A Voltage Controlled DSTATCOM using Hybrid Renewable Energy DC Link VSI for Power Quality Improvement

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Abstract

The work deals with Distribution Static Compensator (DSTATCOM) working in voltage-control mode using photovoltaic (PV) array and Permanent Magnet Synchronous Generator (PMSG) based wind turbine for dc generation; forming hybrid renewable energy sources based dc-link voltage source inverter (VSI). PV is installed along with Perturb and Observe (P & O) maximum power point tracking (MPPT) method applied to dc-dc boost converter, in desire to generate the required dc voltage for one of the split dc capacitor. For the lower dc-link capacitor, required dc voltage is generated using PMSG based wind energy system which extracts maximum power from wind through switch mode rectifier, using simplified output maximization control. The effective combination of PV and wind along with their MPPT controls, eliminate the need of battery, pre-charge capacitor circuitry and dc-link voltage regulation control. It is observed that the DSTATCOM operates effectively providing balanced and sinusoidal source currents with unity power factor (UPF), in the presence of unbalanced and non-linear load. The reference voltages for shunt controller are extracted using instantaneous symmetrical component theory (ISCT) which provides advantages of both voltage control mode and current-control mode. This scheme is found to be advantageous in terms of providing uninterruptable reparations.

Keywords: DSTATCOM, Photovoltaic Array, MPPT Perturb and Observe, Power Quality, Wind Turbine

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I. INTRODUCTION

Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Occurrences affecting the electricity supply that have been once considered acceptable by electricity companies and users are now often considered a problem to users of everyday equipment. Extensive surveys have been carried out to quantify the problems of power quality by different agencies. With the deregulation of the electric power energy market, the awareness regarding the quality of power is increasing day by day among different categories of customers. A major volume of work is reported to understand the importance & relevance of power quality in deregulated market. Because of this, power suppliers are trying their best to give quality power in-compliance to power quality standards laid down by different organizations that attempt to quantify certain aspects of service quality. There has been considerable amount of work on the characterization of individual types of power quality disturbances and corresponding indices and standards. However, there does not exist in the literature a standard approach that allows one to quantify the overall power quality. To develop dynamic and adjustable solutions to the power quality problems, efforts are continued from time to time in the name of passive-filter , active-filter , hybrid filter, custom-power devices[1] and flexible distribution generation (FDG). Among solutions to power quality problems lossless passive filters (LC) have been used for a long time for harmonic mitigation. However, these passive filters have the limitations of fixed compensation and resonance with the supply system, which are normally overcome using active filters (AFs). The power electronic controllers that are used in the custom power solution can be network reconfiguration, compensating commands in terms of current or voltage levels are derived based on different type or compensating type [2][3] . The topology can be shunt (DSTATCOM), series (DVR), or a combination of both (UPQC). DSTATCOM is most widely used for power factor correction, to eliminate current based distortion and load balancing, when connected at the load terminals. It can also perform voltage regulation when connected to a distribution bus. Control strategy plays a vital role in overall performance of the compensating device.

DSTATCOM is very well known and can provide cost effective solution for the compensation of reactive power and unbalance loading in distribution system. The performance of the DSTATCOM depends on the control algorithm[4]. For this purpose there are many control schemes which are reported in the literature and some of these are instantaneous reactive power (IRP) theory[5][6], instantaneous compensation, instantaneous symmetrical components, synchronous reference frame (SRF) theory, computation based on per phase basis, and scheme based on neural network Amongst the different VSI topologies that can be used to realize the compensator, three-leg VSI with split capacitor is considered to be a most popular topology. With increasing growth of renewable energy sources, different solutions are provided in the literature to replace regular DC-link. The use of PV to generate dc bus voltage is more preferable because of its direct dc availability. However, in split topology, it needs two PV arrays with their independent MPPTs, making the system much costlier. On the other hand, amongst the different variable speed wind turbines used for large scale exploration and integration, PMSG becomes a promising solution because of its various benefits[7]. A PMSG with fully controlled voltage source converter provides an effective alternative for the other renewable energy sources. However, the use of only wind energy systems for generating dc-link voltages of both capacitors may require complex coordination control.

To overcome the limitations of independent use of PV and wind system, this paper proposes a combined PV and wind energy systems to generate and maintain dc-link voltage of VSI for DSTATCOM. Amongst various control algorithms listed in the literature for MPPT, the simplest P & O method is implemented for PV and switch mode rectifier based maximization control is selected for wind MPPT. Further, the satisfactory dc voltage regulation and effective load compensation proves the efficacy of hybrid dc-link VSI based DSTATCOM.

II. DISTRIBUTION STATIC COMPENSATOR (DSTATCOM) WITH HYBRID DC-LINK VSI

The Distribution Static Compensator (DSTATCOM) is a voltage source inverter based static compensator (similar in many respects to the DVR) that is used for the correction of bus voltage sags. Connection (shunt) to the distribution network is via a standard power distribution transformer. The DSTATCOM is capable of generating continuously variable inductive or capacitive shunt compensation at a level up its maximum MVA rating. The DSTATCOM continuously checks the line waveform with respect to a reference ac signal, and therefore, it can provide the correct amount of leading or lagging reactive current compensation to reduce the amount of voltage fluctuations. The major components of a DSTATCOM are shown in Fig. 1. It consists of a dc capacitor, one or more inverter modules, an ac filter, a transformer to match the inverter output to the line voltage, and a PWM control strategy. In this DSTATCOM implementation, a voltage-source inverter converts a dc voltage into a three-phase ac voltage that is synchronized with, and connected to, the ac line through a small tie reactor and capacitor (ac filter).

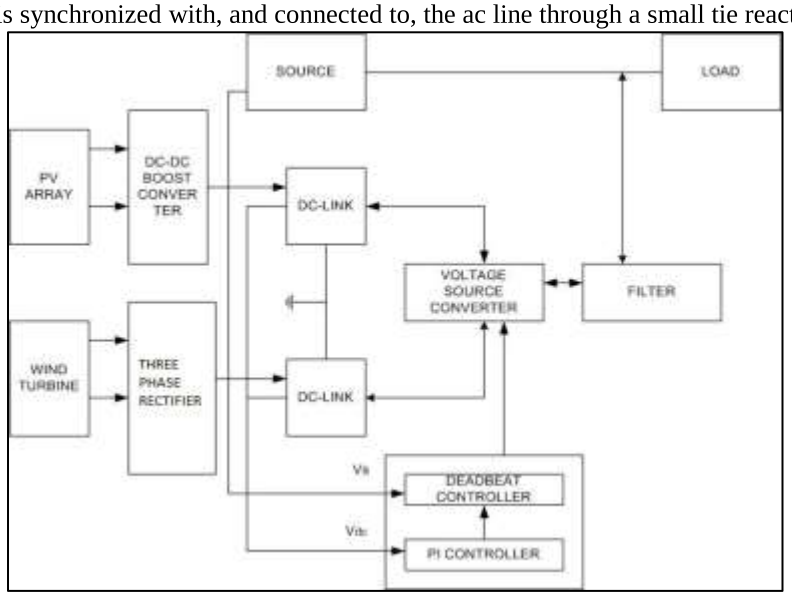

Fig. 1: Block diagram of DSTATCOM with hybrid dc link VSI

The modified system has the advantages of eliminating the need of battery, eliminate pre-charge capacitor circuitry, fast dc-link voltage regulation and provides continuous compensation. Along with this advantages this system bears all the advantages of the previously existing system. The objectives of this paper is to realize a voltage controlled DSTATCOM using hybrid renewable energy dc-link for different cases such as non-linear load and voltage sag.

A. PV System

Numerals of PV cell forming modules are arranged in series and parallel to meet the demand. Series connection is responsible for increasing the voltage of the module whereas the parallel connection increases the current in the array. Series resistance (Rs) and parallel resistance (Rsh) provides the practical realization of cell. The solar array is built up with the collective series/parallel combination of solar cell so as to retain the V-I characteristics using dynamic programming. According to MPPT algorithm, the power output of a circuit is maximum, when thevenin impedance of the circuit (source impedance) matches the load impedance. Amongst the various techniques used to track the maximum power point (MPP), the most simple and popular is perturb and observe (P & O) algorithm, which senses only single parameter with less complexity. The convergence speed varies according to applied condition without any periodic tuning. Because of these advantages, here, P & O method is incorporated to extract the maximum power from PV array. The MPPT control automatically finds the voltage Vmpp or current Impp at which the PV array delivers maximum power under a varying temperature and irradiance. MPPT algorithm is based on the calculation of the PV output power and the power change by sampling both the PV array current and voltage. The tracker operates by periodically incrementing and decrementing the solar array voltage. When the given perturbation leads to an increase (decrease) in output power of the PV, then subsequent perturbation is generated in the same (opposite) direction. Accordingly, the duty cycle for boost converter is varied and the process is repeated until the maximum power point has been reached.

B. *Wind Energy Conversion System*

This system uses Permanent Magnet Synchronous Generator (PMSG) based wind turbine for dc generation. The control objective is to control the duty cycle of the switch S to extract maximum power from the variable speed wind turbine and transfer the power to the load.

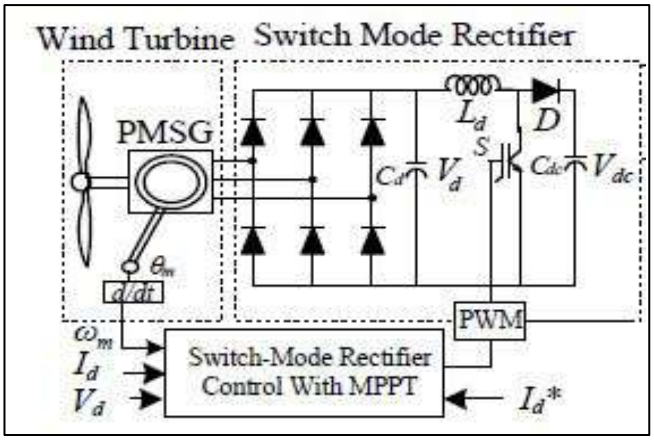

Fig. 2: Wind energy conversion system

C. *Deadbeat Controller based Control Algorithm*

This is an algorithm to generate reference voltage for a distribution static compensator (DSTATCOM) operating in voltage-control mode. This exhibits several advantages and ensures that unity power factor (UPF) is achieved at the load terminal during nominal operation, which is not possible in the traditional method. Also, the compensator injects lower currents and, therefore, reduces losses in the feeder and voltage-source inverter. Further, a saving in the rating of DSTATCOM is achieved which increases its capacity to mitigate voltage sag. Nearly UPF is maintained, while regulating voltage at the load terminal. The state-space model of DSTATCOM is incorporated with the deadbeat predictive controller for fast load voltage regulation during voltage disturbances. With these features, this scheme allows DSTATCOM to tackle power-quality issues by providing power factor correction, harmonic elimination and voltage regulation based on the load requirement. First, discrete modelling of the system is presented to obtain a discrete voltage control law, and it is shown that the PCC voltage can be regulated to the desired value with properly chosen parameters of the VSI. Then, a procedure to design VSI parameters regulate the dc capacitor voltage at a reference value. Based on is presented. A proportional-integral (PI) controller is used to 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.

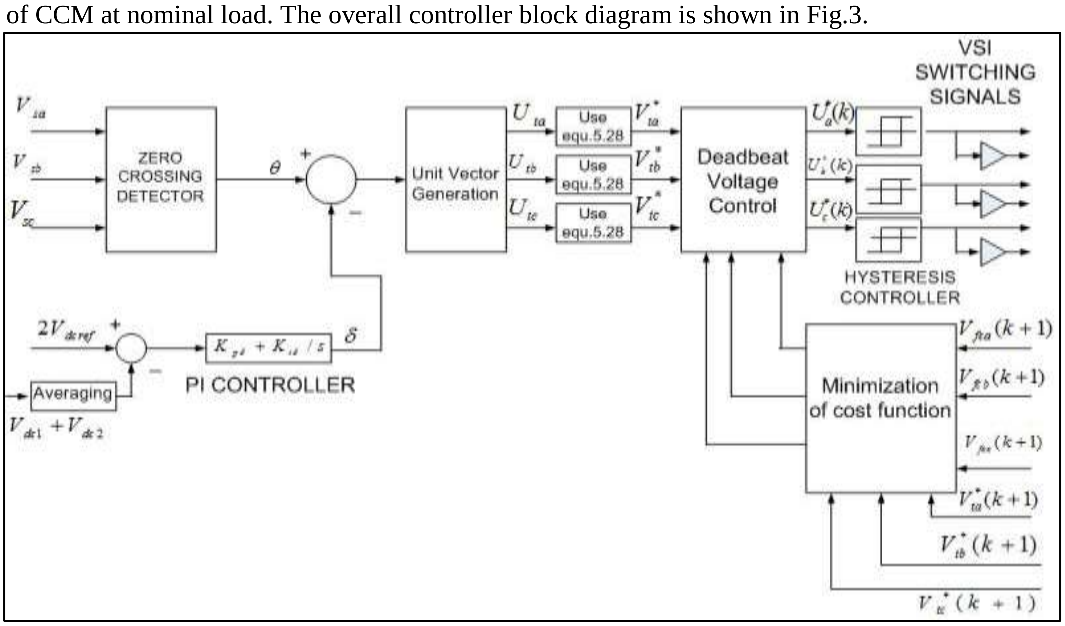

Fig. 3: Overall block diagram of controller

III. SIMULATION RESULTS

DSTATCOM with hybrid renewable energy dc-link VSI is realized here for two cases i.e. for non-linear load and also for voltage sag condition. Also the above system is studied for different fault conditions.

A. Non-Linear Load

When a non-linear load is applied to a test-system without dststcom the variation in source voltage and current is shown in fig.4

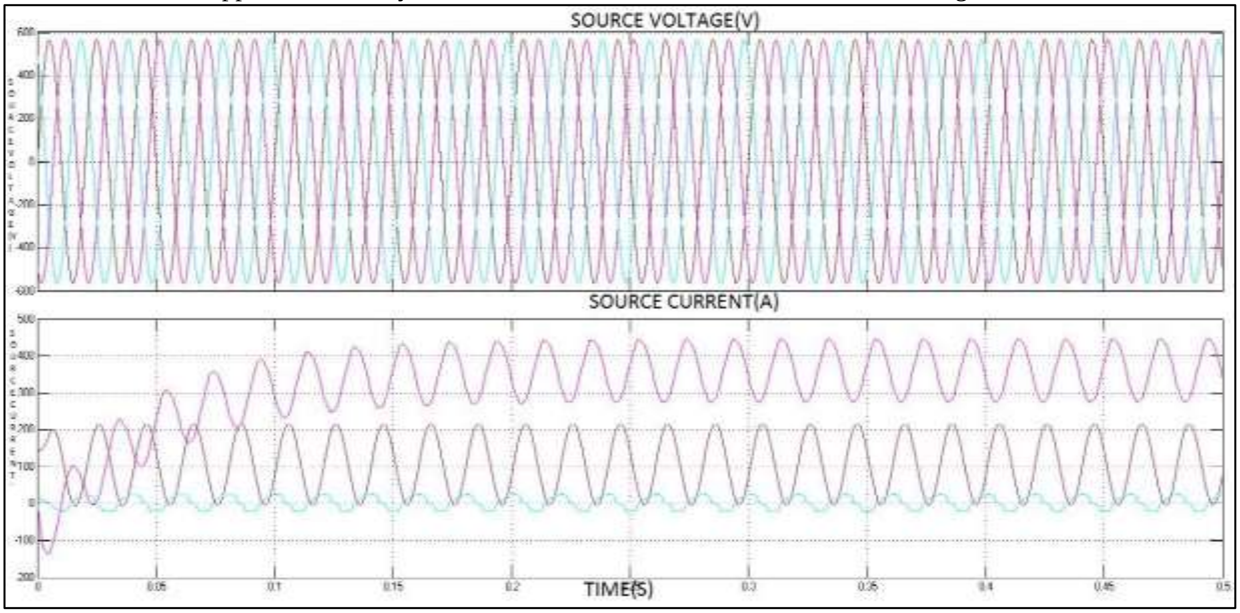

Fig. 4: Source voltage and source current of test system

The DSTATCOM with hybrid VSI makes the source current stable. It is shown in fig.5.

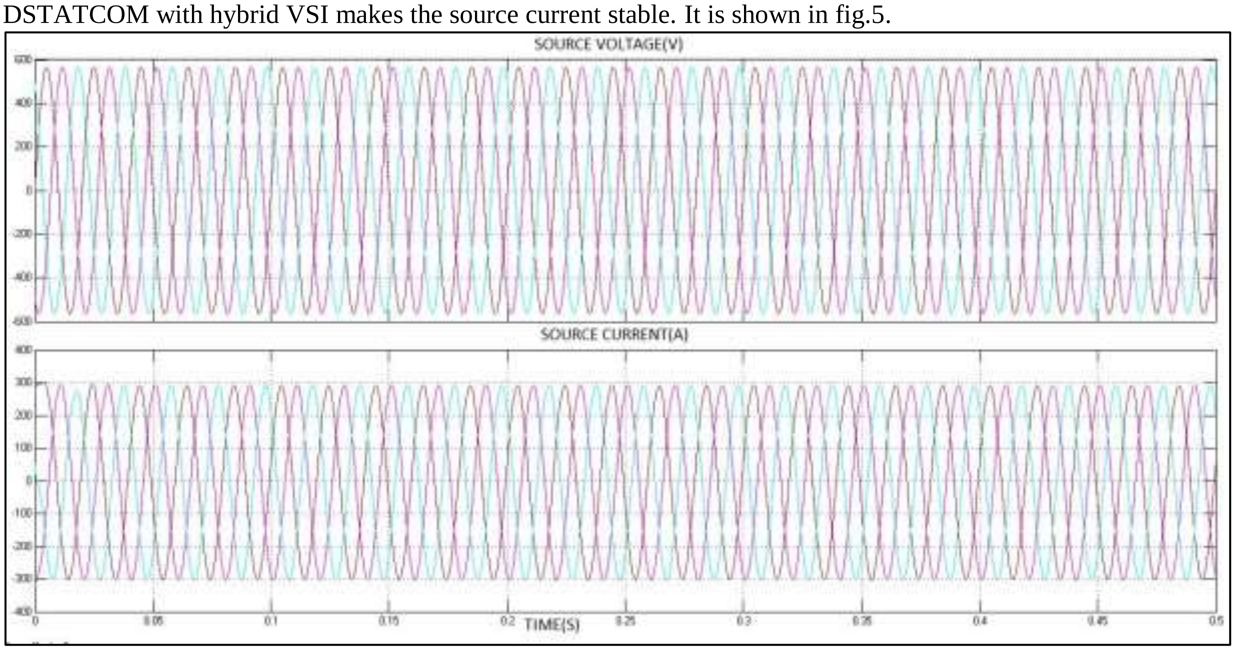

Fig. 5: Source voltage and source current of compensated system

B. Voltage Sag

Voltage sag is applied to the system by injecting a highly inductive load by the help of breakers. The performance of the test system is shown in fig.6.

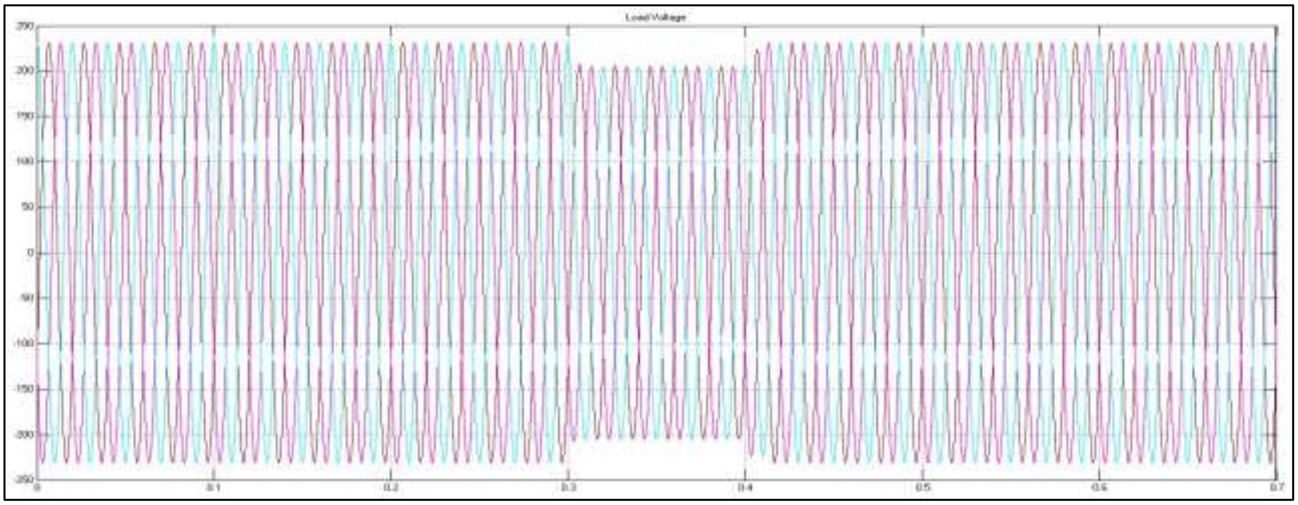

Fig. 6: Load voltage of test system

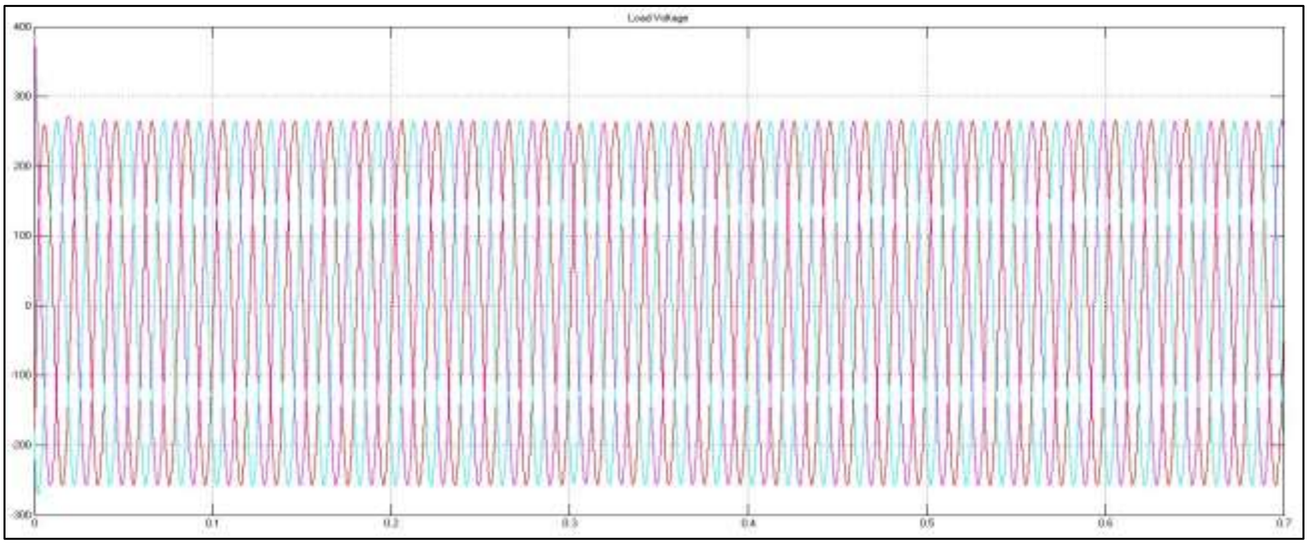

Fig. 7: Load voltage of compensated system

C. Different Fault Conditions

The fault current without DSTATCOM is in very high range but with the DSTATCOM it is limited to a low value. The fig shows an LG fault in phase A.

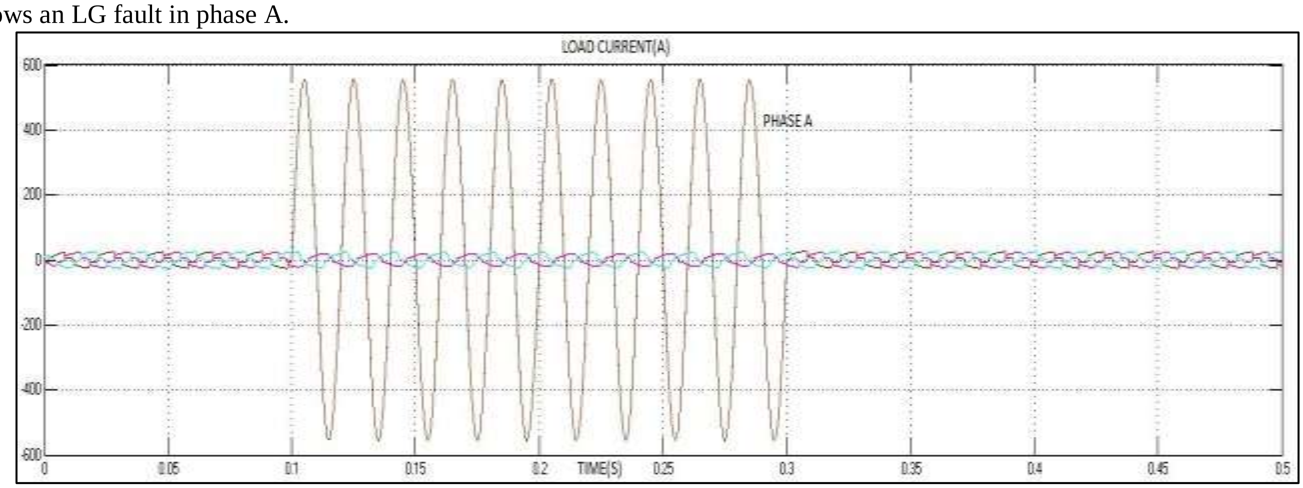

Fig. 8: LG fault in test system

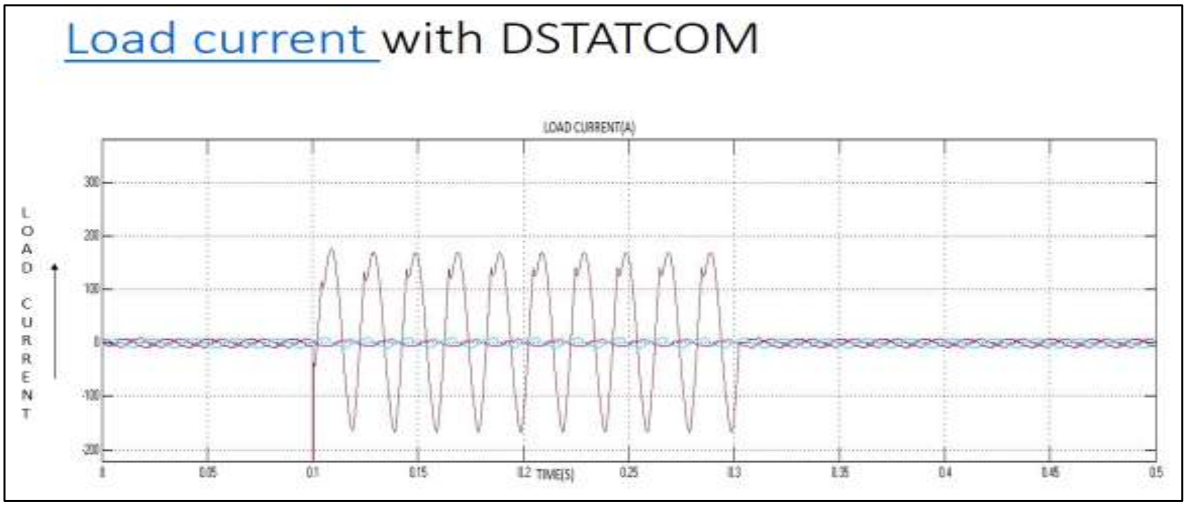

Fig. 9: LG fault in a system with DSTATCOM

IV. Conclusion

This paper proposes a unified renewable energy (PV and wind) DC-link VSI based new DSTATCOM topology, installed in 3p4w distribution system with unbalanced and distorted load, for power quality improvement. The P & O MPPT method for PV and simplified output maximization MPPT control for wind systems are found to be effectively tracking the MPP. The individual and total dc-link voltage regulation in the presence of non-linear load represents the robustness of the system to the load variations. Both the sources operates independently without any coordination control, makes the scheme simpler. Finally, the effective load compensation proves the effectiveness of the proposed scheme for power quality applications.

References

[1] M. L. Crow, \Power quality enhancement using custom power devices ",IEEE Power and Energy Magazine, vol.2, pp.50, April 2004.
[2] J. Arrillaga, M. H.J. Bollen and N.R. Watson, \Power quality following deregulation ",in Proc. IEEE, Vol. 88, pp.246-26 1, Feb.2000.
[3] H Akagi, \New trends in active Filters for power conditioning ", IEEE Trans.Ind Applcat., 1996, 32, pp. 1312-1322.
[4] B. Singh, AL.K. Haddad and A. Chandra, \A review of active filters for power quality improvement ", IEEE Trans. Ind Elect., vol.46, pp. 960- 971,1999.
[5] M.K.Mishra, A. Ghosh, and A. Joshi, \Operation of a DSTATCOM in voltage control mode",IEEETrans.Pow.Del.,vol. 1 8,pp.258-264,Jan.2003.
[6] G. Ledwich and A. Ghosh, \A flexible DSTATCOM operating in voltage or current control mode", Proc. IEE Generation, Transmission and Distribution, vol. 149, pp.215-224, March 2002
[7] Bhim Singh and Jitendra Solanki,\A Comparison of Control Algorithms for DSTATCOM", IEEE Trans. Industrial Electronics, VOL. 56, NO. 7, JULY 2009
[8] Chandan Kumar and Mahesh K. Mishra,\A Voltage-Controlled DSTATCOM for Power-Quality Improvement", IEEE Trans. Pow.Delivery, Vol.29, NO. 3, JUNE 2014
[9] M. Singh, V. Khadkikar, A. Chandra and R. K. Varma, \Interconnection of renewable energy sources at the distribution level with power quality improvement features,", IEEE Trans. Power Del., Vol.26,No.1, pp.307-315, Jan.2011
[10] P.A Stott, M.A Mueller, V. Delli Colli, F. Marignetti and R. Di Stefano ,\DC Link Voltage Stabilisation in Hybrid Renewable Diesel Systems,",IEEE Trans. Power. Del., vol. 23, no. 3, pp. 15811588, Jul. 2008