives an electrical load and the load's ability to function properly with that electric power. A perfect power supply would be one that is always available, always within voltage and frequency tolerances and has a pure noise-free sinusoidal wave shape.

Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor quality power. Many power problems originate in the commercial power grid, which, with its thousands of miles of transmission lines, is subject to weather conditions such as hurricanes, lightning storms, snow, ice, and flooding along with equipment failure, traffic accidents and major switching operations.

Also, power problems affecting today's technological equipment are often generated locally within a facility from any number of situations, such as local construction, heavy startup loads, faulty distribution components, and even typical background electrical noise. Widespread use of electronics in everything from home electronics to the control of massive and costly industrial processes has raised the awareness of power quality. The study of power quality, and ways to control it, is a concern for electric utilities, large industrial companies, businesses, and even home users [05-06].

Additionally, a D-STATCOM can also behave as a shunt active filter, to eliminate unbalance or distortions in the source current or the supply voltage. Since a D-STATCOM is such a multifunctional device, the main objective of any control algorithm should be to make it flexible and easy to implement, in addition to exploiting its multi functionality to the maximum.

Prior to the type of control algorithm incorporated, the choice of converter configuration is an important criterion [11-14].

The two converter configurations are voltage source converter or current source converter, in addition to passive storage elements, either a capacitor or an inductor respectively. Normally, voltage source converters are preferred due to their smaller size, less heat dissipation and less cost of the capacitor, as compared to an inductor for the same rating. This paper focuses on the comparative study of the control techniques for voltage source converter based DSTATCOM, broadly classified into voltage control DSTATCOM and current control D-STATCOM. Under the former, phase shift control is compared with the latter, considering indirect decoupled current control and regulation of AC bus and DC link voltage with hysteresis current control. The first two schemes have been successfully implemented for STATCOM control at the transmission level, for reactive power compensation, and voltage support and are recently being incorporated to control a D-STATCOM employed at the distribution end.

The following indices are considered for comparison - measurement and signal conditioning requirement, performance with varying linear/nonlinear load, THD, DC link voltage variation and switching frequency [15-17].

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II. PROPOSED SYSTEM

2.1 BLOCK DIAGRAM

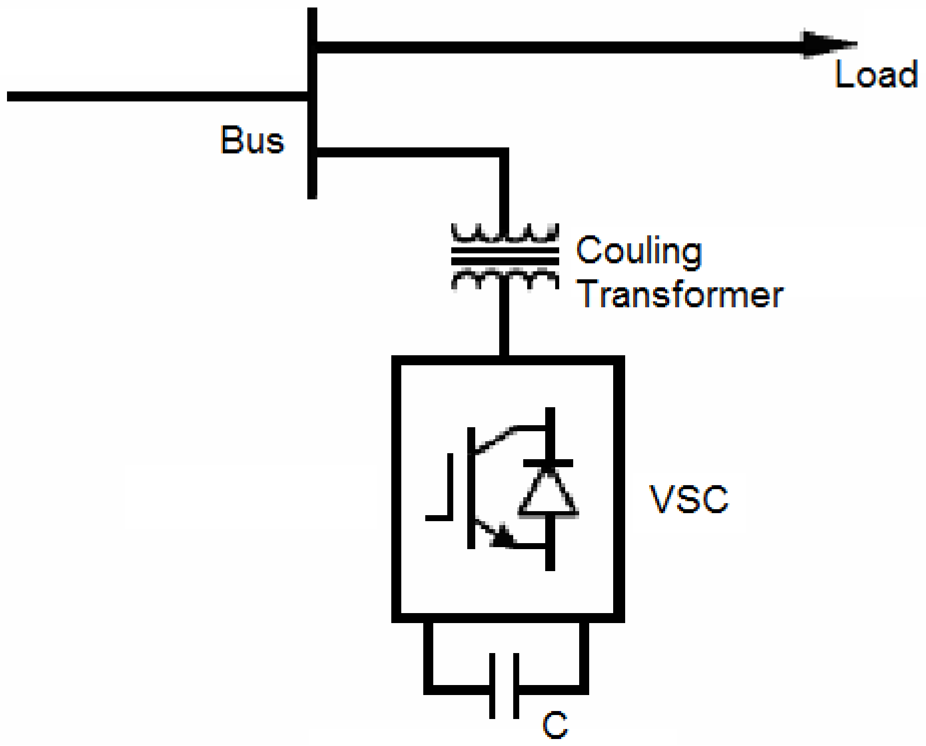

Fig 1 Block Diagram of D-STATCOM

It consist of a source, Non-linear load, D-statcom and controller. The D-Statcom is actually a shunt compensating device which has 3 phase bi-directional voltage source converter with a capacitor and capacitor is called storage device. In addition to this it has a filter and it will be connected to the line through a potential transformer. When the grid voltage is lesser than the capacitor voltage, the capacitor will discharge current to the line and vice versa. The discharge capacitor voltage mentions the voltage sag that is line voltage lesser than capacitor voltage and the capacitor charging mentions the voltage swell. The block diagram of D-Statcom is shown in figure 1.

The PI controller provide in the proposed system will act quickly to suppress the short time variation in the voltage of the grid. It will mitigate both voltage sag and swell that is increase in the voltage or decrease in the voltage caused due to load variation. If the voltage sag and swell or mitigated immediately, it may slowly damage the apparatus in the load side or it may affect the input side that is apparatus of the other's. The voltage sensor provided in the load will sense and give it to controller, according to feedback the controller will vary the firing angle of the inverter.

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2.2 CIRCUIT DIAGRAM

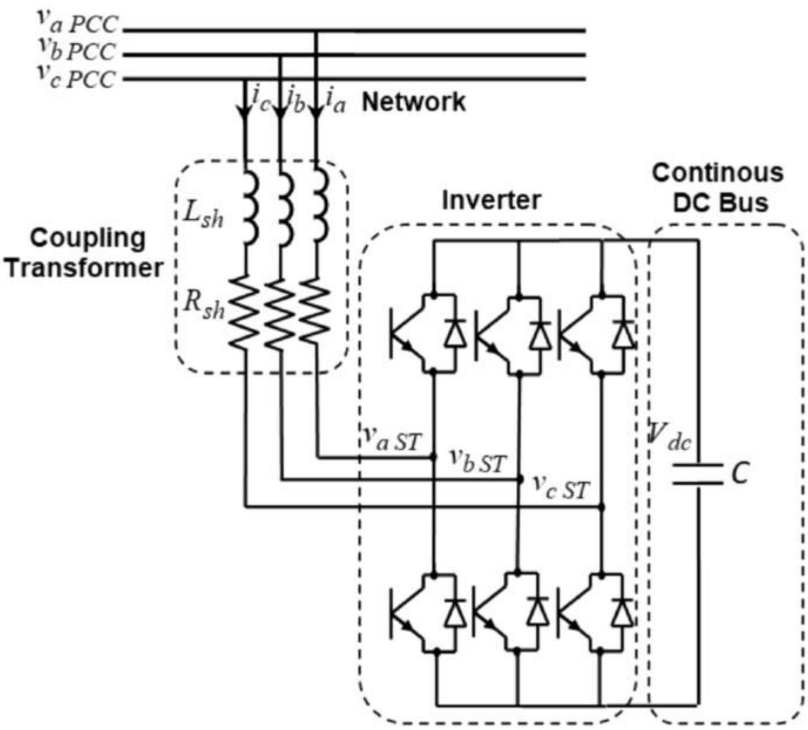

Fig 2 Circuit Diagram of D-STATCOM without Filter

A D-STATCOM is a controlled reactive source, which includes a VSC and a DC link capacitor connected in shunt, capable of generating and/or absorbing reactive power. The operating principles of a D-STATCOM are based on the exact equivalence of the conventional rotating synchronous compensator. The AC terminals of the VSC are connected to the PCC through an inductance, which could be a filter inductance or the leakage inductance of the coupling transformer, as shown in Figure 2.

Advantages of Proposed System

A Static Synchronous Compensator (STATCOM) is a power quality device used to mitigate voltage sags and swells in the distribution system. Some advantages of using a STATCOM include:

1. **Improved Power Quality**: The primary advantage of a STATCOM is that it helps maintain the voltage at a constant level, thereby improving the power quality supplied to sensitive loads. By injecting a voltage with the correct magnitude and phase angle, a STATCOM can compensate for voltage disturbances and provide a stable voltage supply to critical equipment.
2. **Fast Response Time**: STATCOMs typically have very fast response times, on the order of milliseconds. This allows them to quickly detect voltage disturbances and inject compensating voltages to mitigate the impact on connected loads. This rapid response helps prevent disruptions to sensitive equipment.
3. **Selective Compensation**: STATCOMs can be designed to provide selective compensation to specific loads or areas of the distribution system. This targeted compensation ensures that critical loads receive the necessary voltage support during disturbances, while non-critical loads may not be affected.
4. **Cost-Effective Solution**: In many cases, installing a STATCOM can be a cost-effective solution compared to other alternatives for improving power quality, such as installing larger transformers or upgrading distribution infrastructure. STATCOMs can provide targeted voltage support where it is needed most, reducing the overall cost of power quality improvement.
5. **Compatibility with Renewable Energy Sources**: With the increasing integration of renewable energy sources like solar and wind power into the grid, voltage fluctuations can become more common. A STATCOM can help

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mitigate these fluctuations and ensure a stable voltage supply to the grid, improving the overall integration of renewable energy sources.

6. **Increased System Reliability**: By providing voltage support during disturbances, a STATCOM can help improve the reliability of the distribution system. This can lead to fewer interruptions in power supply and reduced downtime for critical equipment and processes.

Overall, the advantage of a STATCOM lies in its ability to improve power quality, provide fast and selective compensation, offer a cost-effective solution, enhance compatibility with renewable energy sources, and increase system reliability.

III. SIMULATION DIAGRAM

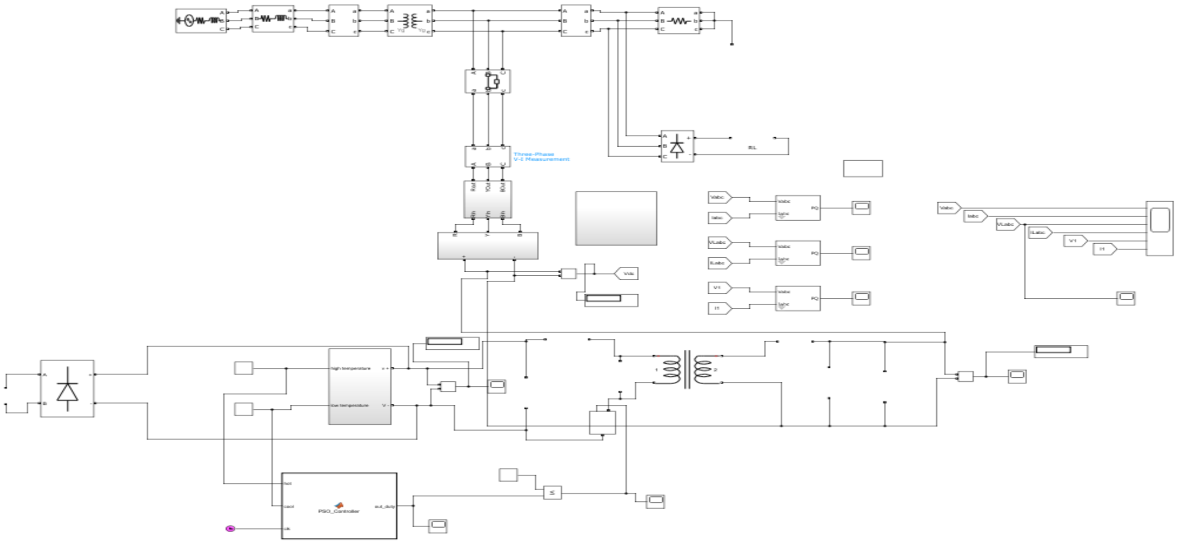

Figure 3 Simulation diagram

The simu-link diagram and the outputs at various conditions are shown in figure 3, 4 and 5.

3.1 SIMULATION OUTPUTS

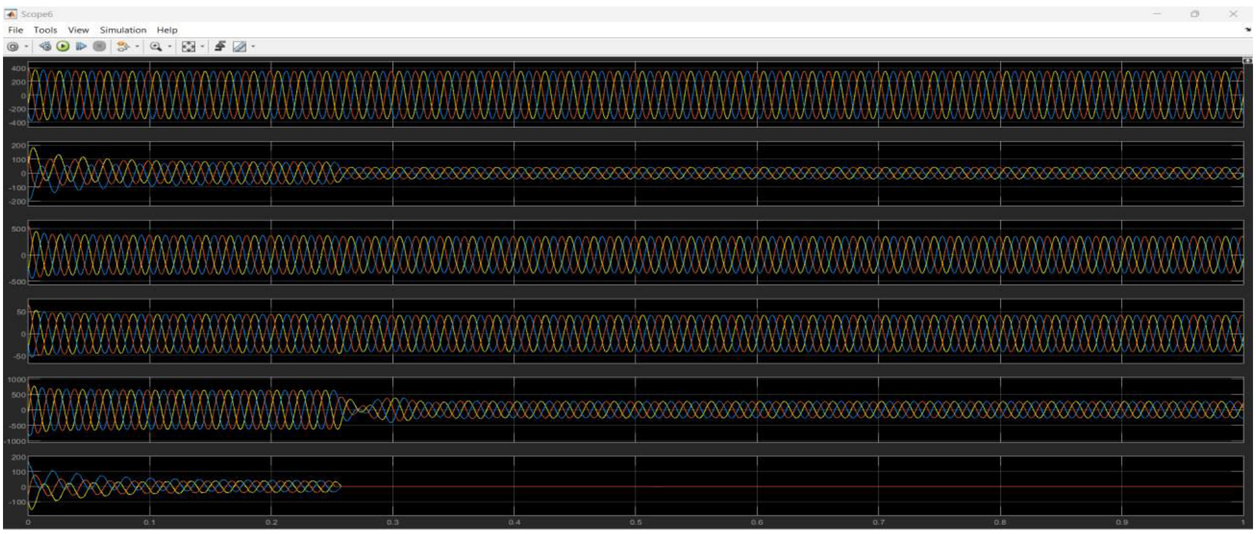

Figure 4 Output waveform without compensation

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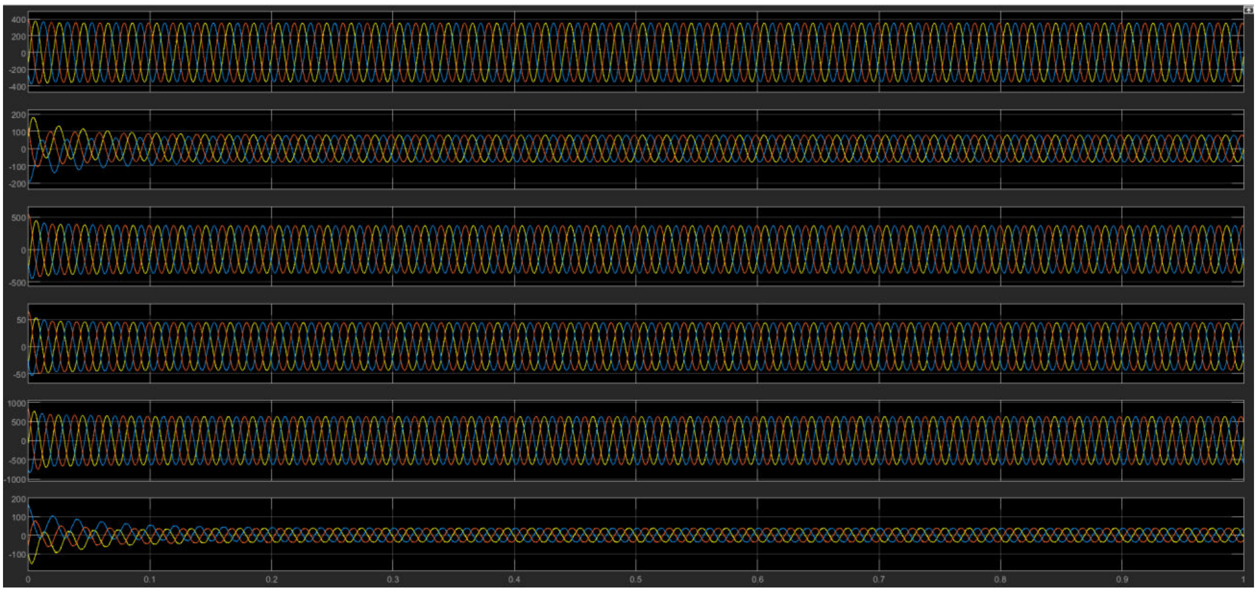

Figure 5 Output With Compensation

IV. CONCLUSION

Through the use of switching function, the effect of the grid voltage unbalance on D-STATCOM output performance is analyzed. And the system equivalent circuit with the third harmonic is proposed which provides theoretical basis for comprehensive and correct analysis of D-STATCOM operation performance. With the improved switching function modulation, the output performance of D-STATCOM is improved, and with negative-sequence feed forward control strategy to restrain device over current, the over current of D-STATCOM under grid voltage unbalance is prevented, and its output performance is improved as well. Simulation results showed that the conclusions of this paper and the proposed control method is correct and effective. The PI controller provided will enhance performance of the D-statcom and tune the output voltage to constant with short time interval after a fault occurred in the distribution system. The proposed paper is validated through MATLAB simulink and the output voltage waveforms are verified.

4.1 SCOPE FOR FUTURE WORK

It has wide future scope implement like extending the type of controllers used, algorithm used method of firing angle control for the D-Statcom.

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