# POWER QUALITY IMPROVEMENT IN LOW-VOLTAGE DISTRIBUTION GRIDS USING VOLTAGE REGULATOR

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Abstract—This paper presents a voltage-controlled DSTATCOM-based voltage regulator for low voltage distribution grids. The voltage regulator is designed to temporarily meet the grid code, postponing unplanned investments while a definitive solution could be planned to solve regulation issues. The power stage is composed of a three-phase four-wire Voltage Source Inverter (VSI) and a second order low-pass filter. The control strategy has three output voltage loops with active damping and two dc bus voltage loops. In addition, two loops are included to the proposed control strategy: the concept of Minimum Power Point Tracking (mPPT) and the frequency loop. The mPPT allows the voltage regulator to operate at the Minimum Power Point (mPP), avoiding the circulation of unnecessary reactive compensation. The frequency loop allows the voltage regulator to be independent of the grid voltage information, especially the grid angle, using only the information available at the Point of Common Coupling (PCC). Experimental results show the regulation capacity, the features of the mPPT algorithm for linear and nonlinear loads and the frequency stability.

## 1. INTRODUCTION

ELECTRIC utilities and end users of electric power are becoming increasingly concerned about meeting the growing energy demand. Seventy five percent of total global energy demand is supplied by the burning of fossil fuels. But increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution. Since the past decade, there has been an enormous interest in many countries on renewable energy for power generation. The market liberalization and government's incentives have further accelerated the renewable energy sector growth.

Renewable energy source (RES) integrated at distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of intermittent RES in distribution systems as it may pose a threat to network in terms of stability, voltage regulation and power-quality (PQ)issues. Therefore, the DG systems are required to comply with strict technical and regulatory frameworks to ensure safe, reliable and efficient operation of overall network.

With the advancement in power electronics and digital control technology, the DG systems can now be actively controlled to enhance the system operation with improved PQ at PCC. However, the extensive use of power electronics based equipment and non-linear loads at PCC generate harmonic currents, which may deteriorate the quality of power.

Generally, current controlled voltage source inverters are used to interface the intermittent RES in distributed system. Recently, a few control strategies for grid connected inverters incorporating PQ solution have been proposed. In an inverter operates as active inductor at a certain frequency to absorb the harmonic current. But the exact calculation of network inductance in real-time is difficult and may deteriorate the control performance. A similar approach in which a shunt active filter acts as active conductance to damp out the harmonics in distribution network is proposed. A control strategy for renewable interfacing inverter based on – theory is proposed. In this strategy both load and inverter current sensing is required to compensate the load current harmonics.

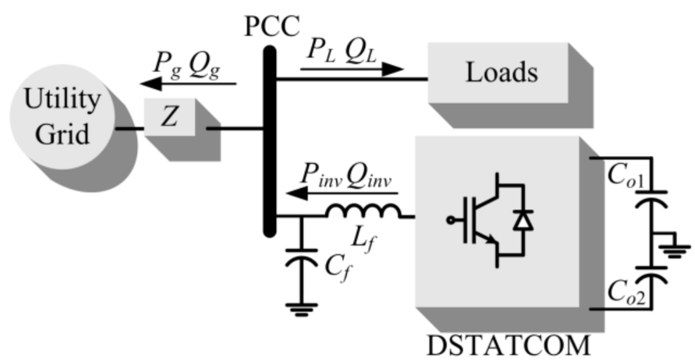


Fig. 1. Low voltage distribution grid under analysis with the voltage regulator

## 2. Existing system:

To meet the voltage regulation requirement, a voltage-controlled DSTATCOM-based voltage regulator is proposed with shunt connection to PCC .The shunt connection avoids power supply interruption while the voltage regulator is installed or disconnected. The proposed DSTATCOM allows the power company to postpone investments and enhances the flexibility of grid management.

Voltage-controlled DSTATCOM can maintain the PCC voltages balanced even under grid or load unbalances. The PCC voltage is directly controlled by the DSTATCOM and sudden load changes have no significant impact in the PCC voltage waveforms. Moreover, the voltage-controlled DSTATCOM decouples the grid and the loads, serving as a low impedance path for harmonic distortions due the voltage source behavior. Current harmonic distortions from the loads have small impact in the grid and vice versa. The grid current quality, therefore, is exclusively given by the grid voltage quality.

3. Proposed system:

A voltage-controlled DSTATCOM-based voltage regulator for low voltage distribution grids, using a three-phase four-wire VSI with an LC low-pass output filter is proposed . Operation principles of the voltage-controlled DSTATCOM and the control strategy are presented. Additionally, two loops are included to the proposed control strategy: the concept of minimum power point tracking (MPPT) and the frequency loop.

The MPPT avoids unnecessary reactive compensation, increasing the compensation capability. The frequency loop overcomes the practical difficulty of synchronization by correcting the frequency of the voltage reference. This proposes the combination of both loops, providing to the power company a solution for the poor voltage regulation in real distribution grids with superior PCC voltage quality.

Block Diagram of Proposed Method

A distribution system suffer from current as well as voltage related power quality problems, which include poor power factor, distorted source current and voltage disturbances .A STATCOM connected to the point of common coupling has been utilized to mitigate both types of PQ problems .When operating in CCM it injects reactive and harmonics components of load current to make source current balanced, sinusoidal and in phase with the point of common coupling voltages. In VCM the STATCOM regulates PCC voltages at a references value to protect critical loads from voltage disturbances such as sag, swell and unbalances. However the advantages of CCM and VCM cannot be achieved simultaneously with one active filter device, since two modes are independent of each other. A load works satisfactorily for a permissible voltage range. Hence, it is not necessary to regulate the PCC voltage at 1.0 p.u. While maintaining 1.0-p.u. voltage, DSTATCOM compensates for the voltage drop in feeder. For this, the compensator has to supply additional reactive currents which increase the source currents. This increases losses in the voltage-source inverter (VSI) and feeder. Another important aspect is the rating of the VSI. Due to increased current injection, the VSI is de-rated in steady-state condition. Consequently, its capability to mitigate deep voltage sag decreases. Also, UPF cannot be achieved when the PCC voltage. STATCOM can be replaced by DSTATCOM. The proposed block diagram is shown in the fig.2.It is applicable for both linear as well as non linear load.

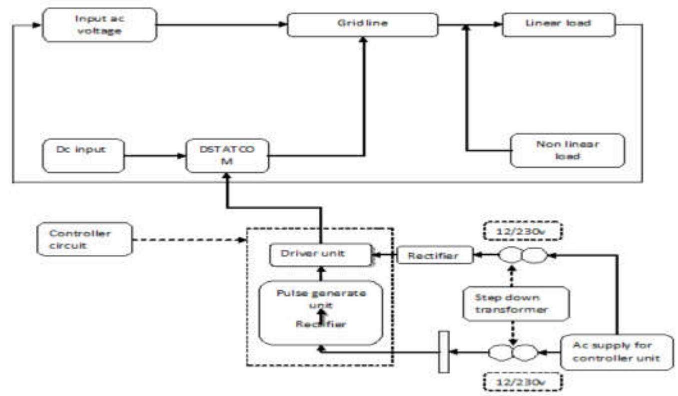


Fig.2 proposed block diagram

The singlephase equivalent circuit of STATCOM is shown in the fig.4.2

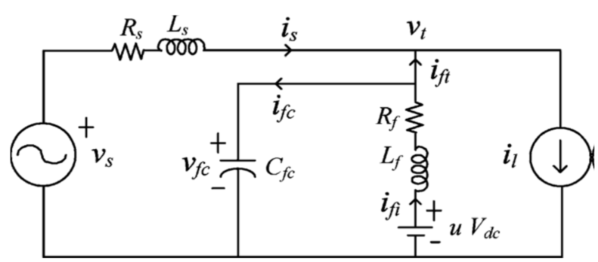


Fig.3 single phase equivalent circuit of STATCOM

MATLAB/SIMULINK RESULTS

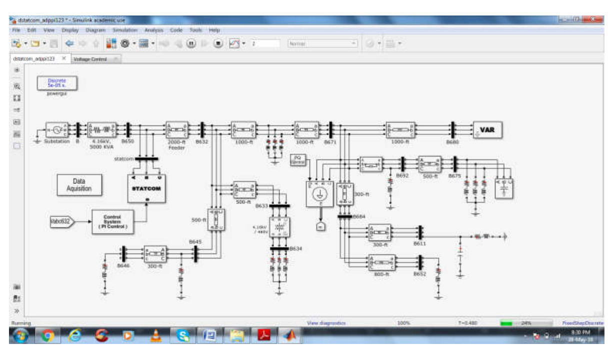

Fig 4 Block diagram of low voltage distribution grid under analysis with the voltage regulator

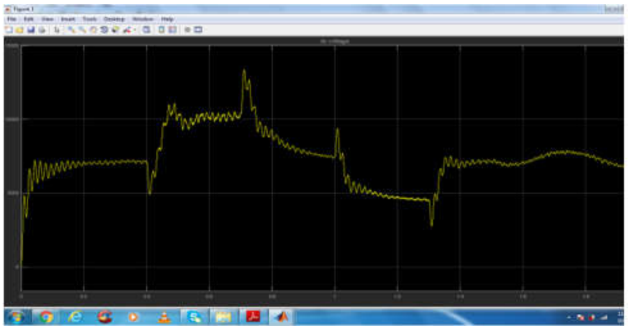

Fig 5 DC bus voltages during the DSTATCOM intialization

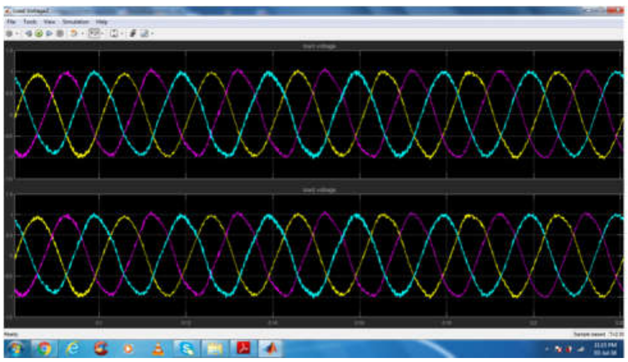

Fig 6 PCC voltages with and with out compensation for linear loads

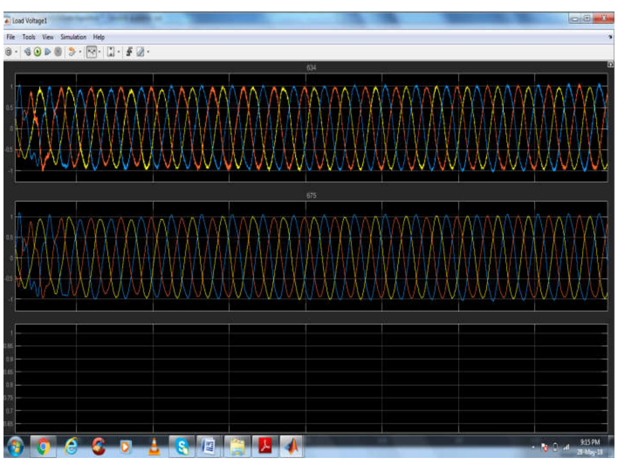

Fig 7 Total dc bus voltage, PCC voltage, grid voltage and voltage regulator currents waeforms of VABC AND IABC

## 4. CONCLUSION

This paper presents a three phase DSTATCOM as a voltage regulator and its control strategy, composed of the conventional loops, output voltage and dc bus regulation loops, including the voltage amplitude and the frequency loops. Experimental results demonstrate the voltage regulation capability, supplying three balanced voltages at the PCC, even under nonlinear loads The proposed amplitude loop was able to reduce the voltage regulator processed apparent power about 51 % with nonlinear load and even more with linear load (80%). The mPPT algorithm tracked the minimum power point within the allowable voltage range when reactive power compensation is not necessary. With grid voltage sag and swell, the amplitude loop meets the grid code. The mPPT can also be implemented in current-controlled DSTATCOMs, achieving similar results. The frequency loop kept the compensation angle within the analog limits, increasing the autonomy of the voltage regulator, and the dc bus voltage regulated at nominal value, thus minimizing the dc bus voltage steady state error. Simultaneous operation of the mPPT and the frequency loop was verified. The proposed voltage regulator is a shunt connected solution, which is tied to low voltage distribution grids without any power interruption to the loads, without any grid voltage and impedance information, and provides balanced and low-THD voltages to the customers..

## 5. REFERENCES


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