IJETST- Volume||01||Issue||09||Pages 1411-1421||November||ISSN 2348-9480 2014

Open access Journal International Journal of Emerging Trends in Science and Technology

Correction of Power Quality Issues in Distribution System Using DSTATCOM with SSULMS Control Algorithm

Authors

Vikas Purushothaman[1], Bobin K Mathew[2]

[1]Mahatma Gandhi University, Amal Jyothi College of Engineering, Kottayam, Kerala, India

Email: *vikaspe88@gmail.com*

[2]Mahatma Gandhi University, Amal Jyothi College of Engineering, Kottayam, Kerala, India

Email: *bobinkmathew@amaljyothi.ac.in*

Abstract

Power quality disturbances is the major concern in the distribution system, that leads to tripping and malfunction of sensitive equipments in distribution system. A Distribution Static Synchronous Compensator (DSTATCOM) can be used to mitigate the power quality issues by injecting/absorbing real and reactive power to the point of connection(PCC). This study presents how the DSTATCOM used to compensate the voltage sag, voltage swell, power factor problems and harmonics and thus to improve the distribution system performances by using an advanced control based on step size updating LMS algorithm.

A 6 pulse Voltage Source Inverter based D-STATCOM with proposed control algorithms are designed and graphic based model of the same is developed using MATLAB/Simulink simulation program. The results obtained in different cases are analysed. Based on this analysis the capability of DSTATCOM to mitigate the power quality disturbances using SSULMS algorithm under various circumstances is validated.

Keywords: *Power Quality, DSTATCOM, Distribution System, Step Size Updating LMS control.*

1. Introduction

The power quality issues have become an increasing concern in distribution system due to the wide applications of sensitive load and disturbances. Poor power quality results in power disruption for the user and huge economic losses due to the interruption of production processes. Various power filtering technology i.e. passive filters, active power filters, hybrid filters have applied from time to time for giving the solution of power quality problems to users, But could not fully satisfied them.

In this paper DSTATCOM is used to control the power quality issues. There are many power quality surveys have been done, which shows that voltage sag, swell and harmonics problems have been identified as the most serious power quality problems facing industrial customers today. The DSTATCOM has emerged as a promising device to provide not only for voltage sag mitigation but a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction and harmonic control and many control techniques have been developed to mitigate these problems also. Most of the papers are single function based.

In this work, the DSTATCOM is treated. The main focus is on the converter topology for the DSTATCOM and its control system. Both of these treated theoretically, and in simulations. A three phase six pulse voltage source inverter based DSTATCOM is considered with an advanced step size updating LMS control algorithm [1]. Which is simulated under different operating conditions such as voltage sag, voltage swell, harmonics, and power factor correction modes. In this paper, VSI converts the dc link voltage into a three phase ac voltages and which are coupled with the ac system through the reactance of coupling transformer. The DSTATCOM inject or absorbs the reactive power/current at the point of common coupling (PCC) according to the demand of distribution system, thus way the compensation have been done. There are three controllers inside the system, PI controller for maintaining the voltage, step size updating LMS control algorithm is used for generating the reference current signals and hysteresis current control for generating the appropriate gate pulses.

2. DSTATCOM

The main features in this study are those concerning voltage and current deviations, such as: sags, swells, harmonics and unbalances. A Distribution Static Synchronous Compensator (DSTATCOM) can be used to mitigate above problems by Injecting / absorbing reactive power to the point of connection. There are different DSTATCOM topologies developed according to different converters [2]. Generally Voltage source inverter based DSTSTCOM's are used.

The D-STATCOM is three phase shunt connected power electronics based device. It is connected near the load at the distribution system. It is also a one type of the six pulse voltage-source converter, which converts a DC input voltage into AC output voltage in order to compensate the active and reactive power needed by the system [3]. The connection and schematic view of DSTATCOM is shown in figure 1. In this topology the DSTATCOM consists of DC voltage source behind self-commutated inverters (VSI) using 6 IGBT's, dc capacitor, ripple filter and a reactance of coupling transformer. It provides a multifunctional topology which can be used for up to three quite distinct purposes:

- Voltage regulation and compensation of reactive power.
- Correction of power factor and
- Elimination of current harmonics.

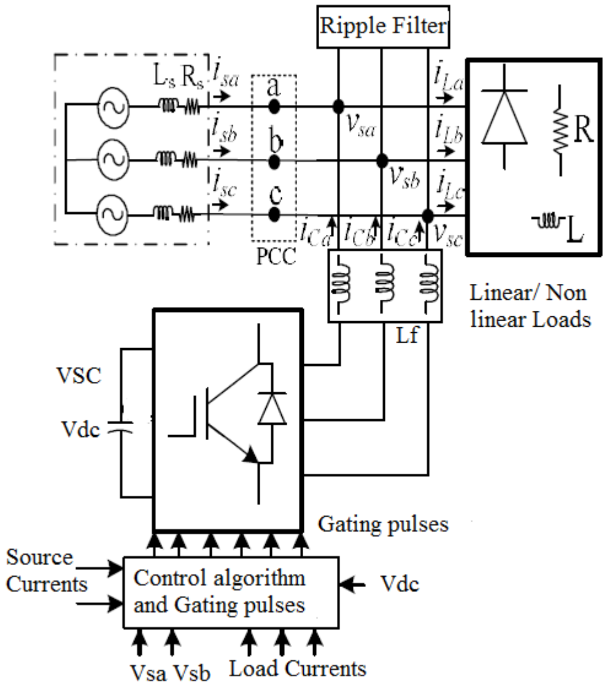

Figure 1: Circuit Diagram of DSTATCOM

The capacitor in the D-STATCOM is used to maintain dc voltage to the inverter. The amplitude of the inverter voltage V_i is proportional to the dc voltage of the capacitor, which is proportional to the amount of energy stored in capacitor. If there is a small lagging or leading phase shift, active power flows through the inverter, charging or discharging the capacitor. The reactive power exchange can be done by using this dc link capacitor, but only a limited amount of active power compensation can be achieved with this capacitor. To obtain more active power compensation, additional dc sources are used (battery bank, ultra capacitor bank etc.). A passive resistive and capacitive element (ripple filter) is connected at load terminal in point of common coupling (PCC) and it is useful for filtering the noise signal (or ripples) due to firing of power devices of VSC.

2.1 Working Modes

There are three modes of operation in DSTATCOM for real/reactive power generation/absorption that are explained below with figures [3], [4]. If the amplitudes of the DSTATCOM output voltage and the AC system voltage are equal, the reactive current is zero and the DSTATCOM does not generate/absorb reactive power.

If the amplitude of the DSTATCOM output voltage is increased above the amplitude of the AC system voltage, the current flows through the transformer reactance from the DSTATCOM to the AC system, and the device generates reactive power (capacitive).

If the amplitude of the DSTATCOM output voltage is decreased to below that of the AC system, then the current flows from the AC system to the DSTATCOM, resulting in the device absorbing reactive power (inductive).

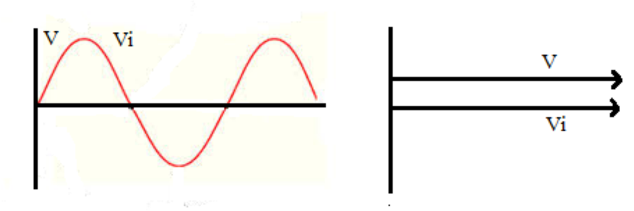

Figure 2: Normal Mode [4]

The losses in the transformer winding and converter switches consume ac power in distribution system. Therefore there will be a small phase difference of angle ±α between V_{bus} and V_i to compensate the losses of transformer winding and inverter switching and receive the active power from ac system. In inductive mode phase angle α will positive while capacitive mode it becomes negative. The vector diagram for active power mode is shown in figure 4.

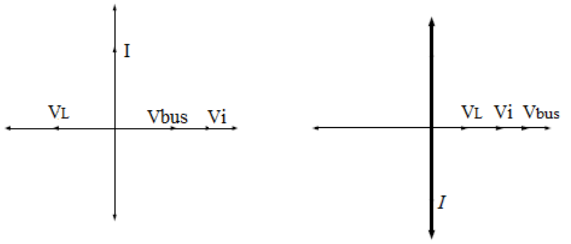

Figure 3:Modes of Operation of Reactive Power (a)
Capacitive Mode (b) Inductive Mode [3]

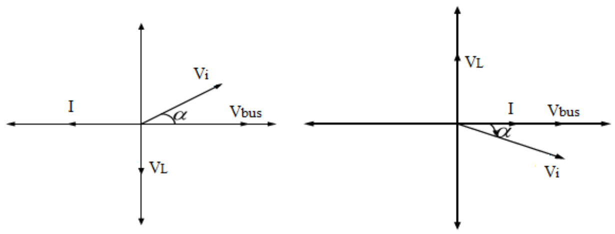

Figure 4: Modes of Operation of Active Power (a) Inductive Mode (b) Capacitive Mode [4]

2.2 Voltage Dip/Swell Mitigation

During the voltage dip/swell, the voltage at the bus to which the DSTATCOM is connected can be boosted / bucked by injecting / absorbing current on the network impedance, which is source impedance in parallel with load impedance. When the phase of the V_i is in quadrature with the I_{sh}, without injecting real power the DSTATCOM can achieve the voltage sag mitigation.

3. Control Methodology

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 [5]

- Measurements of system voltages and current and
- Signal conditioning
- Calculation of compensating signals
- Generation of firing angles of switching devices
- Generation of proper PWM firing pulses is the most important part of DSTATCOM

control and has a great impact on the compensation objectives, transient as well as steady state performance. Since a DSTATCOM shares many concepts to that of a STATCOM at transmission level, a few control algorithms have been directly implemented to a DSTATCOM, incorporating Pulse Width Modulation (PWM) switching, rather than Fundamental Frequency switching (FFS) methods.

3.1 Proposed Step Size Updating LMS Algorithm

In this paper, an updatable step size least mean square (LMS) algorithm is proposed for the control of a three wire DSTATCOM for analyzing its function in power factor
Correction (PFC), voltage sag and swell mitigation, and harmonics elimination modes of operation[1],[6]. This control algorithm is used for calculation of reference signal
source currents in terms of average weighted active and reactive components/elements. A fast convergence rate, reduced steady state error and good noise immunity performance are the main features of this control algorithm because it uses autocorrelation time mean estimate error signal for updating the step size in place of simple error
signal. It is also effective when disturbance in AC mains is more means low signal to noise ratio (SNR). Block diagram of the proposed control technique is shown in figure 5. Control system

involves two PI controllers, one for maintain the dc link voltage and other for maintaining the terminal voltage amplitude [5]. For reducing the ripples in sensed dc link voltage a Low Pass Filter is used. The steps involved for the calculation of reference source currents will explain in the following section.

The source voltages or the voltage at the point of common coupling (PCC), source currents, load currents, and DC link voltage are sensed from the system. Calculate the in phase(Upa, Upb and Upc) and quadrature (Uqa, Uqb and Uqc) unit vector templates[5].

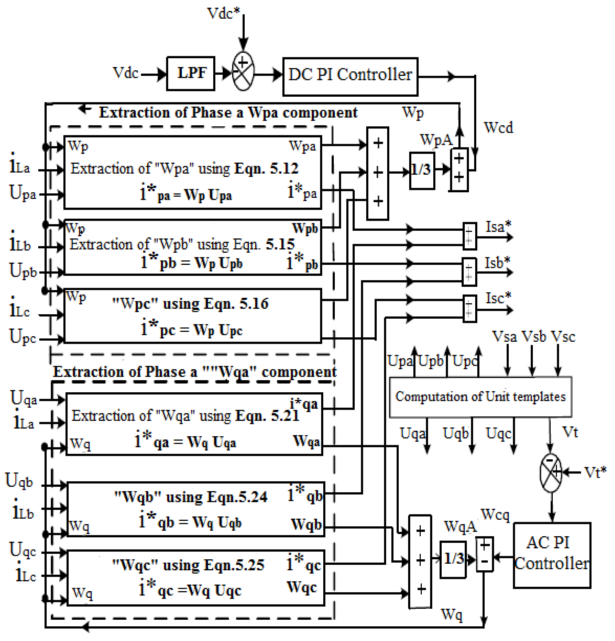

Figure 5: Proposed control algorithm

Calculation of active element of reference source currents

The sensed and filtered dc link voltages are compared with reference value and the error is passed though a dc link PI controller, the output of the PI controller at k_{th} instant is,

$$W_{cd}(k) = W_{cd}(k-1) + K_{pa}\big(V_{dcer}(K) - VdcerK{-}1{+} \quad KiaVdcerK \quad (1)$$

Where V_{dcer}(k) denotes the error in V_{dc} at the k_{th} sampling instant. The weights of active element of phase 'a' load current is estimated as,

$$W_{pa}(k) = W_{pa}(k-1) + 2\tau_p\big(i_{La}(k) - W_{pa}(k-1)U_{pa}\big) \quad (2)$$

Where τ_p is the adjustable step size of LMS control algorithm and which is the main feature of this algorithm. In here the step size in sampled value based on the theory of step size updating [6]. The update equation is,

$$\tau_p(k) = \delta(1 - \exp(-\sigma|Z(k)^2|) \quad (3)$$

$$Z(k) = \lambda Z(k) + (1-\lambda)\big[\big(i_{La}(k) - W_{pa}(k)U_{pa}(k)\big) - \big(i_{La}(k-1) - W_{pa}(k-1)U_{pa}(k-1)\big)\big] \quad 4)$$

The terms δ, σ, λ are the constants, and the accuracy of estimation depends upon the values of these constants. Similarly the weights of active element of phase 'b' and 'c' load currents are calculated. The average weights of active element of reference source current is computed as,

$$W_{pA} = {(W_{pa} + W_{pb} + W_{pc})}/{3} \quad (5)$$

Then calculate the total weight of fundamental active element of reference source currents (W_p), and The active element of reference source current of three phases as,

$$i_{pa} *= W_pU_{pa};\ i_{pb} *= W_pU_{pb};\ i_{pc} *= W_pU_{pc} \quad (6)$$

Calculation of reactive element of reference source currents

The amplitude of sensed PCC voltage is compared with reference value and the error is processed with a PI controller. The calculations are done as same in the way of previous case. The total reference source currents are the sum of active elements and reactive elements of the reference source currents. These total reference source currents are compared with sensed source currents and

the error signals are used for the generation of firing pulses in hysteresis controller [7],[8].

4. Simulation Studies

The modelling of test system, control system, and DSTATCOM of proposed system have been done, After the modelling of each systems separately, combined together and developed a complete system. The simulation is done with complete system in MATLAB platform at four different conditions/modes as given below.

- Voltage Sag
- Voltage Swell
- Power Factor Correction

- Harmonics Elimination

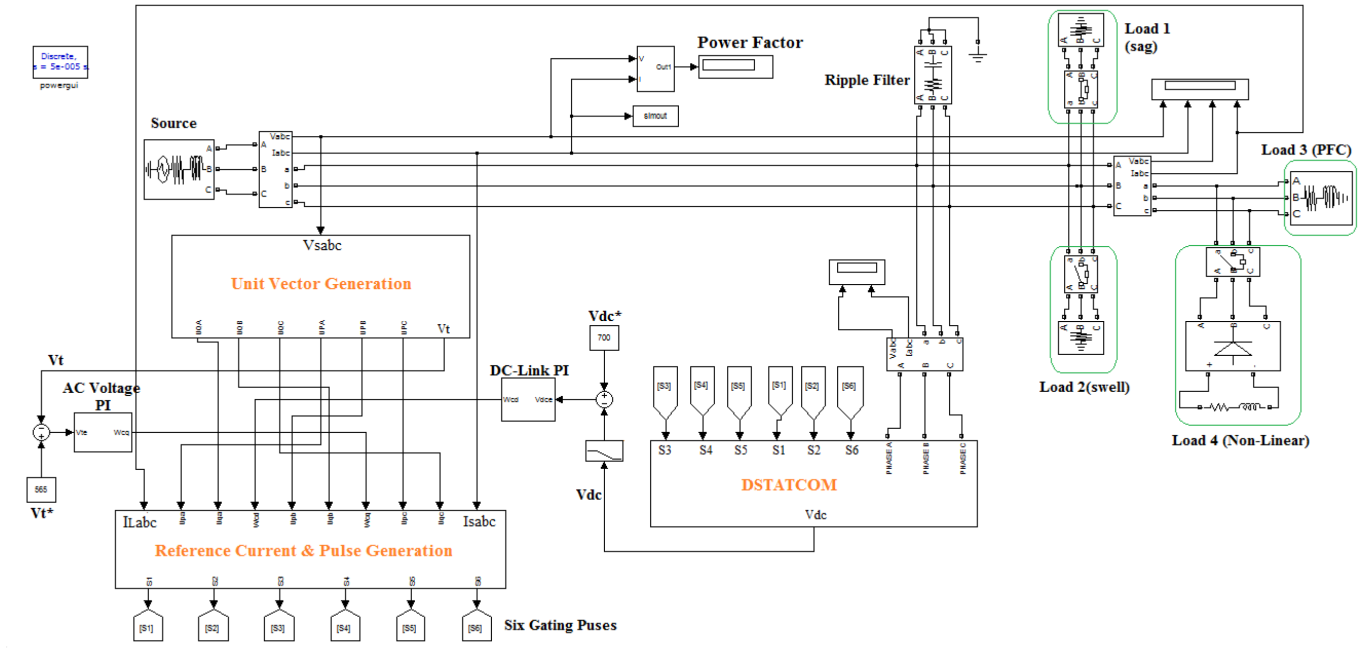

Figure 6: Simulink Model of Complete System with Proposed Control System

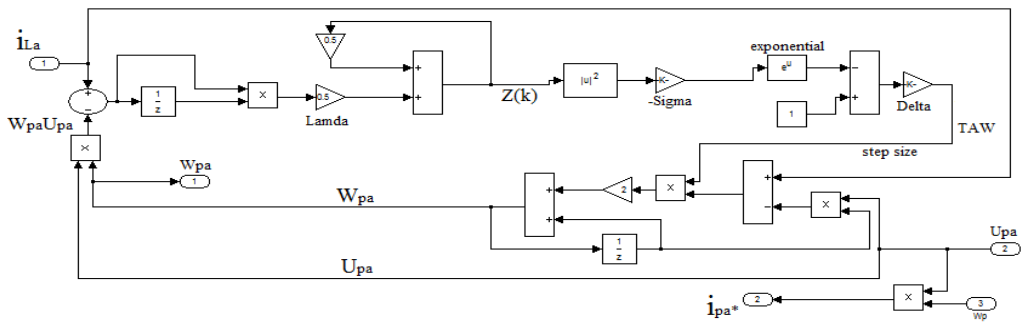

Figure 7: Simulink Model of extraction of weight and reference current of active components of phase 'a'

4.1 Voltage Sag Compensation

The voltage sag is the phenomena at the load side voltage of distribution system. Initially the DSTATCOM is not connected to the system and there is a fixed three phase Resistive load of 150KW is connected to the line for creating a voltage sag (Initial status of the breaker is open). After 0.3 seconds the circuit breaker is closed and the load and terminal voltage (PCC) is decreased from 332V to 262V, that means the voltage sag magnitude is 70 (22%). The sag is lasts for 15 cycles. The simulation results without connecting DSTATCOM are shown in fig.8.

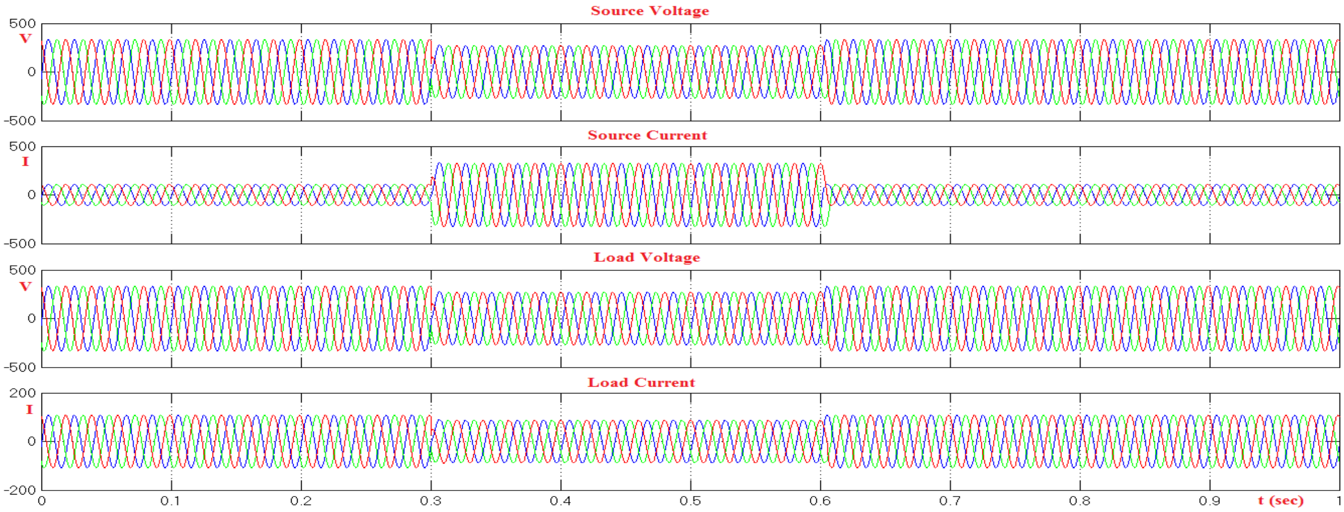

Figure 8: Waveforms of (a) source voltage (b) source current (c) load voltage (d) load current Without DSTATCOM

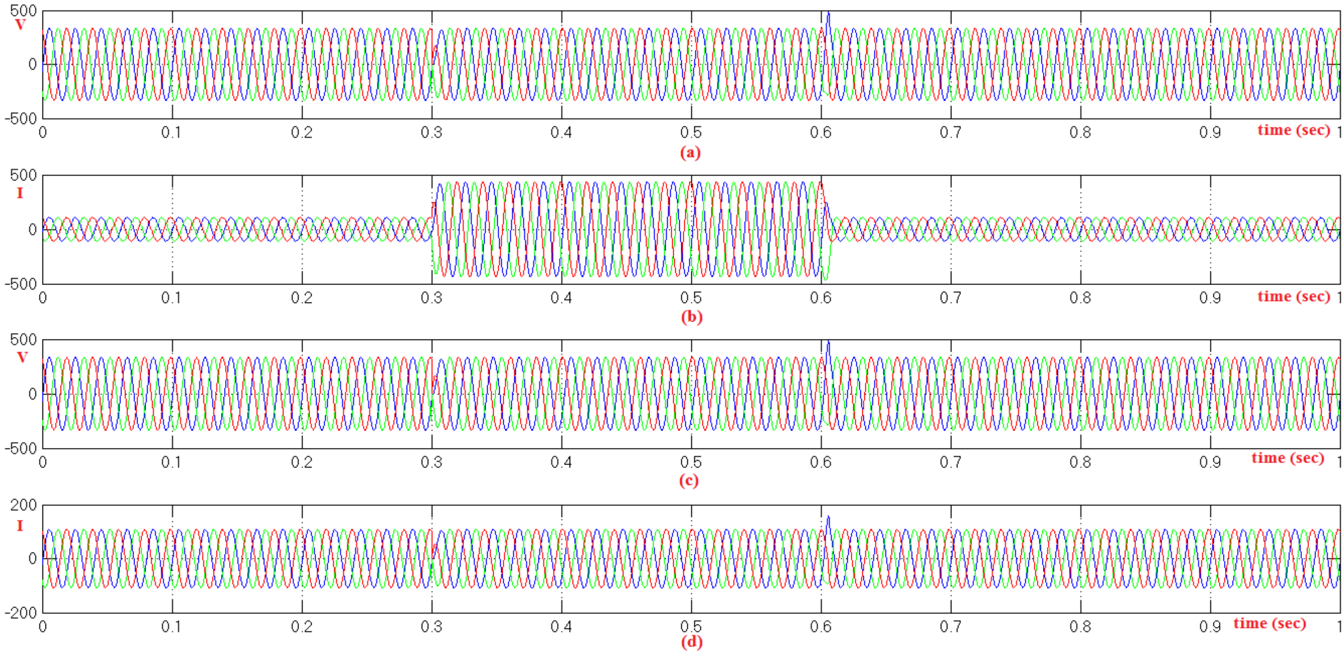

Figure 9: Waveforms of (a) source voltage (b) source current (c) load voltage (d) load current With DSTATCOM

DSTATCOM with proposed Step size Updating LMS control system is connected to the ac system without using breakers. The obtained waveforms of fig.9 shows that the DSTATCOM with proposed system compensated the load voltage (also the load current) to 330V, which is very near to its original value(332). The response of this system is far better than conventional systems, there were no delay to respond to the fault.

4.2 Voltage Swell Compensation

The voltage swell at the load side is created by switched off or breaking the resistive load of 150KW from the load side. The switching transition or the voltage swell is take place from 0.3 sec to 0.8 sec. At that time the load voltage is increased from 272V (normal) to 332(18% increase) for a duration of 25cycles. The waveforms of load voltage and source voltage during swell without any compensation is shown in fig.10.

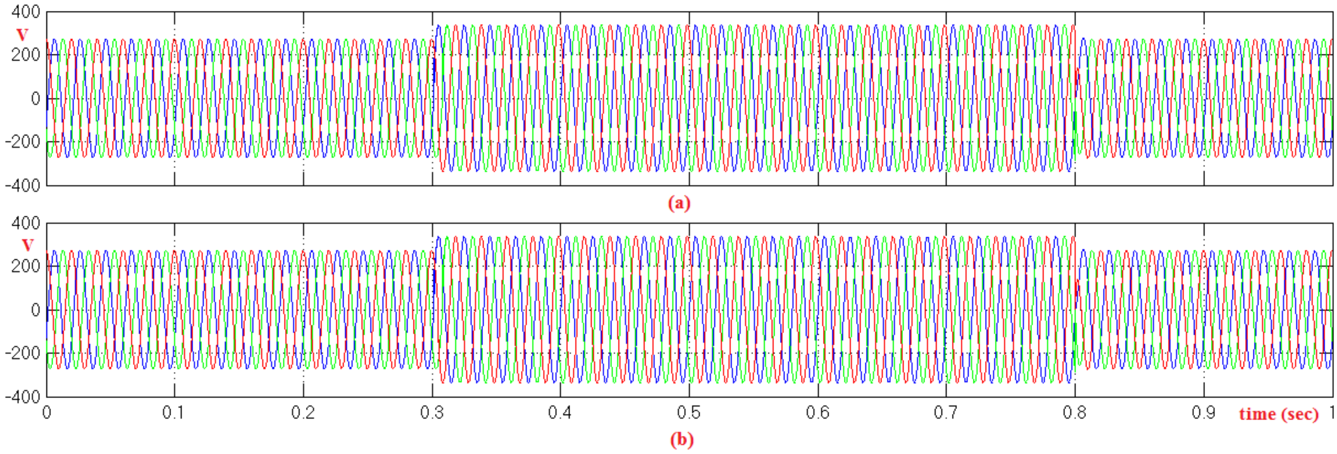

Figure 10: Waveforms of (a) source voltage (b) load voltage during swell Without DSTATCOM

The waveforms of fig.11. shows that the load voltage swell from 0.3 seconds to 0.8 seconds can be completely compensated without any distortions by using the proposed SULMS control algorithm. The results also proved that the response of the system is very faster.

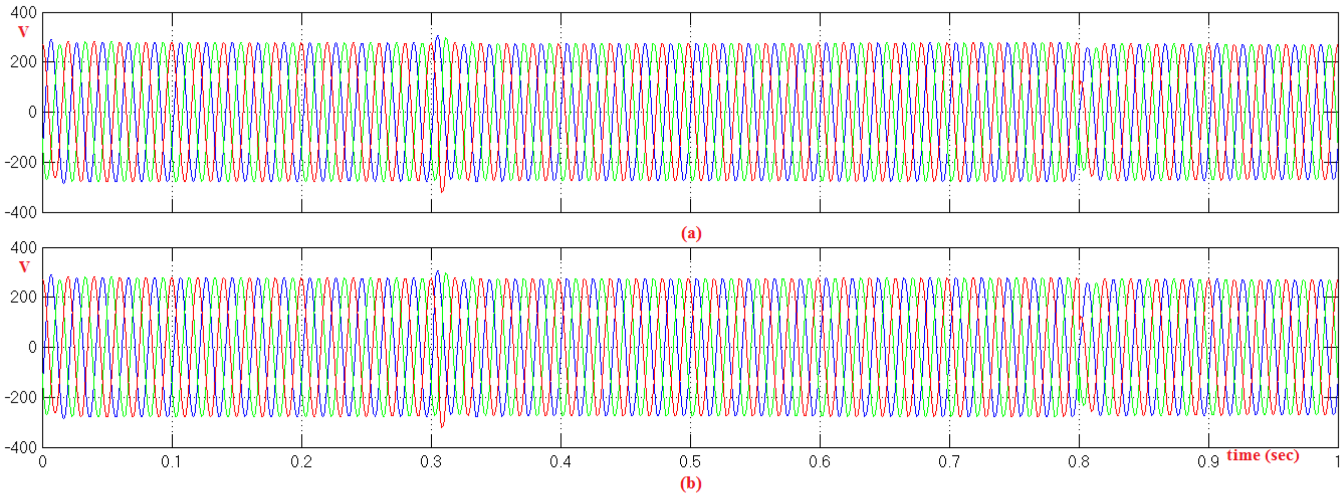

Figure 11: Waveforms of (a) source voltage (b) load voltage during swell With DSTATCOM

4.3 Power Factor Correction Mode

The power factor problems are mainly due to the unbalance in voltage and current waveforms and harmonics due to various loads. In this work, phase 'a' of a linear R-L load is suddenly switched off for a duration of 0.15 to 0.3 seconds to create the reduced or low power factor by unbalance in load current and source current. A breaker with time sequence 0.15 to 0.3 sec is used to switched off the load. The figure 12. shows the unbalance in load current and source current, for a duration of 0.15 to 0.3 sec phase 'a' of load and source current is zero which create a reduced power factor of 0.7117 at source and load side. Our objective is to improve the source side power factor near to unity.

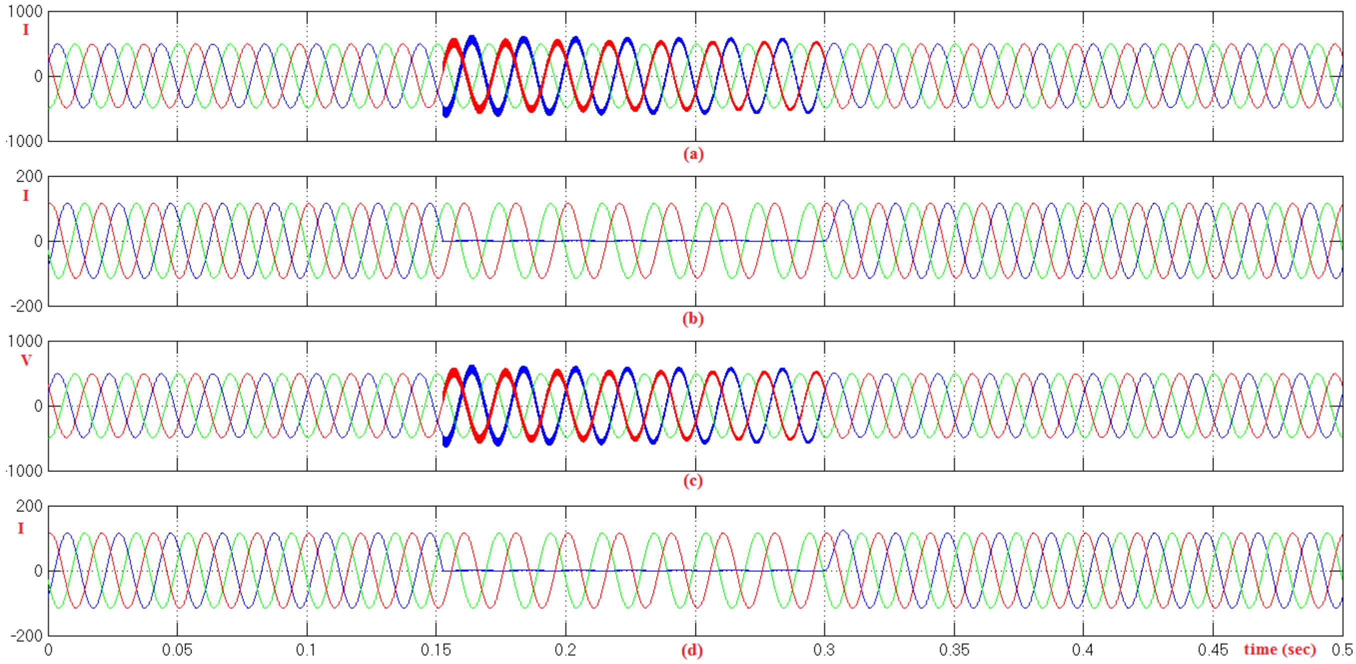

Figure 12: Waveforms of (a) source voltage (b) source current (c) load voltage (d) load current during PFC mode Without DSTATCOM

DSTATCOM with SULMS control system is applied to the system to improve the power factor and reduce the unbalance. The figure shows the compensation effectiveness of proposed compensation. The unbalance in magnitude of source current at 0.15 sec is almost compensated by using proposed control algorithm shown in fig.13. The angle unbalance in voltage and current due to the inductive nature of load is also mitigated and thus improved the power factor from 0.7117 to 0.999 which is more closer to unity. The results shows that the power factor was more improved and more quickly. But the voltage waveforms occurs some distortions (within acceptable range) even when the ripple filter is used.

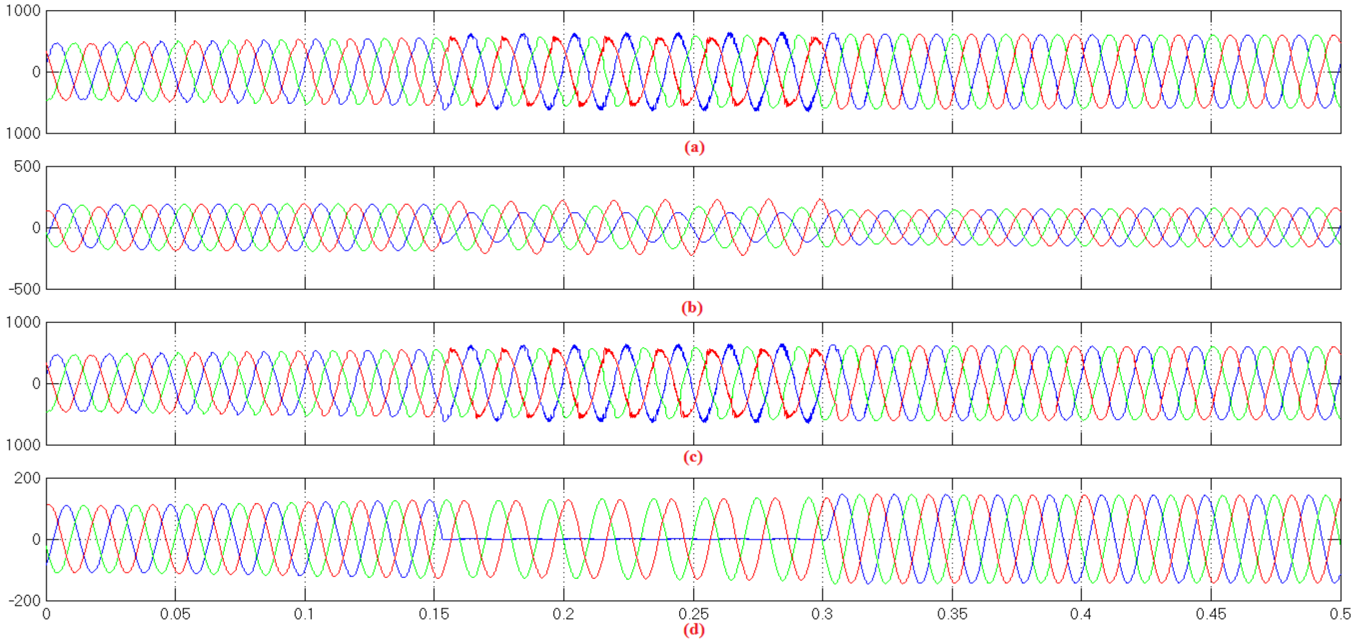

Figure 13: Waveforms of (a) source voltage (b) source current (c) load voltage (d) load current during PFC mode With DSTATCOM

4.4 Harmonics Elimination

Harmonics in the distribution systems are mainly due to non-linear load operations. In here, a diode rectier with R-L load is connected to the load side to create the harmonics in both the load and source side waveforms, then DSTATCOM with conventional and proposed control strategies are used to mitigate these harmonics problems (only at the source side) and compare the results. Figure 14 shows the waveforms without any compensation.

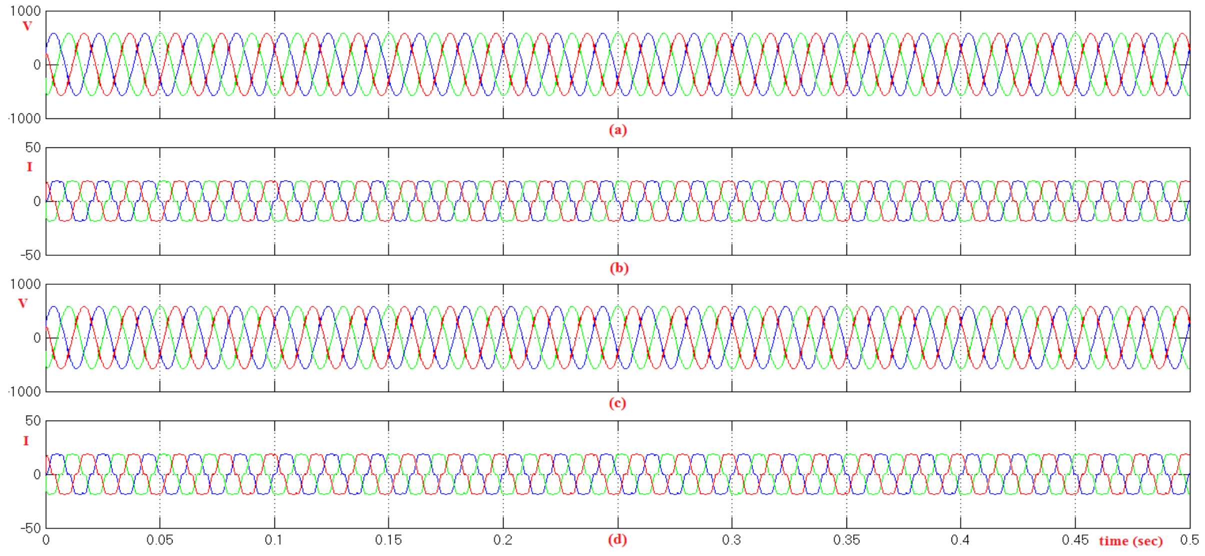

Figure 14: Compensated waveforms of (a) source voltage (b) source current (c) load voltage (d) load current during Harmonics With DSTATCOM

DSTATCOM with proposed SULMS control algorithm is applied to the affected test system, which compensate the harmonic components in the source current waveform.

The resultant waveforms are plotted in fig.15, and the results shows that the proposed system compensated more effectively and the response is better. THD percentage is also lesser than conventional controller, i.e the THD of 17.89% at the source side current is reduced to 2.40%.

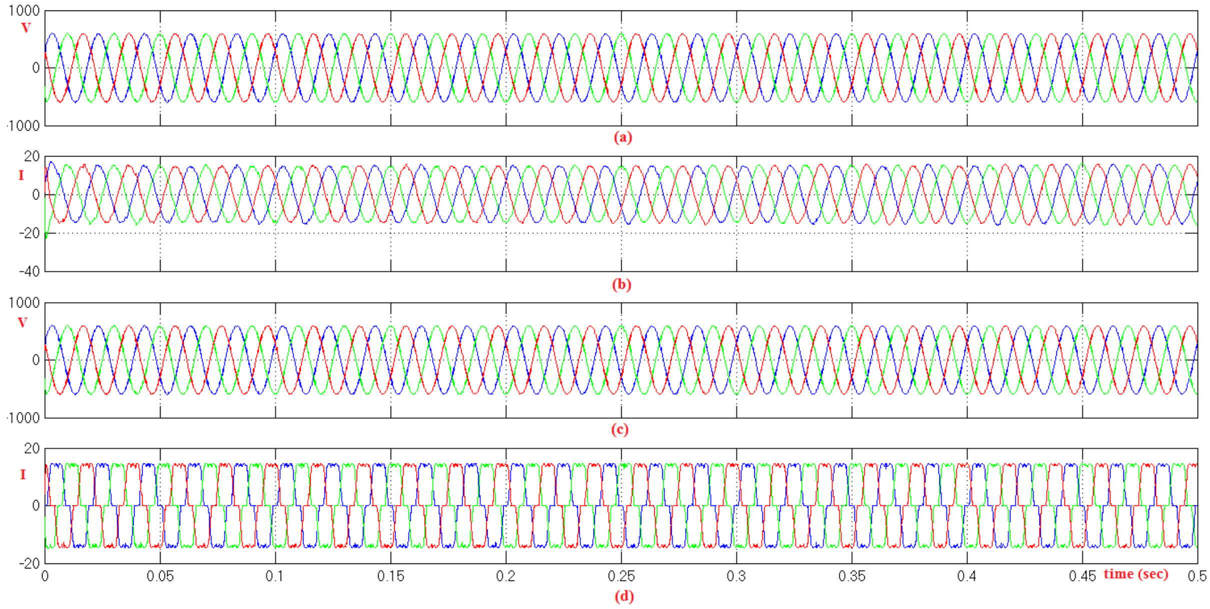

Figure 15: Waveforms of (a) source voltage (b) source current (c) load voltage (d) load current during harmonics with DSTATCOM

4.5 THD Analysis

The total harmonic distortion in the source and load side wave forms at different modes of operations are arranged in the table. Which gives a comparative performance analysis of different modes. The results shows that the proposed system introduced less harmonics components in all the mode.

Table 1: THD analysis

PQ Issue	I_S	V_S	I_L	V_L
SAG	0.86	1.31	1.31	1.31
SWELL	1.43	0.50	0.50	0.50
PFC	1.07	1.36	0.91	1.36
HARMONICS	2.40	0.85	18.42	0.85

Conclusion

In this project, validate the capability of DSTATCOM with a new SULMS control to mitigate four types of power disturbances due to various load applications. A three phase Voltage Source Inverter based Distribution Static Compensator with proposed controller was modelled and simulated in MATLAB/SIMULINK. The performance of the device has been tested with simulations at 415V voltage level.

Simulation results show that DSTATCOM can obtain high performance by using new SULMS control algorithm. The simulation results proved that the voltage dip, swell, unbalances and harmonics can be mitigated effectively and the response of the system is satisfactory . The proposed system introducing less distortions and noises into the system also.

References

1. Sabha Raj Arya, Bhim Singh, Fellow, IEEE "Control of DSTATCOM Using Adjustable Step Least Mean Square Control Algorithm" IEEE 2012, 978-1-4673-0766-6/2012.
2. S. Balasubramaniyan1, T.S.Sivakumaran, Rathinambal, "Voltage Sag Mitigation in Utility Connected System Using Current Source Converter Based DSTATCOM" ACEEE Int. J. on Electrical and Power Engineering, 4(2), pp.74-78, Aug 2013
3. Parmar Hiren.S, Vamsi Krishna.K,Ranjit Roy, "Shunt Compensation for Power Quality Improvement using a STATCOM Controller", ACEEE International Journal on Electrical and Power Engineering, 1(2), pp.40-44, July 2010.
4. Satyaveer Gupt, Ankit Dixit, "Custom Power Devices For Power Quality Improvement: A Review", International Journal of Research in Engineering and Applied Sciences, 2(2) (February 2012),1646-1659, 2012.
5. Ambarnath Banerji, Sujit K. Biswas, Bhim Singh, "DSTATCOM Control Algorithms: A Review", International Journal of Power Electronics and Drive System, 2(3), September 2012, pp. 285-296.
6. Jianning Yang, Jiajun Guan, "A Novel Adaptive Harmonic Detecting Algorithm Applied To Active Power Filters", IEEE, 2010 3rd International Congress On Image and Signal Processing, pp.3287-3290, March 2010.
7. Lakhinana Dinesh, Harish Sesham, Simulation of D-Statcom with Hysteresis Current Controller for Harmonic Reduction", IEEE, International Conference on Emerging Trends in Electrical Engineering and Energy Management 2012, pp.104-108, April 2012.
8. T. Narongrit, K-L. Areerak, "The Comparison Study of Current Control Techniques for Active Power Filters", World Academy of Science, Engineering and Technology, 5, pp.344-349, December 2011.

Biographies

Vikas Purushothaman is a PG Scholar of Power Electronics and Power Systems Electronics and Power Systems at Amaljyothi college of Engg. Kottayam, kerala, and the research interests are in the areas of Power Electronics, FACTS Controllers, Power Quality.

Bobin K Mathew – Assistant Professor in Electrical and Electronics Engg. Department at Amaljyothi College, Kanjirappally. His interests are in the areas of Power Distribution Systems, Power Electronics and FACTS Devices.

.