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Mitigation of Power Quality Issues using Hybrid Solar-Wind Energized UPQC

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ABSTRACT: The primary goal of energy suppliers is to offer its consumers with continuous uninterruptable supply of Voltage having Sinusoidal Nature and Constant Peak Amplitudes. This both factors have dependency on the type of load connected to the system and how sensitively it reacts to the fluctuation occurring in the voltage wave. In recent years, power quality has been a very serious problem in the power system. These problems regarding power quality are most closely related to power-electronic equipment, so all this power-electronic equipment are severely affected by PQ interference. In Conventional techniques, Series Active Power Filter is used for compensating Power Quality Problems related to voltage wave and for compensation of Power Quality problems of Current Wave, Shunt Active Power Filters are used. By the integration of Shunt Active Power Filter and Series Active Power Filter, a new device invented which is known as a Unified Power Quality Conditioner (UPQC). In this paper, a Simulink model of Hybrid Unified Power Quality Conditioner for compensating voltage and Current related power quality issues is presented. All the Simulation models and its corresponding results are validated by using MATLAB/Simulink Platform.

KEYWORDS: Power Quality (PQ), Series Active Power Filter (SAPF), Shunt Active Power Filter, UPQC.

I. INTRODUCTION

India's economy is growing rapidly, with 1.3 billion people facing huge energy needs. In terms of electricity production and consumption, India ranks fifth on global platform. Every Power System Network has four major section- Generation of Electrical Power, Transmission of Electrical Power, Distribution of Electrical Power and Utilization of Electrical Power. For all of this four sections Power Quality plays an important role in determining efficiency and reliability of supplied Power.[1]

Power quality (PQ) is defined by the Institute of Electrical and Electronics Engineers (IEEE) Standard 1159-1995 (519,1195) as the concept of energizing and grounding connection of electronic equipments in a sense that is best suited for the working of the corresponding equipment and having compatible nature with the present wiring system in premises and other connected equipment/devices.[2] Power quality (PQ) problems, such as reactive and harmonic currents, sags/swells in voltage supply, and distortion, are crucial and not new nowadays. With the increasing usage of renewable energy sources (RES), such as inverter-based integration of Photovoltaic (PV) and Wind Power Plant system, Area-wise distributed generations (DG) systems, and interaction of vehicle to grid (V2G) system, power quality concerns are becoming increasingly serious.[6],[7]

There are basically two types of power quality issues: on the one hand, the quality of the current consumed by the load is not good due to the use of non-linear loads, on the other hand, the interruption or interference caused by voltage disturbances. Both of these issues can turn off electronic equipment having sensitive nature, such as Circuit breakers with sensitive relaying systems which introduces serious consequences in industrial plants. The shutdown of main energizing system due to false tripping of circuit breaker can support the shutdown of the entire production plant. [7]

Voltage harmonics, voltage disturbances such as swells and sags are responsible for equipment trips such as sensitive loads, and the consequences can be harmful to industrial plants (e.g. termination of industrial processes). These scenarios are well known in industries that result in high economic losses.[5][6] To overcome this situation, industrial customers install Series APF mitigation devices to protect the plant from disruptions from the grid. The use of power and electronic components is rapidly increasing in modern plants, causing system harmonics and sensitive loads, and for these reasons shunt APF is implemented to overcome the problem. Therefore, a new trend has been established to serve the dual purpose of servicing the first utility and secondly serving the interests of the customer. The importance

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of this trend is to protect both the utility and its customers at the same time, to protect sensitive components from voltage disturbances, and to minimize distortion that enters the utility depending on the load the customer is using. The UPQC model is therefore formed from series and shunt APF compensators in a back-to-back configuration that can simultaneously control the load voltage and grid current.[8]-[11]

This paper provides PV supplied UPQC to solve complex power quality problems, especially during long-term power outages. Various case studies were applied to verify the dynamic performance of the proposed UPQC, PV integration. Finally, the performance of the proposed UPQC system is investigated using MATLAB-Simulink software under various dynamic conditions.

II.SYSTEM ARCHITECTURE

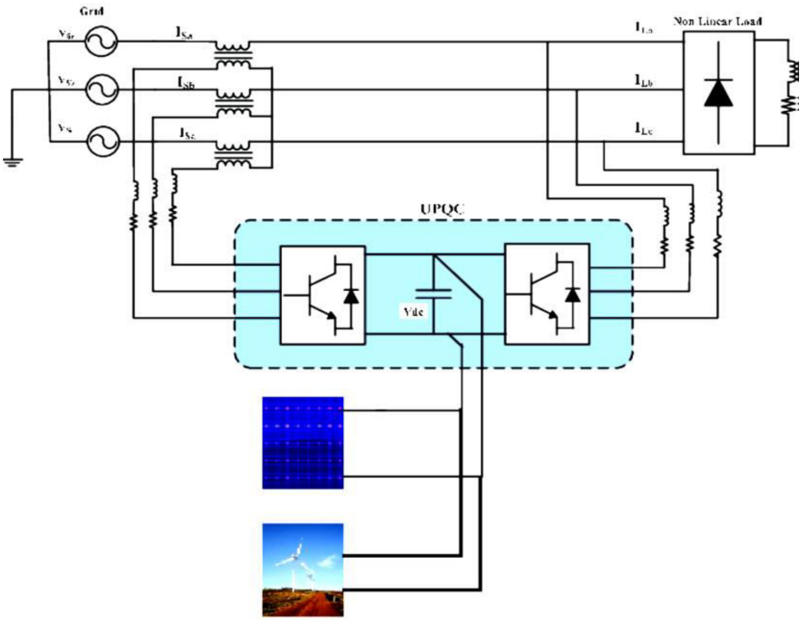

Fig. 1 Proposed System Configuration

The basic configuration of the proposed UPQC system is shown in Figure 1. The system consists of AC Grid mains, series transformer, UPQC composed of series APF and parallel HAPF, as well as sensitive non-equipment applications such as wind turbines and photovoltaic power generation that require high performance. The parallel HAPF and series APF based are connected in a back-to-back manner. The negative feedback passive bypass filter of parallel HAPF is a LC filter, and series APF output filter converter has an LCR low passive filter (LPF).

Here, circuitry of proposed UPQC system is connected between Three-phase Voltage Mains Source and Non-linear Load. Series Active Filter part of UPQC is connected in series manner with transmission line. It injects compensating voltage in the transmission line through series connected transformer when power quality issues related to voltage wave are occurring in system like sag or swell in Voltage. Shunt Active Filter Part of UPQC system is connected in shunt manner of transmission line. It injects current in to the transmission line which compensates the non-linearities or issues occurring in current wave.

In this proposed system, the circuitry of UPQC is energized through a hybrid combination of Wind Energy source and Solar PV Panel which can serve two purposes one is to provide Renewable energy generation and another one is for energization of compensating device

A. Control Scheme for Series Active Filter

The control scheme for Series Active Filter part of proposed UPQC system is as shown in fig. 2.Here, firstly the source voltage (phase voltage) is sensed using voltage measurement device. Then, it is provided to Three-phase Phase Lock Loop (PLL) where the tracking of phase of respected input signal is done. By using this phase angle, three reference voltage vectors having 120°s phase shift with each other are generated. Each reference voltage vector is unit

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in magnitude. This three-unit reference vectors are combined using multiplexer having three input and single output.The generated output Reference Voltage signal from multiplexer is provided to positive terminal of comparator where it is compared with sensed Three-phase Voltage. When sag/swell occurs in source wave, the difference generated between Reference Voltage and source voltage at the output of Comparator. The output of Comparator is further provided to pulse generation block which generates necessary controlling pulses for the operation of series APF. The generation of controlling pulses for Series Active Power Filter is depicted in fig. 3.

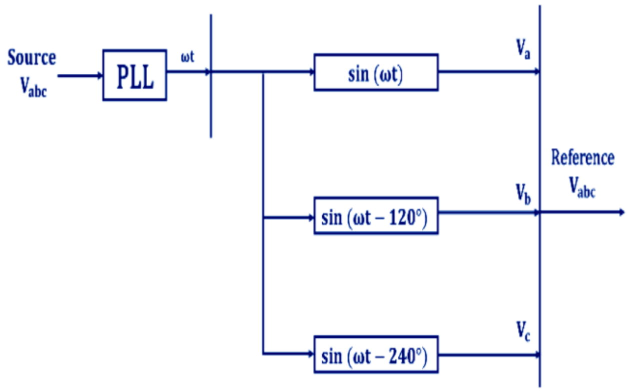

Fig. 2 Reference Vector generation for Series APF Controller

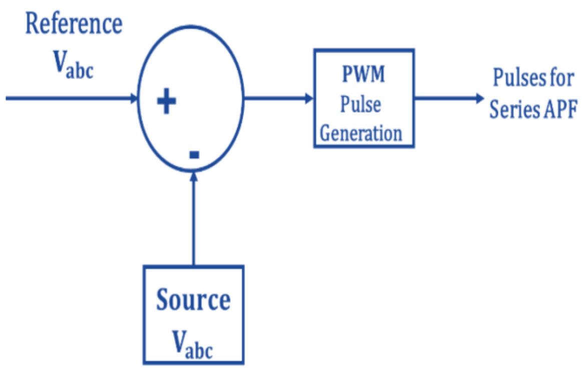

Fig. 3 Generation of Controlling Pulses for Series Active Power Filter

B. Control Scheme for Shunt Active Filter

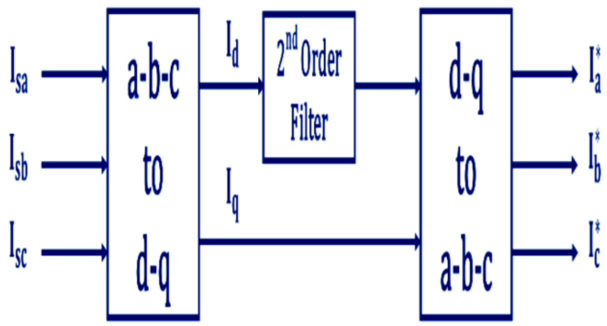

Fig. 4Reference Current Vector Generation

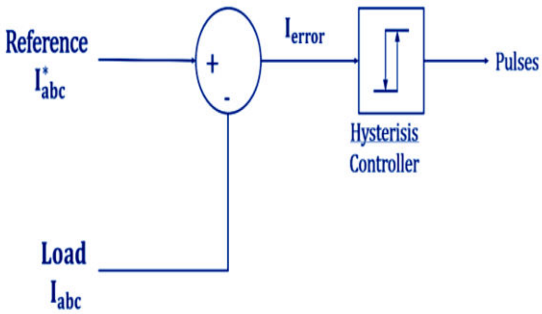

Fig. 5Generation of Controlling pulses for Shunt Active Power Filter

The block diagram for Reference Current Vector Generation is as shown in fig.4. For generation of reference current vector, firstly the supplied three-phase current wave is sensed using current measurement device and it is provided to a-b-c to d-q conversion block. d-axis current vector is then passed through second order filter. Second Order filter filters out the DC components from d-axis component of current. The filtered d-axis component and q-axis component of supplied current is then provided to d-q to a-b-c conversion block which produces reference three- phase a-b-c current vectors.The Reference Three-phase current vectors are then provided to positive terminal of comparator and Load Current Signals are applied at negative terminal of comparator. Here, comparator compares reference current vector and load current signals and generates error signal as per the Non-linearities. Then, this error signal is provided to Current Hysterisis controller which generates necessary controlling pulses for the operation of Shunt Active Power Filter as shown in fig. 5.

III.RESULTS OF PROPOSED SYSTEM

The waveform for DC input fed to the proposed hybrid UPQC device is as shown in fig. 6. Here in this proposed system DC supply is achieved from two sources – Solar and Wind energy system which are connected in parallel. For Solar system in input radiation provided is 1000W/m2 and operating temperature is at 25°C. For wind

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system output achieved is of AC type. Then this AC input is provided to rectifier which converts it into DC and further this DC is provided to proposed UPQC. Hybridization of these two renewables provides the advantages as both renewable source availability is depending on surrounding atmospheric condition. When one of the sources is unavailable, the other source can fulfil the requirement of DC.

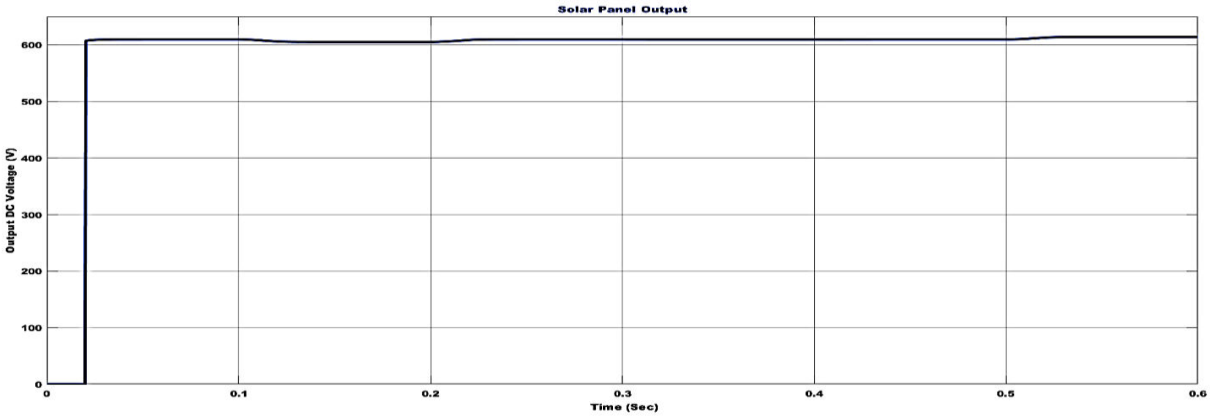

Fig. 6 Reference Current Vector Generation

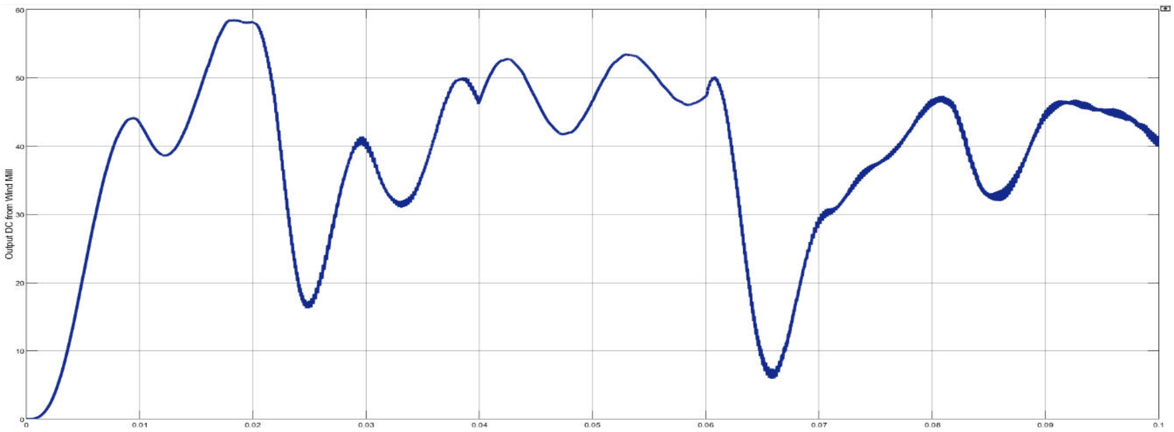

Fig. 7Output DC from Wind Mill

A. Results during Voltage Sag Condition

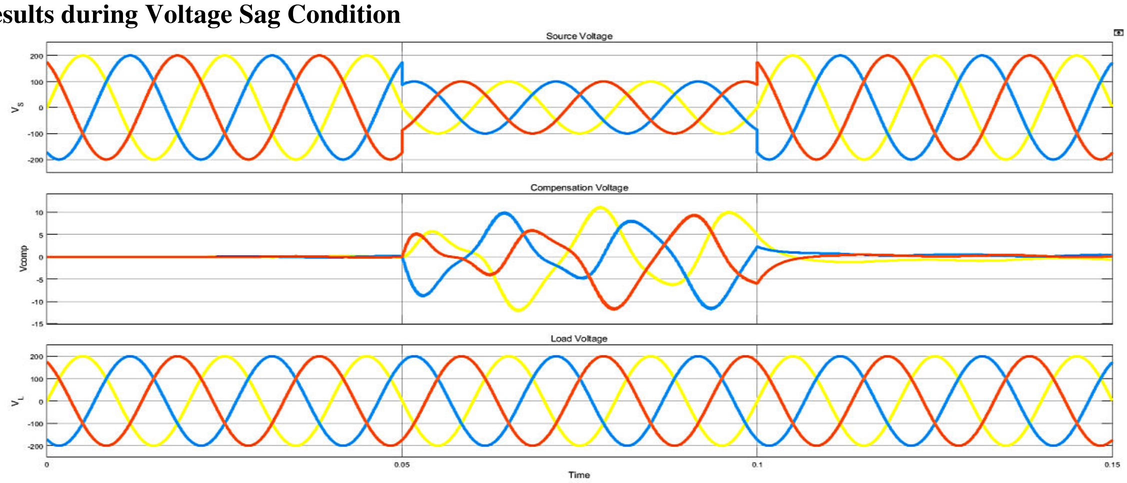

Fig. 8 (a) Source Voltage Waveform consisting Voltage Sag,(b) Compensation Voltage provided by proposed UPQC System and (c) Corrected Load Voltage

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The output results acquired from proposed UPQC System during sag condition is as shown in above fig. 8. The simulation of proposed system is carried out for the time period of 0.15 second. From 0 to 0.05 sec, the system voltage is in nominal condition. It doesn't have non-linearity up to 0.01 sec.

For the time period of 0.05 to 0.1 sec, the sag in Supplied voltage is introduced. So that, a dip in voltage level occurs. If such low voltage is supplied to motoring load, the motor runs at slow speed. So, the output achieved from motor is get affected. To avoid such consequences, Series active filter part of UPQC is utilized.Series Active Filter part of UPQC, senses the sag in voltage level and injects the compensating voltage into the transmission line through series connected transformers. This injected voltage is get added up with supplied voltage. So that,nominal level of System Voltage is maintained and further this maintained Voltage is supplied to the Load. As Load is energized by sag free nominal rated Voltage, the operation of Load is not disturbed. In this way, power quality of Voltage wave during sag is maintained.

B. Results during Voltage Swell Condition

The output results acquired from proposed UPQC System during swelling condition is as shown in fig. 9. For observing the performance of proposed system during Voltage swell condition, here also the simulation is carried out for the time period of 0.15 sec. From starting 0 sec, the system voltage is at nominal level up to 0.05 sec. After 0.05 sec the Swell in supplied Voltage is introduced and it continues up to the 0.1 sec.

During this time period, the system voltage is getting rise above the nominal level. If such rised voltage is supplied to Motoring Load, Motor runs at a dangerously high speed. Due to which, motor gets heated. This heating causes to burning of insulation provided motor winding and other parts and finally motor gets Completely damage.The Swell in Voltage is getting sensed by a Series APF part of UPQC. When the voltage gets risen up, the Series APF injects Compensating Voltage in to the transmission line through Series Connected Transformer. The injected Voltage is in opposite manner with rised voltage. Thus, injected Voltage is get subtracted from Swelled Supplied Voltage. Due to which, the supplied voltage is maintained at nominal rated Value. So that, the swelling free nominal rated voltage is provided to Load and Load operates at Good condition. In such manner, UPQC works for Voltage Swell condition.

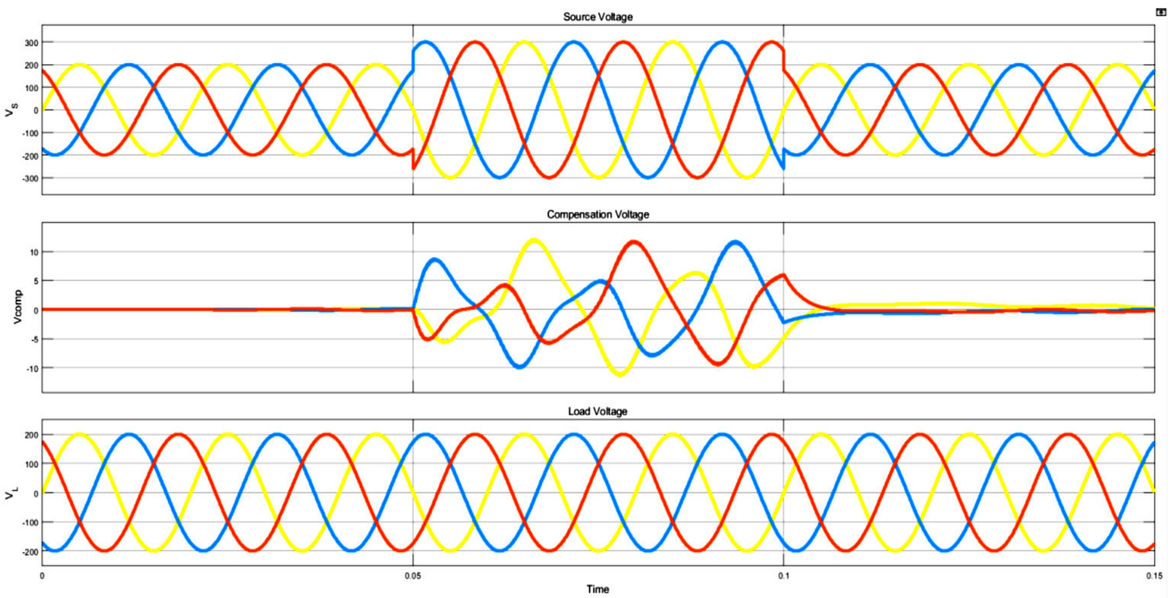

Fig. 9 (a) Source Voltage Waveform consisting Voltage Swell, (b) Compensation Voltage provided by proposed UPQC System and (c) Corrected Load Voltage

The THD Level of Load Voltage is as shown in fig. 10. From fig. 10. it can be observed the proposed Hybrid UPQC system provides the percentage THD Level of 3.05% which is below the 5% as per the Standard mention by IEEE 519. As load voltage contains less amount of harmonics in Load voltages, it provides smooth operation of Loads.

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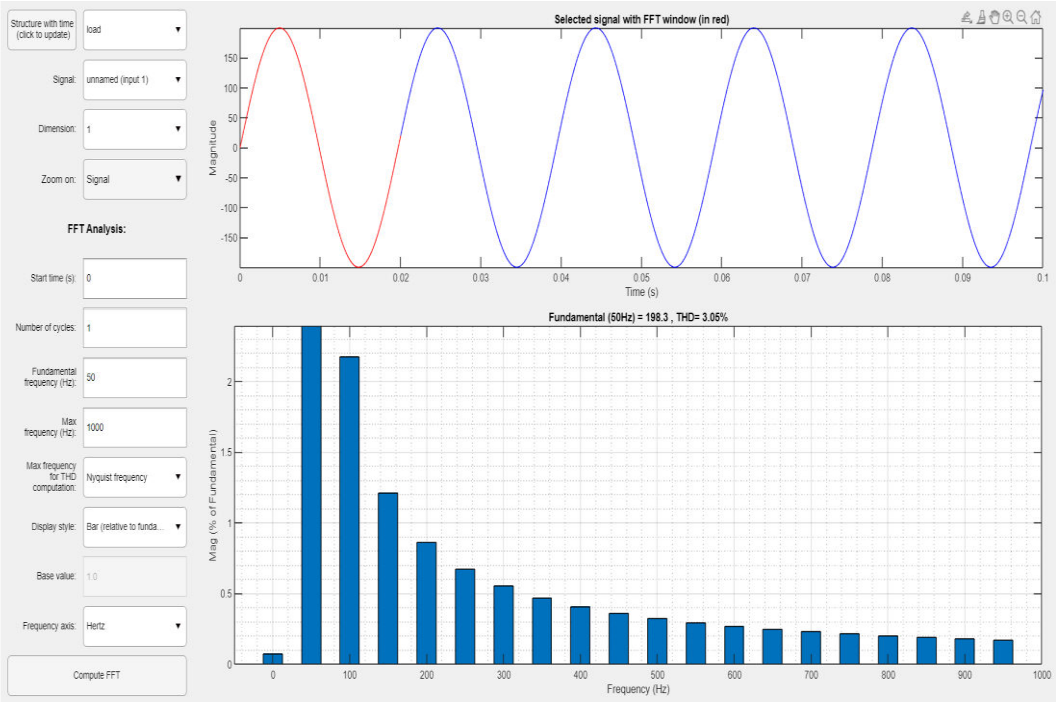

Fig. 10 THD Level of Load Voltage

C. Load Current

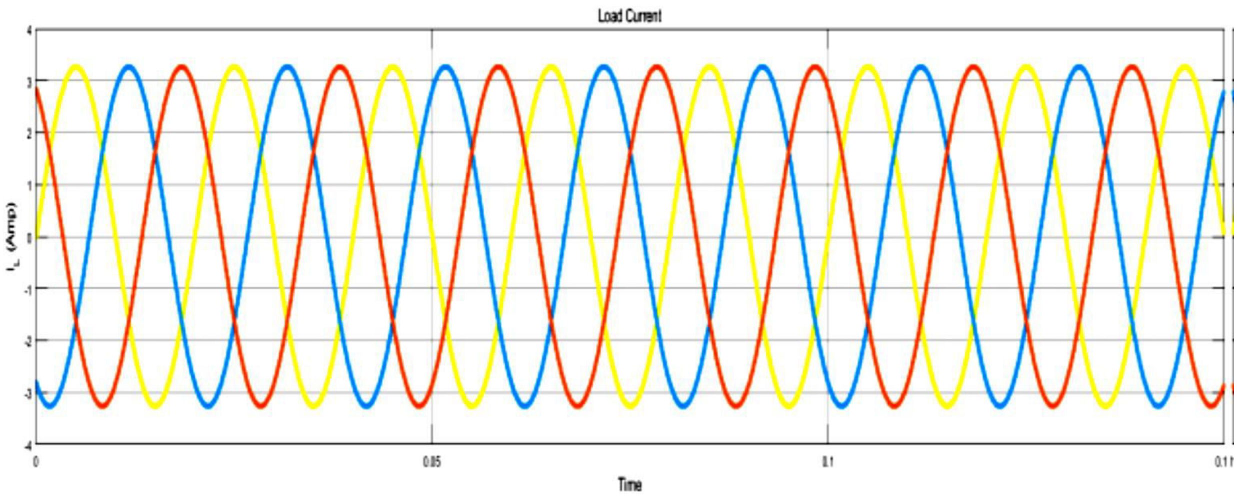

Fig. 11. Load Current Waveform

The Load Current Waveform for proposed system is as shown in fig. 11.
From the output Load Current Waveform, it can be observed that under various Power quality issues regarding Voltage and Current Wave, the current supplied to a load is maintained at rated value. The current supplied to the load is purely sinusoidal in shape and it is harmonics free and distortion less. The power quality issues regarding current wave like harmonics in current wave, are get compensated by Shunt Active Power Filter.

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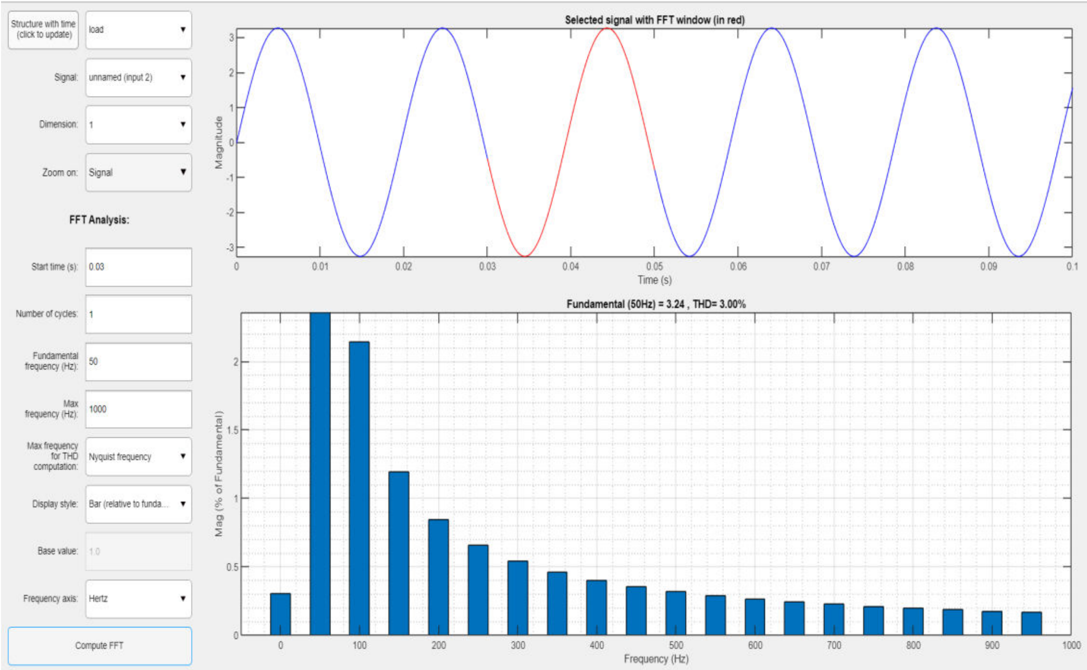

Fig. 12THD Level of Load Current

Fig. 12 shows the FFT (Fast-Fourier Transform) analysis window of Load Current.
It shows the THD level in percentage. FFT analysis is taken out for calculation of THD (Total Harmonic Distortions) in percentage. From fig. 12, it can be observed that the Current provided to load is non-distorted and uniformly maintained at rated value. The current supplied to the load does not consists of harmonic content, as harmonics are get compensated by the Shunt Active Power Filter. Shunt APF injects reverse order harmonics in the transmission line which cancels out harmonic content in current wave and maintains its THD Level as shown in fig. 12

IV.CONCLUSION

The configuration of the three-phase UPQC was investigated for the conditions of unbalanced and distorted systems, taking into account the conditions of complex power quality issues such as harmonics, voltage rise and sag. Integrating Wind System and PV with UPQC provides the network with active power capabilities. Since Solar Photovoltaic Energy is not available all the time because of its availability is depend on the environment, Wind Energy can be integrated to solve the shortage of Photovoltaic renewable energy source. Finally, it can be seen that Wind Energy Generation and PV connected to UPQC can be a great alternative to Distributed Generation (DG) system for upgrading the power quality of modern power distribution systems. Here, the conceptually based analysis of the Hybrid UPQC was carried out for a power quality issues like undervoltage and overvoltage conditions. The APF in series manner introduces phase-to-phase voltages during undervoltage conditions and antiphase voltages during voltage surges and maintains the load bus voltage at the desired constant level. The Shunt APF helps the Series-APF circuit in undervoltage and surge conditions by keeping the DC-link voltage at a predetermined fixed level so that the APF current can efficiently supply or absorb active power.

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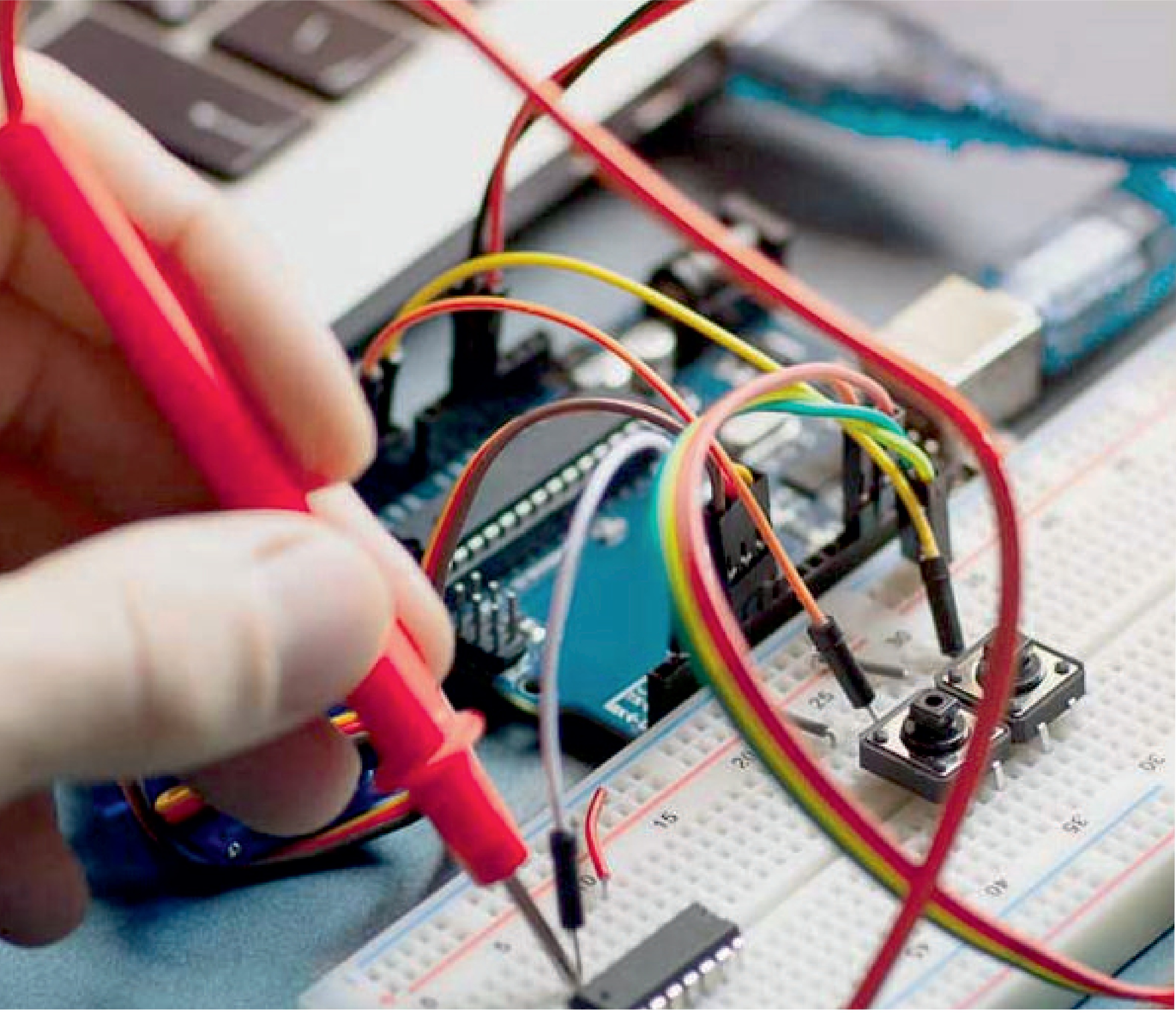

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