Two-Leg VSC- as DSTATCOM Based on Carrier less Hysteresis Current Control Algorithm for Power Quality Improvement

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Abstract: ***In contrast with the past the electrical Power quality (PQ) has become the main matter of interest for both utilities and consumers because the loads on the consumer side get affected and also may get damaged. Now, electricity customers are in a separate position to claim a higher quality of service. Efficient power quality (PQ) of control and analysis systems can help to accomplish this goal. This work displays a Zigzag-Delta transformer-based technique for the disclosure of operational events and power quality disturbances concurred with these events.. The power factor advancement by reactive power, neutral current compensation and load balancing in a three-phase four-wire system are yielded by the proposed DSTATCOM (Distribution Static Compensator). The power factor correction mode of operation of the DSTATCOM have been recognized as expected ones. The dc bus voltage of the DSTATCOM has been monitored with respect to the reference dc bus voltage under all uncertain loads. The thorough simulation study of power quality disturbances has been carried out in MATLAB/Simulink environment.***

Keywords: Power Quality, H-Bridge VSC, DSTATCOM, Zigzag-Delta Transformer, Neutral Current Compensation.

1. Introduction

The power quality is a big issue at the load end in the distribution system. The majority of the load on the power distribution system are linear/nonlinear, balanced/ unbalanced or combination of both [1]. These loads increase the burden on the system by drawing reactive power and injecting harmonics which influence the performance of other loads connected to the same utility end [2]. A variety of custom power devices are developed and successfully implemented to compensate for various power quality problems in a distribution system. These custom power devices are classified as the DSTATCOM [3]. DVR (Dynamic Voltage Restorer)[4] and UPQC (Unified Power Quality Conditioner)[5]. The DSTATCOM is a shunt-connected device [6], which can mitigate the current related power quality problems [7]. The effectiveness of DSTATCOM depends upon the used control algorithm for generating the switching signals for the voltage source converter and the value of interfacing inductor [8]. Momentary voltage sags and interruptions are by far the most common disturbances that adversely impact electric customer process operations in a large distribution system [9]. When PQ problems are arising from nonlinear customer loads, such as arc furnaces, welding operations, voltage flicker, and harmonic problems can affect the entire distribution feeder [10]. Several devices have been designed to minimize or reduce the impact of these variations. Custom power is formally defined as the employment of power electronic or static controllers in distribution systems rated up to 38 kV to supply a level of reliability or power quality that is needed by electric power customers who are sensitive to power variations.[11] Custom power devices or controllers include static switches, inverters, converters, injection transformers, master-control modules and energy-storage modules that can perform current-interruption and voltage-regulation functions within a distribution system [12]. A three-phase four-wire DSTATCOM is used to compensate for the neutral current along with voltage regulation or power factor correction with harmonics elimination and load balancing [13].

In this investigation, a two-leg VSC is utilized for repaying power quality issues in the supply flows. The benefits of the two-stage VSC based DSTATCOM over the other existing structures are the diminished number of switches and the expanded unwavering quality because of control of less number of IGBT (Insulated Gate Bipolar Transistor) switches. The star-delta transformer is utilized in the three-stage dispersion framework for various applications [14]. The diminished switches compensator comprising of a two-leg VSC is utilized for three-stage three-wire applications, for example, dynamic channels, SSSC and STATCOM and compensators for sustainable power source applications [15]. The proposed topology of DSTATCOM in which a two-leg VSC with split capacitors alongside a Zigzag-Delta transformercan play out the required remunerations for a three-stage four-wire conveyance framework. The dynamic execution is seen to be attractive for voltage guideline and power factor remedy of the DSTATCOM.

2. Proposed DSTATCOM

The proposed two-leg connect VSC based DSTATCOM alongside a Zigzag-Delta transformerassociated in the three-stage four-wire distributed structure. The direct and non-linear, balanced and unbalanced loads are associated at the PCC. The DSTATCOM comprises of a 2-leg pulse width modulated (PWM) voltage-source converter (VSC) utilizing four insulated-gate bipolar transistors (IGBTs), two interface inductors, and two dc capacitors. The Zigzag-Delta transformer associated at the load terminal gives a circling way to zero succession consonant and fundamental current. The DSTATCOM gives unbiased current remuneration, music end and burden offsetting alongside power factor adjustment or line voltage guideline. The solidarity power factor (UPF) task utilizing the DSTATCOM is appeared in Fig. 1. The compensator current is to repay the responsive power segment of the load current.. The DSTATCOM infuses a present Ic, with the end goal that the load voltage, V_S and source voltage, V_M are in the locus of same circle. The structure of the Zigzag-Delta transformer, plan and control of the two leg VSC are depicted in the following segment.

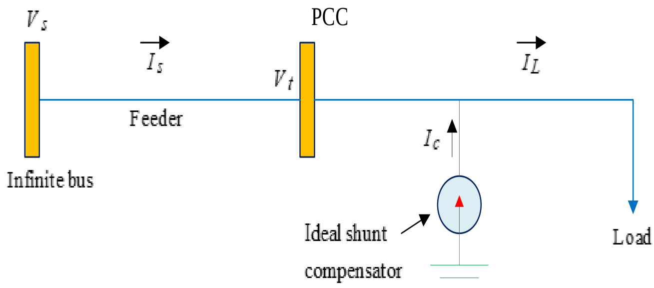

Figure1: Schematic diagram of DSTATCOM

3. Design and control of proposed system

The design of the Zigzag-Delta connected transformer and control of the VSC of DSTATCOM are given in the following sections.

3.1 Design of Zigzag-Deltaconnected transformer

The four-IGBT based two-leg VSC as a DSTATCOM show in figure 2. The DSTATCOM is used as an active shunt compensator along with a Zigzag-Delta transformer for the mitigation of PQ issues such as PFC, VR, balancing the unbalance load and compensation of high neutral current. Zigzag-Delta transformer is used for neutral current compensation. The windings of the Zigzag-Delta transformerare designed in such a way that the magneto motive force (MMF) is balanced properly in the transformer. The Zigzag-Delta transformerprovides the path for load neutral current. Under the unbalance load, the zero-sequence load neutral current divides equally into three currents and take a path through Zigzag-Delta transformerwindings. The two-leg VSC is realized using four-IGBTs switches with a split DC capacitor. To reduce the ripples in the compensating currents, the interfacing inductors are used to connect the VSC to the supply system. An RC filter is connected to the system in parallel with load and compensator reduced the switching ripples at the PCC voltage injected by the fast switching of DSTATCOM. The DSTATCOM is operating in PFC mode of operation and VR mode of operation. For PFC mode of operation, source current should be in phase with source voltage. For VR mode of operation at the PCC by the DSTATCOM, compensation should be such that the source current leads the source voltage

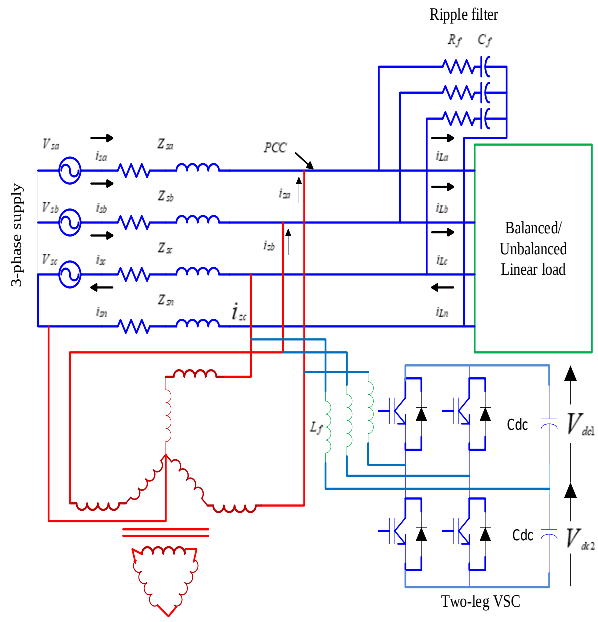

Figure 2: Schematics of proposed H-bridge VSC with Zigzag-Delta transformerbased DSTATCOM

3.2 Design and control of VSC of DSTATCOM

This compensation arrangement is very adaptable and is widely reported for power factor correction, voltage regulation, load balancing, harmonic suppression, and load leveling. Numerous approaches are described for determining the greatness of reference active and reactive current to be produced by DSTATCOM which is a modest technique stated by the use of the PI controller.Figure 3 displays the control arrangement for the PI controller based carrier less hysteresis control. The unit vectors for in-phase and quadrature voltages are achieved from the source voltage. The in-phase unit vectors (U_a, $U_{b,}$ U_c) are calculated by dividing the ac voltages V_a, V_b and V_c by their amplitude V_t. Additional set of vectors named the quadrature unit vectors (W_a, $W_{b,}$ and W_c) are a sinusoidal function, obtained from an in-phase vector set (U_a, U_b and Uc). To regulate the PCC terminal voltage, its amplitude V_t is compared with the desired voltage V_{tref} and error is processed by a PI controller. The output of the PI controller (I^*_{smq}) decides the amplitude of the reactive current to be produced by the DSTATCOM.Multiplication of the quadrature unit vectors (W_a, $W_{b,}$ and W_c) with I^*_{smq}yields the quadrature component of the reference current (i^*_{saq}, $i^*_{sbq,}$ and i^*_{scq}).The charging current must be provided from the PCC to DC bus for the DSTATCOM. To achieve DC bus voltage (V_{dc}) is sensed and compared with the DC reference voltage (V_{dcref}). The error voltage is treated by an additional PI controller. The yields of the PI controller (I^*_{smd}) decides the amplitude of the active power component of the source current. Multiplication of the in-phase vectors (U_a, U_b and Uc) with I^*_{smd} yields the in-phase component of the reference source currents (i^*_{sad}, $i^*_{sbd,}$ and i^*_{scd}). The reference source currents (i_{sa},$i_{sb,}$ and i_{sc}) are obtained by adding the in-phase and the quadrature components. A pulse width modulation (PWM) current controller compares the reference source currents (i^*_{sa}, $i^*_{sb,}$ and i^*_{sc}) with sensed source currents (i_{sa}, $i_{sb,}$ and i_{sc}) to generate the switching signals for the IGBTs of the DSTATCOM.

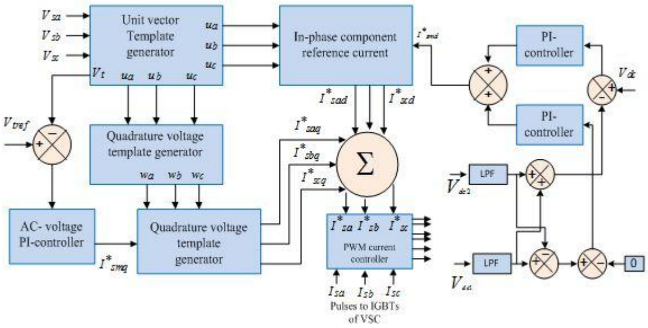

Figure 3: Schematic diagram for Carrier-less hysteresis control of DSTATCOM

4. Modelling of DSTATCOM System

The simulation model of H-bridge VSC based DSTATCOM and the Zigzag-Delta transformerinterfaced to a three phase four wire system shown in Fig.4 is modeled and simulated using the MATLAB and its Simulink and Power System Block set toolboxes. The load considered is a lagging power factor linear load and nonlinear load. The ripple filter is connected to the VSC of the DSTATCOM for filtering the ripple in the terminal voltage. The system data are given in Table 1.

The control algorithm for the DSTATCOM is also modeled in MATLAB. The reference source currents are derived from the sensed PCC voltages ($v_{s.}$), load currents. (I_L) and the dc bus voltages (v_{dc1}, v_{dc2}) of DSTATCOM. A pulse width modulated (PWM) current controller is used over the reference and sensed source currents to generate the gating signals for the IGBTs of the VSC of the DSTATCOM.

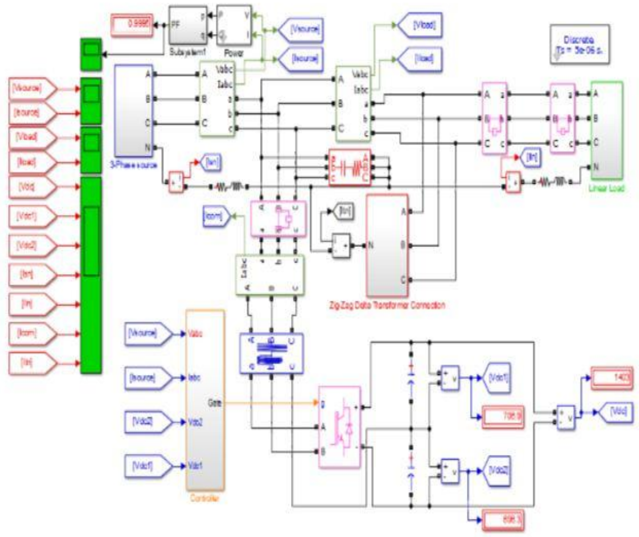

Figure 4: 3-phase 4-wire system with DSTATCOM and Zigzag-Delta transformerin power factor correction mode

Table 1: Detail of System Parameters

System Parameters	Evaluations
Line Impedance	Rs=.01Ω , Ls=2mH
Linear Load	20 KVA, 0.80 pf lag
The nonlinear Load bridge rectifier	Two bridge rectifier
Ripple Factor	Rf=3Ω, Cf=6µF
DC Bus Voltage of DSTATCOM	1400 V
DC Bus capacitance of DSTATCOM	5000 µF
AC inductor	6 mH
DC Voltage PI controller	Kp1=.11,Ki1=.09 , Kp2=0.1,Ki2=.08
PCC voltage PI controller	Kp=.11,Ki=1.1
AC Line voltage	415 Volt
PWM switching frequency	10KHz
Zigzag-Delta transformer	2.4 KVA,240/240V

5. Result and Discussion

The evaluation of two-leg VSC with Zigzag-Delta transformerfor the end-user is designed and simulated by the MATLAB with its Simulink and power system block set software. The Ripple in PCC voltage is eliminated by linking up to the ripple filter directly to the PCC. Delta transformer is linked in parallel, to load. Shunt connected two-leg VSC as DSTATCOM consists of four IGBTs associated at PCC through the interfacing AC inductor and Zigzag-Delta transformerfor mitigation of neutral current and cuts the cost. Under the unbalance condition zero-sequence neutral load current splits similarly into three streams.These currents take the path through all the windings ofZigzag-Delta transformer. The controller based on carrier less hysteresis current control, and is modeled in MATLAB/SIMULINK for the better response of DSTATCOM. The reference source current (I^*_{sa}, I^*_{sb}, I^*_{sc}) is resultant from PCC voltages (V_{sa}, V_{sb}, V_{sc}), Source currents (I_{sa},I_{sb},I_{sc}) and DC bus voltage (V_{dc}) of DSTATCOM. A PWM current controller is applied to produce pulses for two-leg VSC. So that switching operation of DSTATCOM can be proper. PI controller is used for amplifying the current error in every phase before comparison with a triangular carrier wave.

It contains three three-phase circuit breakers, linear load, zigzag-Delta transformer, ripple filter, power factor correction, controller and the measurement scopes as exposed in figure 4.5. Originally the three-phase four-wire distribution system is in steady-state (CB1 and CB2 are closed), and the controller circuit is not linked to the balanced three-phase four-wire distribution system. CB_1 becomes open at 1.6 Sec. One phase of the load is disconnected, the resulting load develops unbalanced. CB_1 persist open from 1.6 Sec to 1.9 Sec. At 1.7 Sec., The CB_2 becomes open, disconnecting additional phase.

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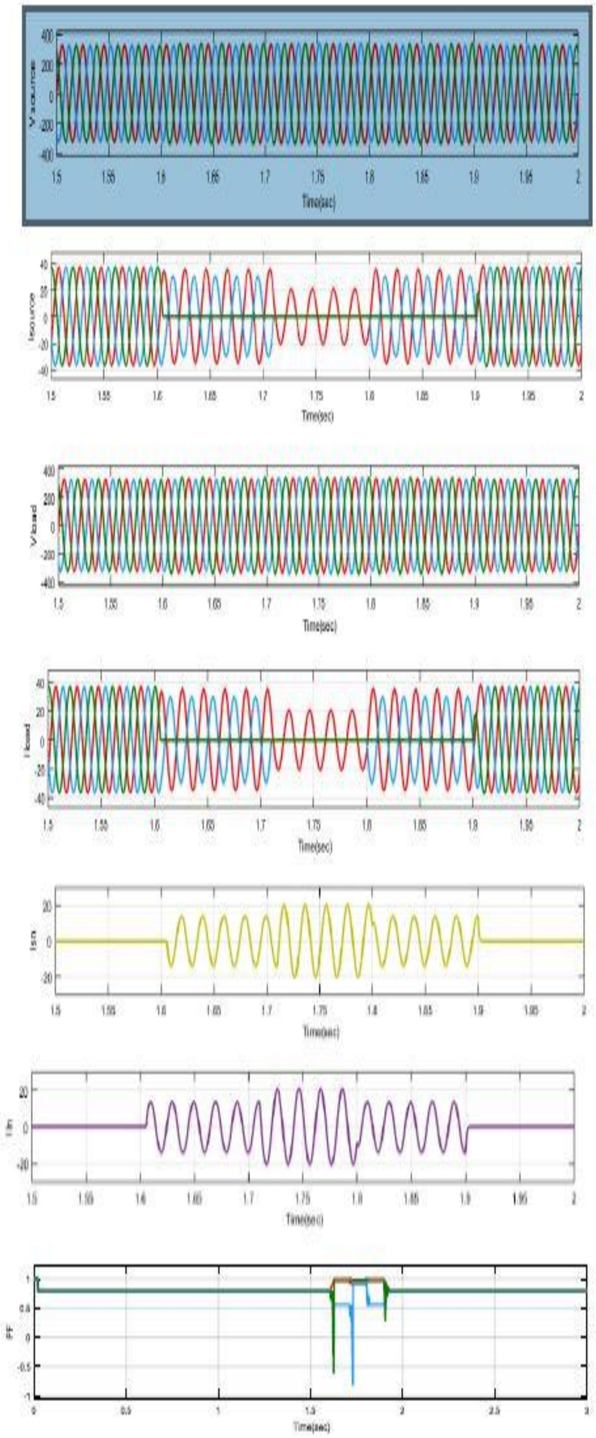

Figure 5: Performance of 3-phase 4-wire system Zigzag-Delta transformerwithout compensation.

The CB_2 leftovers closed from 1.7 Sec. to 1.8 Sec. The CB_1leftovers open from 1.6 to 1.9 Sec.The CB_2 leftovers closed from 1.7 Sec. to 1.8 Sec. The CB_1leftovers open from 1.6 to 1.9 Sec.The source voltage (V_{source}), the source current (I_{source}), load current (I_{load}), load neutral current (I_{ln}), source neutral current (I_{sn}) is measured from the matching scopes of figure 5. The source voltage (V_{source}), the source current (I_{source}), load current (I_{load}), load neutral current (I_{ln}), source neutral current (I_{sn}), transformer neutral current (I_{tn}), AC voltage (V_{ac}), DC voltage (V_{dc}), DC voltage across C1 (V_{dc1}), DC voltage across C2 (V_{dc2}), compensating current (I_{com}) with controller circuit are also exposed in figure 6.

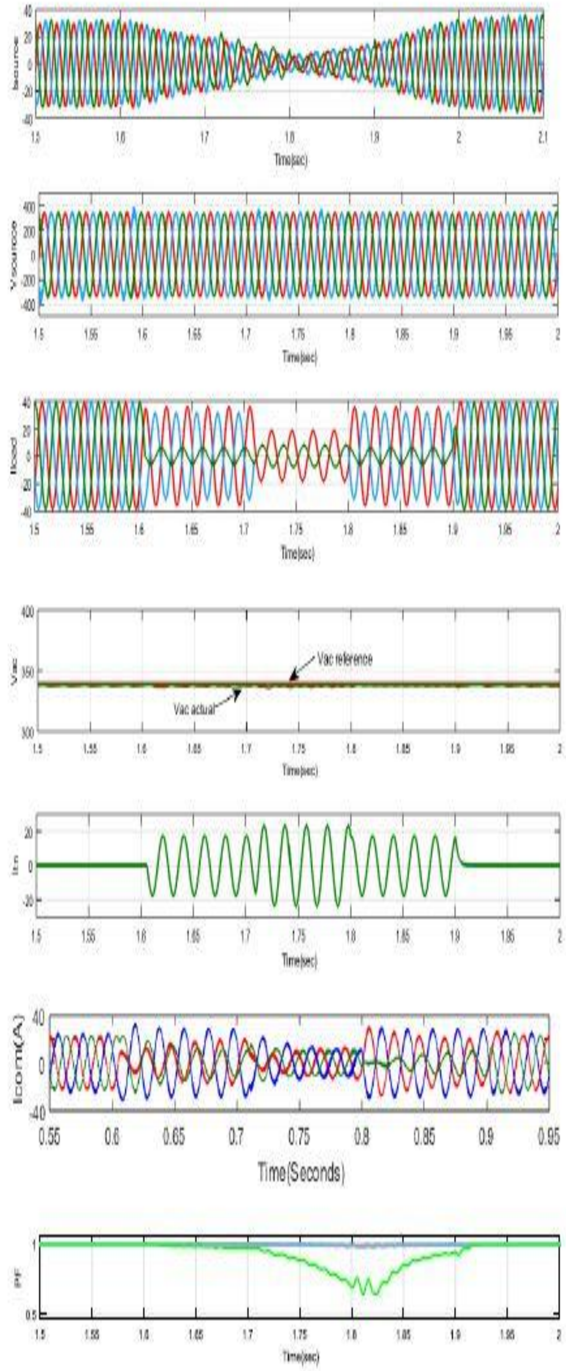

Figure 6: Performance of proposed DSATCOM for neutral current compensation, load balancing and PFC

6. Conclusion

The two-leg VSC as a DSTATCOM with Zigzag-Delta transformeris modelled and thoroughly investigated. The study focused on control scheme and easy to implement, for faster and dynamic system response. Controller grounded on carrier less hysteresis current control is presented in this thesis. MATLAB simulation reveals that the controller is able to balance the load, voltage regulation, improve the power factor to unity and compensate the neutral current effectively. The control algorithm is more effective to control the DSTATCOM response in the PFC mode of operation. In PFC mode power factor is improved, source current is balanced sinusoidal and in phase the voltage.

Source current is balanced, sinusoidal and slightly leading with voltage. The DC link voltage is maintained to its reference value in PFC mode. AC terminal voltage is likewise retained to its mention value. Zigzag-Delta transformerreduced neutral current. It also raises the load balancing capacity of DSTATCOM

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