INTERNATIONAL JOURNAL
OF TECHO-ENGINEERING

ISSN: 2057-5688

POWER QUALITY ENHANCEMENT BY USING FUZZY BASED PV-UPQC

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ABSTRACT:

A solar photovoltaic integrated unified power quality controller (PV-UPQC) using a fuzzy logic controller (FLC) has been proposed. The results obtained through the FLC are good in terms of dynamic response because of the fact that the FLC is based on linguistic variable set theory and does not require a mathematical model of the system. Moreover, the tedious method of tuning the PI controller is not required in case of FLC. Simulations are carried out using MATLAB/Simulink to validate the theoretical findings.

Keywords: MPPT, PV, P&O, H Bridge inverter.

1. INTRODUCTION:

Distributed generation (DG) systems based on renewable energy sources (RES) are currently emerging as an alternative for large and decentralized conventional power plants connected to long power transmission/distribution networks [1], [2]. DG systems based on RES can be added to new electric power systems (EPS) to meet increasing power demands, reduce power transport costs, improve system reliability due to increased demand, and reduce harmful environmental impacts caused by pollutant sources of energy, such as oil, coal, and natural gas. Given the low environmental impact and abundance, primary RES, such as solar and wind, have been widely used in the scenario involving the proliferation of DG systems [2], [3]. In particular, the power generation by means of photovoltaic (PV) systems connected to the utility grid deserves special attention, since they can involve small-, medium-, and large-scale power generation systems. PV systems, when connected to the single-phase or three phase EPS, have the purpose of injecting into the grid the energy coming from PV arrays [4]–[17], which can consist of one or more series- or parallel-connected solar panels. Once the PV array generates energy in the form of dc current, an inverter stage is required, i.e., it is necessary to use at least one power converter between the PV array and the grid [4]–[11]. In contrast, when the voltage in the dc bus of the PV array is not high enough to supply the dc bus of the inverter stage, a boost dc–dc converter must be used [12]–[14]. Thus, the PV systems can be classified as single- or double-stage power conversion systems. In the single-stage PV system, maximum power point tracking (MPPT) is necessarily performed by the dc–ac converter [9], [10], while in the double-stage PV system, this task is usually performed by a boost dc–dc converter [14]. Regardless of the PV system topology, the power balance between the PV system and the power grid is performed by the inverter dc-bus voltage control. In other words, the dc-bus voltage controller must increase or decrease the amplitude of the inverter sinusoidal current references to ensure that the power generated by the PV array is equal to the power injected into the grid plus the system losses, so that the power balance is maintained.

The functionalities of PV systems can be highlighted in several applications. This happens because, besides injecting active power into the grid [3]–[13], [18], [19], PV systems can simultaneously perform some type of power-line conditioning [14]– [18] and subsequently improve power quality (PQ) indicators, which are related to the following indexes [20]: line utilization factor [power factor (PF) and fundamental PF], harmonic pollution factor, and load unbalance factor. PV systems have acted similarly as parallel active power filters (P-APF), compensating for reactive power, as well as suppressing current harmonics generated by nonlinear loads. PV systems have been employed to operate integrated with unified power quality conditioners (UPQC). Although the main role of UPQC systems is performing series–parallel compensation, so that they can simultaneously act as series APF, compensating for mains voltages, as well as acting as P-APF, compensating the load currents, in [21] experimental results of the single-stage PV system integrated with UPQC performs only the function of a dynamic voltage restorer. In this case, only the disturbances of the grid voltages are compensated. In [22], a double-stage PV system integrated with the UPQC, named SPV-UPQC-P, has been evaluated only through computer simulations. However, this system only compensates reactive power of the load and unbalances of the grid voltage. Thus, the suppression of grid voltage as well as load current harmonics has not been taken into account. Another application in which the PV system is integrated with the UPQC is presented in [23]. In this application, the system can operate as a grid forming in an acmicrogrid [19], since different types of DG sources (PV, wind, and others), as well as energy storage systems, can be used as grid-forming units in an islanded microgrid [29]. However, transients/disturbances could be observed in the voltages that fed the load when the system was transferred from the grid-connected operation mode to the grid-islanded operation mode. This happens because the parallel converter of the UPQC needs to change its control mode from current source to voltage source. The same effect occurs when the system returns to operate in the grid-connected mode, because the parallel converter must be controlled again as the current source.

2 UPQC MODULE

Since the parallel converter is voltage controlled, so that balanced and regulated voltages can be provided to the load, there is no need to change its control mode when the system operates as grid forming in an ac microgrid. In other words, the parallel converter is voltage controlled in both grid-connected and grid-islanded modes. On the other hand, the mentioned system can also operate either as grid feeding or grid supporting [1] in an ac microgrid, since the control mode of the parallel converter can also be switched to operate from voltage source to current source. On the other hand, in [4], studies related to stability analysis, detailed study related to active and apparent power flows and mainly the sizing and protection of the power converters that compose the PV-UPQC system, have not been addressed. Thereby, additional research advances and contributions are presented in this paper, as follows.

1) A complete study involving the power flow through the PV-UPQC system for obtaining the overall understanding of the system working under several operation modes is performed. This study represents an important and useful methodological tool for designing the power converters properly. It is supported by means of an extensive number of sizing curves and allows the designer an effective power converters sizing.

2) A strategy to avoid over power rating of the series and parallel power converters is implemented. This strategy is needed in order to establish the priority of the power flow through the converters, since the PV-UPQC system performs, simultaneously, grid active power injection (energy produced from the PV system), as well as the power-line conditioning.

3) The stability analysis of the PV system is performed. In the context of a UPQC, the study involving the ability of the series and parallel converters to remain stable even in the occurrence of disturbances in both the load currents and grid voltages has never been addressed before in the literature and appears as an important and necessary subject to be discussed. Furthermore, it is checked if the system stability is affected or not by different grid impedance characteristics.

4) The PV-UPQC system is also tested in grid-islanded operation. This operation mode allows exploring new aspects related to the multi functionality of the PV-UPQC system.

2. PROPOSED SYSTEM:

Fig.5.1. shows PV-UPQC structure in that Back to back converters having with a common dc link act like a UPQC in this configuration. The PV system is connected at the point of dc-link of the UPQC. The shunt electrical converter of UPQC is connected to a load end and the series inverter of UPQC is connected near to the source part. Interfacing inductors are connected at the output of each series and shunt electrical converter of UPQC. At the load end A diode bridge rectifier RL load is connected.

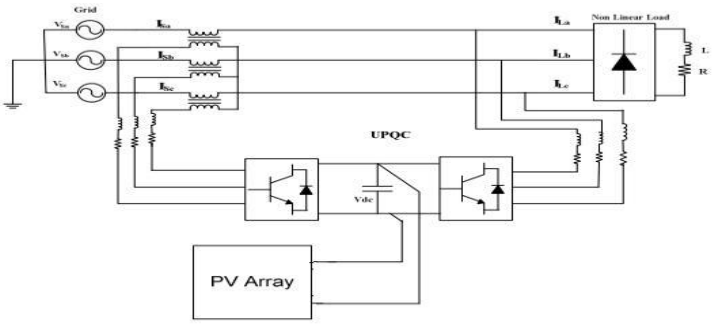


Fig.1. Block diagram.

The sensed DC link voltage v_{dc} is compared with a reference voltage v^*_{dc}. The error signal obtained is processed in Fuzzy Logic Controller. The output of the Fuzzy Controller i^*_{sb} is considered as the magnitude of three-phase reference supply currents. The three-phase unit current vectors (u_{sa}, u_{sb} and u_{sc}) are derived in phase with the three-phase supply voltages (v_{sa}, v_{sb} and v_{sc}). The unit current vectors from the three phase of supply currents. Multiplication of magnitude i^*_{sp} with (u_{sa}, u_{sb} and u_{sc}) results in three phase reference supply currents (i^*_{sa}, i^*_{sb} and i^*_{sc}). Subtraction of load currents (i_{sha}, i_{shb} and i_{shc}) from the reference currents, results in three-phase reference currents (i^*_{sha}, i^*_{shb} and i^*_{shc}) for the shunt APF. These reference currents are compared with the actual shunt compensating currents (i_{sha}, i_{shb} and i_{shc}) and the error signal is converted into PWM gating signals, the shunt APF supplies harmonics currents and reactive power demand of the load.

EXISITNG RESULTS

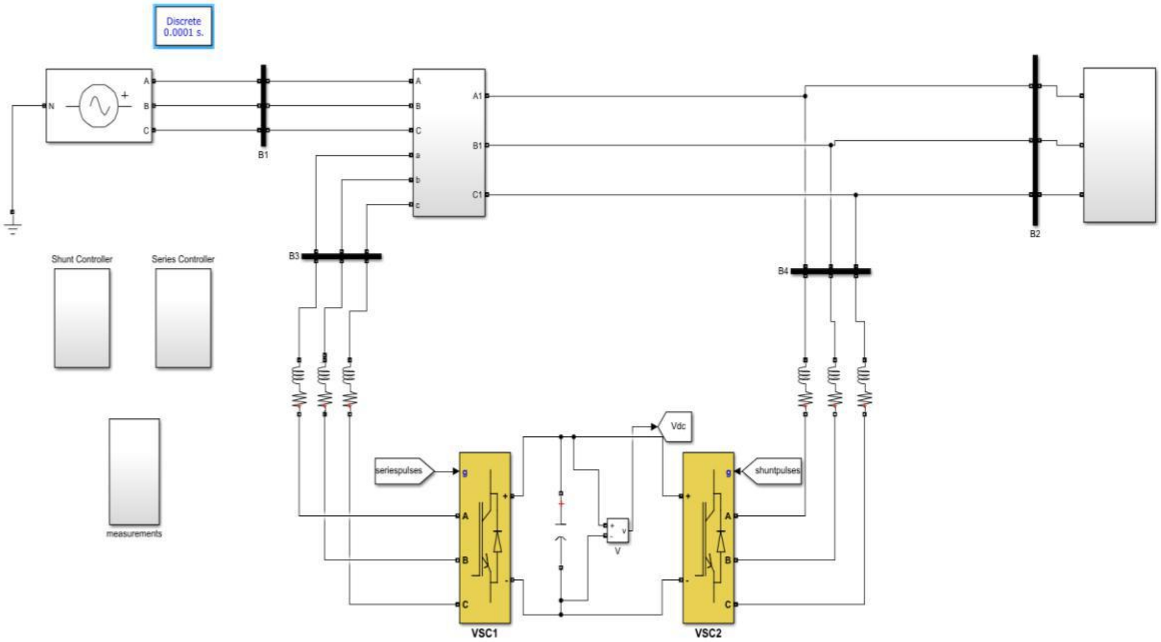


Fig.2 MATLAB/SIMULINK

Case-1 Under Voltage Sag Condition

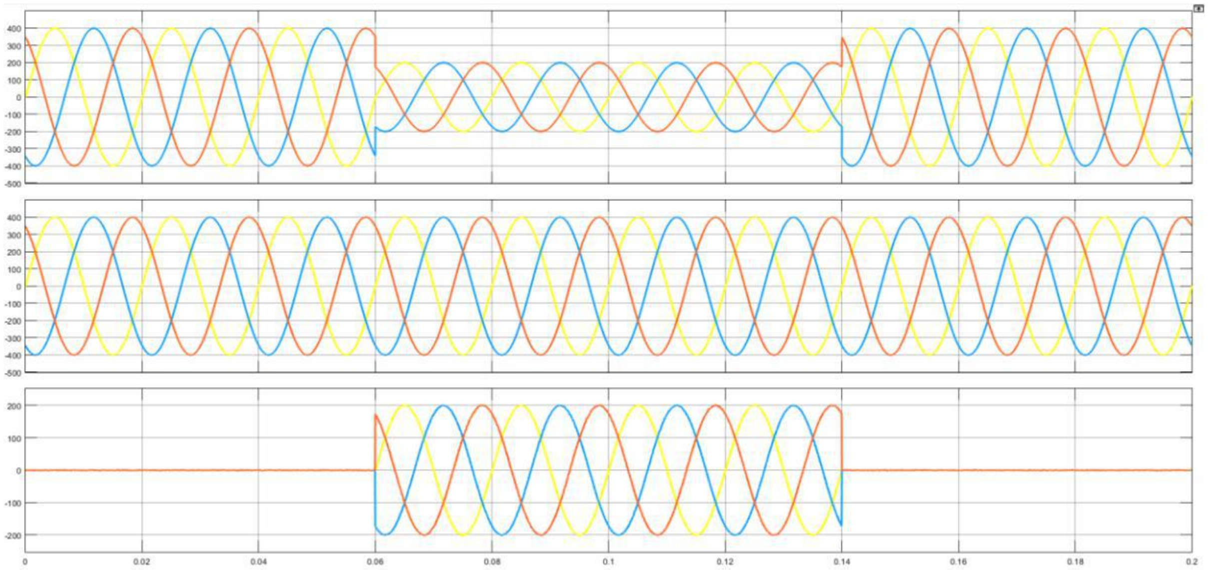


Fig 3 (a) Supply voltage (b) Load voltage and (c)Compensation voltage

Case-2 Under Voltage Swell Condition

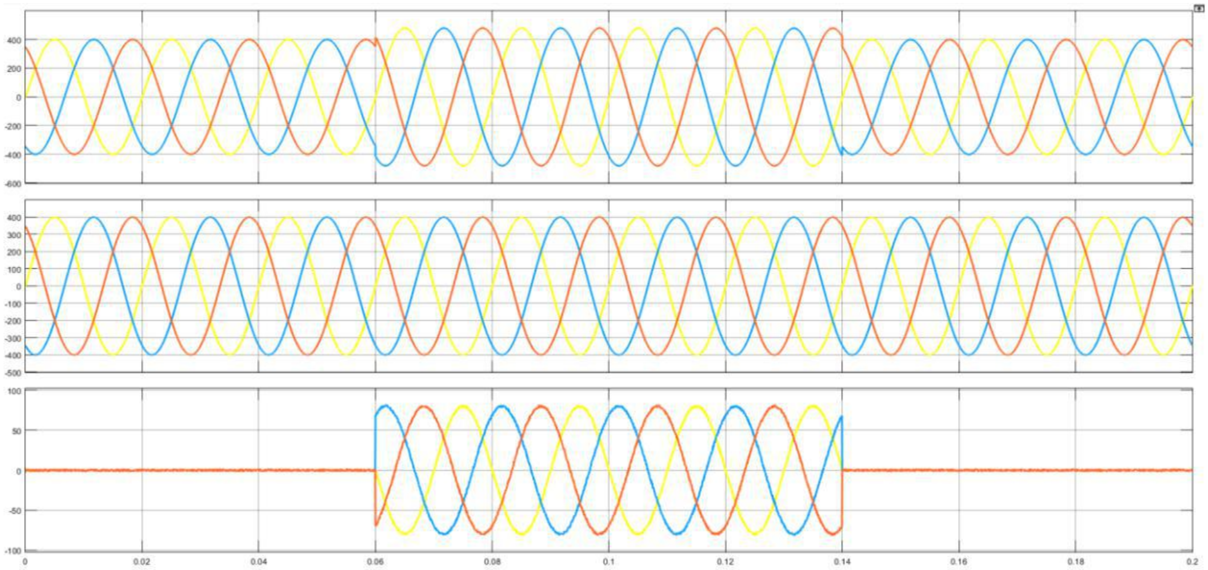


Fig 4 (a) Supply voltage (b) Load voltage and (c)Compensation voltage

Case-3 Under Harmonics

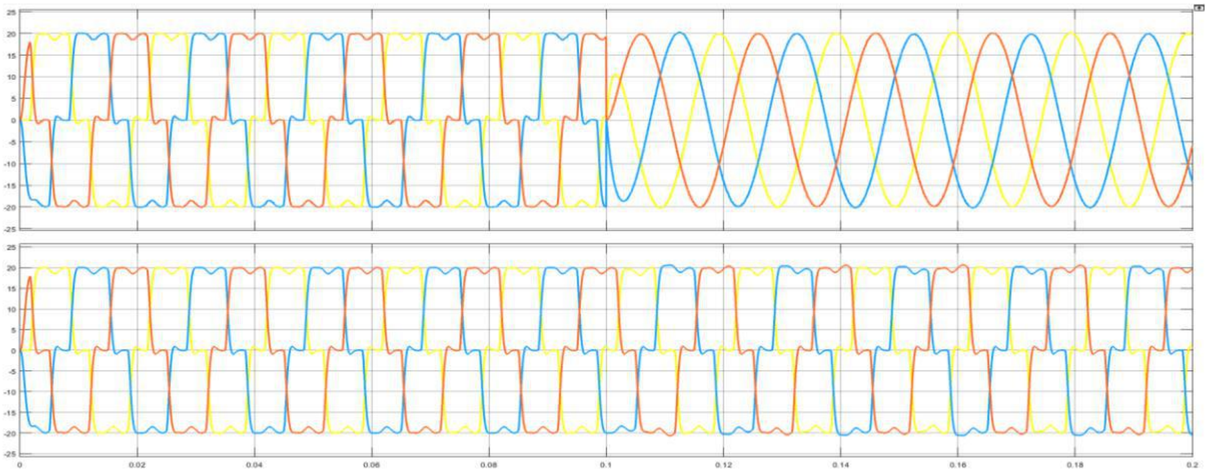


Fig 5 (a) Supply current (b) Load current

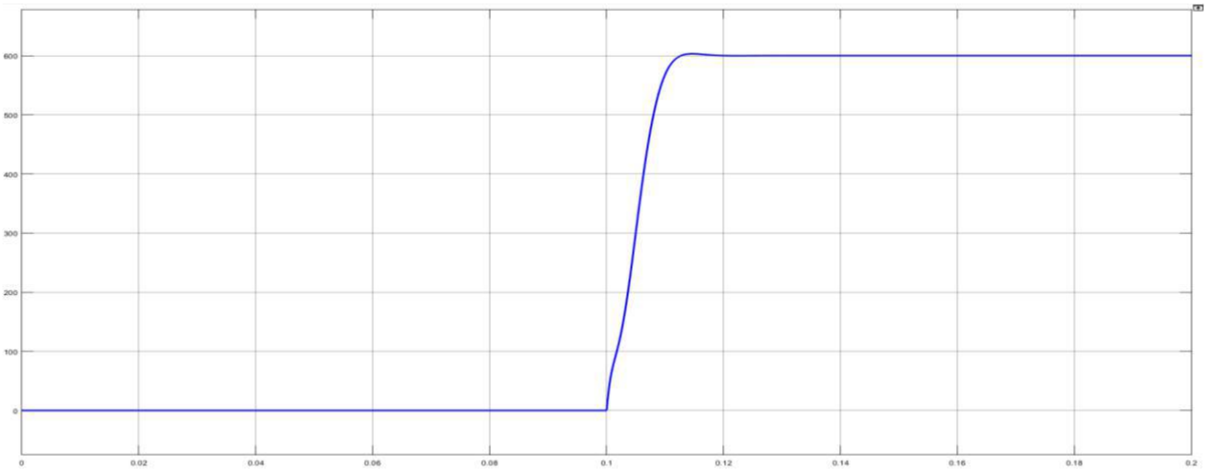
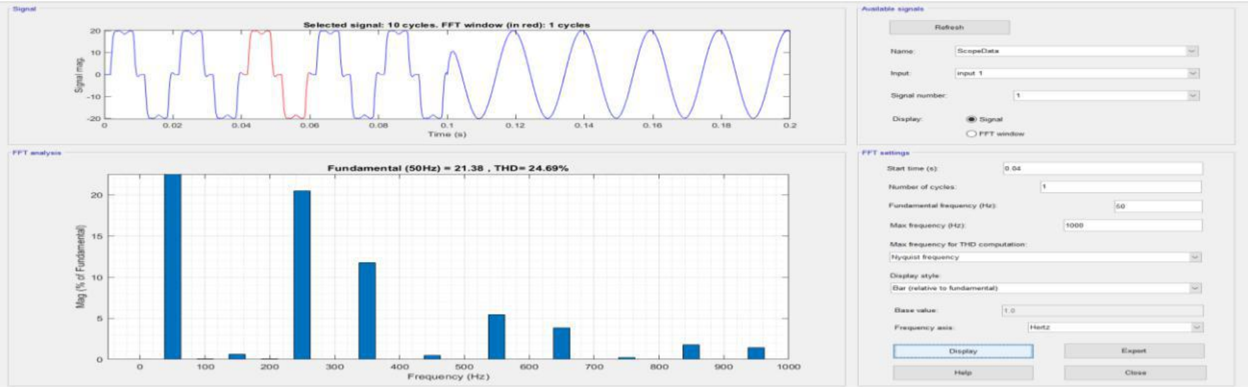


Fig 6. DC link capacitor voltage.



Fundamental (50Hz) = 21.38 , THD= 24.69%

Name: ScopeData
Input: input 1
Signal number: 1
Display: ● Signal ○ FFT window

Start time (s): 0.04
Number of cycles: 1
Fundamental frequency (Hz): 50
Max frequency (Hz): 1000
Max frequency for THD computation: Nyquist frequency
Display style: Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz

Fig 7 THD% current before compensation

EXTENSION RESULTS

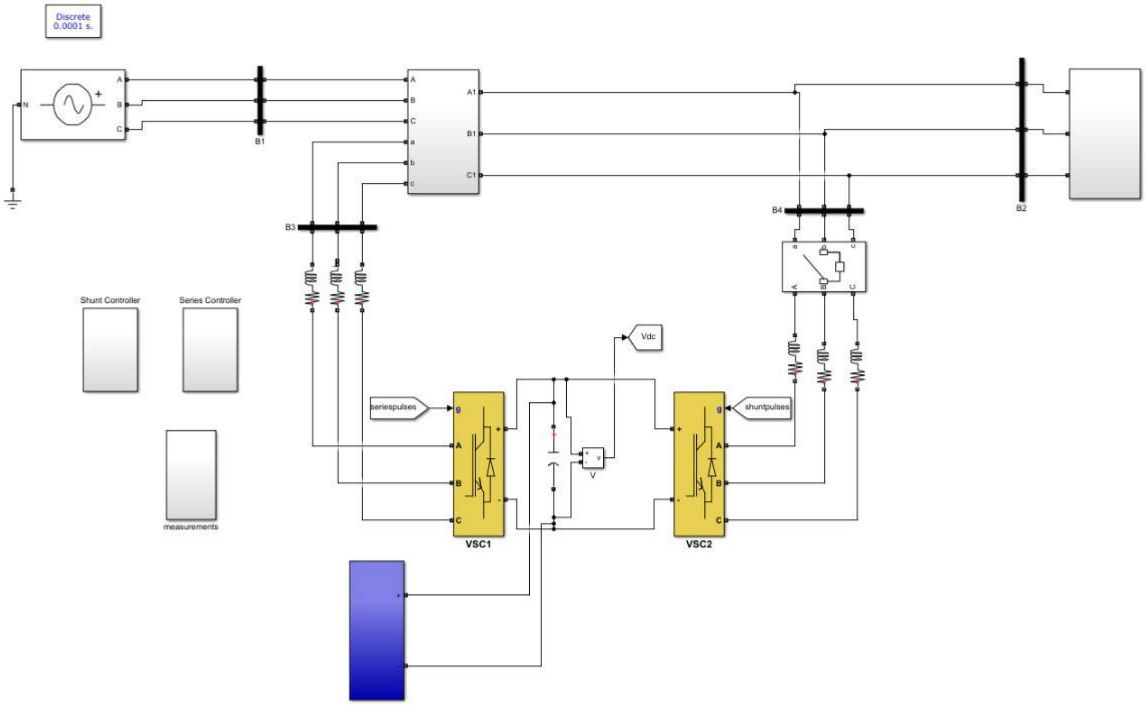


Fig.8 MATLAB/SIMULINK circuit diagram of the three-phase PV-UPQC scheme

Case-1 Under Voltage Sag Condition

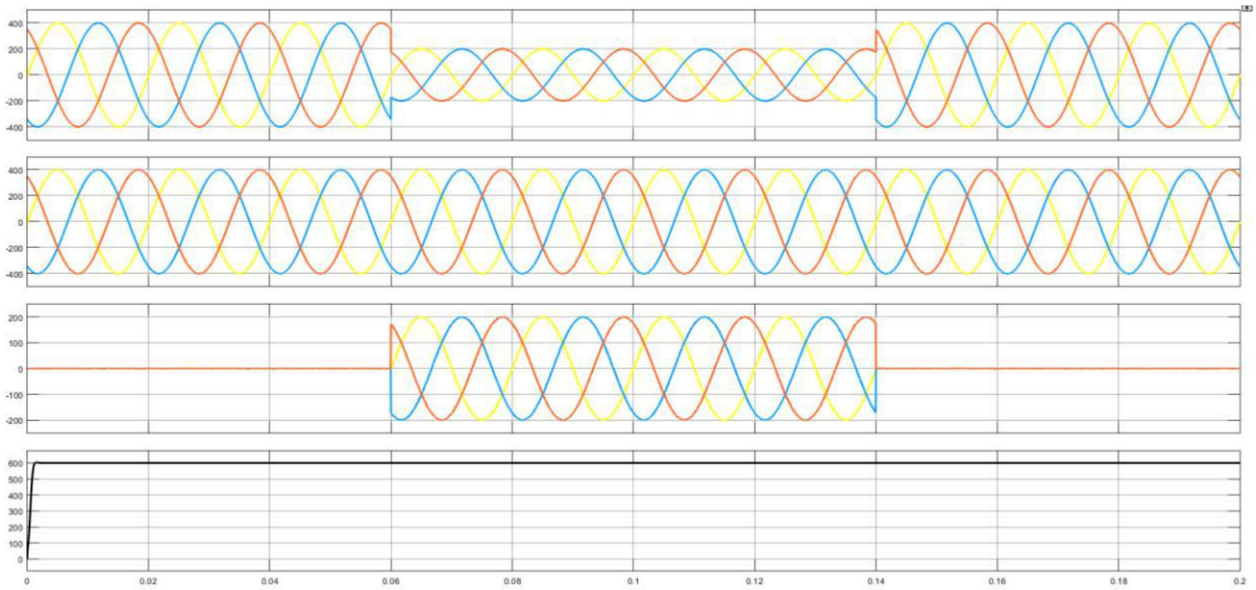


Fig 9(a) Supply voltage (b) Load voltage and (c)Compensation voltage (d) DC link voltage

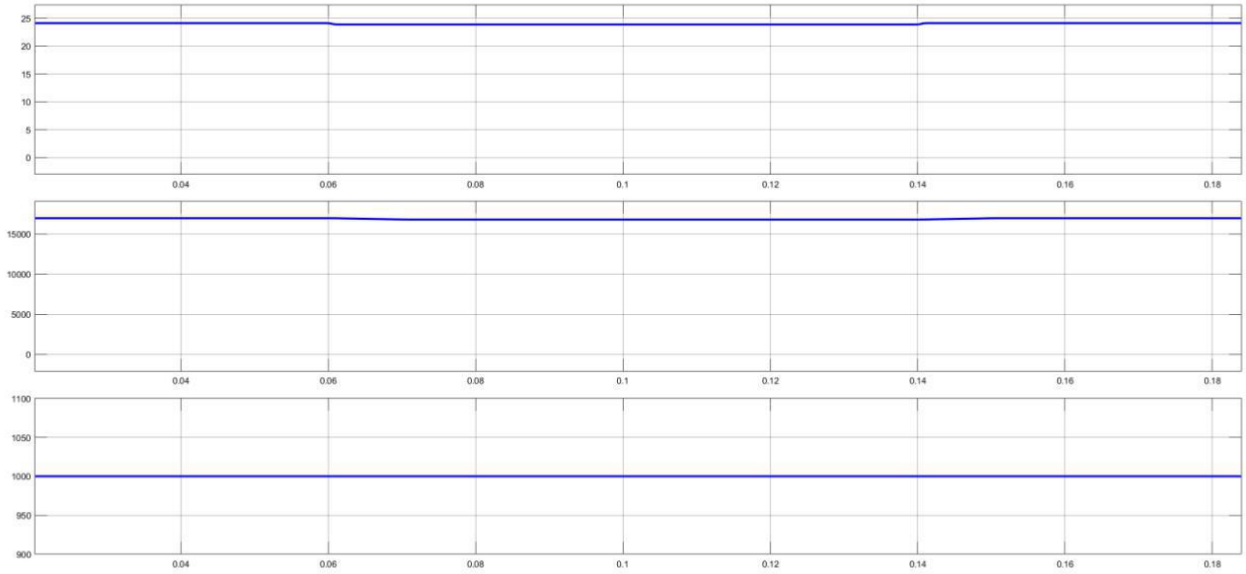


Fig 10 (a)PV current (b)PV power (c) irraidance

Case-2 Under Voltage Swell Condition

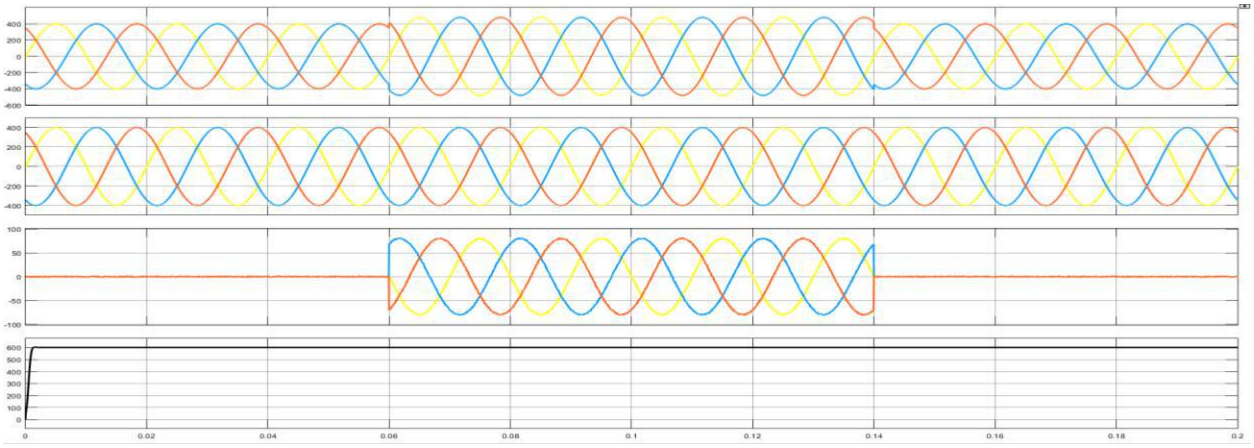


Fig 11 (a) Supply voltage (b) Load voltage and (c)Compensation voltage (d)DC-link voltage

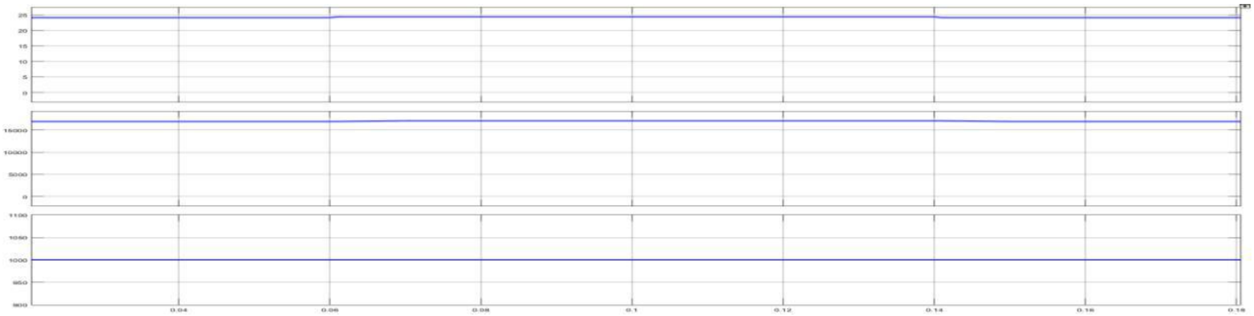


Fig 12 (a)PV current (b)PV power (c) irraidance

Case-3 Under Harmonics

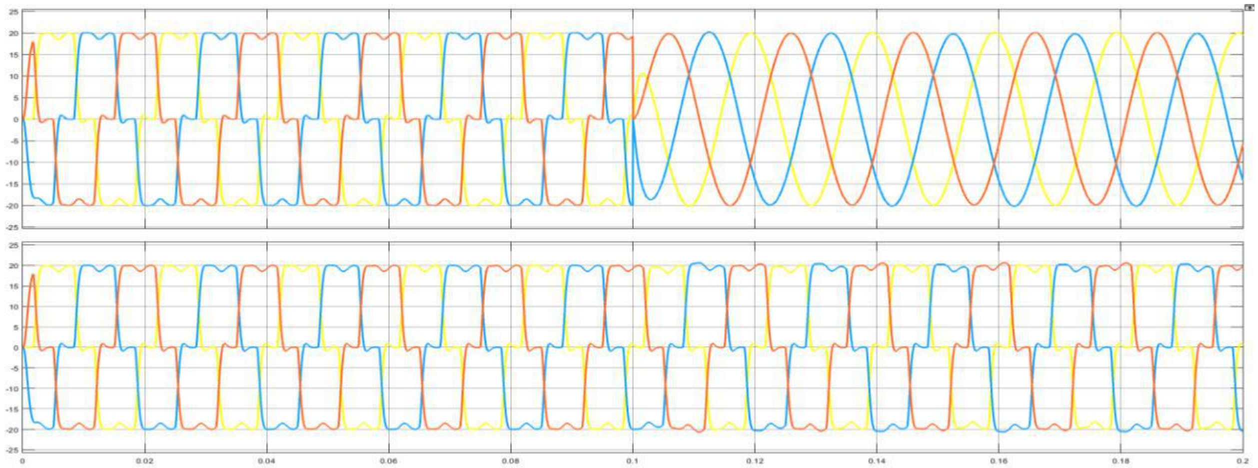
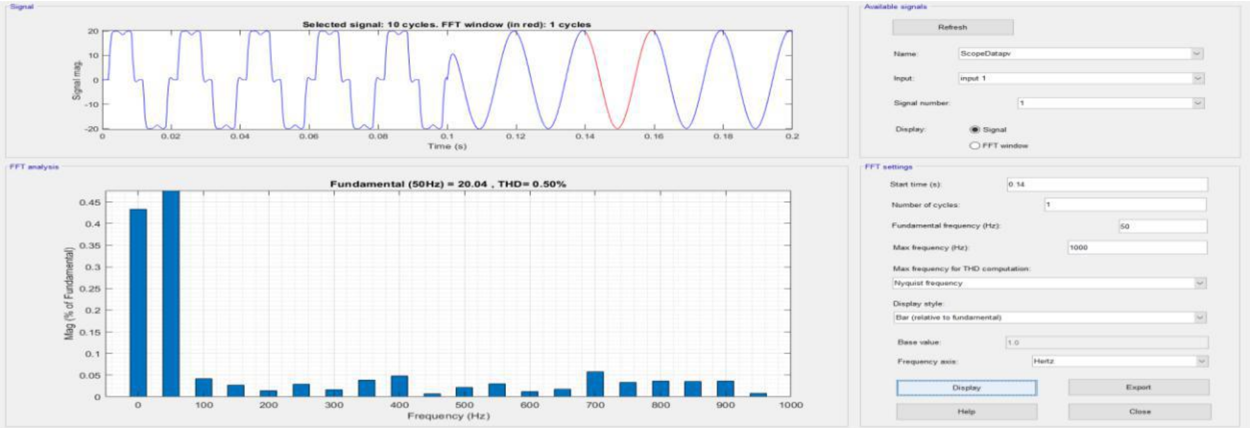


Fig 13 (a) Supply current (b) Load current



Name: ScopeDatapv
Input: input 1
Signal number: 1
Display: ● Signal ○ FFT window
Start time (s): 0.14
Number of cycles: 1
Fundamental frequency (Hz): 50
Max frequency (Hz): 1000
Max frequency for THD computation: Nyquist frequency
Display style: Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz

Fig 14 THD% current after compensation

5. CONCLUSION:

PV integrated UPQC using FLC has been investigated for compensating reactive power and harmonics. It is clear from the simulation results that the PV-UPQC using FLC is simple, and is based on sensing the line currents only. The THD of the source voltage using the proposed FLC is well below 5%, the harmonic limit imposed by IEEE- 519 standard.

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