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COMBINED LMS–LMF-BASED CONTROL ALGORITHM OF DSTATCOM WITH HYBRID RENEWABLE SOURCES FOR POWER QUALITY ENHANCEMENT IN DISTRIBUTION SYSTEM

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Abstract

This paper deals A distribution static compensator (DSTATCOM) to improve the power quality, which includes the total harmonic distortion (THD) of the grid current and power factor (PF), of a mini grid with nonlinear and linear inductive loads. Moreover, the DC-link voltage regulation control of the DSTATCOM is essential especially under load variation conditions. Therefore, to improve the power quality and keep the DC-link voltage of the DSTATCOM constant under the variation of nonlinear and linear loads effectively, the traditional proportional-integral (PI) controller. 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 supply reference currents. The proposed system has advantages of both LMF- and LMS-based control system, 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 LMS-LMF-based method is implemented on the simulation of the proposed system and responses obtained are found satisfactory with harmonic spectra of the supply currents meeting the power quality standards.

Keywords: distribution static compensator; power quality; total harmonic distortion; compensatory neural fuzzy network; asymmetric membership function

(I) INTRODUCTION

Solace and complex way of life has been on a exponential keep running since the innovation of the strong state devices. The current innovations and the new advancements in strong state types of gear and devices have prompted an extremely serene what's more, smooth life however it builds the power quality issues due to these strong state devices based burdens. Power quality issues are of real worry in the dispersion system which prompts diminish in effectiveness of the system and a genuine consideration is to be given to the expanding power contamination. The inexhaustible employments of nonlinear loads, for example, strong state control change devices, medicinal hardware, fluorescent lighting, sustainable power source systems, office and family hardware, HVDC (High Voltage Direct Current) transmission, electric traction, curve heaters, high frequency transformers, and so forth infuse sounds into the system and decrease the nature of energy. Additionally, because of unequal three phase or single phase loads, the idea of waveforms in the dissemination system is irritated which in the long run influences the gear and clients close-by. Late research on control quality concentrates on relief of current quality issues like music disposal, control factor redress, stack adjusting, commotion cancelation and voltage quality issues like list, swells, driving forces, voltage unbalances, vacillations and different perspectives.

Custom power devices (CPD) i.e. DVR (Dynamic Voltage Restorer), DSTATCOM (Distribution Static Compensator), also, UPQC (Unified Power Quality Conditioner) are contrasting options to relieve propositions current and voltage based power quality issues [1]. As the current based power quality issues are real worry in the appropriation system because of strong state based burdens, voltage source converter (VSC) based DSTATCOM is the reasonable innovation or potentially answer for relieve every one of these issues notwithstanding established or existing alleviating innovation like static Var compensators, control capacitors and so on. Different topologies of DSTATCOM have been talked about in the writing and a wide region of research is open to take a shot at the power quality issues [2]. DSTATCOM moreover discovers applications in electric ship control systems [3], micro grid [4], circulated era [5-7] and so on.For the suitable operation of VSC based DSTATCOM, an appropriate control is required. So one forms algorithm for creating the suitable heartbeats for VSC to overcome the current based power quality issues. These algorithms are composed either in frequency space or in time area based on the kind of process they create the beats for the devices of VSC. Singh et. al. [2, 8] have very much clarified different designs and control algorithms, for example, unit format, PBT (control adjust hypothesis), I-cosø, CSD hypothesis (Current Synchronous Detection), IRPT (Instantaneous Reactive Power hypothesis), SRF (Synchronous Rotating Frame) hypothesis, ISC (Instantaneous Symmetrical Components) hypothesis, single PQ hypothesis, single DQ hypothesis, nonpartisan system LMS (Slightest Mean Square) adaline based control algorithm for DSTATCOM in both PFC (control factor redress) and ZVR (zero voltage control) mode. Singh et. al. have too planned new control for the DSTATCOM with progressed execution with customary algorithm, for example, defective LMS algorithm, composite spectator algorithm, versatile hypothesis based enhanced straight sinusoidal tracer algorithm, SPD (straightforward pinnacle recognition) hypothesis algorithm , back propagation algorithm, Learning-based against hebbian algorithm, hyperbolic digression work based LMS algorithm, piece incremental met convergence algorithm, and variable overlooking component recursive slightest square algorithm . Every one of these algorithms are intended for ZVR and PFC for the specific system. This is accomplished by

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separating the reference supply currents from the detected signs of the system and after that contrasting them and they watched supply currents to deliver the required heartbeats for the VSC. Luo et. al. have outlined enhanced DPC (coordinate power control) algorithm in light of bum current controller and twofold bum current controller. Kumar et. al. have too outlined the controller for DSTATCOM with enhanced power quality, for example, voltage controlled DSTATCOM,[multifunctional DSTATCOM with new control algorithm, enhanced cross breed DSTATCOM topology, intelligent DSTATCOM working in CCM (current control mode) and VCM (voltage control mode). The most recent couple of decades have seen a noteworthy surge in the quantity of specialists chipping away at control quality issues and they have thought of various propelled control procedures for the sounds concealment, PFC, ZVR, stack adjusting issues and numerous other power quality issues.

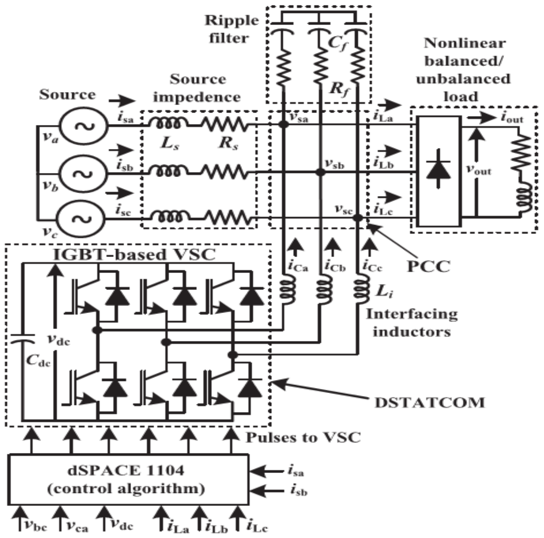

Fig.1. Schematic of the distribution system with DSTATCOM

2 Proposed System Configuration

The power quality in the distribution system can be improvedusing the proposed configuration, as shown in Fig.1. This system includes a three-phase nonlinear load that is supplied froma 415-V, 50-Hz, three-phase ac supply with supply resistance(Rs) and supply inductance (Ls), VSC with a dc-bus capacitor (C_{dc}), and ripple filters (R_f and C_f) to eliminate the highswitching frequency noise during the operation of VSC. TheVSC is linked to the point of common coupling (PCC) throughthe interfacing inductors (Li) that are tuned such that theyreduce the ripples in the compensating currents. A three-phasediode bridge rectifier (DBR) is used as a nonlinear load with anRL branch on the dc side. For the simulation using MATLABsoftware, the passive elements such as ripple filters (R_f andLf) and interfacing inductors (Li) are designed consideringthe specifications of three-phase PCC voltage at 415 V and theload to operate at 20-kW power rating [33].

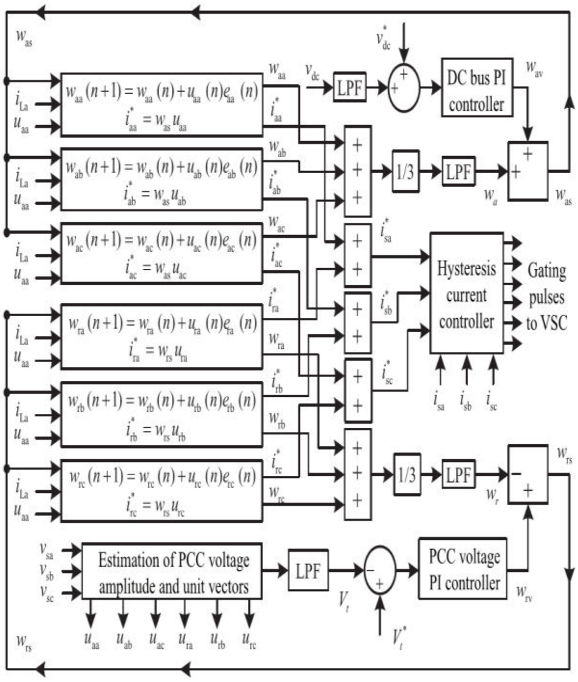

Fig.2. Block diagram of the combined LMS–LMF-based control algorithm

3 Control Algorithm

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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 required reference supply currents from the observed load currents (iLa, iLb,and iLc), unit templates (uaa, uab, and uac) derived from thesensed supply voltages (vsa, vsb, and vsc), the dc-link voltageacross the compensator (vdc), and the magnitude of supply voltages (Vt). The reference supply currents that are generated fromthe algorithm are correlated with the supply currents sensedfrom the system and the resulting error difference is used togenerate the appropriate pulses for the DSTATCOM by passingthese error signals through hysteresis-based current controller.Initially, one derives the active unit template components(uaa, uab, and uac) for the three phases that are in-phase to thesupply voltages (vsa, vsb, and vsc) are expressed as [2]

$$u_{aa} = \frac{v_{sa}}{V_t}; \quad u_{ab} = \frac{v_{sb}}{V_t}; \quad u_{ac} = \frac{v_{sc}}{V_t} \tag{1}$$

whereVt is the amplitude of sensed supply voltages (vsa, vsb,and vsc) or PCC voltage and is expressed as [2]

$$V_t = \sqrt{\frac{2}{3}(v_{sa}^2 + v_{sb}^2 + v_{sc}^2)} \tag{2}$$

These unit templates are used to synchronize the obtainedactive weights (waa, wab, and wac) with the phase of supplyvoltage to obtain the appropriate errors (eaa, eab, and eac).

The active weight component of the phase "a" at samplinginstant $(n + 1)^{th}$ is estimated as

$$w_{aa}(n+1) = w_{aa}(n) + u_{aa}(n)e_{aa}(n) \tag{3}$$

where $e_{aa}(n)$ is the actual active error vector of phase "a"for the proposed combined LMS–LMF-based control algorithmand this error component is expressed as [31], [32]

$$\begin{aligned} e_{aa}(n) &= \mathrm{er}_{aa}(n) \text{ if } \mathrm{er}_{aa}(n) \geq 1 \\ &= \mathrm{er}_{aa}^3(n) \text{ if } \mathrm{er}_{aa}(n) < 1 \end{aligned} \tag{4}$$

whereer$_{aa}$(n) is the error in active load component of phase"a," at sampling instant (n)th and is estimated as

$$\mathrm{er}_{aa}(n) = k\{i_{La}(n) - u_{aa}(n)w_{aa}(n)\} \tag{5}$$

The factor used in the formation of these equations is k whichis a step size and the suitable value for this application is 0.1.Similarly, the active weight component for phases "b" and"c" are expressed as

$$w_{ab}(n+1) = w_{ab}(n) + u_{ab}(n)e_{ab}(n) \tag{6}$$

$$w_{ac}(n+1) = w_{ac}(n) + u_{ac}(n)e_{ac}(n) \tag{7}$$

By adding (3), (6), and (7), the mean value of the fundamental active weight components is obtained as

$$w_a = (w_{aa} + w_{ab} + w_{ac})/3 \tag{8}$$

The set dc voltage reference value is correlated with senseddc-link voltage (vdc) of VSC and the error is given to theproportional integral (PI) controller of dc-bus voltage. Theoutput of this controller is taken to be the dc loss weightcomponent and is expressed as

$$w_{av}(n+1) = w_{av}(n) + K_{pd}\{v_{dd}(n+1) - v_{dd}(n)\} + K_{id}v_{dd}(n+1) \quad (9)$$

where $w_{av}(n + 1)$ and vdd(n + 1) are the dc-bus loss component and error between of sensed dc-link voltage of VSC andreference dc value at (n + 1)th sampling time. Kid and Kpdare the integral and proportional gains of the dc-bus voltagecontroller.By adding the dc loss component to the average fundamentalactive weight component, one obtains the total active weightcomponent (was) of the supply reference currents as

$$w_{as} = w_a + w_{av} \quad (10)$$

The active in-phase reference supply current components forthe three phases are expressed as

$$i^*_{aa} = w_{as}u_{aa}; \quad i^*_{ab} = w_{as}u_{ab}; \quad i^*_{ac} = w_{as}u_{ac} \quad (11)$$

The reactive unit template components (ura, urb, and urc) forthe three phases that are quadrature to the supply voltages (vsa,vsb, and vsc) are expressed as [2]

$$u_{ra} = -\frac{u_{ab}}{\sqrt{3}} + \frac{u_{ac}}{\sqrt{3}}; \quad u_{rb} = \frac{\sqrt{3}u_{aa}}{2} + \frac{(u_{ab} - u_{ac})}{2\sqrt{3}}$$
$$u_{rb} = -\frac{\sqrt{3}u_{aa}}{2} + \frac{(u_{ab} - u_{ac})}{2\sqrt{3}}. \quad (12)$$

The reactive weight components for three phases a, b, and care estimated using the following equations:

$$w_{ra}(n+1) = w_{ra}(n) + u_{ra}(n)e_{ra}(n) \quad (13)$$

$$w_{rb}(n+1) = w_{rb}(n) + u_{rb}(n)e_{rb}(n) \quad (14)$$

$$w_{rc}(n+1) = w_{rc}(n) + u_{rc}(n)e_{rc}(n) \quad (15)$$

By adding (13)–(15), the mean value of the fundamentalreactive weight components is obtained as

$$w_r = (w_{ra} + w_{rb} + w_{rc})/3. \quad (16)$$

The average magnitude of the supply voltage is sensed andis correlated with set reference magnitude value and the errordifference is given to the ac voltage PI controller. The ac voltage controller output is weighted to be the ac loss weightcomponent and is expressed as

$$w_{rv}(n+1) = w_{rv}(n) + K_{pt}\{v_{dt}(n+1) - v_{dt}(n)\} + K_{it}v_{dt}(n+1) \quad (17)$$

where$w_{rv}(n + 1)$ and vdt(n + 1) are the reactive power component and error between sensed ac-link voltage and referencemagnitude value at $(n + 1)^{th}$ sampling time. Kit and Kpt arethe integral and proportional gains of ac voltage controller.By subtracting the average fundamental reactive weight component from the reactive power component, one obtains thetotal reactive weight component (wrs) of the supply referencecurrents and it is estimated as

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$$w_{rs} = w_{rv} - w_r \quad (18)$$

$$i^*_{ra} = w_{rs}u_{ra}; \quad i^*_{rb} = w_{rs}u_{rb}; \quad i^*_{rc} = w_{rs}u_{rc} \quad (19)$$

Finally, adding the active and reactive reference componentsof the supply currents of each of the three phases, referencesupply currents are expressed as

$$i^*_{sa} = i^*_{aa} + i^*_{ra}; \quad i^*_{sb} = i^*_{ab} + i^*_{rb}; \quad (20)$$

These reference supply currents (i^*_{sa},i^*_{sb} andi^*_{sc}) and sensedsupply currents (i_{sa},i_{sb} and i_{sc}) are given to hysteresis currentcontroller that generates the gating pulses to VSC [8].

4 Hybrid renewable energy system

Hybrid renewable energy systems (HRES) are becoming popular as stand-alone power systems for providing electricity in remote areas due to advances in renewable energy technologies and subsequent rise in prices of petroleum products. A hybrid energy system, or hybrid power, usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply.

4.1 Biomass-wind-fuel cell

For example, let us consider a load of 100% power supply and there is no renewable system to fulfill this need, so two or more renewable energy system can be combined. For example, 60% from a biomass system, 20% from wind system and the remainder from fuel cells. Thus combining all these renewable energy systems may provide 100% of the power and energy requirements for the load, such as a home or business.

4.2 Photovoltaic and wind

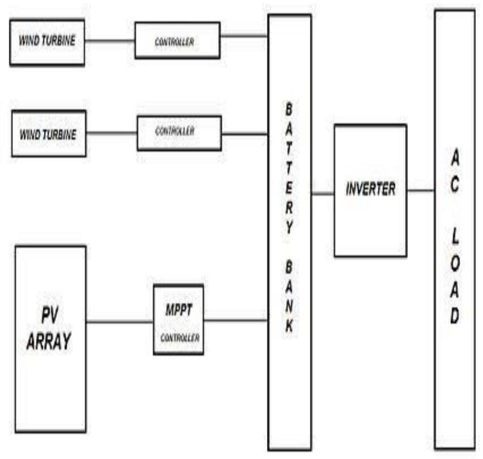

Fig 3 Hybrid energy systems

Another example of a hybrid energy system is a photovoltaic array coupled with a wind turbine. This would create more output from the wind turbine during the winter, whereas during the summer, the solar panels would produce their peak output. Hybrid energy systems often yield greater economic and environmental returns than wind, solar, geothermal or trigeneration stand-alone systems by themselves.

Drawbacks: Most of us already know how a solar/wind/biomass power generating system works, all these generating systems have some or the other drawbacks, like Solar panels are too costly and the production cost of power by using them is generally higher than the conventional process, it is not available in the night or cloudy days. Similarly Wind turbines can't operate in high or low wind speeds and Biomass plant collapses at low temperatures.

How to overcome: So if all the three are combined into one hybrid power generating system the drawbacks can be avoided partially/completely, depending on the control units. As the one or more drawbacks can be overcome by the other, as in northern hemisphere it is generally seen that in windy days the solar power is limited and vice versa and in summer and rainy season the biomass plant can operate in a full flagged so the power generation can be maintained in the above stated condition. The cost of solar panel can be subsided by using glass lenses, mirrors to heat up a fluid,that can rotate the common turbine used by wind and other sources. Now the question arises what about the winter nights or cloudy winter days with very low wind speeds. Here comes the activity of the Hydrogen. As we know the process of electrolysis can produce hydrogen by breaking water into hydrogen and oxygen, it can be stored; hydrogen is also a good fuel and burns with oxygen to give water. Hydrogen can be used to maintain the temperature of the biomass reservoir in winter so that it can produce biogas in optimum amount for the power generation. As stated above biogas is a good source in summer; in this period the solar energy available is also at its peak, so if the demand and supply is properly checked and calculated the excess energy can be used in the production of hydrogen and can be stored. In sunny, windy &hot day, the turbine operates with full speed as the supply is maximum, and this excess power can be consumed for the process of manufacturing hydrogen. In winter, the power consumption is also low so the supply limit is low, and obtained with lesser consumption. Driving hybrid cars will disable this outcome.A house or small industrial facility can produce sufficient energy by combining two or even three energy sources to handle the energy requirements. By combining solar cells and wind turbines, photovoltaic wind power will generate the energy, which is combined in a battery bank. From there, the energy is transformed to the inverter, which generates alternate current.

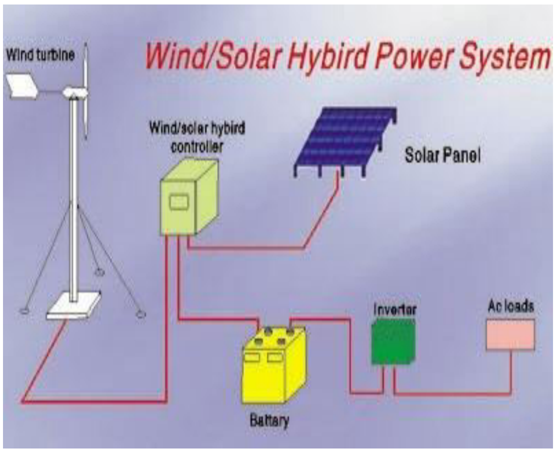

Fig 4 Wind/Solar Hybrid Power System

Before such energy is employed, important considerations must be taken into account, such as the input to output relationship. Variations in the energy sources must be monitored using a charge controller, and a power inverter is required to transform electric current to alternate current.To generate electricity by combining solar panels and wind power, an array of solar panels will be needed, plus wind generators, a storage and battery system along with a power converter. The storage system conserves the energy generated by the solar panels and wind turbines. This energy is then converted to usable energy by using the inverter.

Fig 5 Combining solar panels and wind power

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Another source of energy is geothermal energy, which is one of the least expensive sources of renewable energy. It uses the same principle as a heat pump to extract the geothermal energy and use it for heating and cooling of your home. Because a geothermal heating and cooling system does not require much electric power to operate, it can be powered by a relatively small solar PV system. When you combine a geothermal heating and cooling system with sufficient solar panels to operate the heat pump, a fan and a water pump, you can achieve a 100% green energy system and turn your house into a net zero energy home.

5 MATLAB/SIMULINK RESULTS

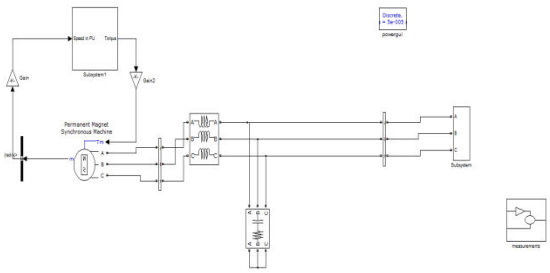

Fig 6 simulink diagram of without Dstatcom with linear load

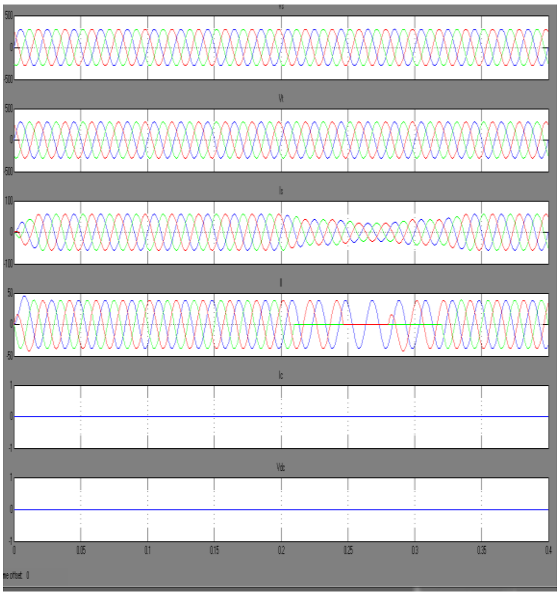

Fig 7 system response waveforms of voltage and current (source, loads) with linear load with out Dstatcom

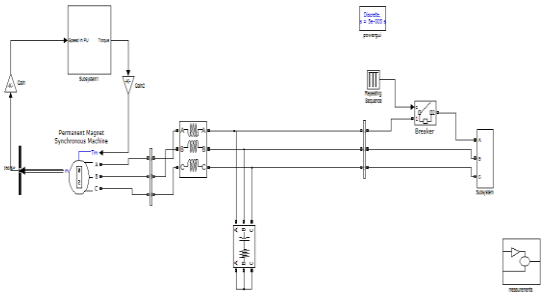

Fig 8 simulink diagram of without Dstatcom with Non linear load

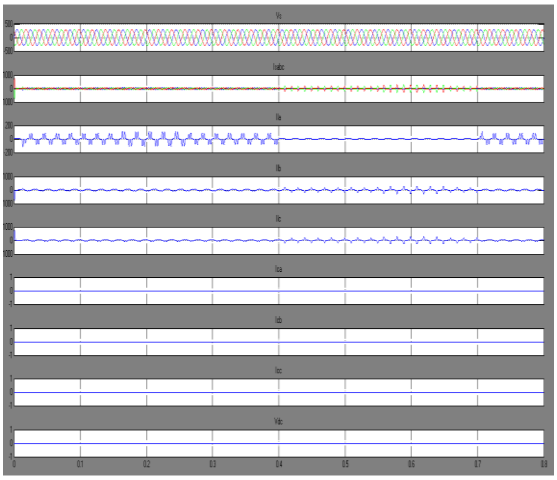

Fig 9 system response waveforms of voltage and current (source, loads) with Non linear load with out Dstatcom

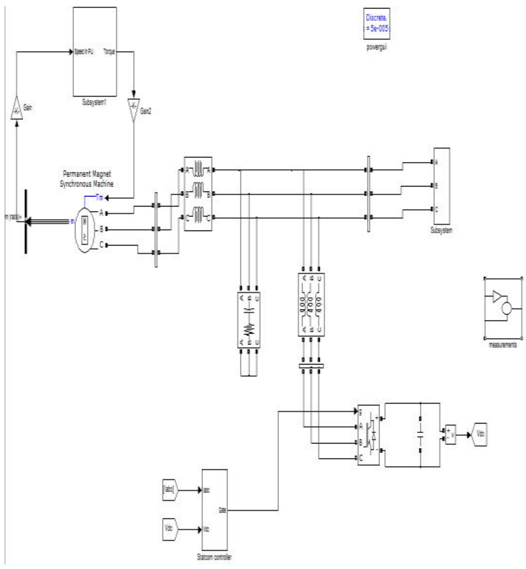

Fig 10 simulink diagram of proposed system with linear load DTATCOM

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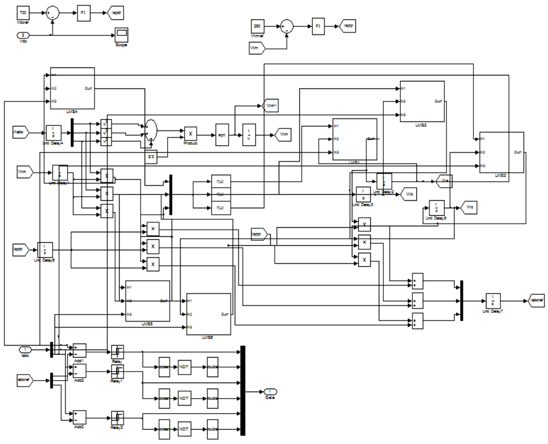

FIG 11 simulink diagram of proposed Dstatcom controller

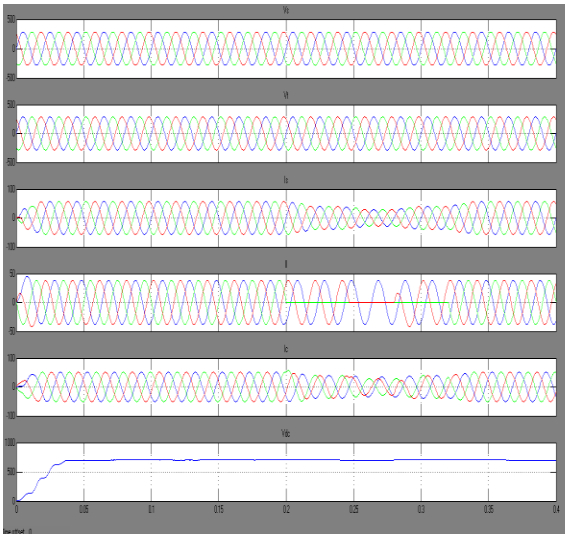

Fig 12 system response waveforms of voltage and current (source, loads) with linear load DSTATCOM

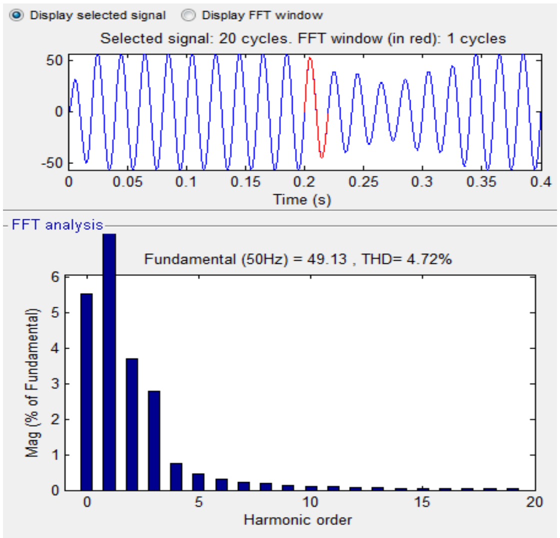

FIG 13 Harmonic Analysis Of proposed system with linear load DSTATCOM

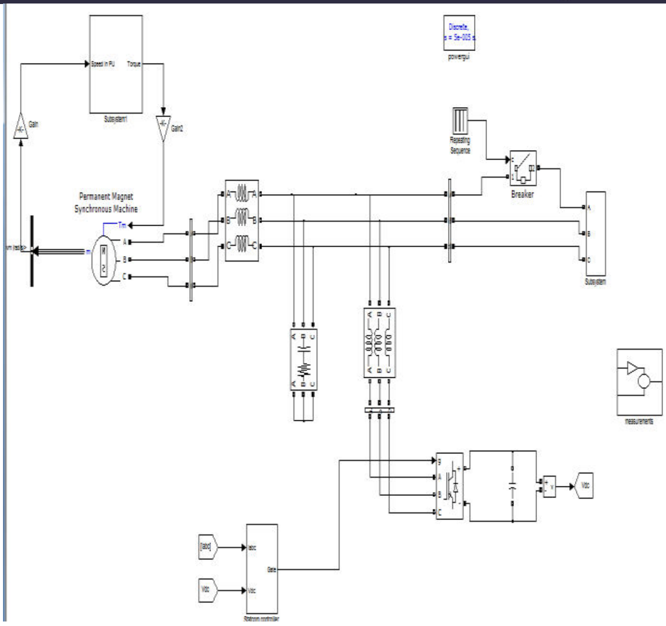

Fig 14 simulink diagram of proposed system with non-linear load DSTATCOM

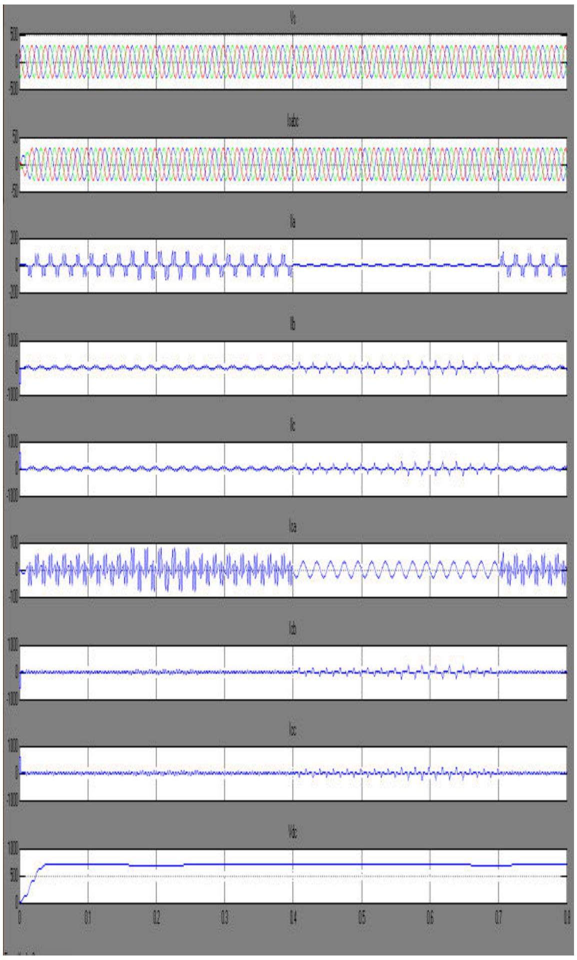

Fig 15 system response waveforms of voltage and current (source, loads) with non linear load DSTATCOM

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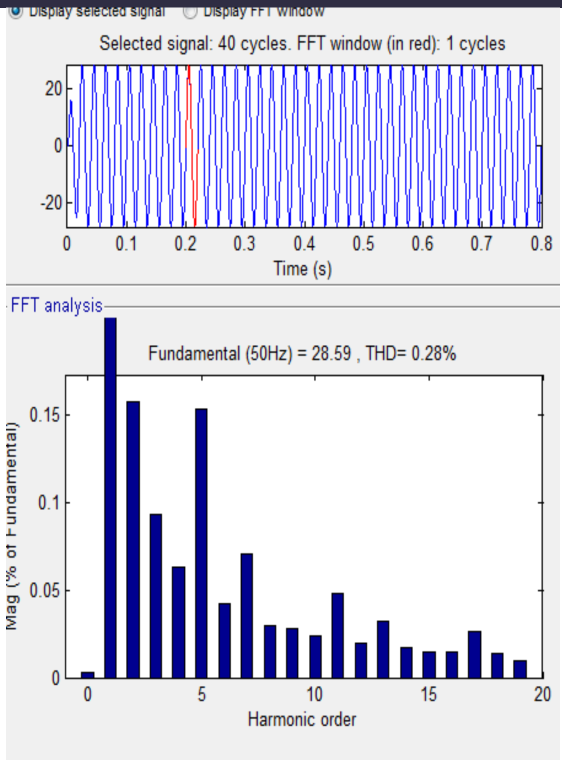

FIG 16 Harmonic Analysis Of proposed system with non-linear load DSTATCOM

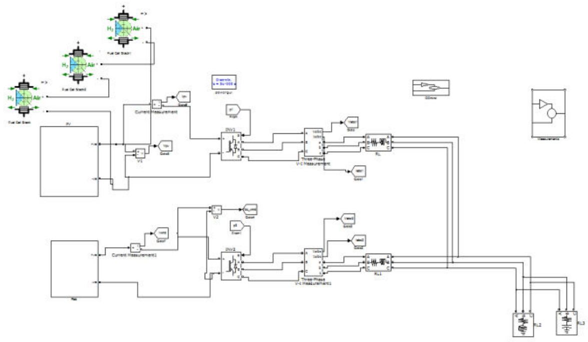

Fig 17 simulink diagram of proposed system with hybrid renewable resources

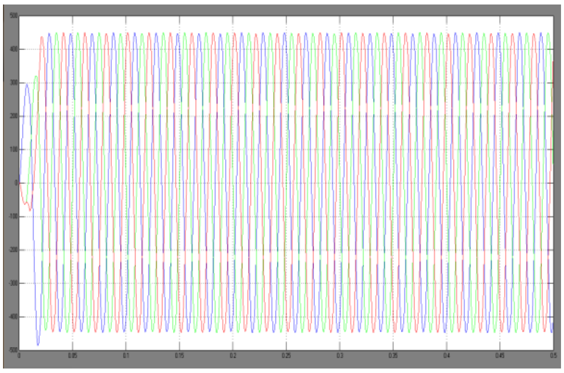

Fig. 18 The three-phase output voltages

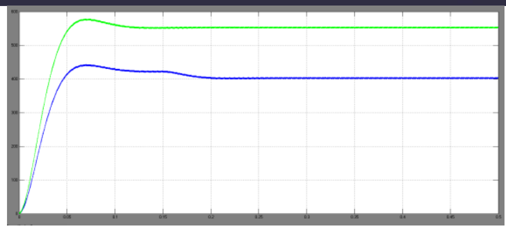

Fig. 19 The DC input voltage of the PV cell and Wind system

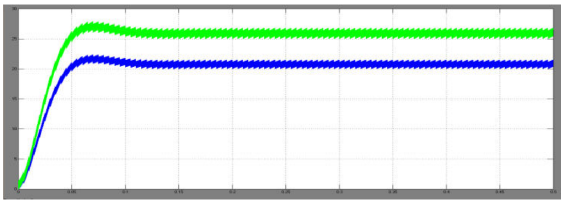

Fig. 20 The DC input currents of the PV cell and Wind system

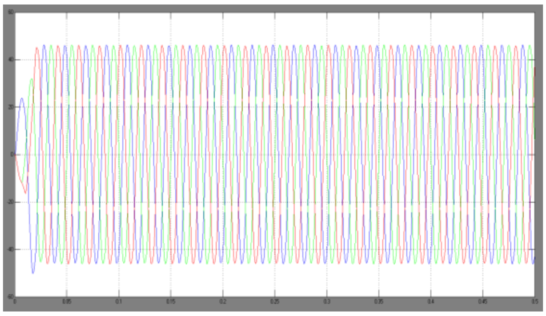

Fig. 21 The output currents of the Pv cell of Proposed Dstatcom

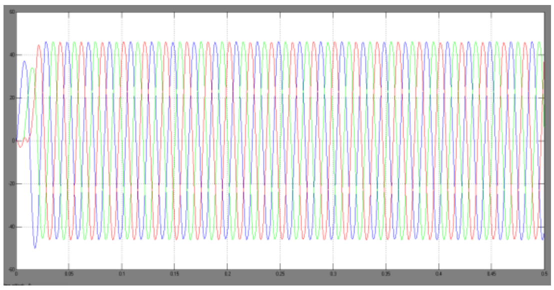

Fig. 22 The output currents of the wind system of Proposed Dstatcom

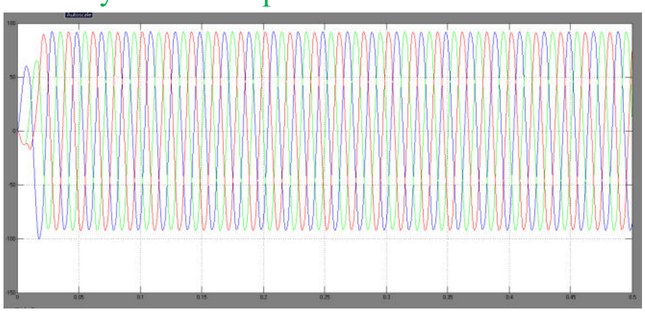

Fig. 23 The output currents of the load Proposed Dstatcom

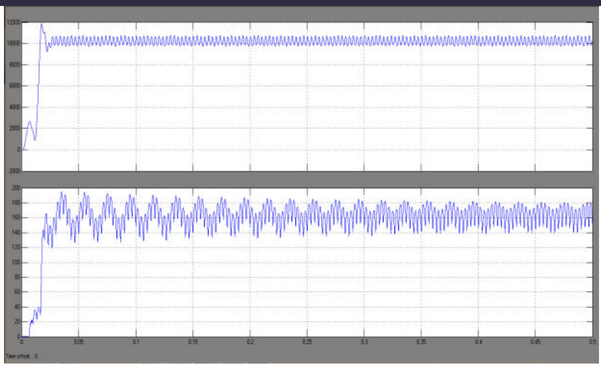

Fig. 24 The active and the reactive power of pv cell Proposed Dstatcom

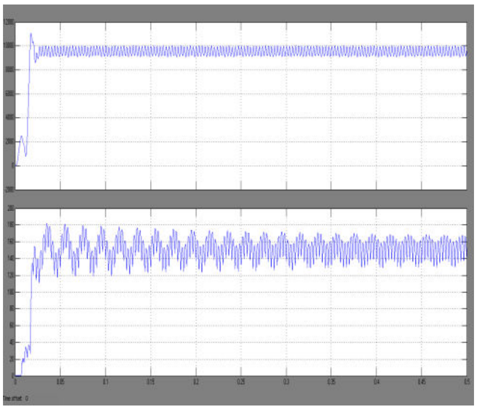

Fig. 25 The active and the reactive power of wind system Proposed Dstatcom

CONCLUSION

The proposed combined LMS–LMF-based control of DSTATCOM with hybrid renewable sources has been implemented and simulated for both ZVR and PFC modes under nonlinear balanced and unbalanced loads. Moreover, this DSTATCOM with hybrid renewable sources has also been verified on the software mat lab of the DSTATCOM developed in the laboratory. The proposed DSTATCOM with hybrid renewable sources has been used for obtaining the reference supply currents from the active and reactive weight components with distortions of the PCC voltages and supply currents well, which is well within the specified standard. The load balancing has also been achieved keeping the waveforms of PCC voltages and currents as sinusoidal and in-phase.

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