DDSRF Theory Based DSTATCOM for Power Quality Enhancement in Distribution System

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Abstract-

This paper deals with the combined least mean square-least mean fourth (LMS-LMF)-based control algorithm for distribution static compensator (DSTATCOM) in three-phase distribution system to alleviate the power quality problems caused by solid-state equipments and devices. The combined LMS-LMF-based algorithm is simulated using Sim Power System (SPS) toolbox in MATLAB for obtaining the corresponding active and reactive weights and supply reference currents. The proposed control algorithm has advantages of both LMF- and LMS-based control algorithms, which helps in fast and accurate response with a robust design. Depending on the value of error signal obtained in any of the phases either of LMS- or LMF-based control is used to minimize the error. The developed combined Decoupled double synchronous reference frame(DDSRF) theory based implemented on the prototype of the proposed system and responses obtained are found satisfactory with harmonic spectra of the supply currents meeting the power quality standards. The proposed algorithms is simulated in MATLAB 2013a and simulink

Index terms **–LMF based algorithm, LMS based algorithm,LMS-LMF based algorithm, DSTATCOM, power quality, DDSRF.**

I. INTRODUCTION

Comport and sophisticated lifestyle has been on aexponential run since the invention of the solid statedevices. The recent inventions and the new technologies insolid state equipments and devices have led to a very peacefuland smooth life but it increases the power quality problems dueto these solid state devices based loads. Power qualityproblems are of major concern in the distribution system whichleads to decrease in efficiency of the system and a seriousattention is to be given to the increasing power pollution. Theabundant uses of nonlinear loads such as solid state powerconversion devices, medical equipment, fluorescent lighting,renewable energy systems, office and household equipment,HVDC (High Voltage Direct Current) transmission, electrictraction, arc furnaces, high frequency transformers, etc injectharmonics into the system and decline the quality of power.Moreover, due to unbalance three phase or single phase loads,the nature of waveforms in the distribution system is disturbedwhich eventually affects the equipment and users nearby.Recent research on power quality focuses on mitigation ofcurrent quality problems like harmonics elimination, powerfactor correction, load balancing, noise cancellation andvoltage quality problems like sag, swells, impulses, voltageunbalances, fluctuations and various other aspects.

Custom power devices (CPD) i.e. DVR (Dynamic VoltageRestorer), DSTATCOM (Distribution Static Compensator),and UPQC (Universal Power Quality Conditioner) are alternatives to mitigate theses current and voltage based powerquality problems [1]. As the current based power quality issuesare major concern in the distribution system due to solid statebased loads, voltage source converter (VSC) basedDSTATCOM is the suitable technology and/ or solution tomitigate all these problems in addition to classical or existingmitigating technology like static Var compensators, powercapacitors etc. Various topologies of DSTATCOM have beendiscussed in the literature and a wide area of research is opento work on the power quality issues [2]. DSTATCOM alsofinds applications in electric ship power systems [3], microgrid[4], distributed generation [5-7] etc.

For the appropriate operation of VSC based DSTATCOM,a proper control is required. So one builds algorithm forgenerating the appropriate pulses for VSC to overcome thecurrent based power quality problems. These algorithms aredesigned either in frequency domain or in time domain basedon the type of process they choose to generate the pulses forthe devices of VSC. Singh et. al. [2, 8-10] have well explainedvarious configurations and control algorithms such as: unittemplate, PBT (power balance theory), CSD theory(Current Synchronous Detection), IRPT (InstantaneousReactive Power theory), SRF (Synchronous Rotating Frame)theory, ISC (Instantaneous Symmetrical Components) theory,single PQ theory, single DQ theory, neutral network LMS(Least Mean Square) adaline based control algorithm for DSTATCOM in both PFC (power factor correction) and ZVR(zero voltage regulation) mode. Singh et. al. [11] have alsodesigned new control for the DSTATCOM with improvedperformance with conventional algorithm such as leaky LMSalgorithm, composite observer algorithm [12], adaptive theorybased improved linear sinusoidal tracer algorithm [13], SPD(simple peak detection) theory algorithm [14], backpropagationalgorithm [15], Learning-based anti-hebbianalgorithm [16], hyperbolic tangent function based LMSalgorithm [17], kernel incremental metaconvergence algorithm[18], and variable forgetting factor recursive least squarealgorithm [19]. All these algorithms are designed for ZVR andPFC for the particular system. This is achieved by extractingthe reference supply currents from the sensed signals of the system and then comparing them with the observed supplycurrents to produce the required pulses for the VSC. Luo et. al.[20-21] have designed improved DPC (direct power control)algorithm based on deadbeat current controller and doubledeadbeat current controller. Kumar et. al. [22-25] have alsodesigned the controller for DSTATCOM with improved powerquality such as voltage controlled DSTATCOM [22],multifunctional DSTATCOM with new control algorithm [23],improved hybrid DSTATCOM topology [24], interactiveDSTATCOM operating in CCM (current control mode) andVCM (voltage control mode) [25]. The last few decades haveseen a major surge in the number of researchers working onpower quality issues and they have come up with numerousadvanced control techniques for the harmonics suppression,PFC, ZVR, load balancing problems and many other powerquality issues [1-2, 26].

The decoupled DSRF (DDSRF) is proposed in this paperas a solution to eliminate the 2ω oscillations produced by theinjection of positive- and negative-sequence currents to thegrid. Finally experimental tests have been performed in order todemonstrate the validity of the theoretical results.

II.EXISTING SYSTEM

A. System configuration

The power quality in the distribution system can beimproved by using the proposed configuration as shown inFig.1. This system includes a three phase nonlinear load whichis supplied from a 415 V, 50 Hz, 3-phase AC supply withsupply resistance (*Rs*) and supply inductance (*Ls*), VSC with aDC bus capacitor (*Cdc*) and ripple filters (*Rf*, *Cf*) to eliminatethe high switching frequency noise during the operation ofVSC. The VSC is linked to the Point of Common Coupling(PCC) through the interfacing inductors (*Li*) which are tunedsuch that they reduce the ripples in the compensating currents.A 3-phase diode bridge rectifier (DBR) is used as a nonlinearload with a RL branch on the DC side. For the simulationusing MATLAB software, the passive elements such as ripplefilters (*Rf* and *Lf*) and interfacing inductors (*Li*) are designedconsidering the specifications of three phase PCC voltage at415 V and the load to operate at 20 kW power rating [33].

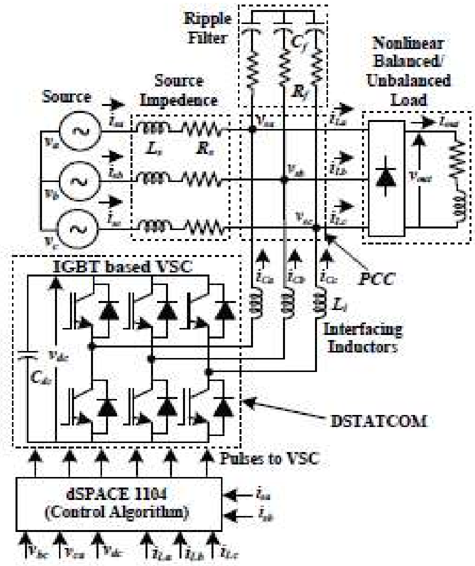


Figure.1 Schematic diagram of distribution system with DSTATCOM

B. Control Algorithm

The schematic of the combined LMS-LMF based controlalgorithm of DSTATCOM is shown in Fig. 2. This combinedLMS-LMF based algorithm is used to derive the requiredreference supply currents from the observed load currents (*iLa,iLb, iLc*), unit templates (*uaa*, *uab*, *uac*) derived from the sensedsupply voltages (*vsa, vsb* and *vsc*), the DC link voltage across thecompensator (*vdc*), and the magnitude of supply voltages (*Vt*).The reference supply currents which are generated from thealgorithm are correlated with the supply currents sensed fromthe system and the resulting error difference is used to generatethe appropriate pulses for the DSTATCOM by passing theseerror signals through hysteresis based current controller.

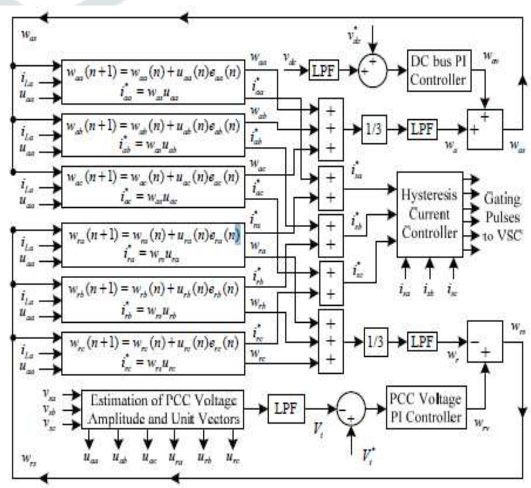


Figure. 2 Block diagram of combined LMS-LMF Based control algorithm

III.PROPOSED METHOD

A. Block Diagram

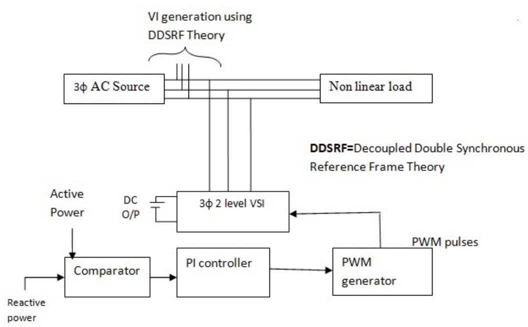


Figure.3 proposed block diagram

The DDSRF introduced inthis paper is based on the estimation of the oscillation forminimizing this undesirable effect.

As it was evidenced in (1) and (2), the amplitude of theoscillation in the positive-sequence measured currentmatches the dc value of the *dq* negative-sequence currentcomponent and vice versa; therefore it can be easily statedthat there exists a cross-coupling effect between bothsequences. However, the PIcontroller achieves the tracking of the dc value due to itsinfinite dc gain but cannot avoid the 2ω ripple. In theproposed DDSRF case, not only the PI will track the dcvalue, but also the decoupling-network will estimate andeliminate the oscillation from the measured current. The above figure 4 shows the block diagram of proposed technique which shows the how to get current using DDSRF theory.

$$\mathbf{i}_{dq}^{+'} = \underbrace{\overline{i_{dq}^{+}}}_{\text{DC term}} + \underbrace{\left[e^{-J(\theta^{+}-\theta^{-})}\right]\cdot \underbrace{\overline{i_{dq}^{-}}}_{\text{DC term}}}_{\text{AC term}} - \underbrace{\left[e^{-J(\hat{\theta}^{+}-\hat{\theta}^{-})}\right]\cdot \underbrace{\widehat{i_{dq}^{-}}}_{\text{DC term}}}_{\text{Cross Coupling Term}}$$

$$\mathbf{i}_{dq}^{-'} = \underbrace{\overline{i_{dq}^{-}}}_{\text{DC term}} + \underbrace{\left[e^{-J(\theta^{-}-\theta^{+})}\right]\cdot \underbrace{\overline{i_{dq}^{+}}}_{\text{DC term}}}_{\text{AC term}} - \underbrace{\left[e^{-J(\hat{\theta}^{-}-\hat{\theta}^{+})}\right]\cdot \underbrace{\widehat{i_{dq}^{+}}}_{\text{DC term}}}_{\text{Cross Coupling Term}}$$

The DDSRF equations are directly obtainedfrom by subtracting the undesirable acterm using the decoupling-network. As a result, the estimatedcurrent is free from the 2ω oscillating ac term.

The proposed DDSRF current controller scheme isshown in Figure 4.The dc value of one sequence is the value for theopposite sequence oscillation´s amplitude. On the otherhand, the Park´s transformation is applied over the angularposition difference of both frames with the aim of obtainingthe estimated oscillation waveform.The DDSRF current controller filters the correspondingopposite sequence current to obtain its dc value anddecelerate (if the sequence to be compensated is the positiveone) or accelerate (if the sequence to be compensated is thenegative one) by two times the rotating frequency(considering also the initial voltage phase shift) in order toestimate the undesirable oscillations.

The low-pass (LP) filter for obtaining the mean valuedoes not have a high selectivity because in steady-stateconditions, the decoupled current is free from oscillationsand matches its dc value. The cut-off frequency of the LPfilter is set to:

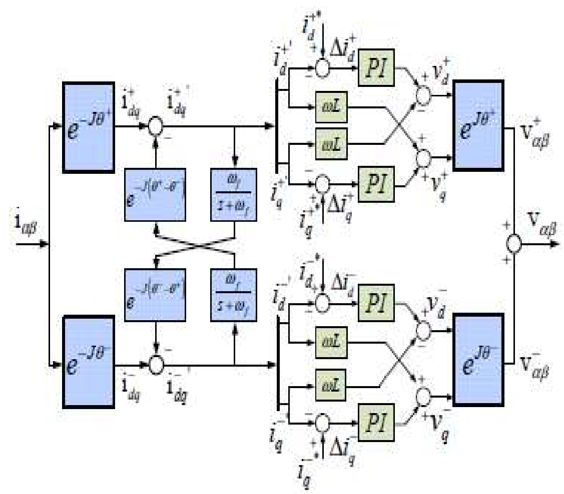


Figure 5. DDSRF current controller based on the measured current.

The proposed DDSRF current controller scheme isShown in Figure 5.
The cut-off frequency of the LPfilter is set to:

$$wf = \frac{w}{\sqrt{2}}$$

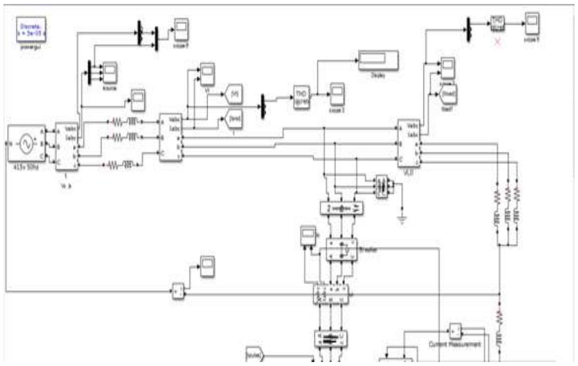
The cross-decoupling network allows a perfectestimation of the oscillations in the measured currents,achieving the elimination of the 2ω oscillations after a shorttransient error. This transient error is produced by thedeviation in the estimation of the dc value by the decouplingnetworkunder a current reference step. The cross-decoupling network concept for the current controller is similar that the one that is applied for a different problem like voltage synchronization with a PLL, but with different constraints [18]. Actually, the decoupled output magnitudes are not obtained from the same point in the structure, so that the processing paths followed by the signals are different.

The decoupled DSRF (DDSRF) is proposed in this paper as a solution to eliminate the 2ω oscillations produced by the injection of positive- and negative-sequence currents to the grid. Finally experimental tests have been performed in order to demonstrate the validity of the theoretical results.

IV SIMULATION RESULTS

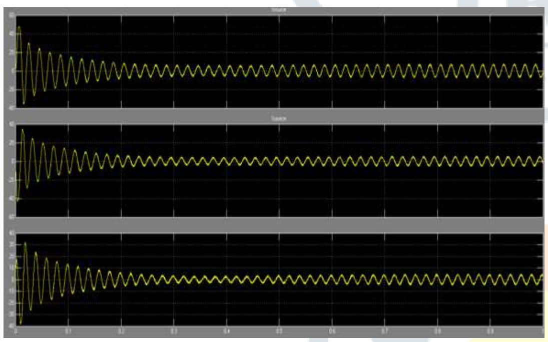
4.1 EXISTING SYSTEM

Existing circuit



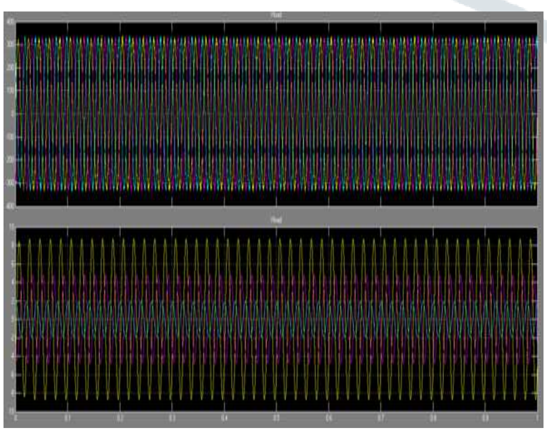
The above circuit shows existing simulink model.

Source current



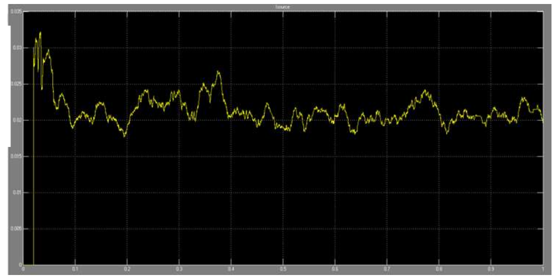
The above figure shows the source current for the simulink circuit.

Output voltage and current



The above figure shows the load side voltagein volts and current in Amperes it's on y axis and time in x axis.

Threshold voltage

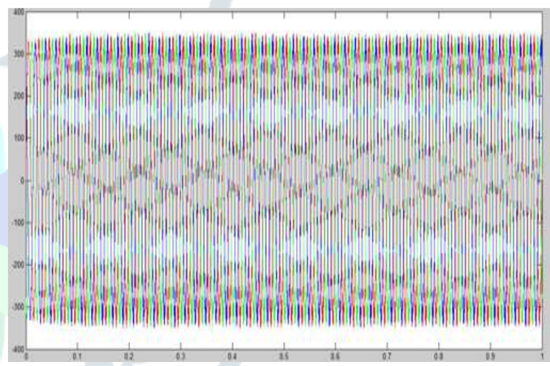


The above figure shows the output threshold voltage.

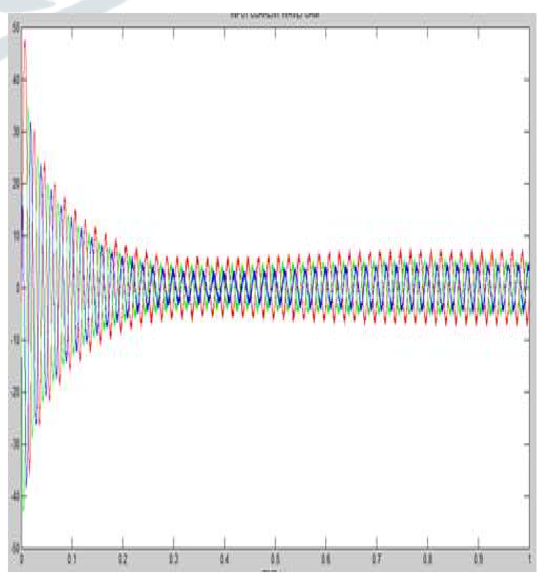
4.2 PROPOSED SYSTEM

The propsoed results simulated based on sourse code. The corresponding results at diffent points from the proposed simulink model shown below.

Input voltage wave form

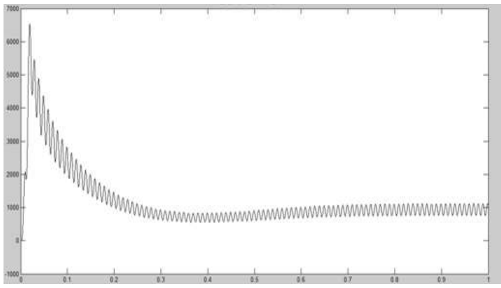


Input current wave form



Real power wave form

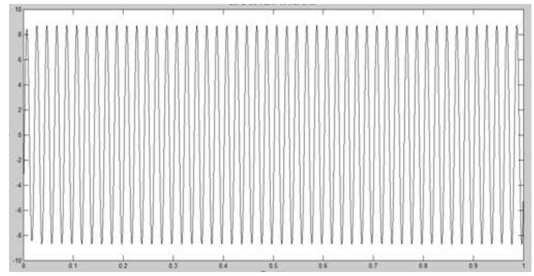
Real power (W)



Time in Sec

Current at Load Side

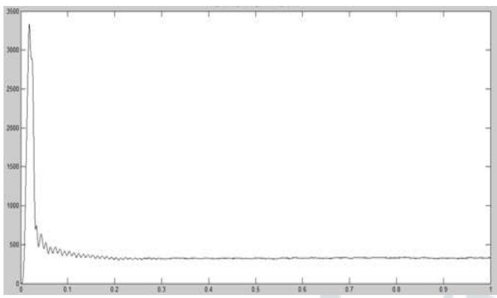
Current (A)



Time in Sec

Reactive power wave form

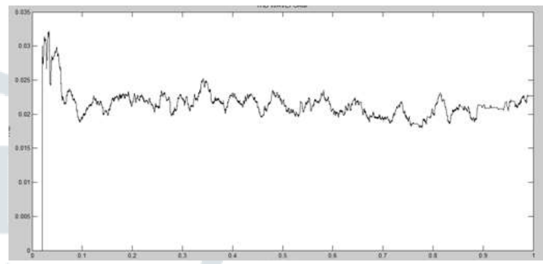
Reactive power (VAR)



Time in Sec

THD waveform

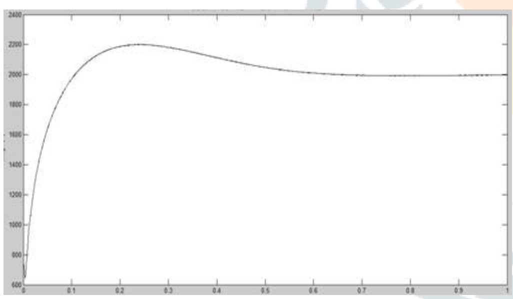
THD



Frequency in Hz

DC link voltage in the capacitor

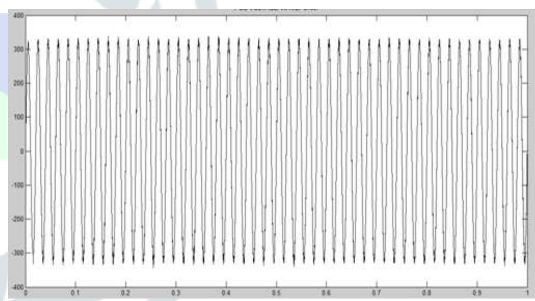
Voltage(V)



Time in Sec

PCC Voltage wave form

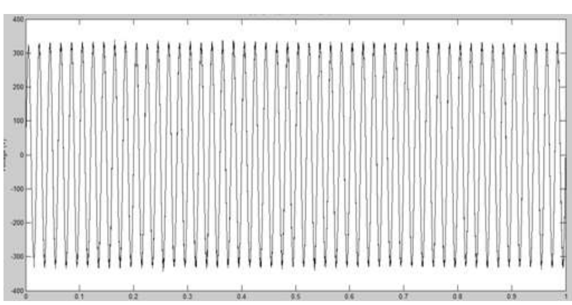
Voltage(V)



Time in Sec

Voltage at Load Side

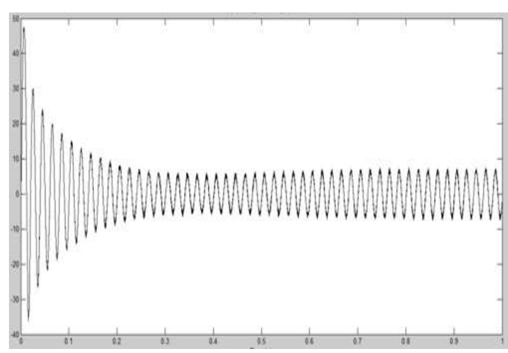
Voltage(V)



Time in Sec

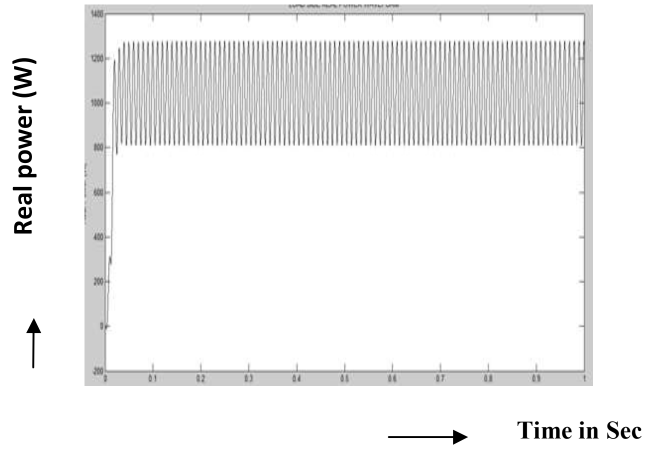
PCC Current wave form

Current (A)

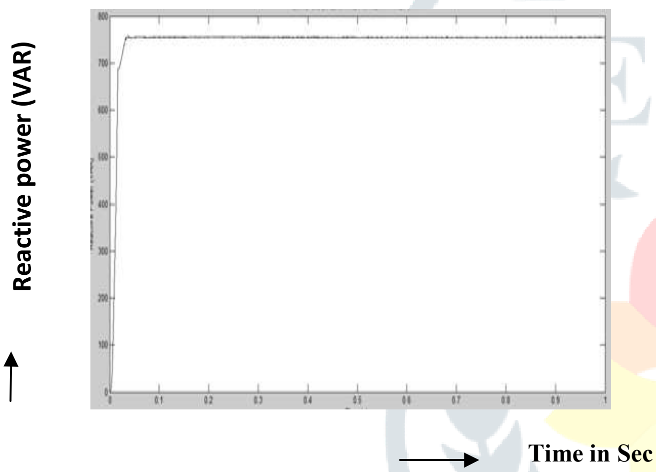


Time in Sec

Real power at load side



Reactive power at load side



C. COMPARISON TABLE

S.NO	Type of model	Existing method	Proposed method
1	THD (Current)	6.5	3.8
2	THD (Voltage)	2.9	2.1
3	Input Voltage, Current	100V, 15A	100V, 15A
4	Power Factor	0.83	0.96
5	Reactive Power	900VA	170VA
6	Voltage Source Inverter Level	Two Level	Two Level
7	Current Control Technique	LMS Algorithm	DDSRF Theory
8	Voltage Control Technique	PI Controller	PI Controller

The above table shows the threshold values of existing and proposed methods. It shows the proposed threshold value is less than the existing system.Hence by using the Decoupled double synchronous reference theory frame in proposed system reduced the Threshold current and voltage values. So that improves the performance of operation in proposed system.

VI CONCLUSION

In this paper, the DDSRF current controller for gridconnected inverter under unbalanced conditions is proposed.This *dq* current controller decouples the performance of eachpositive and negative reference frame by estimating thecross-coupling oscillations. The significance of thiscontroller is that positive- and negative-sequence active andreactive power can be controlled independently.

Experimental results under different grid conditionsdemonstrate the capability of the controller for compensatingthe oscillations and the good performance that is obtainedhas been compared to the LMS Algorithm.

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