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Control Strategies of UPQC by Adaptive Hybrid PV/PEMFC Distributed Generation System with BLDC Motor Drive

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***Abstract*-In this concept presents the integration of photovoltaic (PV), fuel cell (FC) and energy storage systems for reliable power generation. In this system FC is used as main power source and power from PV whenever available is harvested completely with storage system compensating for power fluctuations. This topology has high efficiency, modularity and fuel flexibility. The sources in this hybrid system complement each other very well against environmental variations and load variations. UPQC is used to mitigate the power quality problems like harmonics and sag. The power fed is linked through common DC link and maintains constant real power exchange. The DC link is connected through the reactor. The BLDC motor is suited to many low- and medium-power applications ranging from household appliance; medical equipment; position actuators; heating, ventilation and air conditioning; motion control; and transportation. BLDC motors are synchronous motors having permanent magnets on the rotor and three phase windings on the stator. BLDC motor drives have gained importance in the last decade due to power quality improvements. The proposed concept can be implemented to hybrid PV/PEMFC distributed generation with bldc motor using Matlab/ Simulink software.**

Keywords—Power Quality, UPQC, Load Variation, Voltage Sags, Renewable Energy Source.

I.INTRODUCTION

This proposed topology also helps to match the dc-link voltage requirement of the shunt and series active filters of the UPQC. The topology uses a capacitor in series with the interfacing inductor of the shunt active filter, and the system neutral is connected to the negative terminal of the dc-link voltage to avoid the requirement of the fourth leg in the voltage source inverter (VSI) of the shunt active filter. The average switching frequency of the switches in the VSI also reduces; consequently the switching losses in the inverters reduce. The main aim of this project this topology enables UPQC to have a reduced dc-link voltage without compromising its compensation capability. The three phase three wires UPQC system used for compensation of power quality issues. In this method the UPQC which requires more rating of series and shunt active filters. Additionally to maintain the Low harmonics level by adding passive filters.

The different topologies reported in literature of three-phase four-wire UPQC use active compensation for the mitigation of source neutral current along with other PQ problems. For the mitigation of source neutral current, the uses of passive elements are advantageous over the active compensation due to ruggedness and less complexity. There are many techniques proposed for the compensation of neutral current using star-delta transformer in a three-phase four-wire distribution system and some of these have been patented. The application of star-delta transformer along with an APF is also used for harmonic current reduction in the neutral conductor. A filter employing three single-phase transformers with a capacitor has been used for removing harmonic current from the neutral conductor and has been patented. Another scheme by providing a six-phase system, with the help of two transformers connected in anti-phase has been reported for canceling third harmonic current in neutral conductor. The star-delta transformer along with a diode rectifier and a half-bridge PWM inverter is also

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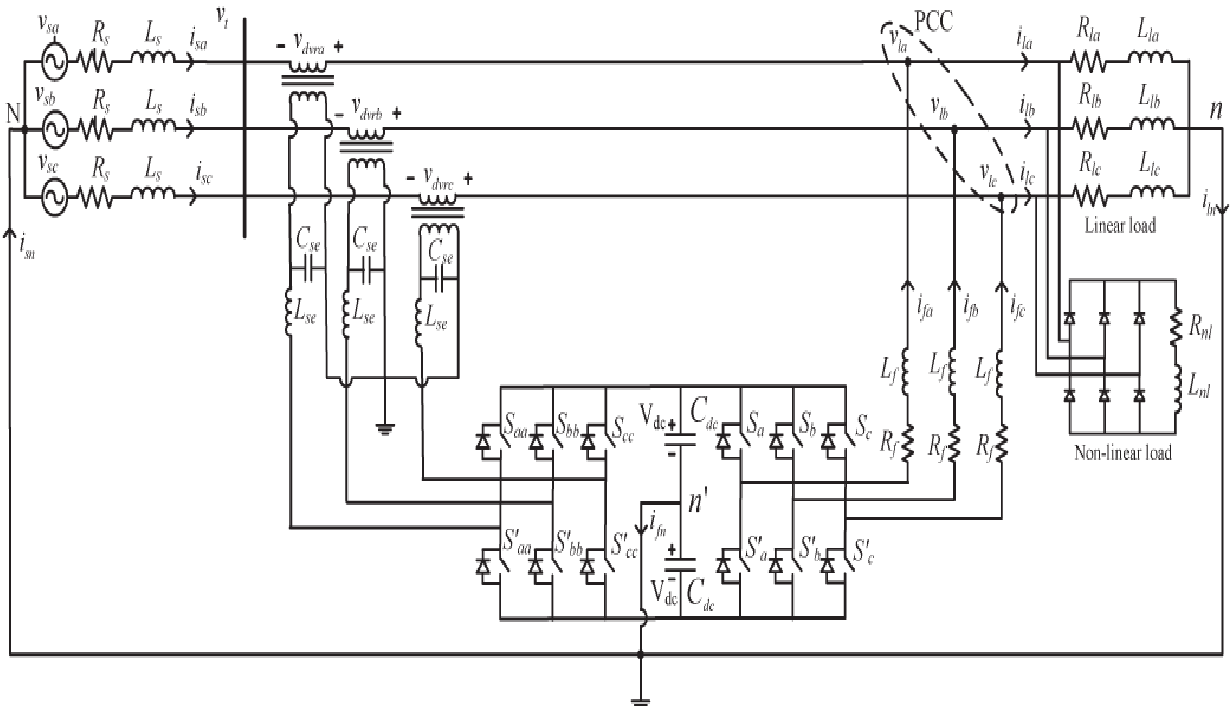

Fig.1. Equivalent circuit of neutral-clamped VSI topology-based UPQC

reported for the compensation of neutral current. For the mitigation of source neutral current along with other current based distortions, the integration of readily available three-leg VSI with star-delta transformer has been reported in literature for 3P-4W DSTATCOM [6]. Unfortunately, for the mitigation of neutral current the performance of the star-delta transformers is affected to an extent under distorted or unbalanced source voltages, which is very common in practice. The UPQC is one of the key CPDs, which takes care of both voltage and current based distortions simultaneously. Hence, for neutral current mitigation the integration of star-delta transformer with UPQC is more justified. In this paper, a simple star-delta configuration is utilized for the mitigation of source neutral current, while other options such as zig-zag transformer or T-connected transformer require specially designed transformers.

The conventional and proposed topologies of the UPQC are discussed in detail. Fig. 1 shows the power circuit of the neutral-clamped VSI topology-based UPQC which is considered as the conventional topology in this study. Even though this topology requires two dc storage devices, each leg of the VSI can be controlled independently, and tracking is smooth with less number of switches when compared to other VSI topologies. In this figure, *vsa*, *vsb*, and *vsc* are source voltages of phases *a*, *b*, and *c*, respectively. Similarly, *vta*, *vtb*, and *vtc* are terminal voltages. The voltages *v*dvr*a*, *v*dvr*b*, and *v*dvr*c* are injected by the series active filter. The threephase source currents are represented by *isa*, *isb*, and *isc*, load currents are represented by *ila*, *ilb*, and *ilc*. The shunt active filter currents are denoted by *ifa*, *ifb*, *ifc*, and *iln* represents the current in the neutral leg. *Ls* and *Rs* represent the feeder inductance and resistance, respectively. The interfacing inductance and resistance of the shunt active filter are represented by *Lf* and *Rf* , respectively, and the interfacing inductance and filter capacitor of the series active filter are represented by *L*se and *C*se, respectively. The load constituted of both linear and nonlinear loads as shown in this figure. The dc-link capacitors and voltages across them are represented by *C*dc1 = *C*dc2 = *C*dc and *V*dc1 = *V*dc2 = *V*dc, respectively, and the total dc-link voltage is represented by *Vd*bus (*V*dc1 + *V*dc2 = 2*V*dc).

II PV ARRAY MODELING & CHARACTERSTICS

The power that one module can produce is seldom enough to meet requirements of a home or a business, so the modules are linked together to form an array. Most PV arrays use an inverter to convert the DC power produced by the modules into alternating

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current that can power lights, motors, and other loads. The modules in a PV array are usually first connected in series to obtain the desired voltage; the individual strings are then connected in parallel to allow the system to produce more current The PV array is made up of number of PV modules connected in series called string and number of such strings connected in parallel to achieve desired voltage and current. The PV module used for simulation study consists of polycrystalline cells.

A. PV Model

The electrical equivalent circuit model of PV cell consists of a current source in parallel with a diode as shown in Fig.2

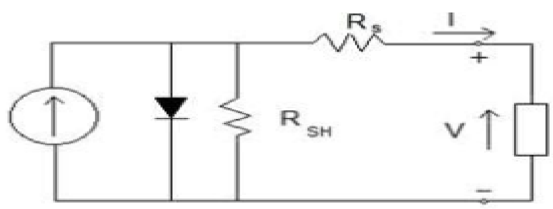

Fig. 2.Electrical Equivalent Circuit Model of PV Cell

III GENERATION OF REFERNCE CURRENTS

UPQC is operated in such a way that the source currents are balanced, sinusoidal, and in phase with respective terminal voltages. Also, average load power and losses in the VSI are supplied by the source. Since, source considered here is non stiff in nature, direct use of terminal voltages to calculate reference currents will not provide satisfactory compensation. Here, three phase reference currents (i*f2a, i*f2b, i*f2c) are generated using instantaneous symmetrical component theory [9] to satisfy all aforementioned load compensation conditions simultaneously and are given as follows

$$i^*_{fsa} = i_{la} - i^*_{sa} = i_{la} - \frac{v^+_{ta1}}{\Delta^+_1}(P_{lavg} + P_{loss})$$
$$i^*_{fsb} = i_{lb} - i^*_{sb} = i_{lb} - \frac{v^+_{tb1}}{\Delta^+_1}(P_{lavg} + P_{loss}) \quad (1)$$
$$i^*_{fsc} = i_{lc} - i^*_{sc} = i_{lc} - \frac{v^+_{tc1}}{\Delta^+_1}(P_{lavg} + P_{loss})$$

where, v+tal, v+tbl, and v+tc1are fundamental positive sequence voltages at the respective phase load terminal and Δ+1=(v+tal)2+(v+tbl)2+(v+tcl)2. Here, Plavg represents average load power and Ploss represents the total looses in the inverter. Average load power is calculated using a moving average filter for better performance during transients and can have a window width of half cycle or full cycle depending upon the type of harmonics present in the load currents. Total losses in the inverter Ploss, computed using a proportional integral (PI) controller, helps in maintaining the dc link voltage(vdc1 + vdc2) at a predefined reference value (2Vdcref) by drawing a set of balanced currents from the source and is given as follows

IV PRINCIPLE OF BLDC MOTOR WITH FUEL CELL

BLDC engine comprises of the perpetual magnet rotor and an injury stator. The brushless engines are controlled utilizing a three stage inverter. The engine obliges a rotor position sensor for beginning and for giving legitimate compensation arrangement to turn on the force gadgets in the inverter extension. In light of the rotor position, the force gadgets are commutated consecutively every 60 degrees. The electronic compensation takes out the issues connected with the brush and the commutator plan, in particular starting and destroying of the commutator brush course of action, along these lines, making a BLDC engine more rough contrasted with a dc engine. Fig.1 demonstrates the stator of the BLDC engine and fig.2 shows rotor magnet plans.

Fig 3 BLDC motor stator construction

Fig 4 BLDC motor Rotor construction

The brush less dc engine comprise of four fundamental parts Power converter, changeless magnet brushless DC Motor (BLDCM), sensors and control calculation. The force converter changes power fro m the source to the BLDCM which thus changes over electrical vitality to mechanical vitality. One of the remarkable highlights of the brush less dc engine is the rotor position sensors, in view of the rotor position and order signals which may be a torque charge, voltage summon, rate order etc; the control calculation s focus the entryway sign to every semiconductor in the force electronic converter. The structure of the control calculations decides the sort of the brush less dc engine of which there are two principle classes voltage source based drives and current source based drives. Both voltage source and current source based commute utilized for perpetual magnet brushless DC machine. The back emf waveform of the engine is demonstrated in the fig. 3. Be that as it may, machine with a non sinusoidal back emf brings about diminishment in the inverter size and lessens misfortunes for the same influence level.

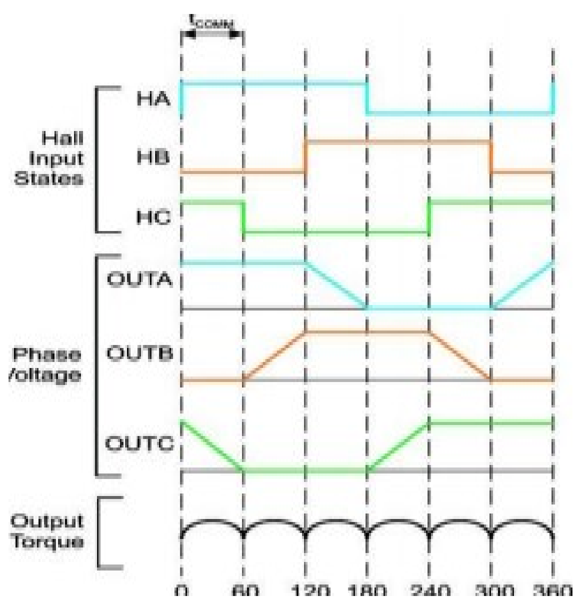

Fig 5 Hall signals & Stator voltages

Fuel Cells Working

A single fuel cell consists of an electrolyte sandwiched between two electrodes, an anode and a cathode. Bipolar plates on either side of the cell help distribute gases and serve as current collectors. In a Polymer Electrolyte Membrane (PEM) fuel cell, which is widely regarded as the most promising for light-duty transportation, hydrogen gas flows through channels to the anode, where a catalyst causes the hydrogen molecules to separate into protons and electrons. The membrane allows only the protons to pass through it. While the protons are conducted through the membrane to the other side of the cell, the stream of negatively-charged electrons follows an external circuit to the cathode. This flow of electrons is electricity that can be used to do work, such as power a motor. On the other side of the cell, air flows through channels to the cathode. When the electrons return from doing work, they react with oxygen in the air and the hydrogen protons (which have moved through the membrane) at the cathode to form water. This union is an exothermic reaction, generating heat that can be used outside the fuel cell.

Fuel cells directly convert the chemical energy in hydrogen to electricity, with pure water and potentially useful heat as the only byproducts. Hydrogen-powered fuel cells are not only pollution-free, but also can have more than two times the efficiency of traditional combustion technologies. The power produced by a fuel cell depends on several factors, including the fuel cell type, size, temperature at which it operates, and pressure at which gases are supplied. A single fuel cell produces barely enough voltage for even the smallest applications. To increase the voltage, individual fuel cells are combined in series to form a stack. (The term “fuel cell” is often used to refer to the entire stack, as well as to the individual cell.) Depending on the application, a fuel cell stack may contain only a few or as many as hundreds of individual cells layered together.

V. MATLAB MODELING AND SIMULATION RESULTS

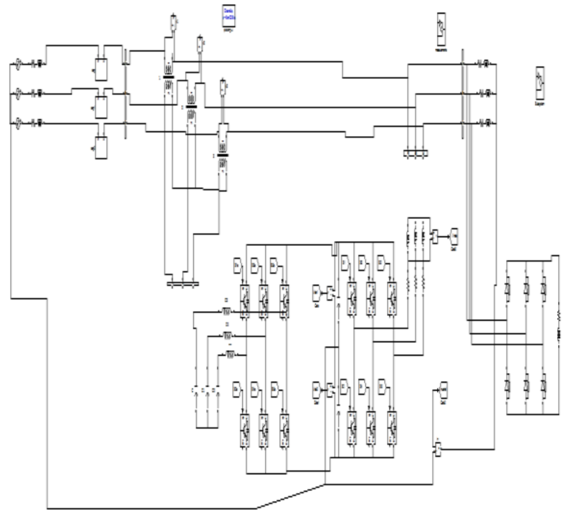

Fig 6.Simulink model of power system without UPQC.

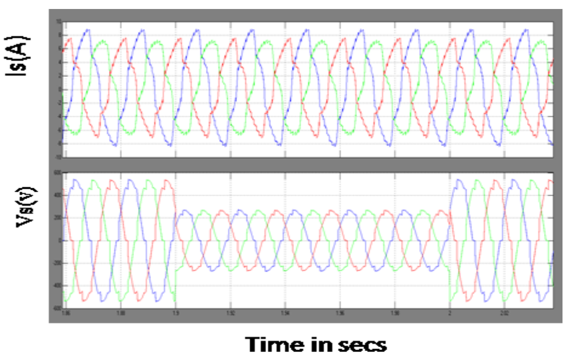

Fig 7 simulation wave form of Source current and Source voltage without UPQC.

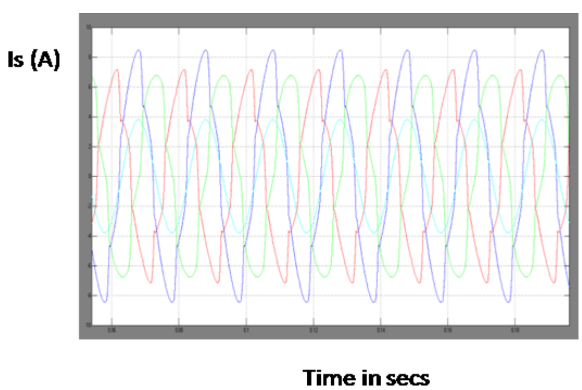

Fig. 8 Simulated wave form of the load current for RL load.

Below figure shows the source voltage ,compensating voltage and load voltage under sag 1.9 sec to 2 sec without UPQC

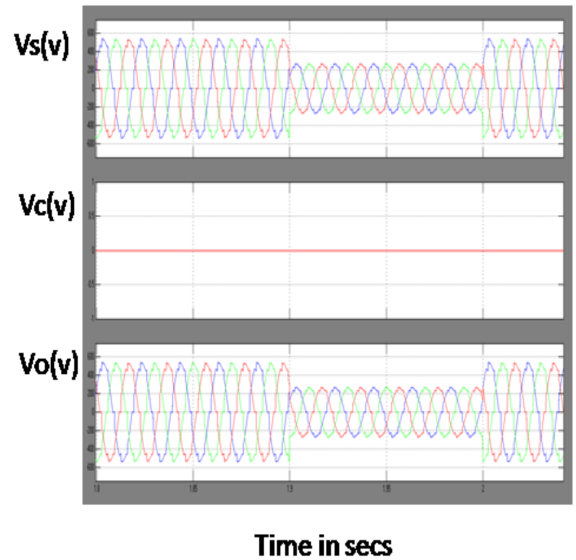

Fig.9 Simulated output wave form of Source voltage, Compensating voltage and Load voltage without UPQC.

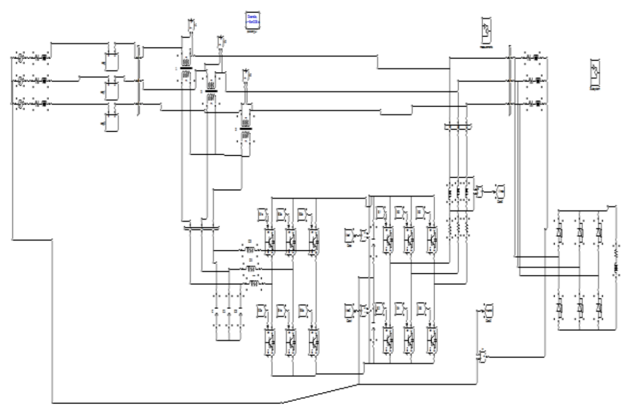

Fig 10.simulation circuit of power system network with UPQC

Below fig shows the source voltage, compensating voltage and load voltage under sag applied from 1.9 sec to 2 secs without UPQC.

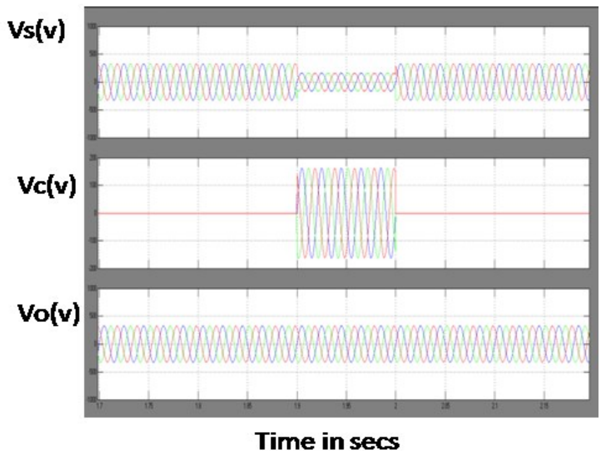

Fig 11 Simulated output wave form of Source voltage, Compensating Voltage and Load Voltage with UPQC.

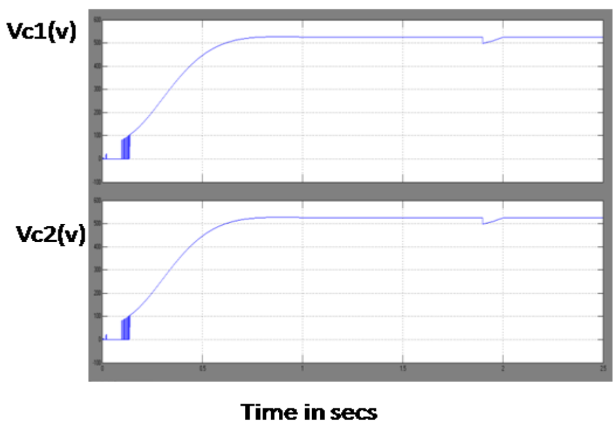

Fig. 12. Simulated output wave form of the Voltage across C1 and C2 capacitors.

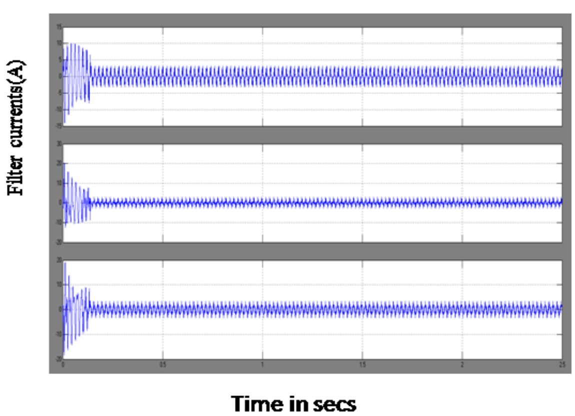

Fig. 13.Simulated output wave form of the filter side currents with UPQC

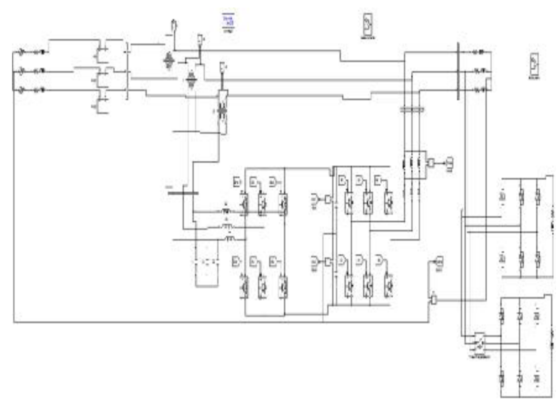

Fig 14 Simulink circuit of proposed UPQC under normal DC link

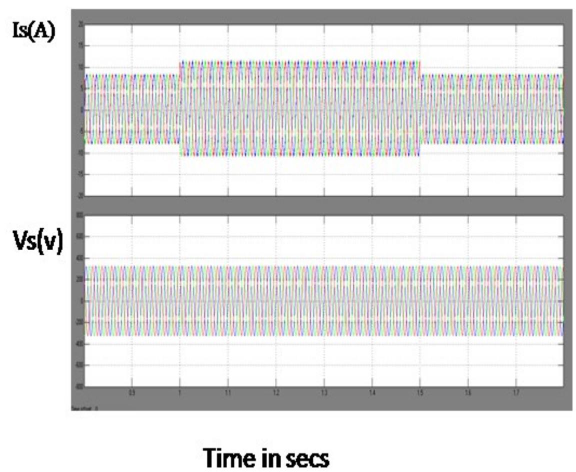

Fig 15 simulation wave form of Source voltage and current

Below figure shows the variations in load currents drawn by different diode bridge rectifier and RL loads.

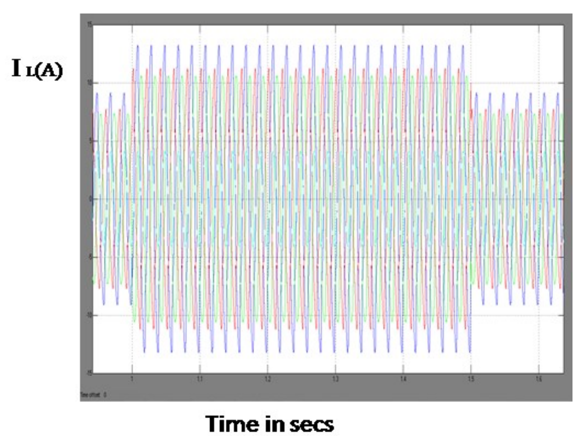

Fig 16 simulation wave form of Load current

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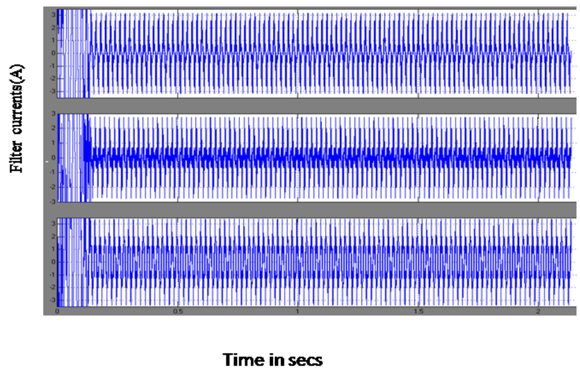

Fig. 17.Simulated output wave form of the filter side currents not changing

Below figure shows the power system network with UPQC with PV cell due to which even the variable loads drawing the un balanced currents the source currents will be in constant magnitude.

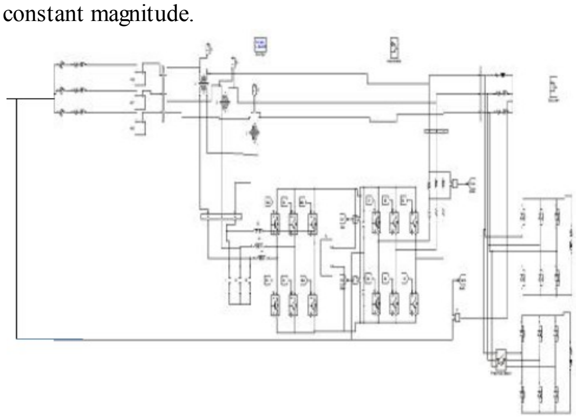

Fig 18 :Simulink circuit of proposed UPQC under PV as Renewable Energy Sources

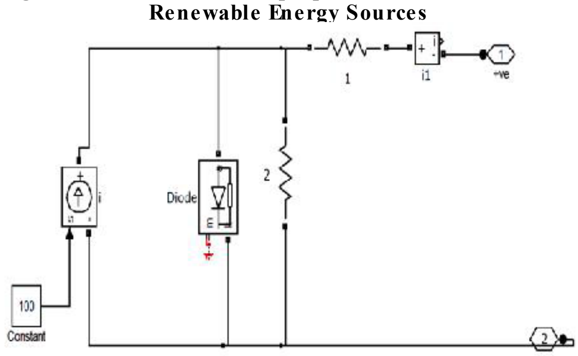

Fig.19.Simulink circuit of Photo Voltaic Cell for UPQC

Below figure shows the balanced source current without harmonics and source voltage without distortions with UPQC under Pv cell.

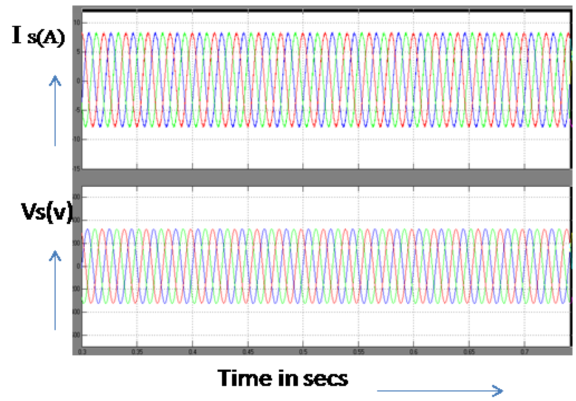

Fig 20 simulation wave form of Source voltage and current UPQC PV systems

Below figure shows the variations in load currents drawn by different diode bridge rectifiers and RL loads

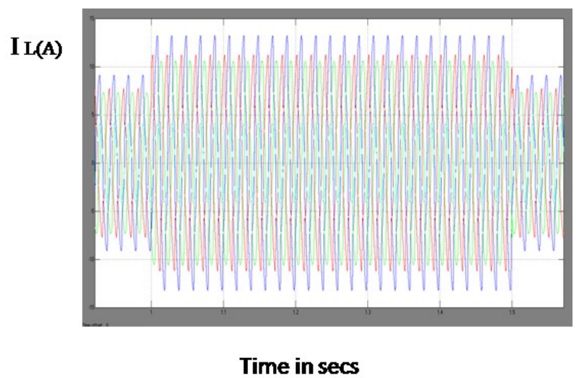

Fig 21.simulation wave form Load current.

Below figure shows the filter currents changing its magnitude form 1 to 1.5 sec to reduce the variable load effects on the source currents.

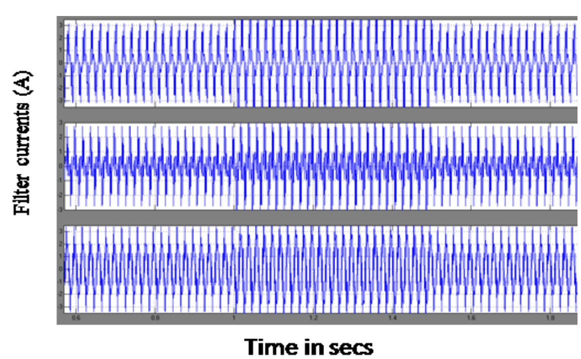

Fig. 22. Simulated output wave form filter currents changing to reduce variations of source currents.

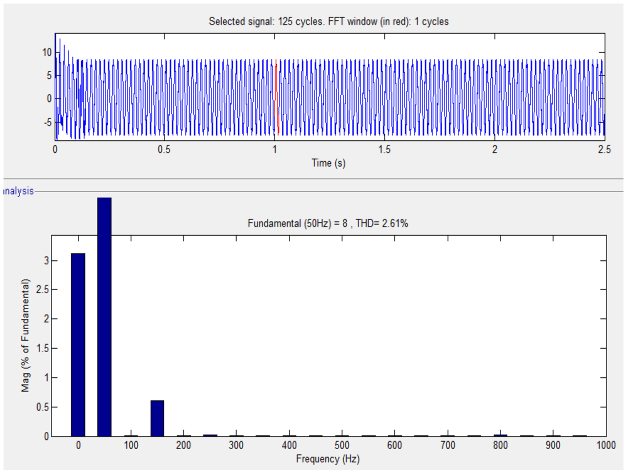

Fig 23.Thd for PI controller

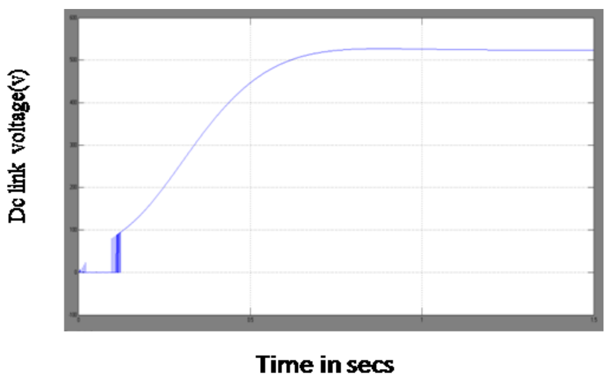

Fig 24 simulation wave form dc-link voltage for BLDC motor controller.

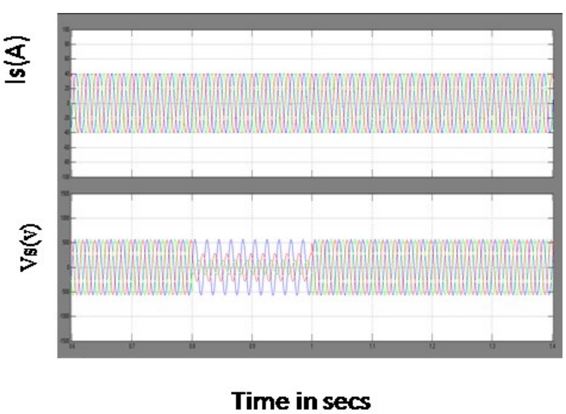

Fig 25 simulation wave form source current and voltage when BLDC load connected.

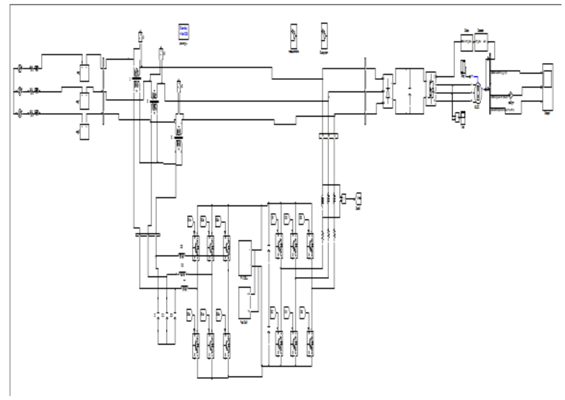

Fig 26. Simulink Circuit of proposed upqc with PV/PEMFC and BLDC Motor.

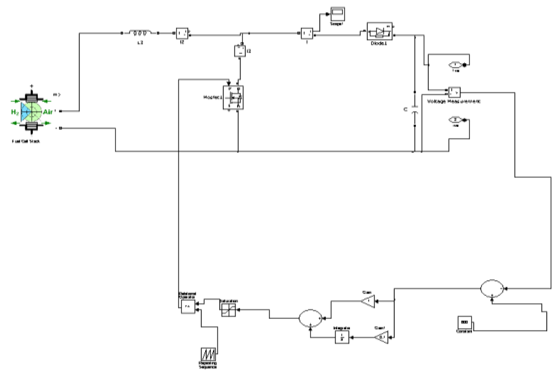

Fig 27. Simulink circuit of Fuel Cell for UPQC

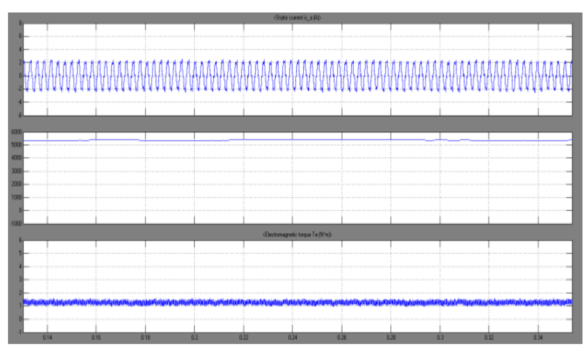

Fig 28.Simulation wave form of stator current, speed and electromagnetic torque

VI. CONCLUSION

UPQC topology has been proposed in this paper which has the capability to compensate voltage sags and current harmonics. The analysis has taken with and without UPQC under Hybrid PV/PEMFC as renewable energy sources. The proposed method is BLDC motor validated through MATLAB simulation. This simulation study shows that the source current harmonics reduced with UPQC and final it has proven that the best among the 4 conditions is UPQC with Hybrid PV/PEMFC as renewable energy source, which maintains the source currents with constant magnitude even the load currents are varying and torque and speed also changing by control of BLDC motor

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