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Some Aspects on Design and Analysis of Three-Phase Unified Power Quality Conditioner(UPQC) Integrated with Solar PV Generation

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Abstract - This paper presents a new topology of model predictive current MPC controller based PV-UPQC to improve power quality problems in electrical power systems. with the use of MPC controller based PV-UPQC, the speed of response and accuracy of power system increases. UPQC is the combination of both series and shunt controllers connected to the transmission or distribution system to improve power quality. The shunt controller improves current profile and series controller improves voltage profile in the electrical power system, therefore with the help of UPQC we can control active and reactive power profiles. In this paper the proposed MPC controller based PV-UPQC is analyzed under three different scenarios. In the first scenario analyze the MPC controller performance under grid sag/swell condition.. In the second scenario analyze the MPC controller performance under load unbalance condition. In the third scenario analyze the MPC controller performance under ramp change in solar irradiation by using MATLAB Simulink software.

Key Words: **Solar Irradiation, MPC controller, Power Quality, UPQC, Sag, Swell.**

1.INTRODUCTION

There is an emphasis on clean energy generation is increasing day by day and the solar pv generation is such clean energy generation sources available abundantly. The power quality of electric power has become an important issue in electrical power system operation in the last few years. But due to the sporadic behavior of the pv energy sources and also the increased interconnection of such pv systems particularly in weaken distribution systems leading to voltage quality(power quality) problems like voltage swells/voltage sags which ultimately lead to the grid instability. With the advancement of semiconductor technology there is an increased penetration of power electronic loads which draws nonlinear currents these currents cause voltage distortion problems at the point of common coupling in the distribution systems. These voltage quality problems lead to frequent false tripping of power electronic systems, malfunctioning and false triggering system components. Power quality issues at both load side and grid side are the major problems faced by modern distribution systems integrated with the three-phase renewable Grid interfaced sources.

In this work, a unified power quality conditioner UPQC was considered. Solar PV integrated with UPQC has substantial advantages, including improved grid power quality and protection of critical loads from grid side disturbances. UPQC is a hybrid of shunt and series compensators. Shunt compensators address load power quality issues such as load current harmonics and load reactive power while also extracting power from the PV-array using Maximum Power Point Tracking (MPPT). By injecting an appropriate voltage in phase with the grid voltage, the series compensator protects the load from grid side power quality problems such as voltage sags/swells. The generation of reference signals is the most important task in UPQC control.

The techniques for generating reference signals are broadly classified as time-domain and frequency-domain techniques. Instantaneous reactive power theory (p-q Theory), synchronous reference frame theory(d-q theory),and instantaneous symmetrical component theory are the most commonly used techniques. The main problem with using synchronous reference frame theory is that when the load is unbalanced, a double harmonic component is present in the d-axis current. As a result, UPQC's dynamic performance suffers. A moving average filter (MAF) is used to filter the d-axis current to obtain the fundamental load active current.

The Present Work Concentrated on Analysis of an UPQC integrated with Solar PV using MAF along with MPC to improve the dynamic performance. The proposed system is demonstrated/analyzed under the steady state and dynamic conditions by using MATLAB Simulink software.

II.SYSTEM CONFIGURATION PV-UPQC

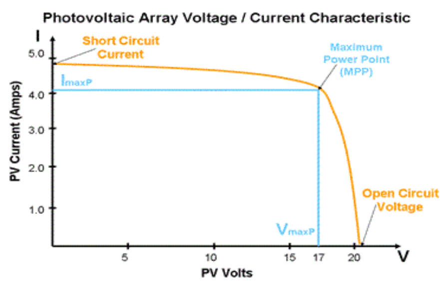

Figure 1. Shows that PV-UPQC system configuration

which consist of three phase non-linear load which is fed through the PV integratedthree phase UPQC consists of both the series and shunt compensators which are connected through a common DC-bus. The shunt compensator connected at the load side where as the series compensator operated in series voltage control mode and compensates the grid voltage swells and sags. The solar pv system is directly connected to the DC-link of the UPQC. A series injection transformer is used to inject the voltage generated by the series compensator and the series and shunt compensators are connected to the grid through the interfacing inductor which will reduce the harmonics which are generated through the converter switching action.

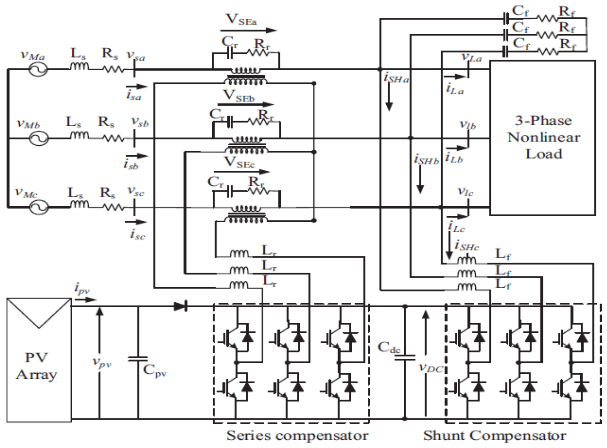

Fig -1: **PV-UPQC System configuration**

III. CONTROL OF PV-UPQC

(a)Control of PV-Array

Figure 2. Indicate the PV array model that is represented with independent current source paralleled with diode bank. PV Array generates voltage/current that is DC connected through the rectifier to the main grid. Figure 3. Shows the VI characteristics of the PV Array.

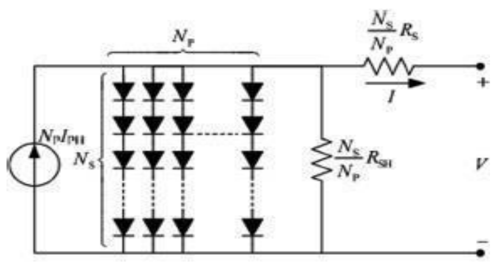

Fig-2:PV Array Model

Fig-3:PV Array characteristics

(b)Control scheme of shunt compensator

The UPQC's shunt APF control algorithm based on synchronous reference frame theory is used to control the shunt APF The shunt APF's goal is to improve the power quality of the supply current while also supporting the common DC bus of the shunt APF and the Series APF by absorbing active power. A block diagram of the Shunt APF's control scheme. As feedback signals, the UPQC's load currents(i_{La}, i_{Lb}, i_{Lc}), PCC voltages(v_{sa}, v_{sb}, v_{sc})), and DC bus voltage (V_{dc})are sensed.

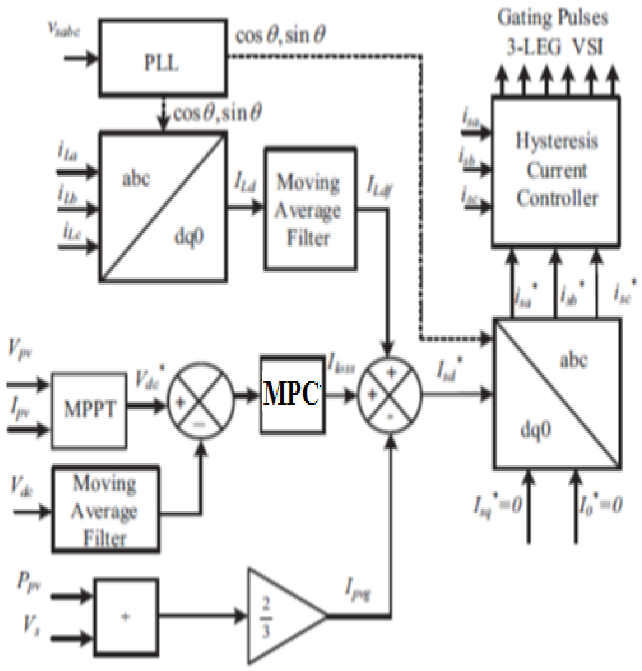

Fig 4: Control scheme of shunt compensator

(c)Control of Series compensator(Series APF):

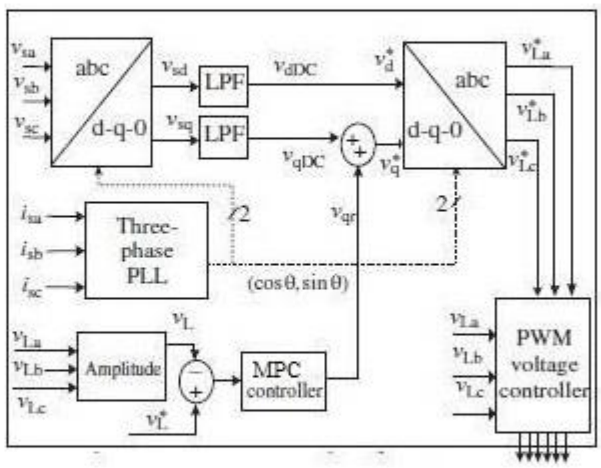

Fig 5: Control Scheme of Series Compensator

IV. Simulation Results:

PCC line voltage and system frequency	415V,50Hz
DC-link Voltage	700V
DC-link capacitor	9.3mF
Shunt and series compensator	1mH,3.6mH

interfacing inductors	
PWM switching frequency	10KHz
Ripple filter	10micro F
MPC controller parameters	Ts=0.1,p=10, m=2
PV Array open circuit voltage	864V
Short circuit current of PV Array	62.65A
MPP Voltage	701V
MPP Current	58.94A
PV Array power	41.35KW

Table-1

System parameters used for MPC based PV-UPQC

(a)Performance of PV-UPQC under voltage sag and swell conditions:

A voltage sag of 0.3pu is applied from 0.7 to 0.75s and a 0.3pu voltage swell from 0.8 to 0.85s is applied. The behavior of the PV-UPQC under these conditions is shown below.

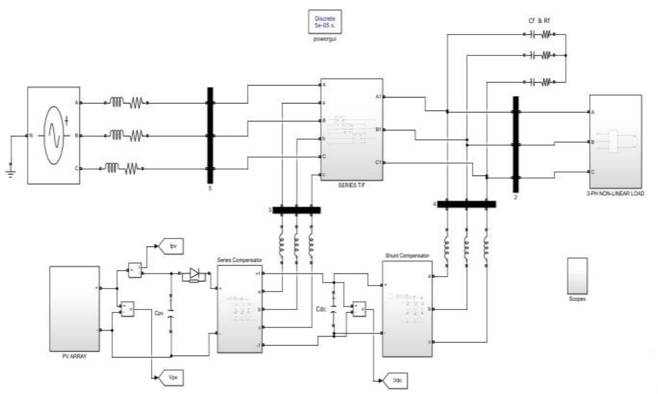

Fig6: Simulation model of MPC based PV-UPQC under Voltage Sag and Swell Conditions.

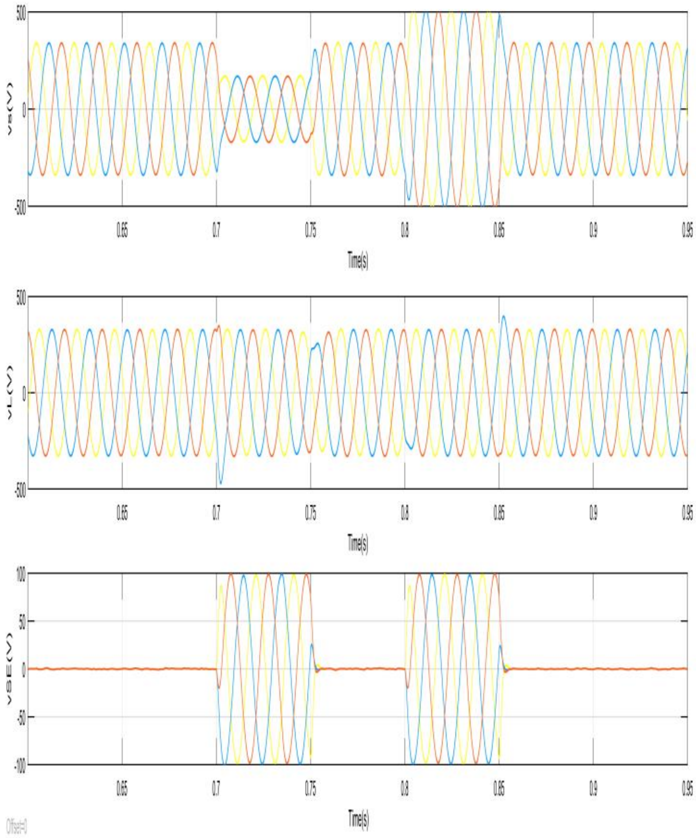

Fig 7(a):PCC Voltages(Vs),Load Voltages(vL),Dc link volates(Vdc)

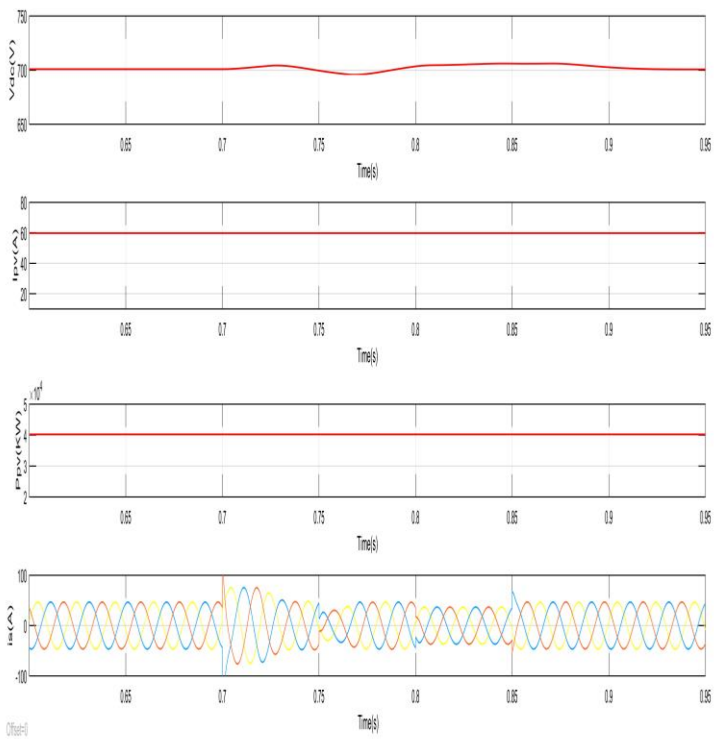

Fig 7(b): Solar PV array current(Ipv),Solar PV Array power(Ppv),Grid Current(is),Solar irradiation(G).

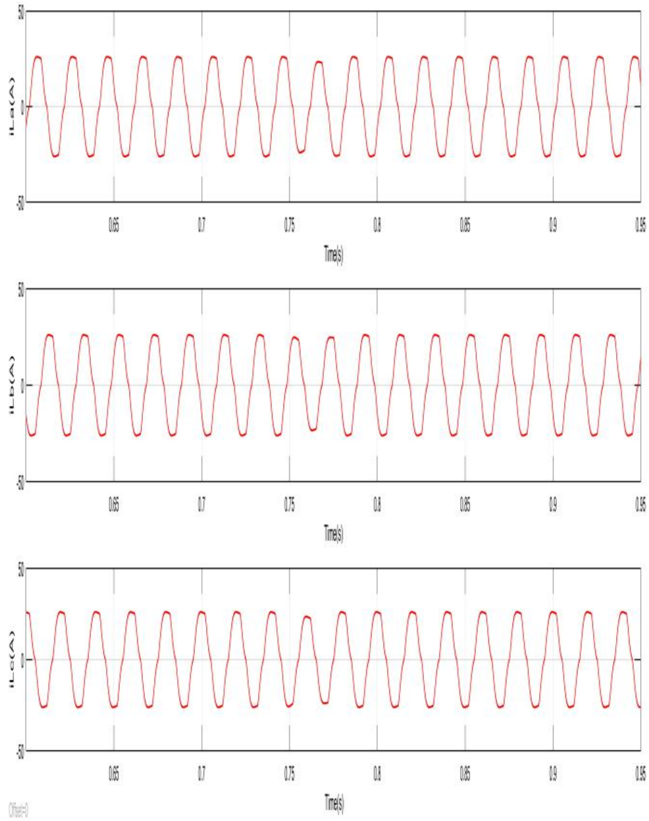

Fig7(c): Load Currents(iLa,iLb,iLc)

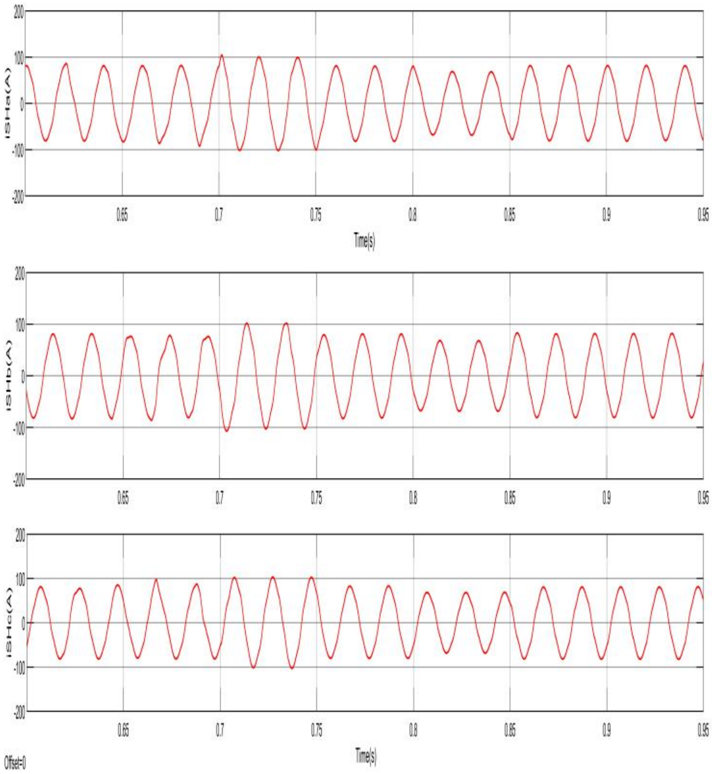

Fig 7(d): Shunt Compensator Currents(iSHa,iSHb,iSHc)

(b)Performance of PV-UPQC under load Un-balance Condition:

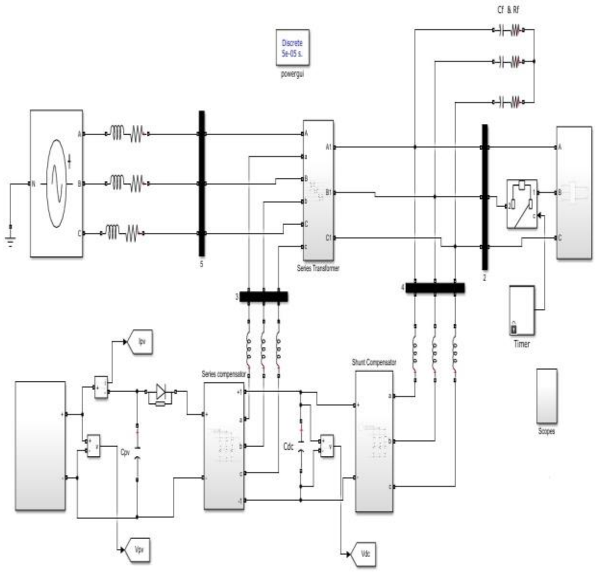

Fig 8: Simulation model PV-UPQC under load un-balance condition.

Figure 8 depicts the dynamic performance of PV-UPQC under load unbalance conditions. The load's phase 'b' is separated at t=0.8s. The voltage across the DC-link is close to the regulated value of 700V. The source current is sinusoidal, with a power factor of one. Because of the decrease in overall load, the current supplied to the grid is increased.

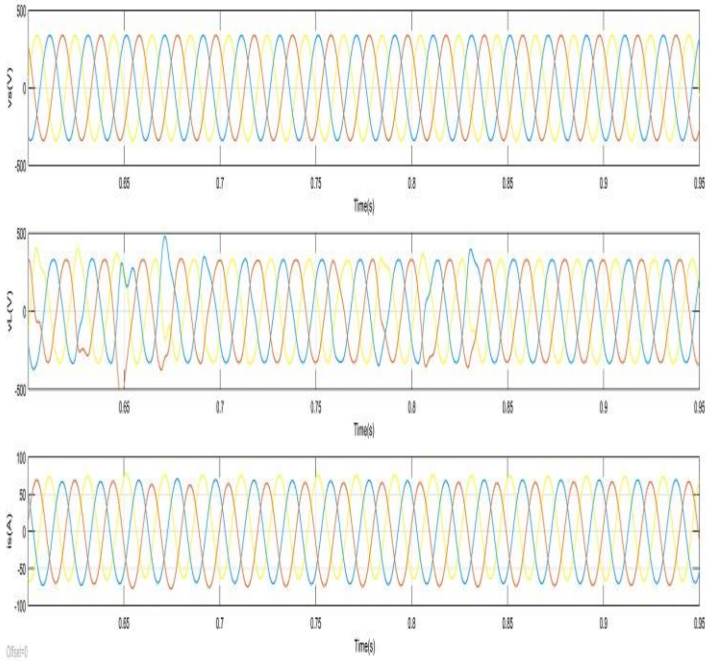

Fig 9(a): PCC voltages(Vs),Load Voltages(vL),Dc Link voltage(Vdc)

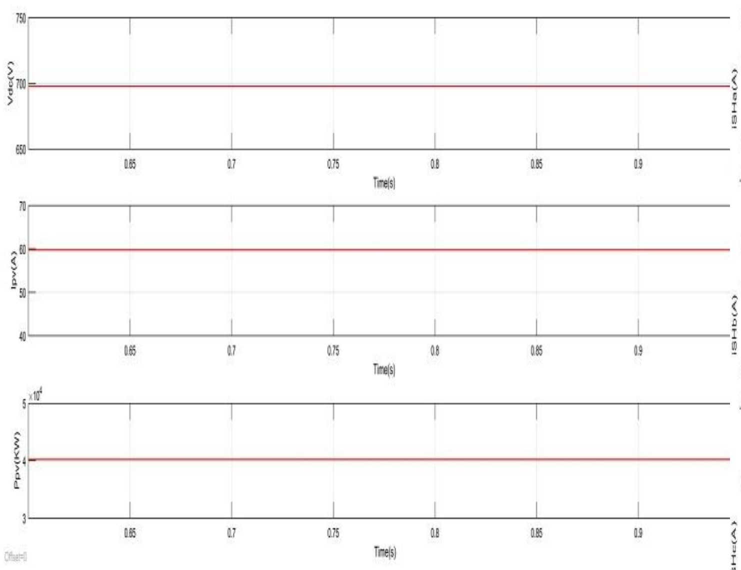

Fig 9(b): Solar PV array current(Ipv),solar PV array power(Ppv),Grid current(is)

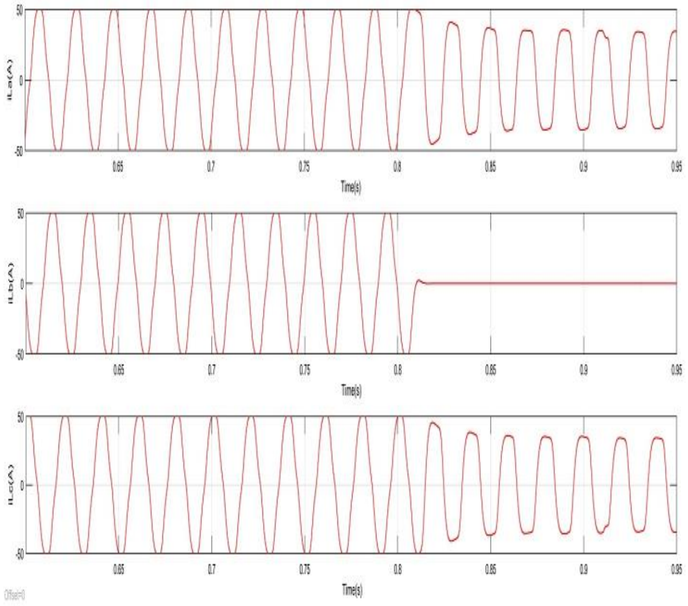

Fig 9(c): Load Currents(iLa,iLb,iLc)

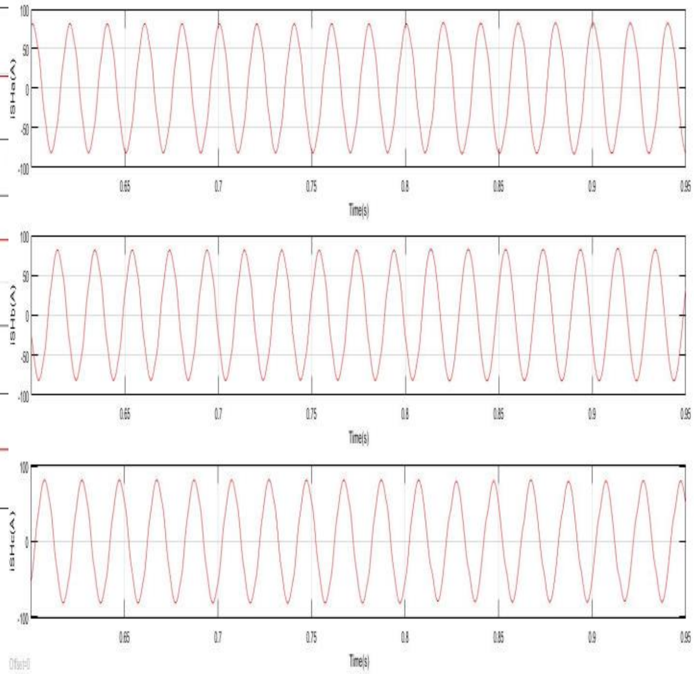

Fig 9(d): Shunt Compensator currents(iSHa,iSHb,iSHc)

(c) Performance of PV-UPQC under varying irradiation condition:

Figure 10 depicts the dynamic performance of PV-UPQC under changing irradiation. The irradiation fluctuates between 500W/m2 at 0.85s .As irradiation increases, the PV array output increases, and thus the system current rises as the PV Array induces power into the system. The shunt compensator tracks MPPT by regulating harmonics, considering loadcurrent.

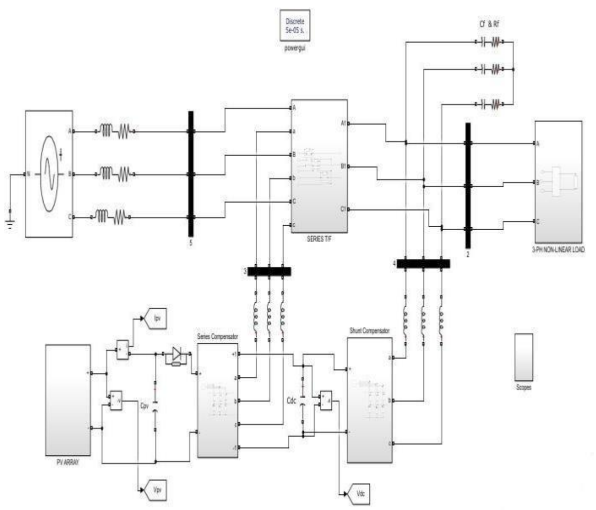

Fig 10: Simulation model PV-UPQC under varying irradiation condition

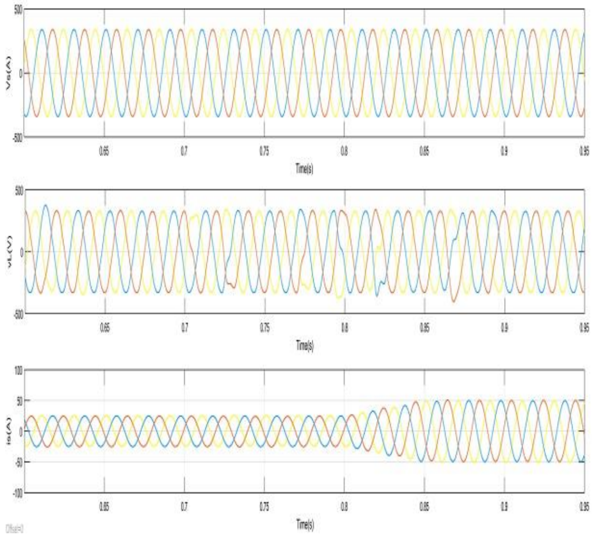

Fig 11(a): Source voltage(Vs),Load voltage(vL),grid Current(is).

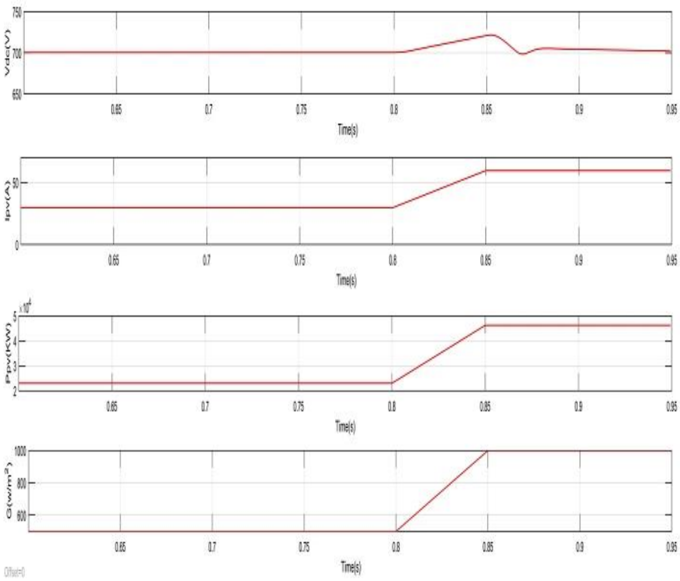

Fig11(b):DC Link Voltage(Vdc)solar PV current(Ipv),Solar PV power(Ppv),Solar irradiance(G).

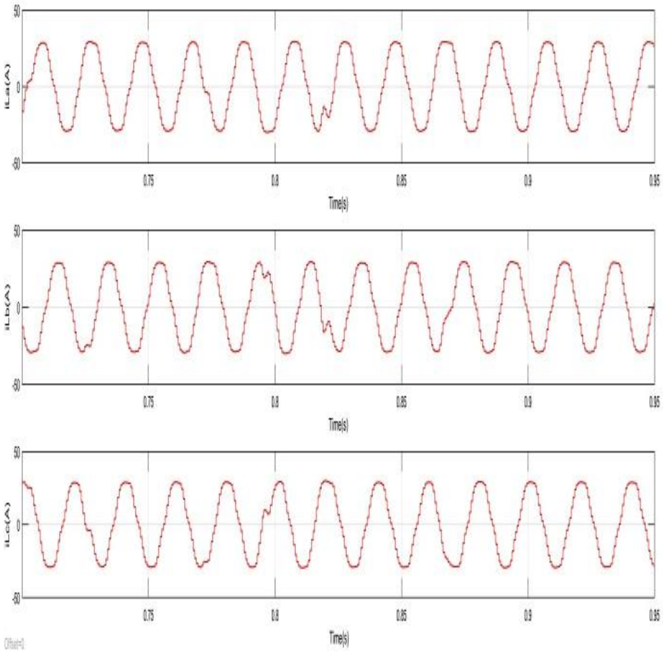

Fig 11(c): Load Currents(iLa,iLb,iLc)

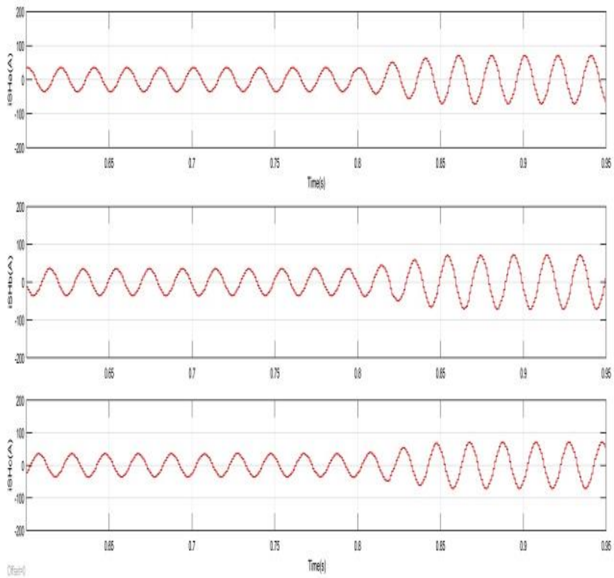

Fig 11(d): Shunt Compensator currents(iSHa,iSHb,iSHc)

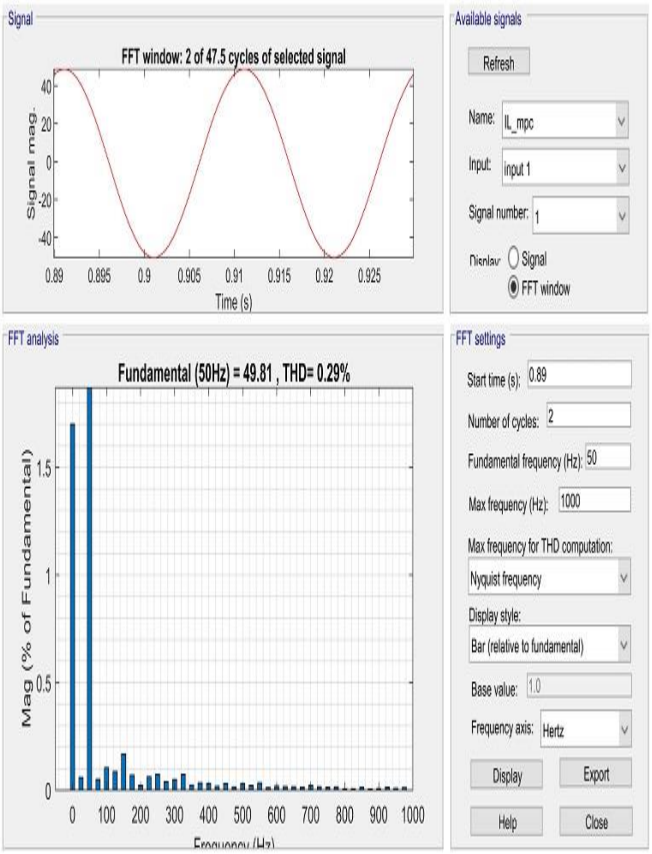

Fig 11(e): Total Harmonic Distortion(THD) in Grid Current

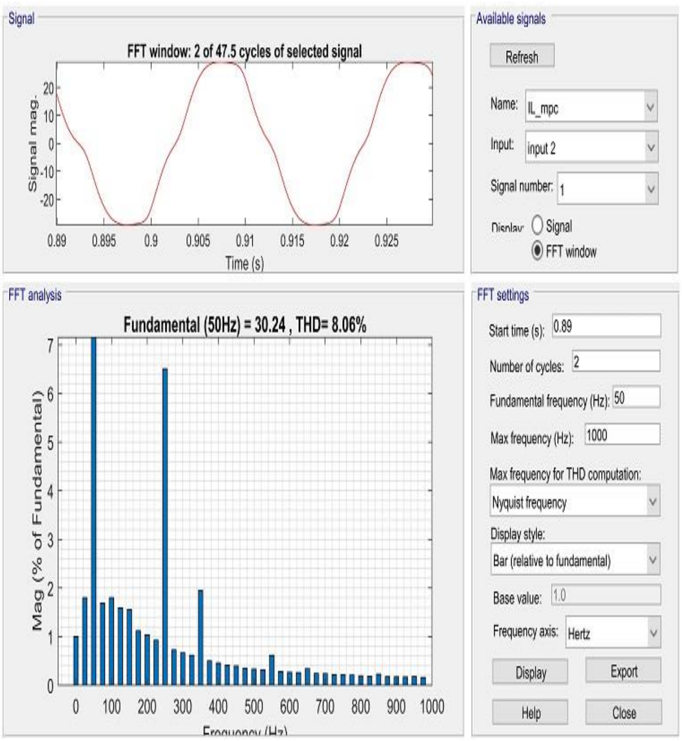

Fig 11(f): Total Harmonic Distortion(THD) in Load Current.

Table-2: Comparison of THD values:

Comparison of Total Harmonic Distortion	
THD PI CONTROLLER	THD(MPC Controller)
Grid Currents=21.06%	Grid Currents=8.06%
Load Currents=1.49%	Load Currents=0.29%

The THD Value of the both PI and MPC controllers are compared in the above table no.2.It is observed that the Grid Current and Load current THD Value are reduced with MPC when compared with the PI Controller and are maintained under the limitation of IEEE 519-1992 Standards.(31)

CONCLUSION

The Design and simulation of MPC controller based PV-UPQC have been analyzed under some aspects such as load unbalance,variable irradiation and grid voltage sags/swells. The performance of the system has been tested and verified through MATLAB/SIMULINK software. It is observed that PV-UPQC based on MPC Controllers mitigates harmonics caused by nonlinear load and keeps grid current THD within IEEE-519 limits. By using model predictive current(MPC) controller, the performance of d-q control has been improved, particularly in load unbalanced conditions. With the help of a MPC controller based PV-UPQC, system performance is improved under varying irradiation, voltage sags/swell, and load unbalance.

Finally, PV-UPQC based on MPC controllers is a good solution for modern transmission and distribution systems to improve power quality.

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