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Improvement of Power Quality in an Autonomous System using DSATCOM

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Abstract**——**This paper discusses an control scheme of a Distribution Static compensator (DSTATCOM) to rectify unbalance and improve power quality by reducing harmonics at load end of an autonomous system. This scheme does not require any new hardware implementation. In this proposed technique.Three phase load current active and reactive components are dissociated and are used in association with PI controllers and simple arithmetical operators produces carrier signals for and PWM controller. This signal along with the sinusoidal voltage is used to generate firing pulses for the IGBT switches of a 3 level voltage source inverter (VSI). The result shows that the scheme is effective in reducing total harmonic distortion (THD) in voltage at PCC, load current and competent to overcome unbalance at load end.

Keywords—DSTACOM*;* PCC*;* PI controller*;* PWM controller*;* VSI

I. INTRODUCTION

DEPLETION of fossil fuel has forced the modern world to think differently about electric power generation and this thought develops the concept of autonomous power generation which is also important for developing countries where grid extension is not economically or technically viable in some regions. Thus autonomous generation can serve as a bridge in between a decent living standard with eco friendly system [1]. Small embedded generations and renewable or non-conventional energy production system like solar-cell, bio-mass or wind- energy power conversion system attached with power electronic equipments are sources of autonomous power system. At one side this allows communities to be more energy independent and environment-friendly but cost comes in terms of power quality [2]. Industrial loads as well as domestic loads with switching mode power supply, battery charging circuits are possible sources of harmonics in the system which results in non-sinusoidal voltages at the point of common coupling (PCC). Total harmonic distortion (THD) is the usual practice to measure power wastage due to harmonics with respect to fundamental frequency power [3]. Passive filters are not very useful in this context due resonance [4]. Load variation in three phases can cause unbalance in the autonomous system. Thus a custom power device is necessary to overcome such power quality issues in an autonomous system.

A DSTATCOM is a three phase shunt connected power electronic device installed at customer premises to look after the reactive power demand of the consumer as well as to rectify the distorted and unbalanced terminal voltage. The major components of DSTATCOM are voltage source inverter (VSI), dc capacitor, coupling transformer and a controller. Efficiency of the system is solely depends upon proficiency of the controller which provides solution depending upon control algorithm written inside and produce the switching pattern for the inverter [5]. Several control algorithms and various techniques are used among researchers. These algorithms select and tune internal parameters as per requirement for better performance. Extraction of reference current is one of popular techniques which includes several classical methods like Instantaneous reactive power theory (IRP), synchronous reference frame theory (SRF), unit templet control approach [6], amplitude phase locked loop technique [7], linear feedback control etc [8]. Power factor correction and harmonic suppression can also be achieved by proper control strategy [9].

In this paper a control strategy of the DSTACOM is demonstrated where it is able to regulate PCC voltage, maintain sinusoidal load current and restrict the unbalance to enter into a three phase system. The proposed method is simple and cost effective approach to implement, does not require any new hardware implementation, and managed by only simple arithmetical instructions.

II. SYSTEM CONFIGURATION

In the proposed system a self-excited squirrel cage induction generator is chosen as source of power, which is supplying a three phase R-L load. A delta connected capacitor bank is supplying required reactive power at no-load. Additional reactive power demand is managed by the DSTATCOM. This custom power device is used to maintain PCC voltage at load end. Inductance L_r of Voltage Source Inverter (VSI) is suppressing the ripple in the current produced by VSI. C_{ab}, C_{bc}, C_{ac} capacitors are employed to filter harmonics generated during high frequency switching at load end. The heart of the system is PWM controller which is controlled by a simple algorithm implemented on PI controllers. Simple arithmetical expressions are used to control the PWM controller.

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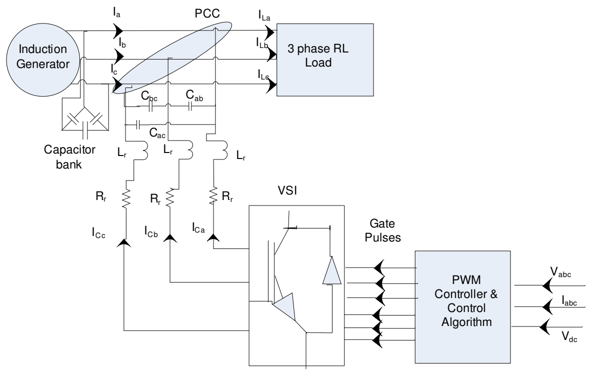

Fig.1. System Layout

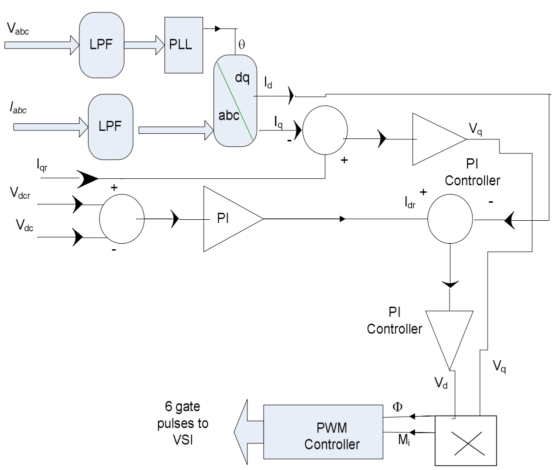

Fig.2. Generation of gate pulse for VSI

III. CONTROL STRATEGY

Reactive power compensation is done in the proposed scheme using DSTATCOM. To maintain PCC voltage, the voltage (V_{abc}) and load current (I_{abc}) are monitored and fed to the controller. Each quantity is passed through low-pass-filter (LPF) to eliminate high-order harmonics. To maintain balanced and active current three phase load current is sensed and splitted into active (I_d) and reactive (I_q) components through Park transformation. In this proposed scheme dc bus voltage (V_{dc}) of the VSI is maintained comparing it with required dc bus voltage (V_{dcr}). The resultant is fed to a PI controller to produce reference active current (I_{dr}). I_{dr} and I_d are compared and PI control action is taken to produce balanced active voltage V_d. The scheme is such that the required reactive power should solely supply by the DSTATCOM. In this scheme reactive reference current (I_{qr}) is set to zero; I_q is the required reactive current demant of the system and V_q is produced using reactive component of monitored current (I_q). They are processed to generate modulation index (M_i) and angle Φ.M_i, Φ are then fed to PWM controller to produce gate pulse for VSI.

IV. SYSTEM OPERATION

A three phase 4 KW, 400V, 50 Hz, 1430 rpm squirrel cage induction machine is chosen as source of power for the MATLAB simulation. Three phase 400 V, 50 Hz ac source is initially connected to it for starting. A negative prime mover torque for generating action is provided to the machine using equation

$$T_{sh} = K_1 - K_2\omega$$

(1)

Where ω is the angular frequency of rotation, T_{sh} is the shaft torque of the induction generator, K_1, K_2 are constants. Self-excitation is provided with 50 VAR fixed capacitor bank at no-load and additional reactive power demand is fulfilled by the DSTATCOM.

The induction 4KW, 400 V, 50Hz, 1430 rpm induction generator is in generator mode and it reaches stable region of three phase circuit breaker. The breaker is initially closed and opened at 0.1 sec making the three phase programmable source to detach from the system. The system is designed with two linear, inductive loads. One of the loads is star connected and another is delta connected. An unbalance is simulated in the delta connected load by opening branch AC for 0.2 sec to 0.3 sec and branch AB for 0.25 sec to 0.4 sec using circuit breaker.

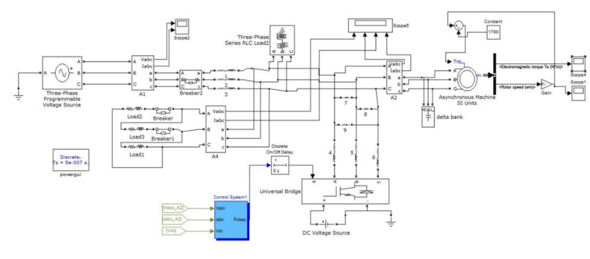

Fig.3. System Implementation in MATLAB

V. RESULTS

Fig 4.1 reveals speed time characteristic curve for the induction generator. Initial transients die out in 0.07 sec. And the generator maintains constant speed with respect to time for rest of the period. The generating action is shown in the Torque Vs time characteristics in Fig.4.2 where it demonstrate negative torque required for generation.The functioning of the DSTATCOM is depicted in the Fig.5 I_{abcL} is the load current. Unbalance prevails in the load current from 0.2 sec up to 0.4 sec. This has been taken care by DSTATCOM connected at the load end and hinders the penetration of unbalance at other load connected at that end. The second figure in Fig.5 reflects the result where I_{abc} is absolutely balanced due to the control action of the DSTATCOM . The third figure represents the PCC voltage at
load end.

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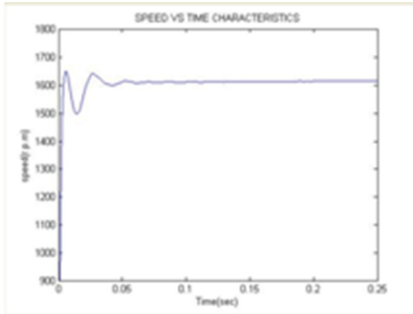

Fig.4.1 Speed-Time Curve of Induction Generator

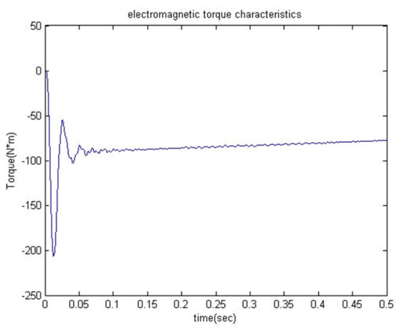

Fig.4.2. Electromagnetic Torque Characteristics

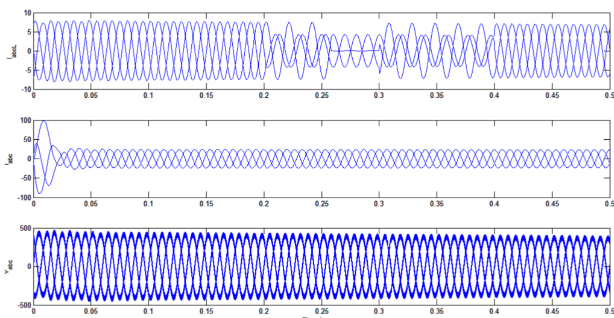

Fig.5. Simulation Results

Total harmonic distortion is the way to ensure power quality of power system. Fourier transform is done to analyze the frequency spectrum of the output voltage and current from the custom power device. Fig.6.1 and Fig.6.2 shows the harmonic contents for voltage of a phase shows the harmonic contents for voltage of a phase and current of phase a at load end. The results demonstrate satisfactory performance.

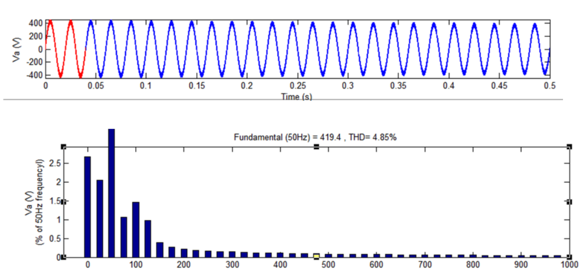

Fig.6.1. Frequency Spectrum of PCC voltage phase 'a'

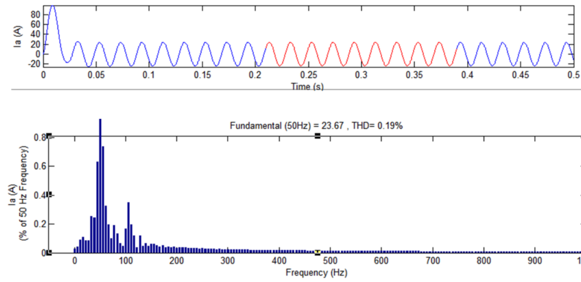

Fig.6.2. Frequency Spectrum of load end current at phase 'a'

VI. CONCLUSION

This paper discusses a simple control algorithm for DSTATCOM installed at PCC and maintains voltage profile at that terminal; eliminates harmonics and prevents disturbances penetrating towards other equipments attached to that end. The results demonstrate satisfactory response of the proposed scheme.

a.

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