Power Factor Improvement in Distribution System using DSTATCOM Based on Unit Vector Template Control Algorithm

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***Abstract*— Power factor plays important role in the function of the power system network. Hence, the power factor improvement will increase the performance of power system equipments. This paper presents the design and implementation of distribution static compensator (DSTATCOM) with the star-delta transformer for improvement of the power factor in three-phase four wire distribution system in the presence of three-phase linear load in the events of single phase, two-phase and three phase trippings. The unit vector template method based control algorithm has been implemented for the control of the proposed DSTATCOM. The proposed test model has been simulated in SIMULINK/MATLAB environment. The simulations results show the effectiveness of proposed algorithm.**

***Keywords*—Distribution static compensator, power quality, power factor improvement, star-delta transformer, unit vector template method.**

I. INTRODUCTION

Distribution systems are facing severe power-quality (PQ) problems, such as poor voltage regulation, high reactive power and harmonics current burden, load unbalancing, excessive neutral current, etc. The source voltages in the distribution systems are also experiencing PQ problems, such as harmonics, unbalance, flicker, sag, swell, etc. [1]. The poor power factor is also a power quality problem and needs necessary correction. Mahmud *et al.* [2], described the power quality issues, abnormalities such as voltage sag, voltage swell, harmonics and capacitor switching which are destruct sinusoidal waveforms and decrease power quality as well as network reliability. These are abnormalities which affect the consumer as well as equipment. DSTACOM is used to compensate, power quality problem such as voltage fluctuation, unbalanced load, harmonics in distribution system. A DVR is proposed for voltage sag and swell protection, voltage balancing and compensating for voltage harmonic distortions while UPQC is applied for compensating for load current harmonic, reactive power compensation, power factor correction, correcting non-load current and regulating DC circuit voltage. Bhim Singh *et al*. [3], presented the various type of custom power devices developed and successfully implemented to compensate various power quality problems in a distribution system. Bhim Singh *et al*. [4], presented a complete review on the power quality issues. In [5], authors proposed that a method for neutral current compensation including Scott transformer, T connected transformer, star hexagon transformer and star polygon transformer designed for mmf (magneto motive force) balance. Bhim Singh *et al*.[6] have discussed the new topology for power quality improvement with contribution of DSTATCOM is integrated for the Improvement of reactive power for voltage regulation or for power factor correction with load balancing and neutral current compensation along with elimination of harmonics at the point of common coupling. In [7] authors have proposed for power quality Improvement based on 3P4W DSTACOM star/delta transformer connection to mitigates the neutral current, power quality, balance the unbalance load, reactive power, and harmonics. Three single phase transformers are connected as star/delta transformer for interfacing to a three phase four-wire power distribution system and the required rating of the VSC is reduced. The star/delta transformer has been found effective for compensating the zero sequence fundamental and harmonics currents and kVA rating of the star/delta transformer has been verified by simulation. It is observed that the kVA rating of the transformer is about 40% of the load kVA and the reactive power to be compensated. In [8], authors has purposed that a neural-network (NN)-controlled distribution static compensator (DSTATCOM) using a dSPACE processor is implemented for power quality improvement in a three-phase four-wire distribution system. With a Zig-zag transformer is used for the compensation of reactive power, for voltage regulation, for load balancing along with balancing the unbalance load elimination of harmonic currents, and neutral current compensation at the point of common coupling. In [9], authors proposed a three-phase four wire power filter comprising a three-phase three-wire APF and a Zig–Zag transformer is developed. Bhim Singh *et al.* [10] has proposed a new topology for power quality improvement in a three-phase four wire distribution system consisting of a H-bridge VSC and a star/delta transformer. In [11], authors has proposed a technique for power quality improvement in three-phase four-wire distribution systems. A three-leg VSC is integrated with a star/hexagon transformer for the compensation of reactive Power for voltage regulation or for power factor correction along with load balancing, elimination of harmonics currents and neutral current compensation. Bhim Singh *et al.* [12], described a new topology for voltage regulation or power factor correction by reactive power compensation along with harmonics elimination or neutral current compensation in three-phase four-wire distribution system with star/delta transformer. The transformer has star connected primary and delta connected secondary and the load neutral point is connected to the neutral of star winding so that it provides a path to the zero sequence fundamental as well as harmonics neutral currents. Bhim Singh *et al.* [13], described two leg VSC and a Zig-Zag transformer for power quality in 3P4W Distribution system. In [14], authors have present for Improvement of PQ with a T-connected transformer for the compensation of reactive power for voltage regulation or elimination of neutral current. In [15], authors presented a comprehensive review of neutral current compensation technique.

This paper presents the power factor improvement in the distribution system using DSTATCOM with star-delta transformer. A unit vector template method based control of the DSTATCOM has been proposed in this paper for power factor improvement.

This paper is organized into five Sections. Starting with an introduction in the Section I, the Section II describes the proposed test system. The proposed control algorithm has been described in the Section III. The simulation results and their discussions for power factor improvement are presented in the Section IV. Finally, the conclusions are presented in the Section V.

II. PROPOSED TEST SYSTEM

The basic circuit diagram of the proposed DSTATCOM connected to the 3-phase four wire distribution systems supplying the power to a three phase four wire loads is shown in Fig. 1. The star-delta transformer gives the path to the neutral current of load. The DTSTATCOM is voltage source converter (VSC) made by using six Insulated Gate Bipolar Transistors (IGBTs) switches with anti-parallel diodes and a DC capacitor. The DC link capacitor helps in improving the ripples by continuously charging and discharging. For reducing the ripples in compensating currents with interfacing inductors are place to connect the VSC to the supply system. RC filter is used to reduce the switching ripples in the PCC voltage injected by the fast switching of DSTATCOM. The DSTATCOM is used to control and compensate the reactive and harmonic currents of the load. This helps in the voltage regulation at PCC. In power factor correction (PFC) mode the supply currents have zero phase shift with respect to PCC voltages. DSTATCOM inject the currents in zero voltage regulation (ZVR) mode to regulate the PCC voltage at the desired reference value of voltage. In this case, the supply currents may be leading or lagging currents depending on the power factor of load and reference PCC voltage. The supply voltage of the system is 415 V, 50 Hz. Supply impedance is 0.1+j0.628. DC link capacitor is 8000µF and operated on voltage is 800 V. Interfacing inductor has the value 2.3 mH. switching frequency 10 kHz. For ripple filter resistance is 2 **Ω** and capacitance 20 µF. The star connected transformer has the rating 7.5 kVA, 415 V. A detailed study of DSTATCOM topologies and control strategies has been reported in [16].

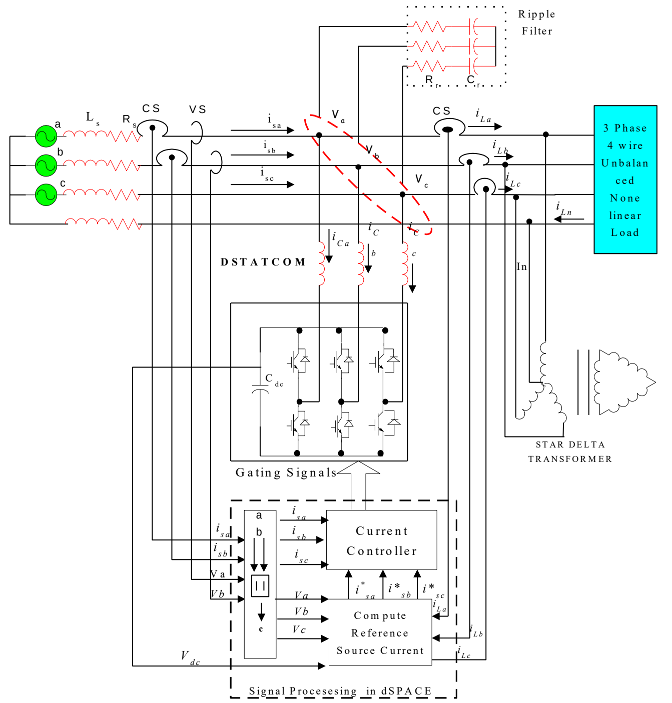

Fig. 1. Single line diagram of the proposed test model.

III. PROPOSED CONTROL ALGORITHM

The schematic diagram for the proposed control is shown in Figure 2. For generating the switching pulses for the IGBTs of the VSC a fixed frequency carrier based sinusoidal PWM is used. This algorithm is based on the unit vector template method. In this method there is two PI controllers are use. One PI controller is use for the regulation of DC link voltage and the second PI controller is used for the regulation of AC terminal voltage The parameters used in the control theory are detailed in the Fig. 2 along with all types of signals used for the control of DSTATCOM.

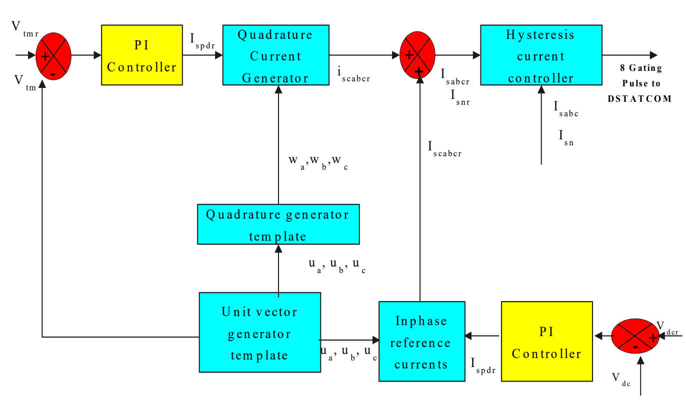

Fig. 2. Proposed control algorithm

IV. SIMULATION RESULTS AND DISCUSSION

This section details the simulation results related to the power factor improvement using DSTATCOM with star-delta transformer. The results without compensation using DSTATCOM, with compensation using DSTATCOM are detailed in the following subsections.

A. Power Factor Correction with Unbalanced Load

The pole of circuit breaker corresponding to the phase A has been opened at 45th cycles and reclosed at 50th cycles to simulate the unbalanced load in the absence of the DSTATCOM. The power factor of all the three phases is shown in the Fig. 6.1. It can be observed that the power factor corresponding to the phase A (shown by red colour) decreases drastically without the presence of the any type compensation in the network. The power factor of other phases is also changed but the change in these phases is less as compared to the phase A. Hence, the without the compensation, the power factor is changed drastically which may affect the efficiency of the system.

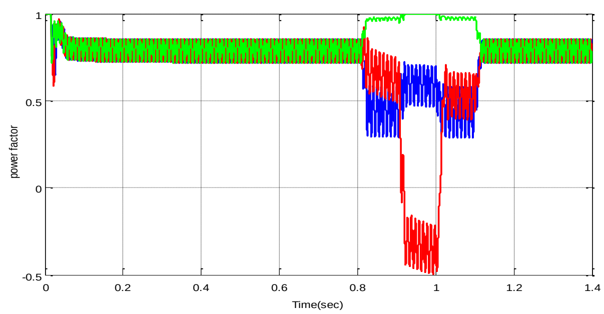

Fig. 3. Power factor of all the phases without DSTATCOM and with unbalanced load.

The pole of circuit breaker corresponding to the phase A has been opened at 45th cycles and reclosed at 50th cycles to simulate the unbalanced load in the presence of the DSTATCOM. The power factor of all the three phases is shown in the Fig. 6.2. It can be observed that the power factor corresponding to all the three has been improved significantly in the presence of DTSTACOM in the network. Hence, the use DSTATCOM significantly improves the power factor in the presence of unbalanced load.

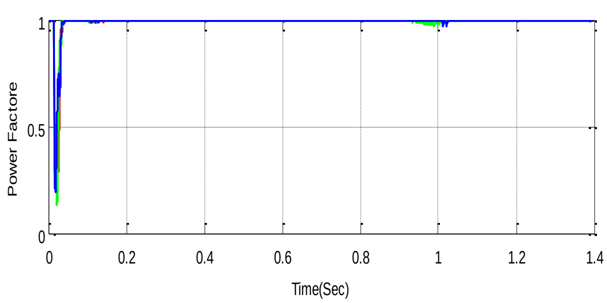

Fig. 4. Power factor of all the phases with DSTATCOM and unbalanced load.

B. Power Factor Correction with Tripping of Three Phase Load

The circuit breaker connecting the load to the system has been opened at 45th cycles and reclosed at 50th cycles to simulate the tripping of three-phase balanced load in the absence of the DSTATCOM. The power factor of all the three phases is shown in the Fig. 6.3. It can be observed that the power factor without the compensation is low and maintained near 0.8. During the transient period power factor is drastically changed. At the time of transients the power factor decreases drastically upto the value of 0.2 and then increases. The similar phenomenon is also observed at the time of reclosing the circuit breaker. Hence, in the absence of compensation, the power factor is changed drastically which may affect the efficiency of the system.

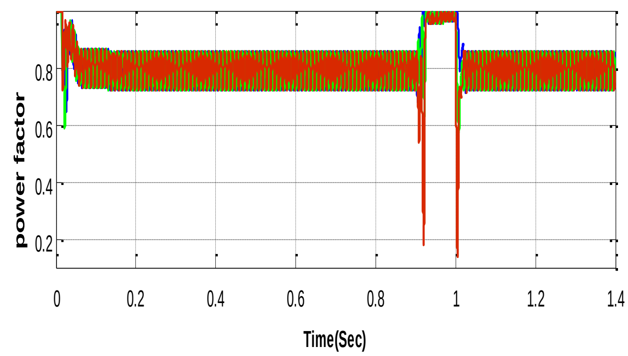

Fig. 5. Power factor of all the phases during tripping of three-phase load without DSTATCOM.

The circuit breaker connecting the load to the system has been opened at 45th cycles and reclosed at 50th cycles to simulate the tripping of three-phase balanced load in the presence of DSTATCOM. The power factor of all the three phases is shown in the Fig. 6.4. It can be observed that the power factor in the presence of DSTATCOM is maintained at unity. During the time when the load is switched off, the power factor is maintained at unity (leading). Hence, in the presence of compensation, the power factor is maintained at the unity with and without load in the presence of the DSTATCOM.

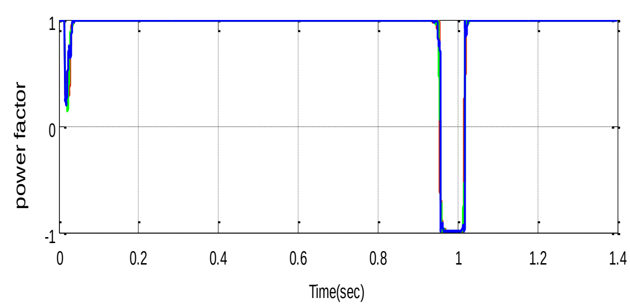

Fig. 6. Power factor of all the phases during tripping of three-phase load with DSTATCOM.

C. Power Factor Correction with Tripping of Two Phases of a Three Phase Load

Two poles (phases A and B) of the circuit breaker connecting the load to the system has been opened at 45th cycles and reclosed at 50th cycles to simulate the unbalanced tripping of three-phase balanced load in the absence of the DSTATCOM. The power factor of all the three phases is shown in the Fig. 6.5. It can be observed that the power factor without the compensation is low and maintained near 0.8. During the transient period power factor is drastically changed in the phases which have been disconnected from the system. At the time of transients the power factor is decreased drastically and reduces to the value of -0.5 during the transient period. The power factor of the other faulty phase (phase B) is also reduced to the value of 0.5. The power factor of the healthy phase also changes but this change is less as compared to the case study I.

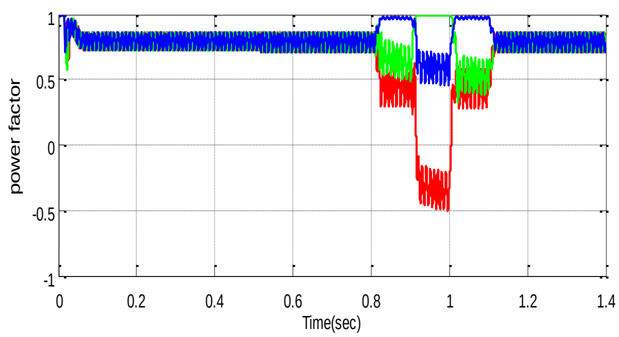

Fig. 7. Power factor of all the phases during tripping of two phases of three-phase load without DSTATCOM.

Two poles (phases A and B) of the circuit breaker connecting the load to the system has been opened at 45th cycles and reclosed at 50th cycles to simulate the unbalanced tripping of three-phase balanced load in the presence of the DSTATCOM. The power factor of all the three phases is shown in the Fig. 6.6. It can be observed that the power factor with compensation using DSTATCOM is maintained near unity. During the transient period power factor is maintained near unity by using the DSTATCOM. Hence, the use of DSTATCOM improves the power factor significantly.

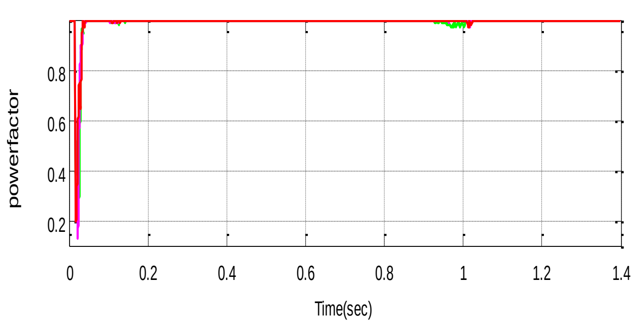

Fig. 8. Power factor of all the phases during tripping of two phases of three-phase load without DSTATCOM.

V. CONCLUSION

This research work also presents power factor correction in the three-phase distribution system using DSTATCOM with star-delta transformer. The unit vector based control of the DSTATCOM has been proposed for the power factor improvement. It has been observed that with the application of the star-delta transformer, the power factor improvement has been achieved with the help of DSTATCOM successfully. The power factor correction has been achieved in all the cases of study such as opening and closing of single pole of the circuit breaker, two poles of the circuit breaker and all the three phases of the circuit breaker connecting the three phase load. The results have been simulated in the MATLAB/Simulink environment.

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