Mitigation of Power Quality Problems by using DSTATCOM with Fuzzy Based DQ Vector Control Algorithm

John De Britto C

Assistant Professor, Dept of EEE, Parisutham Institute of Technology and Science, Thanjavur-613006, Tamilnadu, India.

Abstract:

This Paper presents the improving power quality by using three-phase distribution static compensator (DSTATCOM) with FUZZY logic based decoupled current controller algorithm is presented for compensation of loads in a distribution system. The DSTATCOM is most commonly used for harmonics elimination, load balancing and reactive power compensation with self-supporting dc bus in the distribution system. The DQ-based control algorithm is used for extraction of fundamental weighted values of these active and reactive power components of load currents in which are required for estimation of reference supply currents. It is most commonly based on a dq transformation system into control and balance the load voltage.

The FUZZY controllers reduced the steady state error, overshoot and improve the speed response. Simulation of DSTATCOM the detailed modeling and simulations of different models of control strategies are presented and implemented along with the necessary modeling equations in the MATLAB simulink using the simpower systems toolboxes. Simulation results are discussed and various methods also applied depending on the various loads like linear and nonlinear load on the DSTATCOM processor simulink models and the simulation results are studied. Index terms: Distribution static compensator (DSTATCOM) and voltage source converter (VSC), DQ vector control algorithm, FUZZY controller.

I. INTRODUCTION

Poor power quality (PQ) has undesirable effects on electrical equipment [1]. Continuity and reliability degrade with the poor quality of supply power. PQ can be analyzed based on voltage or current qualities as it is defined in terms of voltage and current [2]. One of the major components for degrading the PQ is harmonics because of spreading of nonlinear loads which are variable in random nature [3, 4]. Most of the AC loads are consuming reactive power due to presence of reactance. Heavy consumption of reactive power gives poor voltage quality. Today these Problems have even higher impact on reliable and secure power supply in the Globalization and Privatization of electrical systems and energy transfer. The development process are in fast and reliable semiconductors devices (GTO and IGBT) allowed new power electronic configurations to be introduced to the tasks of electrical energy Transmission and load flow control. The FACTS devices offer a fast and reliable control ended the transmission parameters, i.e. Voltage, line impedance, and phase angle between the sending end voltage and receiving end voltage. Then again the custom power is for low voltage distribution, and improving the poor quality and reliability of supply disturbing sensitive loads. The Custom power devices are very similar to the FACTS. Most commonly known custom power devices are DSTATCOM, UPQC, DVR among them DSTATCOM is very well known and can provide cost effective result for the compensation of reactive power and unbalance loading in distribution system. Good power quality, conversely is not easy to define because what is good power quality to a refrigerator motor may not be worthy enough for today's personal computers and other sensitive loads. The performance of DSTATCOM with different control systemshave been tested through digital simulations with the different system parameters. The switch on time of the DSTATCOM and the load change time are also stated. DQ vector control algorithm is very fast, flexible, low cost, easily data handling and more efficient. It is main advantages is time consuming is less than other control algorithm.

II. SYSTEM CONFIGURATIONS AND CONTROLALGORITHM

A VSC-based DSTATCOM is connected to a three phase ac mains feeding three-phase linear/non-linear load with internal grid impedance (Zs) which is shown in Fig. 2. The steady state and dynamic performances of DSTATCOM depend upon the accuracy of detection of harmonics currents or disturbances. Interfacing inductors (Lf) are connected at ac output of the VSC to limit the ripple in compensating currents. A series combination of capacitor (Cf) and a resistor (Rf)characterizes the shunt passive ripple filter which is connected at the point of common coupling (PCC) to suppress the high frequency noise because of switching of the VSC. The DSTATCOM currents (iCabc) are injected as required compensating currents to terminate the reactive power components and harmonics of the load currents so that loading because of reactive power section/harmonics is reduced on the distribution system. Fig. 2 shows the block diagram of the DQ algorithm for estimation of reference supply currents through the weighted values of load active power and reactive power current components.

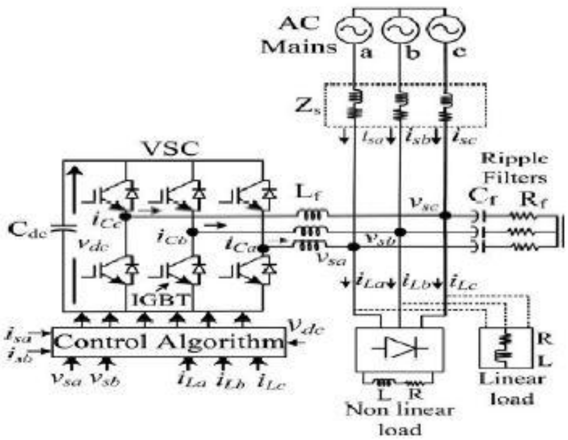

Fig 1: A VSC-based DSTATCOM

Its output layer has a matching pattern with the load current as input signal. In this algorithm, PCC voltages (vsa,vsb and vsc), supply currents (isa, isb and isc), load currents are named as(iLa, iLb and iLc) and dc bus voltage (vdc) are required for extraction of reference supply currents (isa,isb,isc). Amplitude of reactive power components of the reference supply currents is considered zero in the case of PFC mode.

A. *Voltage Source Converter:*

The VSC connected in shunt through the ac system offers a multifunctional topology which can be used for active to three quite distinct purposes:

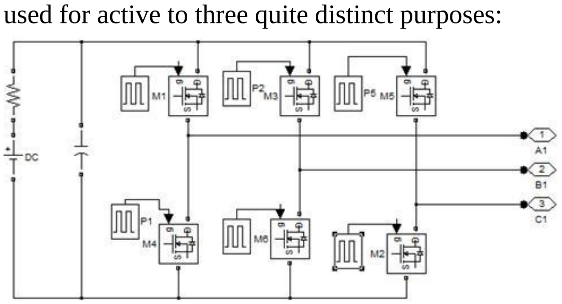

Fig 2: Voltage Source Converter

1. Voltage regulation and compensation of reactive power
2. Adjustment of power factor
3. Elimination of current harmonics
4. Load balancing

Here, such device is active to provide constant voltage regulation using an indirectly controlled converter.

1) IGBT or GTO Based dc-to-ac Inverters:

These inverters are used which create an output voltage wave that's controlled in magnitude and phase angle to produce whichever leading or lagging reactive current, depending on the compensation required.

2) L-C Filter:

The LC filter is used which reduces harmonics and matches inverter output impedance to enable multiple parallel dc to ac currents to share current. The LC filter is chosen in accordance with the type of the system and the harmonics present at the output of the inverter.

3) Control Block:

Control block is used which switch Pure Wave DSTATCOM modules as required. They can control exterior devices such as mechanically switched capacitor banks too.

These control blocks are designed based on the various control concepts and algorithms like instantaneous PQ theory, synchronous frame theory, learning vector quantization control algorithm etc...The performance of the DSTATCOM depends on the control algorithm i.e. the extraction of the current components. The dynamic performance is analyzed and verified through simulation. It is a custom power device which is gaining a wild publicity during these days due to its exceptional features like it provides fast response, suitable for dynamic load reaction or voltage regulation and automation needs, Both leading and lagging VARS can be provided, to accurate voltage surges or sags caused by reactive power demands DSTATCOM can be applied on wide range of distribution and transmission voltage, overload capability of this provides reserve energy for transients.

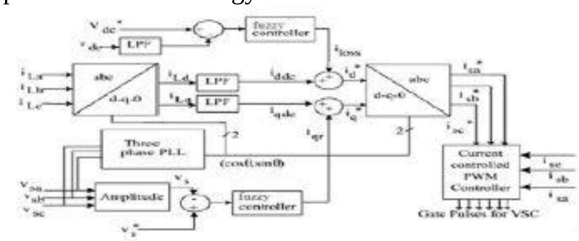

Fig 3: Control Block of D-STATCOM

Technically the ideal AC line supply by the utility system should be a pure sine wave of fundamental frequency(50/60Hz).Different power quality problems, their characterization methods and possible causes are discussed above and which are responsible for the lack of quality power which affects the customer in many ways. It is therefore imperative that a high standard of power quality is maintained.

This project demonstrates that the power electronic based power conditioning using custom power devices like DSTATCOM can be effectively utilized to improve the quality of power supplied to the customers.

B. Compensation Scheme Of D-Statcom:

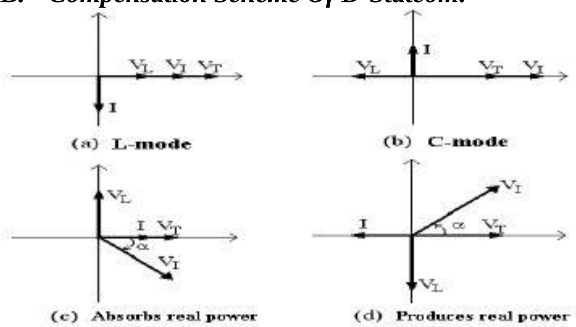

Fig 4: Vector Diagrams of D-STATCOM

The DSTATCOM is a DC/AC switching power converter composed of an air-cooled voltage source converter. Basically, the DSTATCOM is used to suppress voltage variations and control reactive power in phase with the system voltage. DSTATCOM VL is in phase with the bus terminal voltage VT, and VL is greater than VT, the DSTATCOM provides reactive power to the system. If VL is smaller than VT. DSTATCOM absorbs reactive power from the power system. So it absorbs some real power from system. Which show the inverter output voltage VL, system voltage VT, reactive voltage VL and line current I in correlation with the magnitude and phase α.

The compensation is achieved by the control of id and iq. Using the definition of the instantaneous reactive power theory for a balanced three phase three wire system, the quadrature component of the voltage is always zero, the real(p) and the reactive power (q) injected into the system by the DSTATCOM can be expressed under the dq Reference frame as: Since vq=0, id and iq completely describe the instantaneous value of real and reactive powers produced by the DSTATCOM when the system voltage remains constant.

Therefore the instantaneous three phase current measured is transformed by abc to dqo transformation. The decoupled daxiscomponent id and q axis component iq are regulated by two separate FUZZY regulators. The instantaneous id reference and the instantaneous iq reference are obtained by the control of the dc voltage and the ac terminal voltage measured. Thus, instantaneous current tracking control is achieved using four FUZZY regulators. A Phase Locked Loop(PLL) is used to synchronize the control loop to the ac supply
so as to operate in the abc to dqo reference frame.

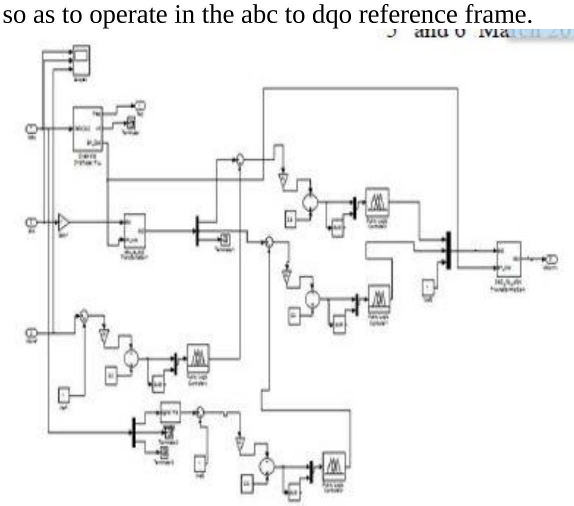

Fig 5: DQ Vector Controller of DSTATCOM.

The proposed D-STATCOM controller consists of current and dc voltage controller. The dc voltage controller regulates the dc voltage at the required level and the current controller forces the D-STATCOM current to follow the references. The main objective of any compensation scheme is that it should have a fast response, flexible and easy to implement. The control algorithms of a DSTATCOM are mainly implemented in the following steps

1. Measurements of system voltages and current
2. Signal conditioning
3. Calculation of compensating signals
4. Generation of firing angles of switching devices

The performance of DSTATCOM with different control schemes have been tested through digital simulations with the different system parameters. The switch on time of the DSTATCOM and the load change time are also mentioned. DQ vector control algorithm is very fast, flexible, low cost, easily data handling and more efficient. It is main advantages is time consuming is less than other control algorithm.

III. RESULTS AND DISCUSSION

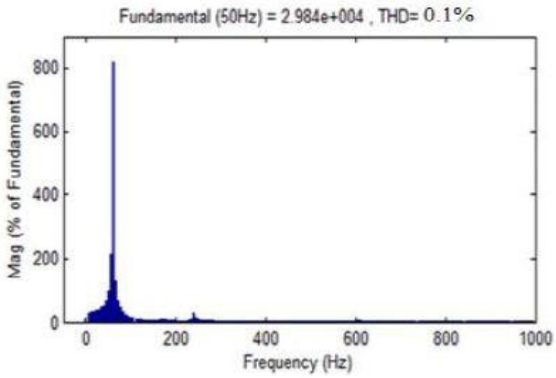

Fig 6: Linear Load Without DSTATCOM

It shows the compensating load voltage, load current, real power, reactive power at the three phase fault condition which T=2.0 to 2.1 sec for without DSTATCOM in linear load. The wave form distortion occurs in load side voltage due to without DSTATCOM.

Theoretical calculation of voltage (vabc) FFT measurement in without DSTATCOM in linear load: The THD value of vh1 to vh19 is taken from the FFT analysis of BAR Relative base value is MATLAB simulation THD =
Assume n=19
FFT analysis value for output voltage (Vabc) for THD =75.26%

The figure6 shows the source voltage and DSTATCOM output voltage for linear load with DSTATCOM. Three phase fault occur in the load side which DSTATCOM act in injecting compensating current into transmission line due to transmission line voltage less than DSTATCOM voltage. The DSTATCOM act in time is 2.0 to2.1 at fault condition.

Figure 7 shows the compensating load voltage, load current, real power, reactive power at the three phase fault condition which T=2.0 to 2.1 sec ,that time DSTATCOM inject the compensating current in load side**.**

The DSTATCOM with DQ vector control algorithm is generating reference signal into produced compensating current to reduce the voltage sag and compensating reactive power at load side. The main purpose of DSTATCOM is reducing the current harmonics in 13%.

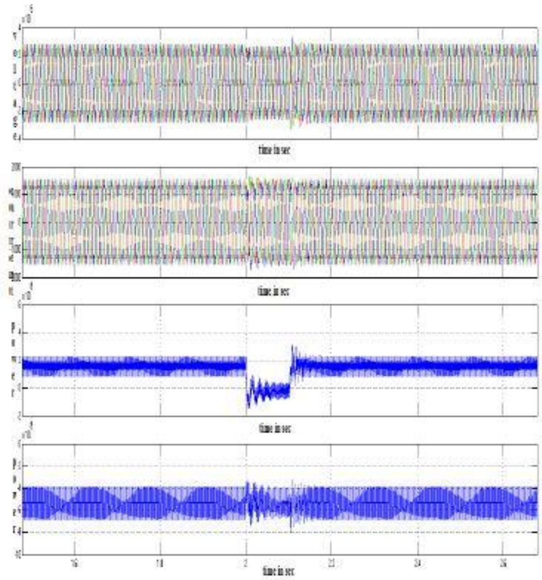

Fig 7: Without DSTATCOM in Load Voltage, Load Current, Real and Reactive Power.

The wave form distortion occurs in load side voltage due to rectifier load and variable load. Theoretical calculation of voltage (vabc) FFT measurement in with out DSTATCOM in nonlinear load: The THD value of vh1 to vh19 is taken from the FFT analysis of BAR Relative base value is MATLAB simulation Assume n=19. FFT analysis value for output voltage (Vabc) for THD =96%. Load current, real power, reactive power at the three phase fault condition T=2.0 to 2.1 sec that time DSTATCOM act as inject the compensating current into reduce voltage sag and current harmonics in 1.2%.

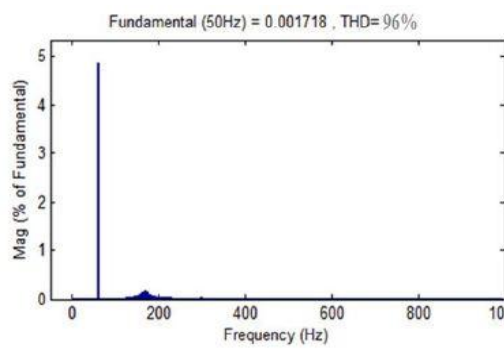

Fig 8: DSTATCOM with Load Current Harmonics.

Theoretical calculation of voltage (vabc) FFT measurement in with dstatcom in nonlinear load:
The THD value of vh1 to vh19 is taken from the FFT analysis of BAR Relative base value is MATLAB simulation. Assume n=19. FFT analysis value for output voltage (Vabc) for THD =1.2%

IV. CONCLUSION

A three-phase DSTATCOM has been implemented for compensation of linear and non-linear loads using the DQ based control algorithm. The proposed DQ based control algorithm has been used for extraction of reference supply currents to generate the switching pulses for IGBTs of the VSC used as DSTATCOM. Various functions of the DSTATCOM such as, reactive power compensation, harmonics elimination and load balancing have been demonstrated with self-supporting dc bus of VSC. From the test results, it is concluded that the DSTATCOM and its control algorithm have been found quite suitable for compensation of linear and non-linear loads. Comparing with reported methods, the proposed controller takes advantages of both faster dynamic response performance and simpler control structure Since the voltage deviation and voltage error signals are much reduced by the (DQ based Control Algorithm with fuzzy controller). The control scheme maintains the balanced voltage level at the D-STATCOM terminal to regulate the DC capacitor voltage. It has been shown that the DSTATCOM is able to regulate voltage in the distribution network against disturbances raised in the network. In addition to power distribution applications and the benefits offered by DSTATCOM for improved system operations.

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