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Solar PV based UPQC for Power Quality Enhancement in Distribution Power System

M.lal sandeep[a], T. Anil Kumar[b]

Abstract

This article presents a improved comprehensive integrator with DC offset suppression ability for controlling UPQC with SPVA. Recently, power generation and transmission capacity has not increased proportionally to meet global demand. FACTS devices reach the interest of the knee as a means of improving the capacity of the existing transmission network. Among the FACTS devices UPQC is the most effective device thanks to its simultaneous or selective sustenance for voltage controlling, UPQC was developed to reduce control costs and the resilience of the electrical grid. In UPQC control based on the existing system there are still some distortions in the output voltage and high distortions in the current waveforms. There should be some other necessary development in the circuit for a complete reduction of harmonics or distortion. So, to overcome the problems. This document proposes an intelligent UPQC configuration based on a photovoltaic cell for a three-phase Micro-grid system. In this document a photovoltaic solar cell is used in the circuit and is connected in parallel to the DC link. By connecting the photovoltaic solar cell to the existing system, the real and reactive power as well as the voltage and current characteristics are improved. The projected controller is executed using MATLAB / Simulink.

Keywords: Power quality, UPQC, PV Solar cell, Voltage and Current distortions

1. Introduction

The extensive use of non-linear loads is foremost to a number of undesirable spectacles in the process of electrical systems. The harmonic apparatuses in the current and voltage wave form are the furthermost significant between them. Conventionally, passive filters have been used to remove harmonics of the current. Though, they present quality into the power system and incline to be immense. Consequently, active filters have developed more widespread than passive filters, as they simultaneously compensate for harmonics and wattless power.

The APF analysis can be associated in series/shunt and mixtures of both. The active shunt filter is more popular than the series APF since most engineering applications need to mitigate of current harmonics . Different kinds of APF have been projected to rise the excellence of the electrical system. The organization is constructed on the subsequent criteria [8]. Insignificant power and response rapidity mandatory in the remunerated system. Structure constraints to recompense. Method used to approximation the orientation current / voltage [13]. Inverters with a current controlled voltage source used with a strategy regulator system to perform the function of an APF[4]. Grid energy includes a huge number of small manufacturers using RES, such as solar plates or wind turbines. [1] deliberated harmonic interface between a huge number of distributed influence inverters and the distribution grid. This effort is to examine the detected harmonic interfering phenomena of huge peoples of these inverters and equivalence the grid interface of unlike inverter topologies and regulator options [14] Offered on the argument of linear and non-linear loads in 3-φ power converters linked in parallel, without statement between the m zones of the converter enlivens the steadfastness of the problem that ascends when two converters with harmonic Returns are linked in parallel [2]. This article recommends the supportive control of multiple voltage complex active filters for harmonic hindering in whole power distribution system. The design of definite supply system would modification based on system presentation and / or fault situations. Still, the shunt capacitors and loads are independently associated or detached from the distribution system [3]. He offered the discovery of the positive sequence component of the important frequency of the mains energy under unstable and partial conditions [12]. Precisely, it recommends a positive arrangement detector based PLL (phase-locked loop)[4] . This article provides an overview of DPGS installations based on fuel cells, photovoltaics and wind turbines [5]. This article recommends that distributed energy resources are progressively required as a accompaniment and substitute to huge conservative power plants. The requirement of an electronic power boundary is focus to supplies connected not only to the RES, but also to its belongings on the process of the electrical system, particularly when the recurrent energy source establishes a noteworthy part of the volume. [6]. The construction of the PV-UPQC is exposed in Fig. 1. The PV-UPQC is calculated for a 3-φ system. The PV-UPQC contains of a series and shunt APF linked to a joint DC bus. The sidestep compensator is allied downstream. [11] The PV is directly combined into the UPQC DC-link by a opposite delaying diode [9]. The series APF works in voltage control mode and mitigate for mains voltage problems. Series and branch APF are combined into the grid by boundary inductors. A series inoculation transformer is used to inoculate the voltage produced by the series APF into the network[10].

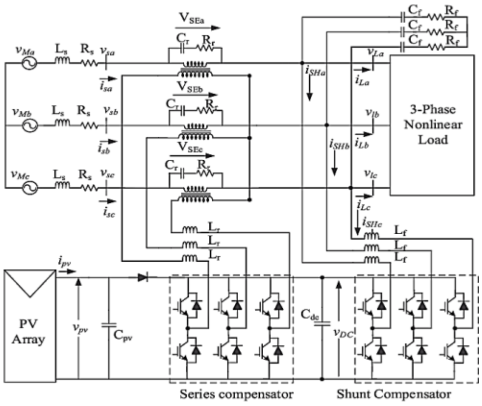

Fig.1. System outline of PV-UPQC

1.1 Series -APF

The purpose of the APF series is to nearby change the resistance of the network. It is measured as a source of harmonic energy that cancels the voltage disturbances coming after the network or formed by the movement of "harmonic" currents in the resistance of the network. Though, the series APFs cannot compensation for the harmonic currents formed by the loads.

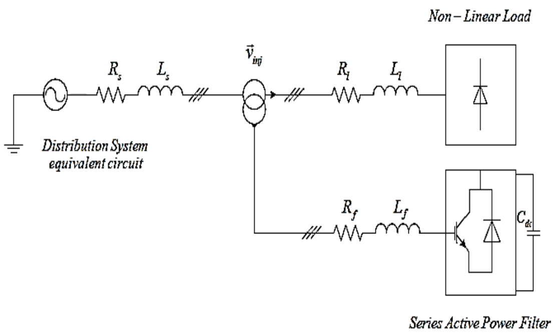

Fig. 2. Series APF

1.2 Shunt APF

The S-APF is linked in shunt with the loads that produce harmonics. They are predictable to inoculate in actual time harmonic currents riveted by the adulterating loads. So, current will convert sinusoidal.

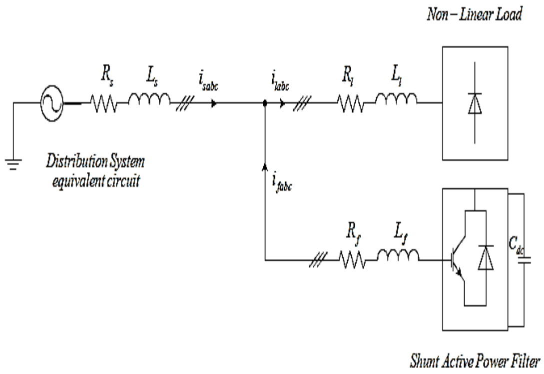

Fig. 2. Shunt APF

2. Active and Reactive Power Theory

The elementary idea is that harmonic currents produced by non-linear loads in the power structure can be remunerated for with other non-linear measured loads. P-Q theory is created on a immediate powers distinct in the time province. 3-φ voltages (va, vb, vc) and currents (ia, ib, ic) are converted by Clarke transformation (or α-β) into a different synchronize system that products instant active and reactive power apparatuses. This alteration can be observed as a estimate of triphasic measures on a motionless two-axis reference frame. The Clarke alteration for the voltage variable quantity is given by

$$\begin{bmatrix} v_\propto \\ v_\beta \\ v_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \quad (1)$$

Likewise, this convert can be functional on the partial load currents to give:

$$\begin{bmatrix} i_{l\propto} \\ i_{l\beta} \\ i_{l0} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \quad (2)$$

The immediate active power *p(t)* is definite by:

$$p(t) = u_a i_{la} + u_b i_{lb} + u_c i_{lc} \quad (3)$$

This appearance can be given in the fixed frame by:

$$\begin{cases} p(t) = u_\propto i_{l\propto} + u_\beta i_{l\beta} \\ p_o(t) = u_o i_{lo} \end{cases} \quad (4)$$

Where, *p(t)* is the instant real power, *p0(t)* is the instant homo-polar arrangement power. Also, the immediate reactive power can be assumed by:

$$q(t) = -\frac{1}{\sqrt{3}}[(u_a - u_b)i_{lc} + (u_b - u_c)i_{la} + (u_c - u_a)i_{lb}] = u_\propto i_{l\beta} - u_\beta i_{l\propto} \quad (5)$$

It is significant to message that immediate reactive power q (t) means more than just responsive power. Immediate reactive power receipts into explanation all current and voltage harmonics, whereas typical reactive power considers only current and "voltage" fundamentals.

From equations (4) and (5) the immediate real and volatile power can be specified in matrix arrangement by:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} u_{\propto} & u_{\beta} \\ -u_{\beta} & u_{\alpha} \end{bmatrix} \begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} \qquad (6)$$

In over-all, each of the real and useless immediate powers covers a direct constituent and an substitute section. The direct constituent of each offerings the power of the essentials of current and voltage. The dissimilar term is the harmonic power of currents and voltages. After unravelling the direct and discontinuous immediate power terms, the harmonic apparatuses of the load currents can be given by means of the opposite of equation (6) which gives:

$$\begin{bmatrix} i_{l\alpha} \\ i_{l\beta} \end{bmatrix} = \frac{1}{v_{s\propto}^2 + v_{s\beta}^2} \begin{bmatrix} v_{s\propto} & -v_{s\beta} \\ v_{s\beta} & v_{s\alpha} \end{bmatrix} \begin{bmatrix} \tilde{p}_l \\ \tilde{q}_l \end{bmatrix} \qquad (7)$$

The APF orientation current can be then given by:

$$\begin{bmatrix} i_{fa}^* \\ i_{fb}^* \\ i_{fc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \tilde{i}_{l\alpha} \\ \tilde{i}_{l\beta} \end{bmatrix} \qquad (8)$$

This technique proposals the benefit of the likelihood of harmonic reimbursement and / or reactive power reimbursement. In the case of reactive power reimbursement, it is sufficient to send the reactive power q(t) straight to the orientation current design block deprived of using any exclusion filter.

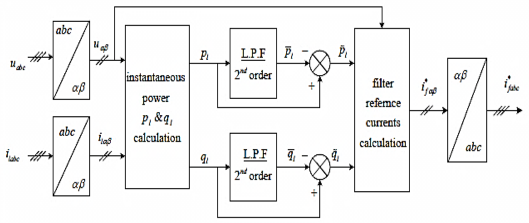

Fig. 3. Configuration of P-Q Theory

2.1 Modeling of Active Power Filter

The construction of the APF to the mutual mains connection point is mostly completed by a LPF RL as shown in Fig. 3. The voltage equation for each phase can be given by:

$$v_{sk} = v_{fk} - v_{L_{fk}} - v_{R_{fk}}$$

$$v_{fk} - L_f \frac{di_{fk}}{dt} - R_f i_{fk} \text{ , k=a,b,c} \qquad (9)$$

3-φ equations are then specified by:

$$L_f \frac{d}{dt} \begin{bmatrix} i_{fa} \\ i_{fb} \\ i_{fc} \end{bmatrix} = -R_f \begin{bmatrix} i_{fa} \\ i_{fb} \\ i_{fc} \end{bmatrix} + \begin{bmatrix} v_{fa} \\ v_{fb} \\ v_{fc} \end{bmatrix} - \begin{bmatrix} s_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \qquad (10)$$

And for the dc side:

$$C_{dc}.\frac{dV_{dc}}{dt} = S_a i_{fa} + S_b i_b + S_c i_f \qquad (11)$$

The equation system important the SAPF in the 3-φ frame is then given by: $$\begin{cases} L_f \frac{di_{fa}}{dt} = -R_f i_{fa} + v_{fa} - v_{sa} \\ L_f \frac{di_{fb}}{dt} = -R_f i_{fb} + v_{fb} - v_{sb} \\ L_f \frac{di_{fc}}{dt} = -R_f i_{fc} + v_{fc} - v_{sc} \end{cases} \quad (12)$$

3.Control method

The main subsystems of PV-UPQC are the shunt APF and the series APF. The shunt APF reimburses for load P.Q difficulties such as load THD and load Var power. In the circumstance of PV-UPQC, the evade compensator achieves the extra purpose of supply power after the PV array. The shunt APF excerpts energy from the PV using MPPT algorithm. The typical compensator defends the load from grid-side P. Q problems, such as voltage sags /swell, by injecting an passable voltage in phase with grid voltage. The sidestep compensator excerpts the extreme power from the PV solar field by working it at its MPPT. The MPPT algorithm generates the orientation voltage for the DC-Interface of the PV-UPQC.

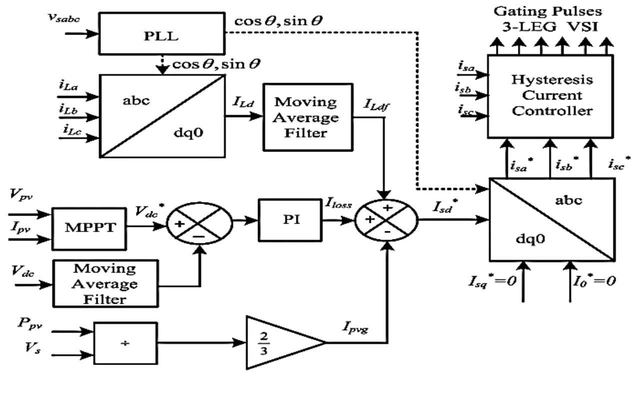

Fig. 5. Control structure of a shunt APF.

The control approaches for the series APF anticipate recompense, phase recompense, and optimum energy recompense. In this work, the series APF inoculates voltage in the similar phase as mains voltage, which results in a lowest inoculation voltage for the compensator series.

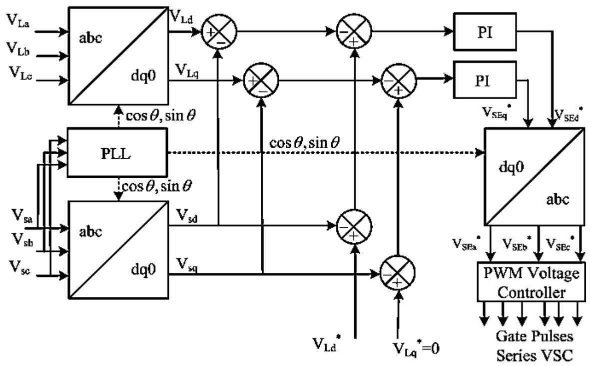

Fig. 6. Control structure of a series compensator.

4. Simulation Result:

The stationary and dynamic presentations of PV-UPQC are examined by pretending the scheme in MATLAB/Simulink. The load used is a nonlinear load containing of 3-φ diode bridge rectifiers with R-L load. The problem solver period scope used for the reproduction is 1e-6s. The system is exposed to several dynamic circumstances such as sag and swell in PCC voltage and PV contamination difference.

4.1. Simulation circuit without UPQC

4.1.1 Voltage with L-G fault

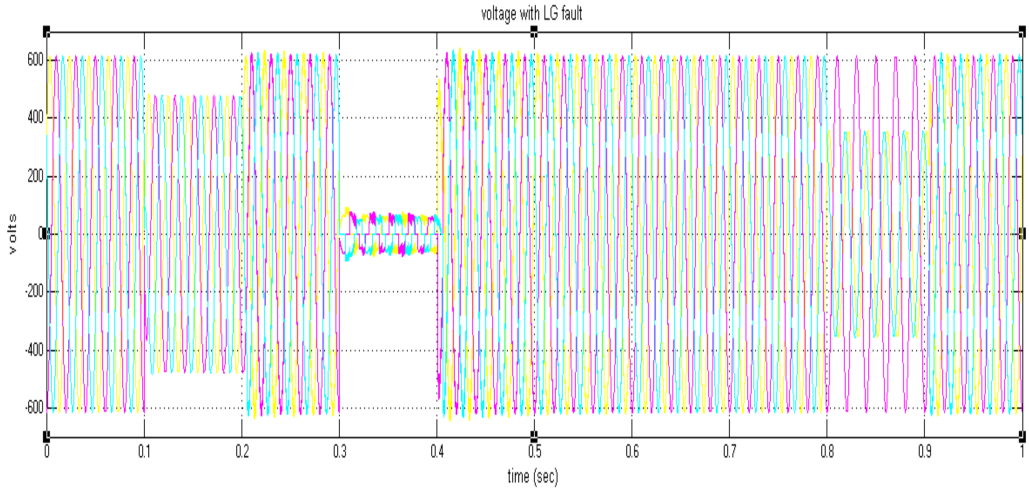

Fig.7. Results of Voltage with LG fault

4.1.2 Current waveform with LG fault

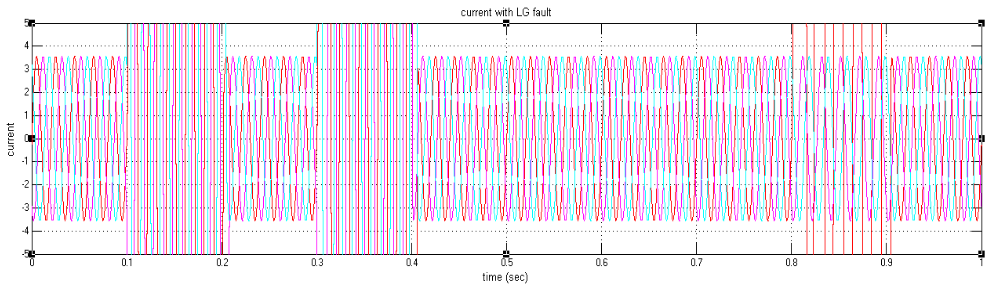

Fig.8. current waveform without UPQC

4.1.3Voltage waveform with LLG Faults

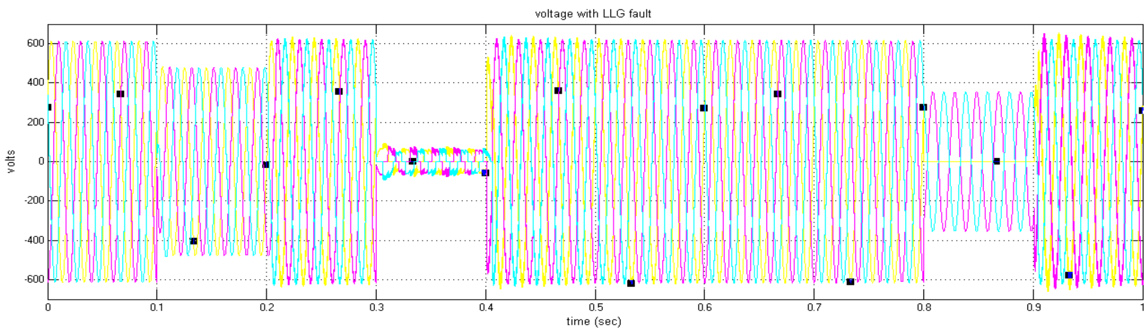

Fig.9. Results of Voltage with LLG fault

4.1.4 Current waveform with LLG Fault

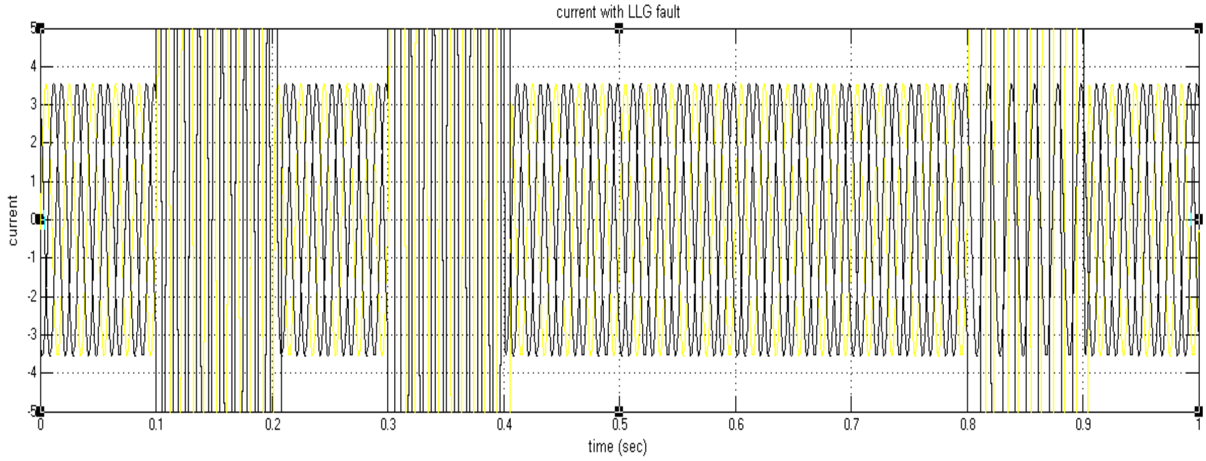

Fig.10. current waveform with LLG fault

4.1.5 Results of Voltage with LLLG Fault

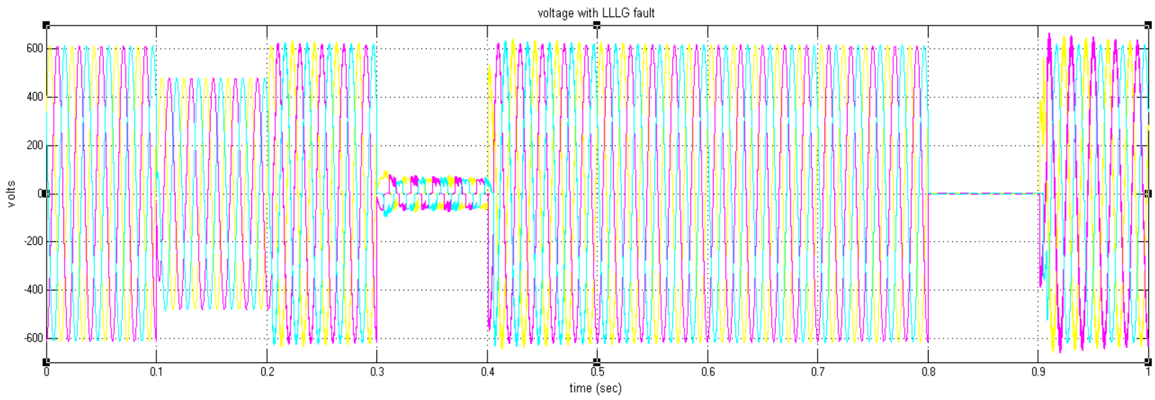

Fig.11. Results of Voltage with LLLG fault

4.1.6 Current waveform with LLLG Fault

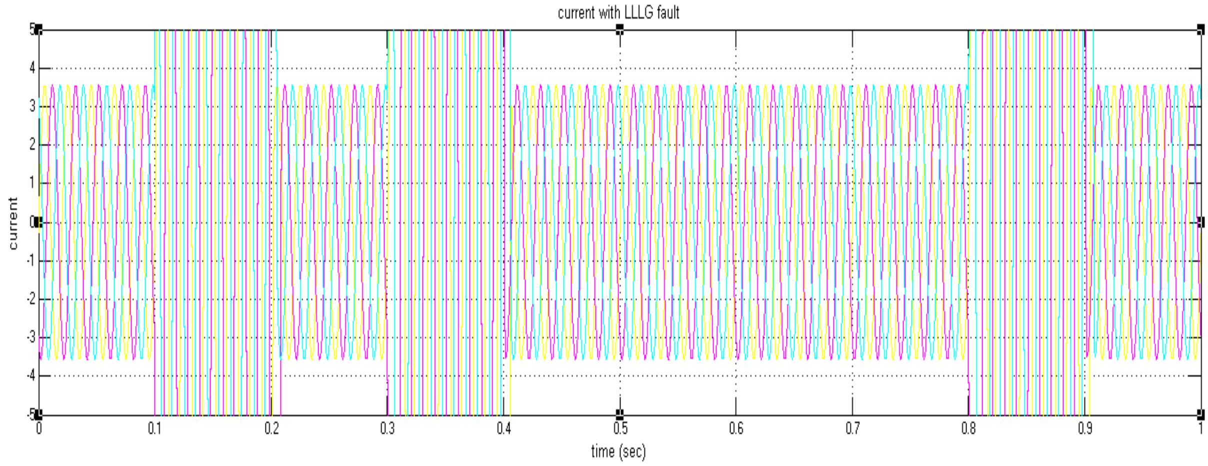

Fig.12. Results of current with "LLLG" fault4.1.7 Total Harmonic Distortion (THD)

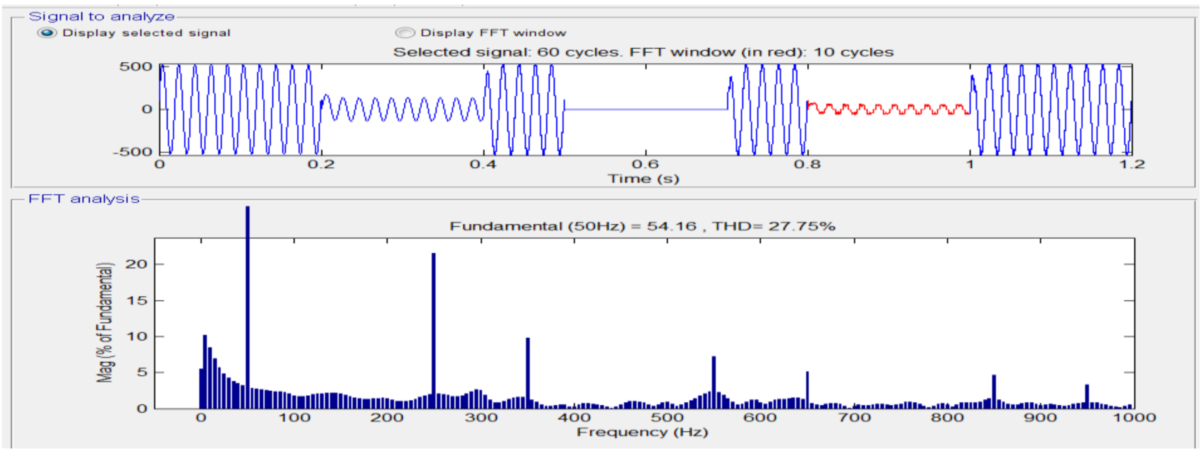

Fig.13. THD without controller

PV fed UPQC:

Output voltage waveform:

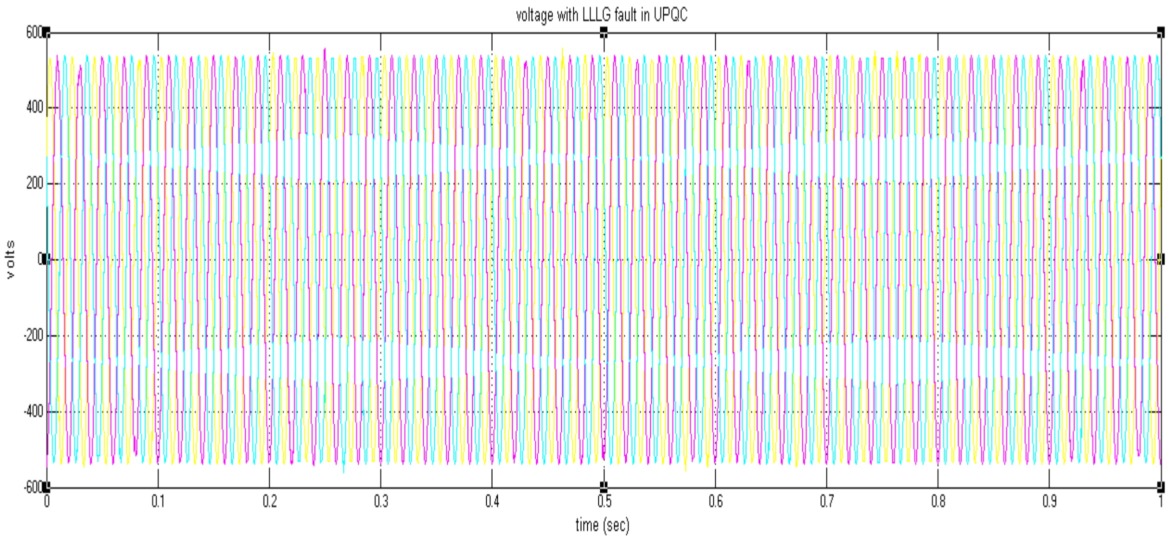

Fig.14. output voltage without any distortions.

The system with UPQC has generated a stabilized output voltage waveform without any distortions maintained during the LLLG fault condition.

Output current waveform:

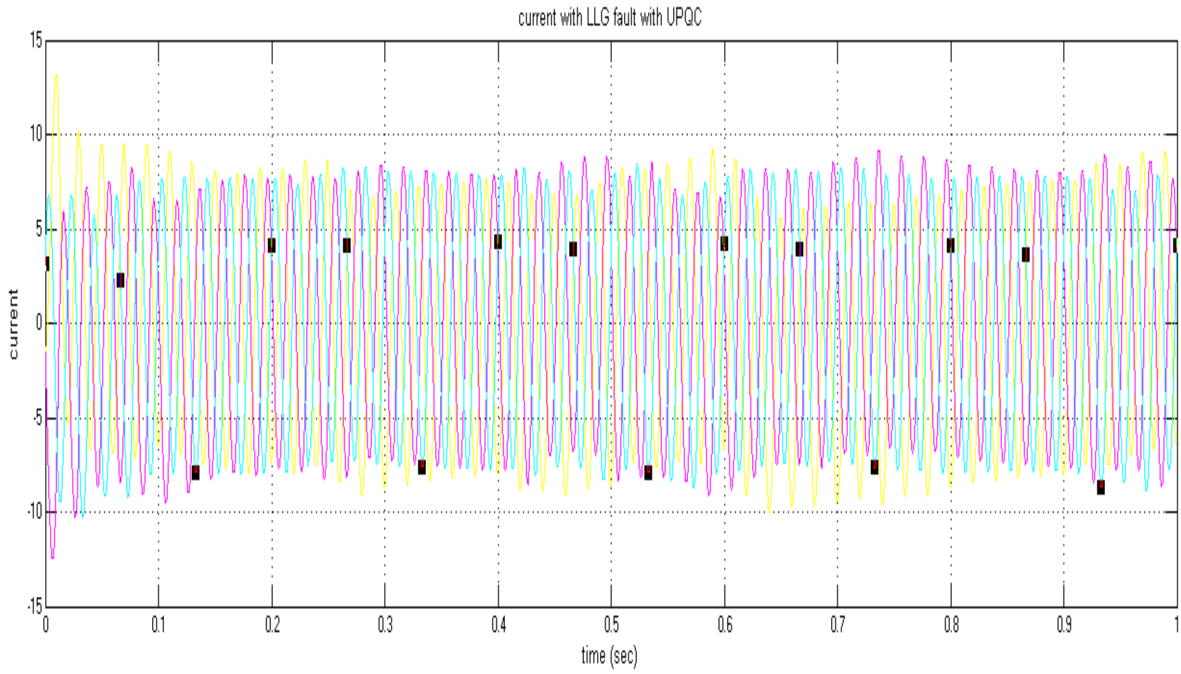

Fig.15.current waveform under LLLG fault.

The current waveform is still having some distortions under LLLG fault condition with UPQC Controller. This effects the system parameters.

4.1.8.THD with UPQC

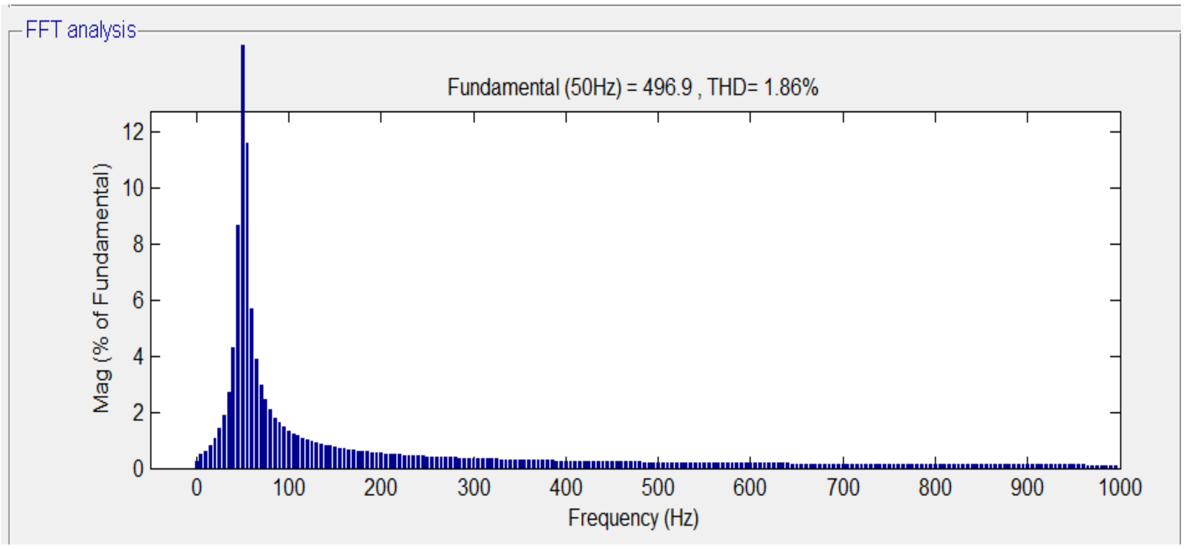

Fig .16. THD with UPQC controller5. Conclusion

The project and dynamic presentation of the 3-φ PV-UPQC have been examined beneath circumstances of adjustable irradiation and sudden / sudden changes in grid voltage. The proposed UPQC PV powered controller model, which is connected in parallel with the DC link capacitor in the three-phase microgrid system, reduced the total harmonic distortion to less than 5% compared to the existing control model and also the Waveforms of voltage and current are obtained without any distortion.

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