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Article

Two Legs Voltage Source Converter with DSTATCOM, T-Connected Transformer for Power Quality Improvement

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A B S T R A C T

The numerous loads can impact the working environment and performance of the source apparatus. Hence, the reimbursement of this current will help in enhancing the presentation of the power system apparatus. This paper presents the strategy and employment of a Distribution Static Compensator (DSTATCOM) with the T-Connected transformer for compensation of load neutral current in the presence of three-phase unbalanced linear load. There are different types of control strategy in that one of the best methods is the unit vector template method-based control algorithm has been implemented for the control of the proposed DSTATCOM. The proposed model has been simulated in a SIMULINK/ MATLAB environment. The simulation results show the effectiveness of the proposed algorithm.

Keywords: Distribution Static Compensator, Power Quality, Neutral Current Compensation, Star-Delta Transformer, Unit Vector Template Method

Introduction

Electrical distribution systems are facing numerous Power-Quality (PQ) problems, such as load balancing, 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 neutral current is also a main power quality issues that affect the performance of the source. Hence, it needs to be compensated suitably by using compensating devices. The literature has been reported on the topic of power quality and neutral current compensation. 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 that affect the consumer as well as equipment. DSTATCOM is used to compensate, power quality problems such as voltage fluctuation, unbalanced load, harmonics in the 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 harmonics, 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 for 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 transf ormer, star hexagon transformer and star polygon transformer designed for MMF (magnetomotive force) balance. Bhim Singh *et al*.[6] have discussed the new topology for power quality improvement with the contribution of DSTATCOM is integrated for the Improvement of reactive power for voltage regulation or power factor correction with load balancing and neutral current compensation along with the elimination of harmonics at the point of common coupling. In[7] authors have proposed power quality Improvement based on 3P4W DSTATCOM 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 the 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 the 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] the authors have purposed that a Neural-Network (NN)-controlled Distribution static compensator (DSTATCOM) using a SPACE processor is implemented for power quality improvement in a three- phase four-wire distribution system. 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] the 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] have proposed a new topology for power quality improvement in a three-phase four-wire distribution system consisting of an H-bridge VSC and a star/delta transformer. In,[11] the authors have 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 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 a three-phase four-wire distribution system with star/ delta transformer. The transformer has a T-Connected transformer that has not provided only a path of zero sequence fundamental current and harmonics current but also neutral currents when it is connected in shunt at point of common coupling, T connected transformer is a center-tapped transformer which is connected in 1:1 ratio to the main transformer, the design of T-connected transformer, one of the winding is divided in this way divided the magnitude of the current balance the unbalance load. Bhim Singh *et al.*[13] described two-leg VSC and a Zig-Zag transformer for power quality in a 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] the authors presented a comprehensive review of the neutral current compensation technique.

This paper presents the compensation of load neutral current using DSTATCOM with T- Connected transformer. A unit vector template method-based control of the DSTATCOM has been proposed in this paper for neutral current compensation.

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

Proposed Test System

The basic circuit diagram of the proposed DSTATCOM connected to the 3-phase four-wire distribution systems supplying the power to three-phase four-wire loads is shown in Figure 1. The T connected transformer gives the path to the neutral current of the load. The DTSTATCOM is a 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 placed to connect the VSC to the supply system. The 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 for the reactive load. This helps in the voltage regulation at PCC. In Power Factor Correction (PFC) mode the supply currents have zero phase shift concerning PCC voltages. DSTATCOM injects 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 Rs=0.01Ω, Ls = 2mH. DC link capacitor is 5000μF and operated on voltage is 1400 V. Interfacing inductor has the value 6 mH. switching frequency 10 kHz.

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For ripple, filter resistance is 2 and capacitance 20 µF. The T connected transformer has a rating of 2.4 KVA,240/240V.

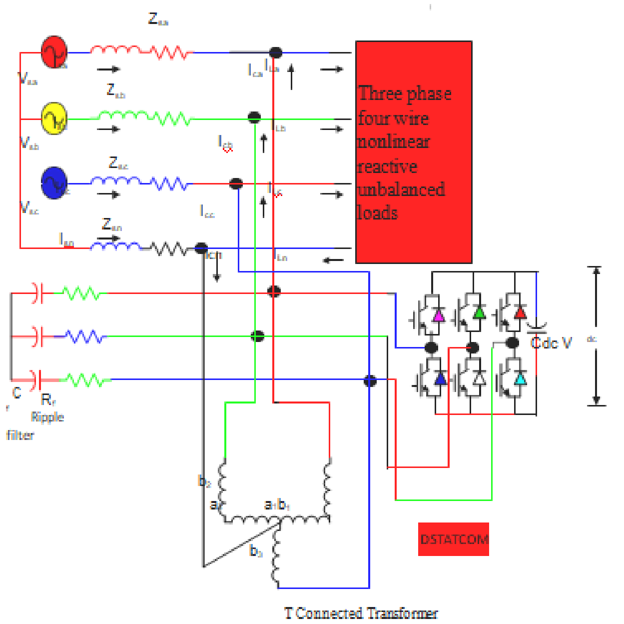

Figure 1.Single line diagram of the proposed test model

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 used. One PI controller is used 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 Figure 2, along with all types of signals used for the control of DSTATCOM.

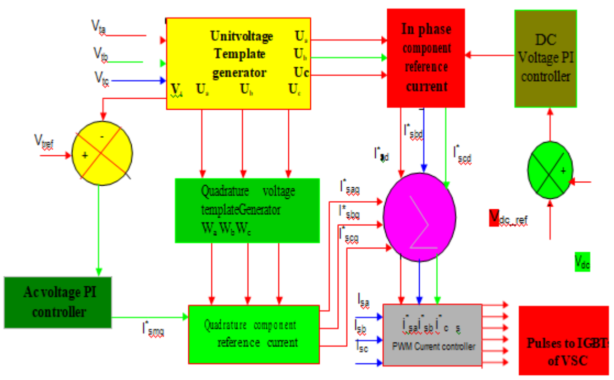

Figure 2.Proposed Control Algorithm

Simulation Results and Discussion

This section details the simulation results related to the neutral current compensation using DSTATCOM with a T-connected transformer. The results without compensation using DSTATCOM, with compensation using DSTATCOM in the absence as well as the presence of the T connected transformer are detailed in the following subsections.

Healthy Balanced System

The test system shown in Figure 1 is simulated in healthy conditions without any disturbance in the system. The 3 phase 4 wire balanced linear load is used in the system. The voltage at PCC and load current are shown in Figure 3. The waveform of the source current is the same as the load current. It is observed from Figure 3 that there is no disturbance in the load voltage and currents. In this condition, there is no neutral current.

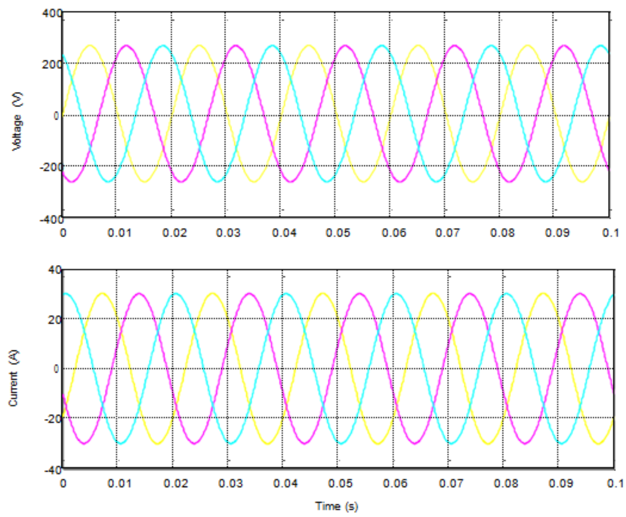

Figure 3.Voltage and without series compensation during LG fault in the presence of wind generation

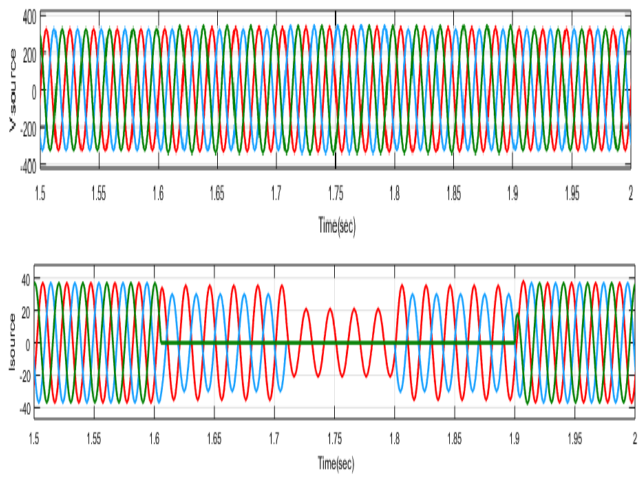

Figure 4.Voltage and current waveforms for an unbalanced system with disturbance without compensation

Unbalanced System Without Compensation

The compensation using the DSTATCOM is not utilized in this case of study. The phases B and C are opened at the 11th cycle to simulate the unbalancing in the system and reclosed

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at the 19th cycle to restore the original state of the system. The voltage and current waveforms are shown in Figure 4. The neutral currents on the source and load side are shown in Figure 5. It is observed that the neutral current flow for the duration for which there is unbalance in the network. For the period, the system is balanced there is no current in the neutral of the system. This neutral current during the unbalanced conditions needs to be compensated to achieve high efficiency of the distribution system.

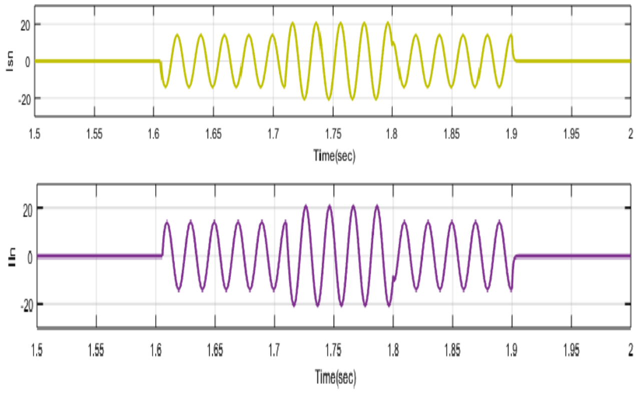

Figure 5.Neutral current on source and load side in unbalance system without compensation

Unbalanced System with Neutral Current Compensation

The DSTATCOM is connected at the PCC as shown in Figure 1, to compensate for the neutral current during the unbalanced load conditions. The source-side voltage and current with neutral current compensation using DSTATCOM are shown in Figure 6. These voltage and currents are obtained with and without the start delta transformer. It is observed that these values are not affected by the presence of the start-delta transformer. The source-side current reduces during the unbalanced conditions which have been simulated by opening the phases B and C on the load side. The voltages of all three phases are not affected due to the unbalancing.

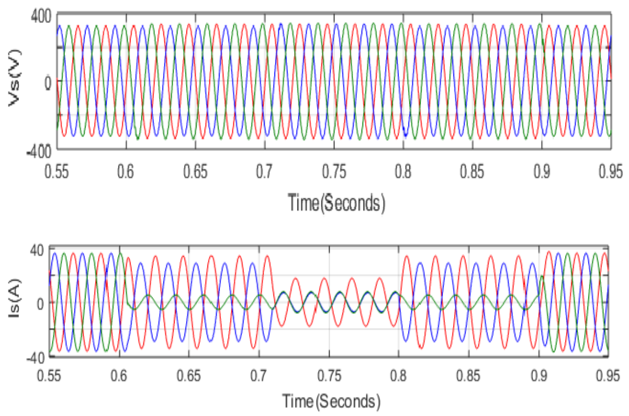

Figure 6.Voltage and current waveforms on the source side with neutral current compensation

The results of compensation using the DSTATCOM in the absence of a star-delta transformer are provided in Figure 7. The Voltage of dc-link capacitor (Vdc), neutral current of the source (Isn), neutral current on the load side (Iln), the current supplied by the DSTATCOM (Icom) and the current flowing in the neutral of the start-side of the transformer (Izn) are provided in Figure 7. The source neutral current is very high without the use of a star-delta transformer. The current injected by the DSTATCOM during the unbalancing conditions is reduced. The small magnitude transient has also been observed in the voltage of the dc-link capacitor. This voltage slightly increases at the time of unbalancing and then attains the original value after the original state of the system is achieved.

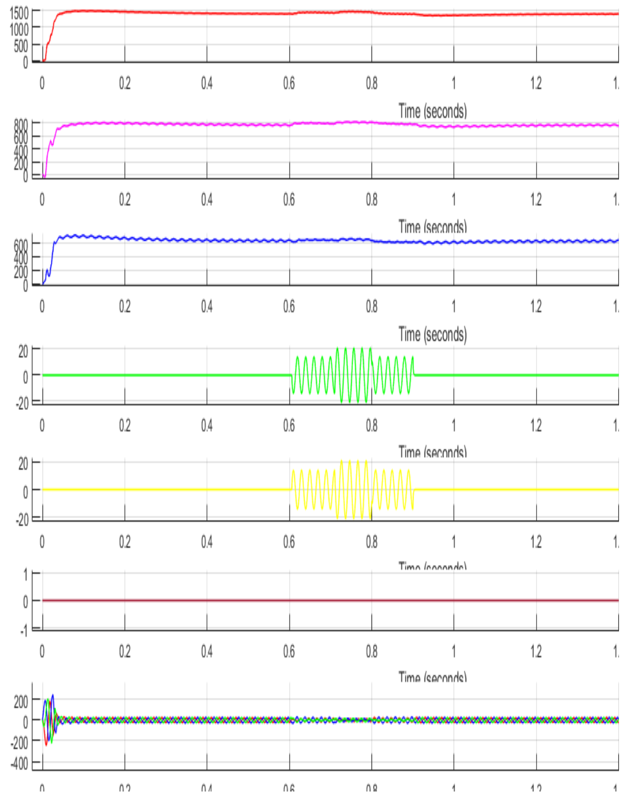

Figure 7.Load neutral current with series compensation in the absence of star-delta transformer

The results of compensation using the DSTATCOM in the presence of the star-delta transformer are provided in Figure 8. The Voltage of dc-link capacitor (Vdc), neutral current of the source (Isn), neutral current on the load side (Iln), the current supplied by the DSTATCOM (Icom) and the current flowing in the neutral of the start-side of the transformer (Izn) are provided in Figure 8. It is observed that the source neutral current is reduced significantly with the use of a star- delta transformer. The current injected by the DSTATCOM during the unbalancing conditions is reduced. Hence, the use of a star-delta transformer with the DSTATCOM reduces the source neutral current. The small

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magnitude transient has also been observed in the voltage of the dc-link capacitor. This voltage slightly increases at the time of unbalancing and then attains the original value after the original state of the system is achieved.

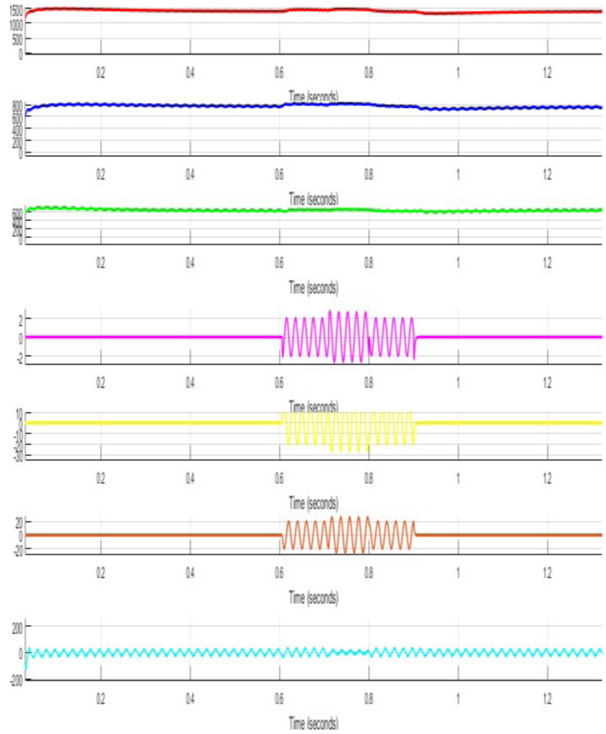

Figure 8.Load neutral current with series compensation in the presence of the star-delta transformer

Conclusion

This paper presents a method for the compensation of source neutral using the distribution static compensator with the star-delta transformer. The unit vector template-based control of the DSTATCOM has been proposed for the neutral current compensation. It has been observed that with the application of the star-delta transformer, the load neutral current circulates through the winding of the star-delta transformer which reduces the source neutral current. Hence, the compensation of source neutral current is achieved successfully. The results have been simulated in the MATLAB/Simulink environment.

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