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Power-Quality Improvement with D-STATCOM Based Voltage Controller for PMSM Drive

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ABSTRACT: Power Quality (PQ) has become an important issue since many Non-Linear loads at various distribution ends have become intolerant to harmonic content. Power Quality (PQ) mainly deals with issues like maintaining a fundamental supply voltage and Load current at the Point of Common Coupling (PCC) for various distribution voltages. The basic operation principle of the DSTATCOM is to inject an appropriate current in parallel with the supply. The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes like, voltage regulation and compensation of reactive power, correction of power factor and elimination of current harmonics.

In this paper a latest algorithm to make reference voltage used for a distribution static compensator (DSTATCOM) working in voltage-control method. The proposed method ensures that unity power factor (UPF) is reached at the load end for the duration of nominal process, which is not achievable in the conventional method. Also, the compensator inserts lower currents and thus, decreases losses in the feeder and voltage source inverter. In this thesis, Power quality circuit is developed with voltage source converter in the Permanent Magnet Synchronous Motor drive. The organize of PMSM drive used is Field Oriented Control by means of pulse width Modulation. The power quality circuit planned in this work increases the power factor and decreases the harmonic distortion. Simulation work is performed by using MATLAB/ SIMULINK software.

KEYWORDS: PQ; PMSM; D-STATCOM;

I. INTRODUCTION

A Distribution system suffers from current as well as voltage-related power-quality (PQ) problems, which include poor power factor, distorted source current, and voltage disturbances [1], [2]. A DSTATCOM, connected at the point of common coupling (PCC), has been utilized to mitigate both types of PQ problems [2]–[12]. When operating in current control mode (CCM), it injects reactive and harmonic components of load currents to make source currents balanced, sinusoidal, and in phase with the PCC voltages [3]–[7]. In voltage-control mode (VCM) [2], [8]–[12], the DSTATCOM regulates PCC voltage at a reference 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.

In CCM operation, the DSTATCOM cannot compensate for voltage disturbances. Hence, CCM operation of DSTATCOM is not useful under voltage disturbances, which is a major disadvantage of this mode of operation [13]. Traditionally, in VCM operation, the DSTATCOM regulates the PCC voltage at 1.0 p.u. [2], [8]–[11]. However, a load works satisfactorily for a permissible voltage range [14]. 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 increases 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 is 1 p.u. In the literature, so far, the operation of DSTATCOM is not reported where the advantages of both modes are achieved based on load requirements while overcoming their demerits.

This paper considers the operation of DSTATCOM in VCM and proposes a control algorithm to obtain the reference load terminal voltage. This algorithm provides the combined advantages of CCM and VCM. The UPF operation at the

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PCC is achieved at nominal load, whereas fast voltage regulation is pro- vided during voltage disturbances. Also, the reactive and harmonic component of load current is supplied by the compensator at any time of operation. The deadbeat predictive controller [15]–[17] is used to generate switching pulses. The control strategy is tested with a three-phase four-wire distribution system. The effectiveness of the proposed algorithm is validated through detailed simulation and experimental results

II. Proposed Control Scheme

Circuit diagram of a DSTATCOM-compensated distribution system is shown in Fig. 1. It uses a three-phase, four-wire, two-level, neutral-point-clamped VSI. This structure allows independent control to each leg of the VSI [7]. Fig. 2 shows the single-phase equivalent representation of Fig. 1. Variable is a switching function, and can be either or depending upon switching state. Filter inductance and resistance are and respectively. Shunt capacitor eliminates high-switching frequency components.

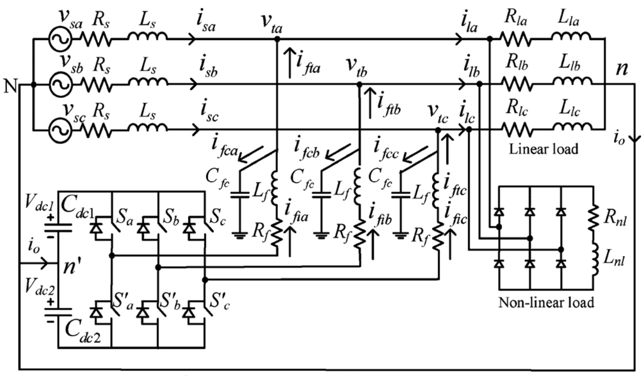

Fig. 1. Circuit diagram of the DSTATCOM-compensated distribution system

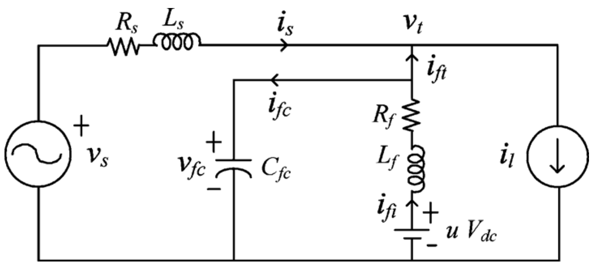

Fig. 2. Single-phase equivalent circuit of DSTATCOM.

The instantaneous symmetrical component theory and complex Fourier transform, a reference voltage magnitude generation scheme is proposed that provides the advantages of CCM at nominal load. The overall controller block diagram is shown in Fig. 3

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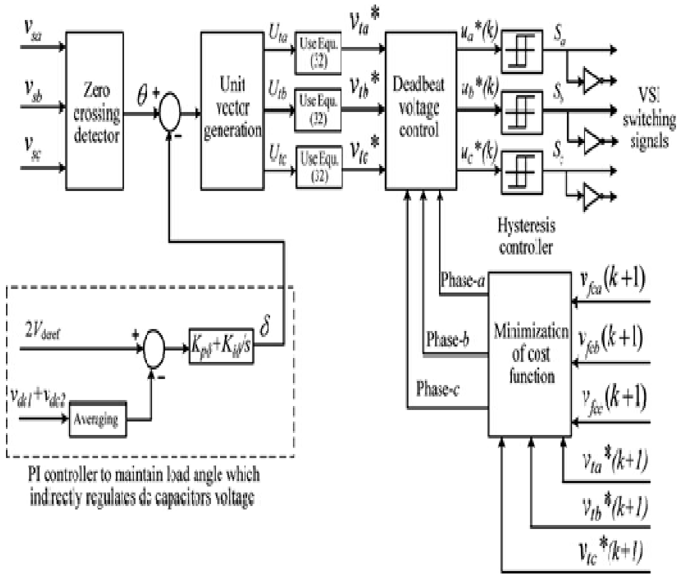

Fig. 3. Overall block diagram of the controller to control DSTATCOM in a distribution system

III. PERMANENT MAGNET SYNCHRONOUS MACHINE

Under steady state condition is proportional to the frequency of the current in its armature. Fig. 4 indicates the PMSM Cylindrical rotor and Salient rotor structures. The magnetic field created by the armature currents rotates at the same speed as that created by the field current on the rotor, which is rotating at the synchronous speed, and a steady torque results. Synchronous machines are commonly used as generators especially for large power systems, such as turbine generators and hydroelectric generators in the grid power supply. Because the rotor speed is proportional to the frequency of excitation, synchronous motors can be used in situations where constant speed drive is required. Since the reactive power generated by a synchronous machine can be adjusted by controlling the magnitude of the rotor field current, unloaded synchronous machines are also often installed in power systems solely for power factor correction. The armature winding of a conventional synchronous machine is almost invariably on the stator and is usually a three phase winding. The field winding is usually on rotor and excited by dc current, or permanent magnets. The dc power supply required for excitation usually is supplied through a dc generator known as exciter, machine which is often mounted on the same shaft as the synchronous.

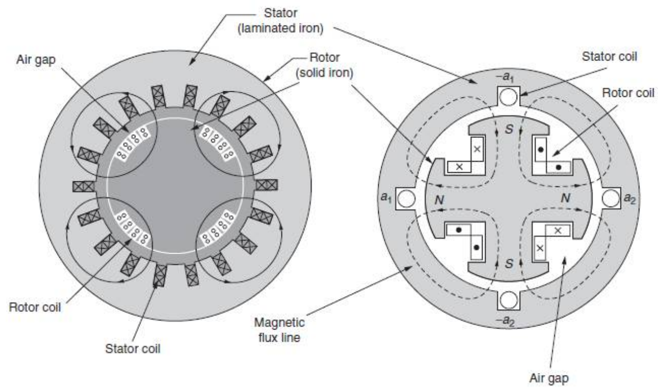

Fig.4. Cylindrical rotor and Salient rotor structures.

A. PHOTOVOLTAIC SYSTEM

A photovoltaic system, converts the light received from the sun into electric energy. In this system, semi conductive materials are used in the construction of solar cells, which transform the self-contained energy of photons into electricity, when they are exposed to sun light. The cells are placed in an array that is either fixed or moving to keep tracking the sun in order to generate the maximum power [9]. These systems are environmental friendly without any kind of emission, easy to use, with simple designs and it does not require any other fuel than solar light. On the other hand, they need large spaces and the initial cost is high. PV array are formed by combine no of solar cell in series and in parallel. A simple solar cell equivalent circuit model is shown in figure. To enhance the performance or rating no of cell are combine. Solar cell are connected in series to provide greater output voltage and combined in parallel to increase the current. Hence a particular PV array is the combination of several PV module connected in series and parallel. A module is the combination of no of solar cells connected in series and parallel.

The photovoltaic system converts sunlight directly to electricity without having any disastrous effect on our environment. The basic segment of PV array is PV cell, which is just a simple p-n junction device. The fig.5 manifests the equivalent circuit of PV cell. Equivalent circuit has a current source (photocurrent), a diode parallel to it, a resistor in series describing an internal resistance to the flow of current and a shunt resistance which expresses a leakage current. The current supplied to the load can be given as.

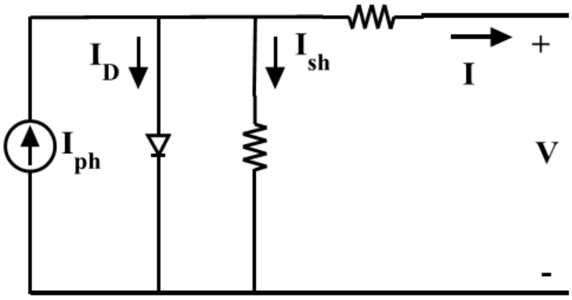

Fig.5. Equivalent circuit of Single diode modal of a solar cell..

IV. MATLAB/SIMULINK RESULTS

Simulation results of this paper is as shown in bellow Figs.8 to 19.

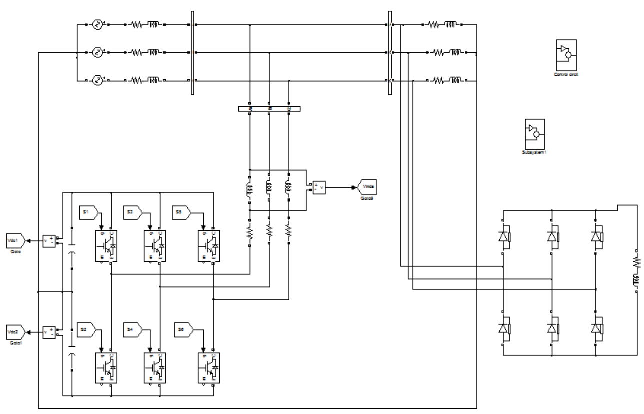

Fig.8.Simulation results for Conventional/Proposed system.

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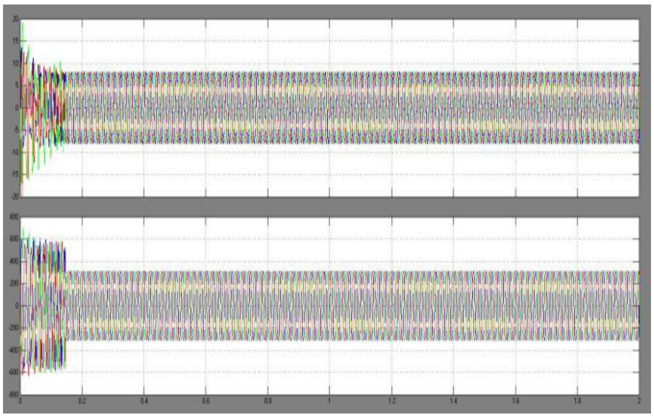

Fig.8.Source voltage and current.

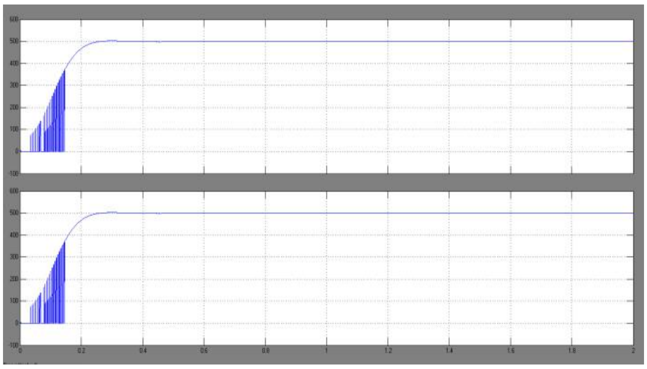

Fig.9.dc link voltage.

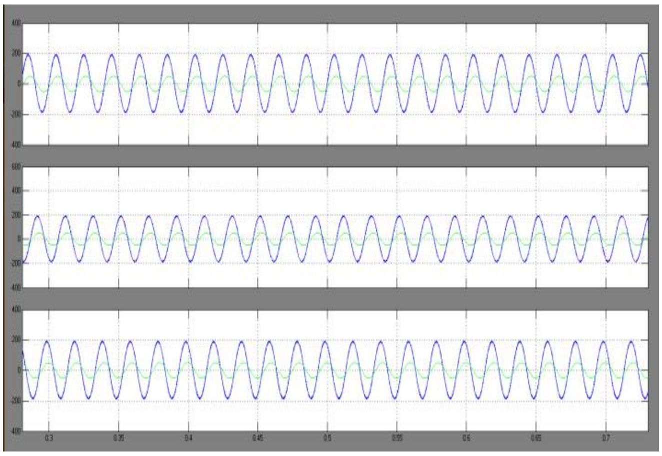

Fig.10. Terminal voltages and source currents using the traditional method. (a) Phase-A. (b) Phase-B. (c) Phase- C.

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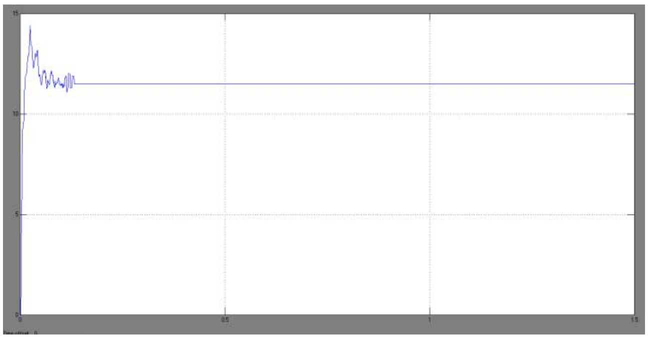

Fig. 11. Phase- source RMS currents.

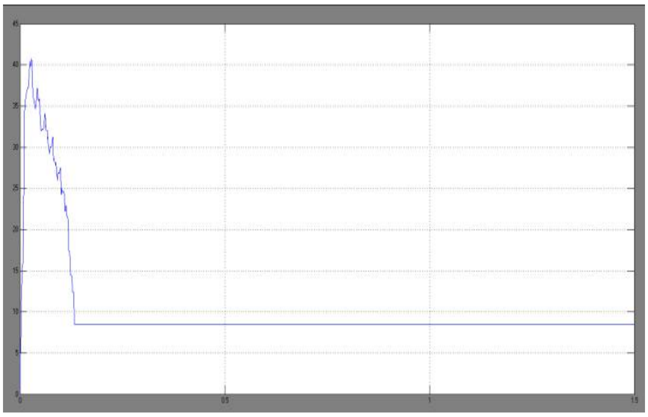

Fig. 12. Phase- compensator RMS currents.

Fig.13. Load reactive power (Q-Load), compensator reactive power (Q-VSI), and reactive power at PCC (Q-PCC).

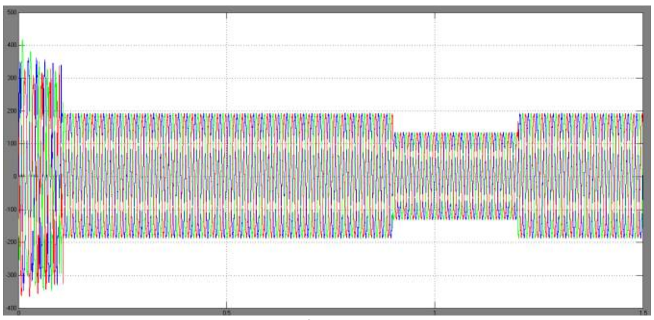

Fig.14. Simulation results for Source Voltage during Sag.

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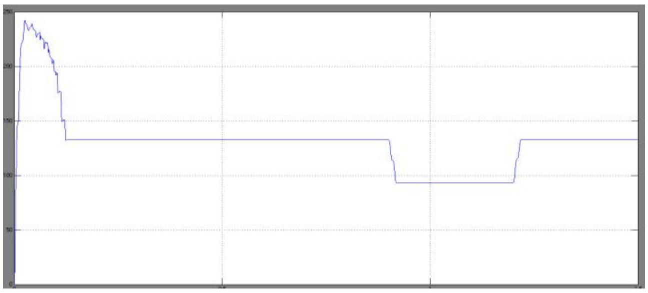

Fig.15. simulation result for RMS value of source voltage during sag.

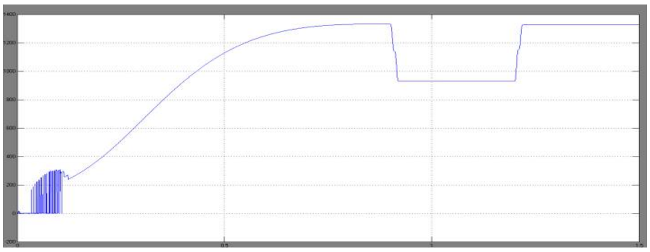

Fig.16.Simulation results for dc link voltage

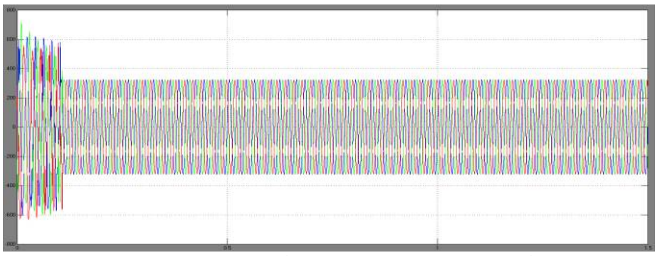

Fig.17. Simulation results for load voltage after compensation

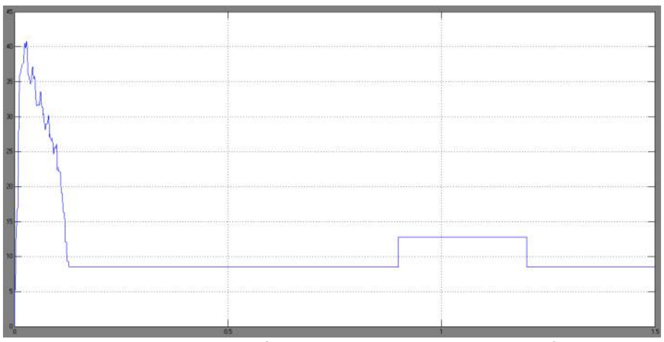

Fig.17. simulation results for compensation current of D- statcom

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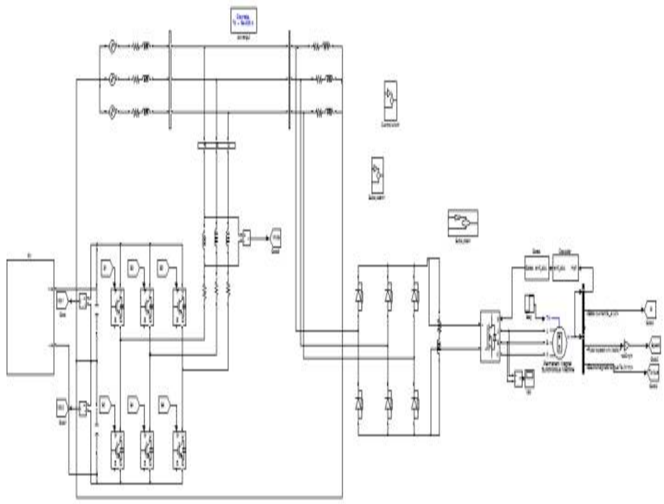

Fig.18. Simulink circuit for conventional D-statcom with PV & PMSM Drive.

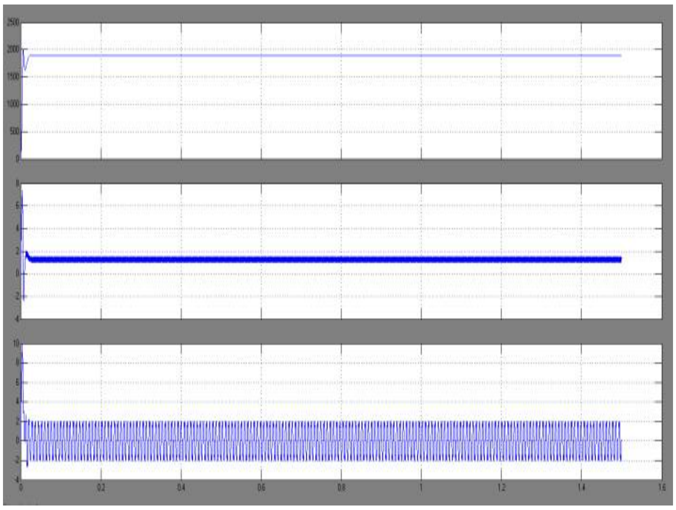

Fig.19.speed, torque and armature current of PMSM drive

V. Conclusion

In this paper, a control algorithm has been proposed for the Generation of reference load voltage for a voltage-controlled DSTATCOM. The performance of the proposed scheme is compared with the traditional voltage-controlled DSTATCOM. The proposed method provides the following advantages:

- At nominal load, the compensator injects reactive and harmonic components of load currents, resulting in UPF;
- Nearly UPF is maintained for a load change;
- Fast voltage regulation has been achieved during voltage disturbances

The SVM inverter increases the output voltage and lowers the output harmonic distortions compared with the conventional sinusoidal PWM inverter. The field oriented control using space vector modulation allows easy implementation of the PMSM drive with fewer harmonic. The advantages of the proposed drive are confirmed by the simulation results.

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