POWER QUALITY ANALYSIS IN A SOLAR PV PANEL CONNECTED GRID SYSTEM USING PI CONTROLLER

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Abstract
In this paper PI controller based power quality (PQ) analysis in grid connected Photovoltaic (PV) system has been proposed. The primary intention of the proposed method is to analize the power quality in a solar grid connected PV system using PI controller for both the normal and abnormal environment. Then the proposed method is implemented in the MATLAB/Simulink platform and the effectiveness is examined

Key words: PQ, PI controller, PV, grid, control signals, gain parameters

1. Introduction

For the last two decades [1] Renewable energy is very well known. Renewable energy sources are forecasted to turn out to be competitive with conventional power generation systems [2]. The efforts to widen the use of renewable energy resources instead of polluting fossil fuels and other forms have raised [3] [4]. Renewable energy source such as photovoltaic (PV), hydro, fuel and wind generation systems have obtained much attention newly as alternative means of producing electricity [5] [6].

The PV energy as an alternative energy source has been extensively employed since it is pollution free, plentiful, and largely accessible. The PV power generation applications can be splitted into two categories, stand-alone systems and grid connected systems. A stand-alone system needs the battery bank to accumulate the PV energy and is appropriate for a low power system. Alternatively, a grid connected system does not need the battery bank and has turned out to be the primary method for high power applications [7] [8].

Power quality is manipulated by three factors such as generation aspects, consumer aspects and network aspects [9]. Effects of poor power quality like sag, swell distortion in waveform, harmonics, and reactive power generation has affected both grid and utility sectors [10]. PV cells and power quality conditioner for voltage sags suggests to work out power quality issue by means of a voltage controlled converter that performs as a shunt controller enhancing the voltage quality in case of small voltage dips and in the presence of nonlinear loads. For stabilizing and improving voltage profile in power systems and to balance current harmonics and unbalanced load current shunt controllers can be employed as static VAR generator.[11]

PV systems can improve the operation of power systems by enhancing the voltage profile and by decreasing the energy losses of distribution feeders, the maintenance costs, and the loading of transformer tap changers during peak hours [12]. Planned for enhancing the energy competence and power quality issues with increasing demand, grid connected solar PV systems are taking a superior place [13]. The injected grid voltage and current with the active filter facilitated and with dissimilar power factors. The reactive power is supplied to the grid, and the total harmonic distortion (THD) of the grid current rise. While the low-power devices with restricted current capability would be implemented in an actual application, the power losses of the full-bridge driving the common-mode transformer would raise[19]. The power switches dependability decreased the size of the power converter increased. The power losses, THD, and errors on dissimilar parts of the system for which the behavior of the system varies considerably and instability may happen inside the system.[15]

This paper proposes PI controller based power quality analysis in grid connected Photovoltaic (PV) system.

2. Grid Connected PV System with PI Controller

In figure 1, described about the grid connected PV system with PI controller. Here, PV system is the source and it generates electricity from the solar energy. The PV connected to the grid via inverter, LC filter and point of common coupling (PCC). The inverter converts the DC supply into AC and fed to the LC filter. The main aim of the grid connected PV topology is give a constant power flow parameters for both the normal and abnormal conditions. During the grid faulty condition develops the PQ issues in the grid connected PV systems. By employing the suggested control technique the reported problems can be corrected. The proposed PI control technique is used to generate the control pulses of the inverter by utilizing the grid parameters.

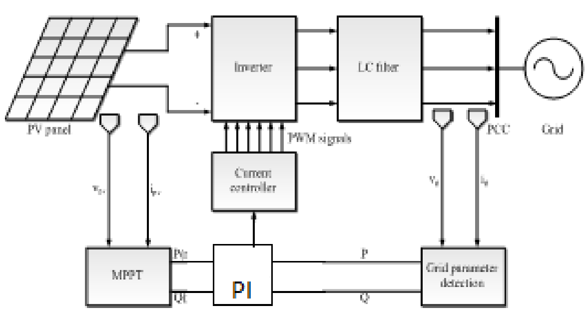


Figure.1: Block diagram of the grid connected PV system with controller

The LC filter is employed as the output filter in order to limit the higher order harmonics coming from the inverter switching behaviour as it can be seen in the figure 1. Hence, ignoring all the filter losses, the system at the ac side can be explained in the subsequent equation [14] (1).

$$\frac{di_g(t)}{dt} = \frac{v_{inv}(t)}{L} - C_f \frac{d^2 v_g(t)}{dt^2} - \frac{v_g(t)}{L} \quad (1)$$

Where, i_g is the injected grid current; v_g is the grid voltage and v_{inv} is the inverter output voltage. The grid parameters like voltage and current are essential to decide the grid side PQ, which is used to determine the active and reactive power of the grid. The active and reactive power delivered to the grid has been calculated by using the following equations [14] (2) and (3).

$$P = \frac{1}{2} v_g^d i_g^d \quad (2)$$

$$Q = -\frac{1}{2} v_g^d i_g^q \quad (3)$$

Where, d and q are the grid voltage and current in a dq rotating synchronous reference frame; P and Q are the active and reactive power respectively. The PQ problem is identified through the error calculation between the actual grid side parameters and the reference power values attained from the PV system. In the PV system, Maximum Power Point Tracking technique (MPPT) is utilized for the power value calculation.[18]. The control diagram under grid fault condition is described in the following figure 2.

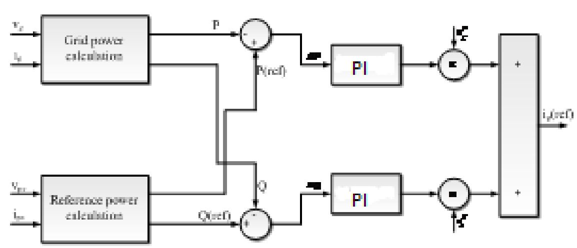


Figure.2: Controller diagram of the grid connected PV system

The error calculation is defined in the following equation (4) and (5).

$$\Delta P = [P(act) - P(ref)] \quad (4)$$

$$\Delta Q = [Q(act) - Q(ref)] \quad (5)$$

Where, ΔP and ΔQ are the error values of the active and reactive power; $P(act)$ and $Q(act)$ are the actual active and reactive power; $P(ref)$ and $Q(ref)$ are the reference active and reactive power. The error values are allowed to the PI controller, which is described in the following figure 3.

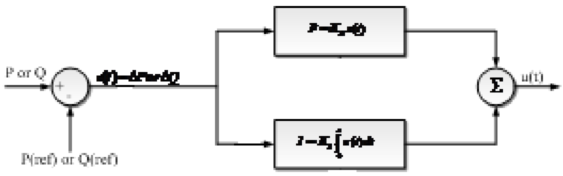


Figure.3: PI controller structure

The output performance of the PI controller is mathematically represented in the following equations (6) and (7).

$$u(t)_P = \Delta P(t) \times \left[K_P + K_I \int_0^t dt \right] \quad (6)$$

$$u(t)_Q = \Delta Q(t) \times \left[K_P + K_I \int_0^t dt \right] \quad (7)$$

Where, $u(t)_P$ and $u(t)_Q$ are the output function of the PI controller for active power and reactive power respectively; K_p is the proportional gain and K_I is the integral gain. The reference current values of the $\alpha\beta$ system are calculated as follows [14].

$$i_g^{\alpha}(ref) = \frac{2(v_g^{\alpha} P(ref) + v_g^{\beta} Q(ref))}{(v_g^{\alpha})^2 + (v_g^{\beta})^2} \quad (8)$$

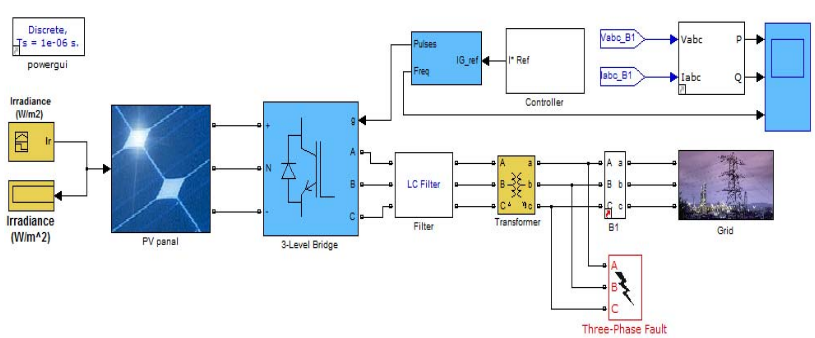
$$i_g^{\beta}(ref) = \frac{2(v_g^{\beta} P(ref) - v_g^{\alpha} Q(ref))}{(v_g^{\alpha})^2 + (v_g^{\beta})^2} \quad (9)$$

Where, $i_g^{\alpha}(ref)$ and $i_g^{\beta}(ref)$ are the reference grid current values of the $\alpha\beta$ system; v_g^{α} and v_g^{β} are the grid voltage of the $\alpha\beta$ system. The outcome of the PI controller is used for the evaluation of reference grid current and which will be utilized for generating the appropriate control pulses of the inverter. In normal condition, the grid side power flow parameters are in normal condition. If any fault condition occurs, the parameters are changed from the normal condition, because of the amplitude variation of the grid side voltage and current. According to the variation of the grid side parameters, the control signals are generated using the proposed PI controller.

The proposed method is implemented in the MATLAB/Simulink platform and the attained results are discussed in the following section 3.

3. Results and discussion

The implementation of the proposed control technique is carried out in the MATLAB/Simulink 7.10.0 (R2012a) platform, 4GB RAM and Intel(R) core(TM) i5. Here, the grid connected PV system is modelled and the PQ of the system is analyzed through the PI controller technique. The proposed control technique produces control pulses of the inverter for both the normal and abnormal conditions of the grid. The simulink model of the grid connected PV system and control technique is described in the figure 5. The implementation parameters are shown in the Table 1. The effectiveness of the proposed technique is analyzed by creating the three phase to ground fault at the grid side and the corresponding performance were analyzed. The attained results are portrayed and discussed in the following.



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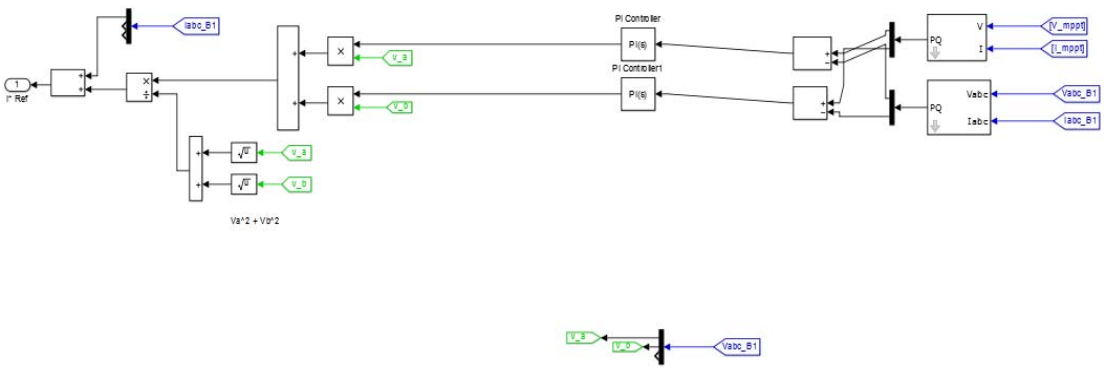

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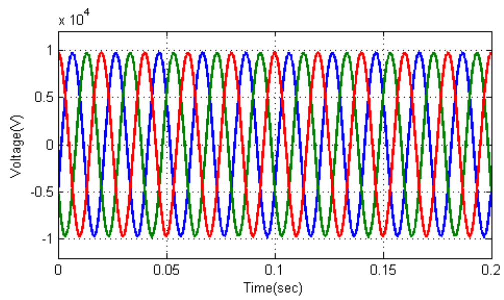
Figure.4: Simulink model: (a) Grid connected PV model; (b) PI controller.

Table.1: Implementation parameters

Parameters	Values
Nominal grid voltage (V)	10kV
Filter inductance (L)	$250\mu F$
Filter capacitance (C)	$10mF$
Grid frequency (ω)	$2\pi \times 50 rad / \sec$
Grid resistance (R_g)	$7\ \mu F$



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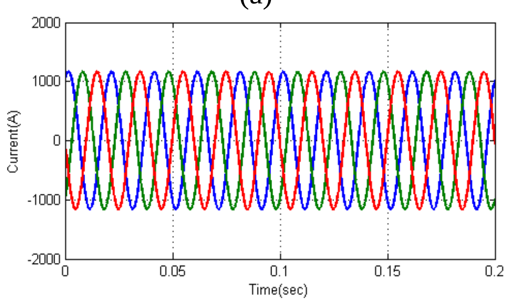

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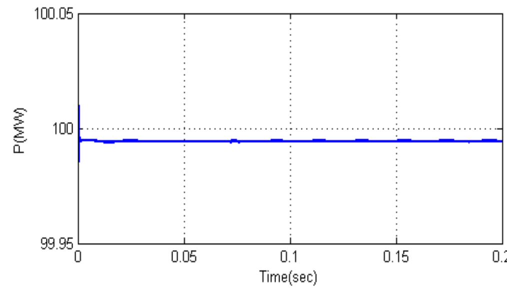

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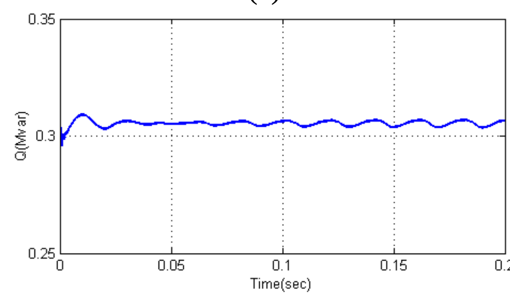

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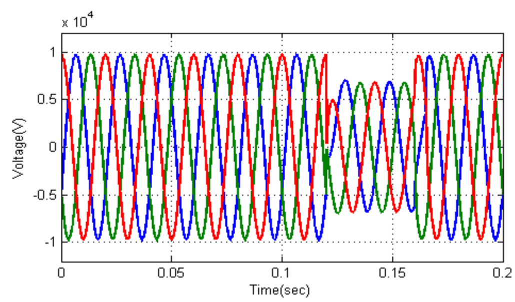
Fig.5: Grid at normal condition: (a) Voltage; (b) Current; (c) Real power; (d) Reactive power.



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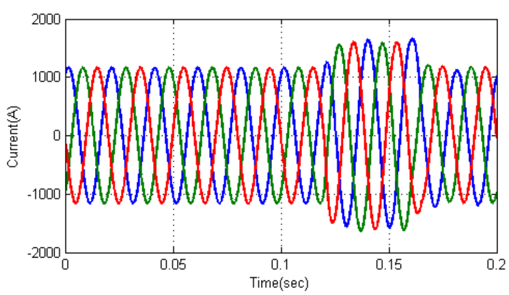

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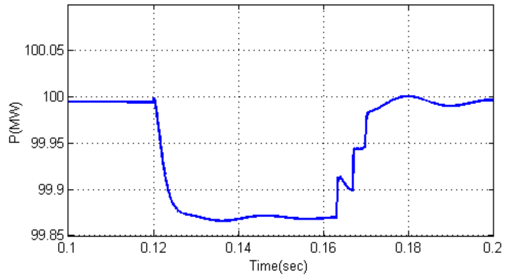

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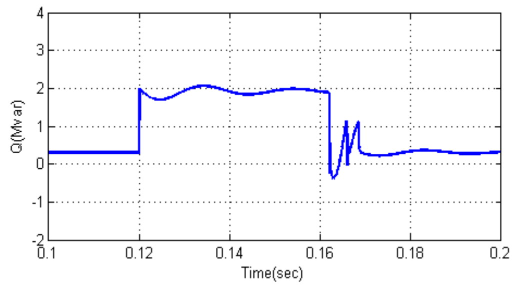

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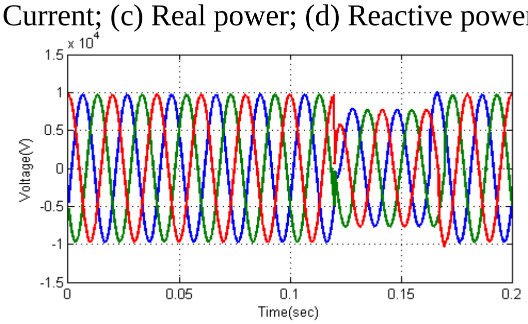
Fig.6: Grid at fault condition: (a) Voltage; (b) Current; (c) Real power; (d) Reactive power.



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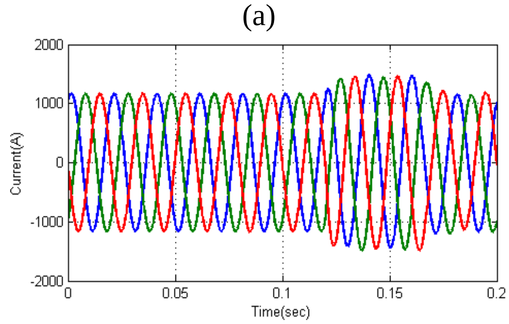

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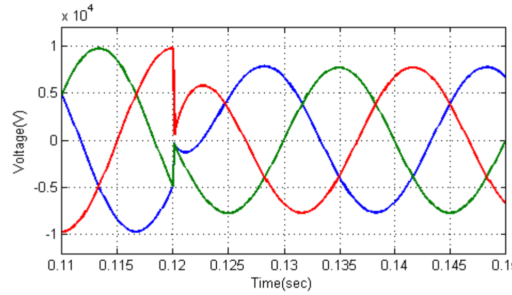

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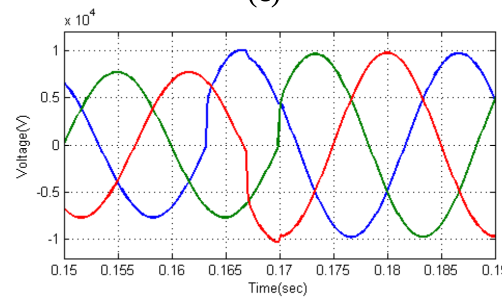

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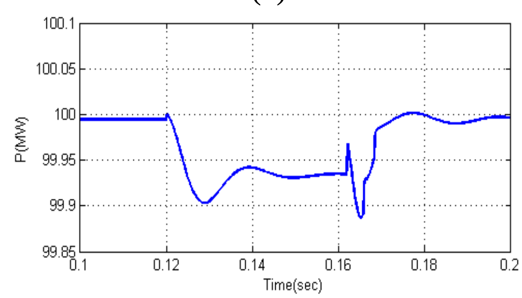

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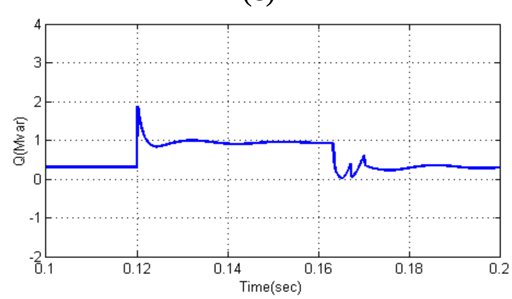

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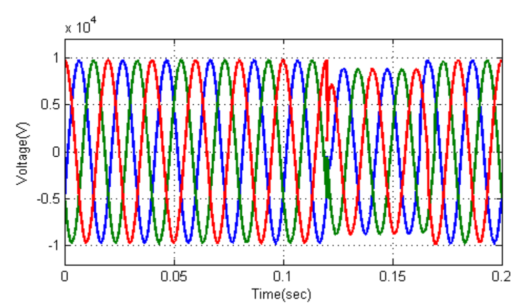
Fig.7: Using PI controller: (a) Voltage; (b) Current; (c) Voltage drop; (d) Voltage recovery; (e) Real power; (f) reactive power.



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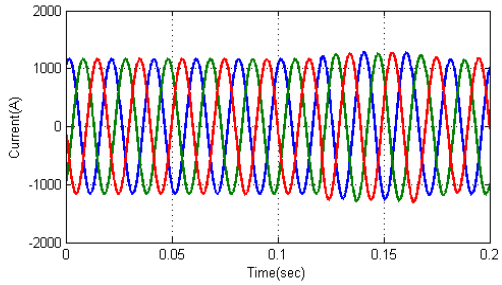

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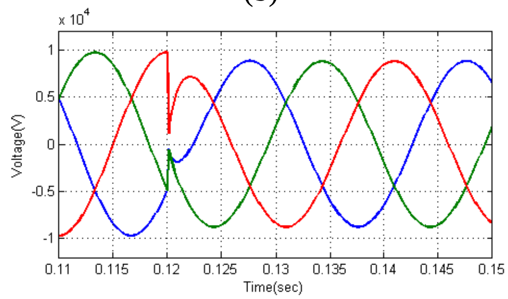

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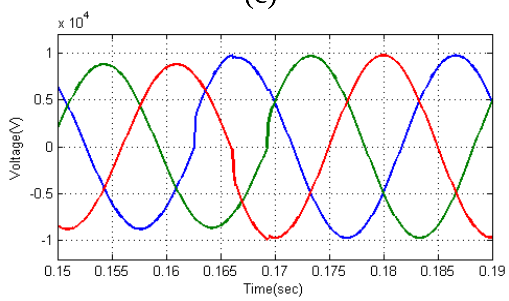

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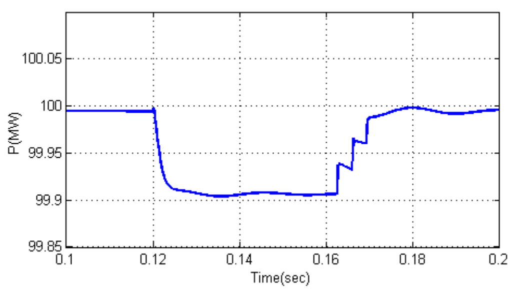

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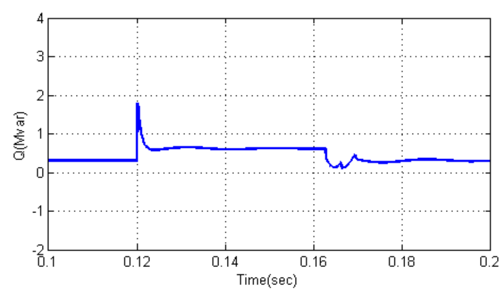

(f)

Table.2: THD analysis

Solution	**THD (%)**
Without	24.97
PI	12.86

To analyze the PQ improvement using PI controller, grid parameters are required like voltage, current, real power and reactive power for both the normal and abnormal conditions. Initially the performance of the grid connected PV system is tested under normal condition, which ensures that the system have no fault at the grid side. The simulation time required for the testing process is 0 to 0.2 seconds. The grid side voltage, current, real power and reactive power at normal condition are described in the Fig. 6. It shows that the grid voltage i10kV, grid current is 1000A, real power is 100MW and reactive power is 0.3MVAr. The grid side parameters under fault condition are described in the Fig. 7. Here, three phases to ground fault was introduced in the grid side at the time duration 0.12 to 0.16 seconds. The grid voltage amplitude has been reduced 25% from the original value and grid current has been increased as vice versa. These conditions affect the real power and reactive power of the grid and make the PQ problem at the grid side. The PI controller based grid connected PV system and their grid side parameters are illustrated in the figure 8. It shows that the grid voltage has amplitude reduction 22% from the original value at the fault applied time 0.12 to 0.16 seconds..

The attained THD (%) value was publicized in the Table 2. The table demonstrates that the THD value at the fault condition is 24.97%,whereas with PI controller THD has been reduced to 12.86%.

5. Conclusion

This paper proposed a PI controller based PQ analysis in the grid connected PV system. The mentioned results show that with PI controller, the percentage total harmonic distortion is reduced. The PI controller only utilizes the fixed gain parameters such as K_P=1.4 and K_I=18 for all the conditions. An hybrid technique can be used to improve the power quality.

References

[1] Joan Rocabert, Alvaro Luna, Frede Blaabjerg and Pedro Rodriguez, "Control of Power Converters in AC Microgrids," IEEE Transactions on Power electronics, Vol. 27, No. 11, pp.4734-49, 2012

[2] Thounthong, Phatiphat, Arkhom Luksanasakul, Poolsak Koseeyaporn, and Bernard Davat, "Intelligent model-based control of a standalone photovoltaic/fuel cell power plant with super capacitor energy storage," IEEE Transactions on Sustainable Energy, Vol.4, No. 1, pp.240-249, 2013

[3] F.Bouchafaa, D. Beriber, and M. S. Boucherit, "Modeling and simulation of a gird connected PV generation system with MPPT fuzzy logic control," 7th International Multi-Conference on Systems Signals and Devices (SSD), pp.1-7, 2010

[4] Patcharaprakiti.N and Premrudeepreechacharn.S, "Maximum power point tracking using adaptive fuzzy logic control for grid-connected photovoltaic system", IEEE Power Engineering Society Winter Meeting, Vol.1, pp.372-377, 2002

[5] S.Samerchur, S. Premrudeepreechacharn, Y.Kumsuwun, and K.Higuchi. “Power control of single-phase voltage source inverter for grid-connected photovoltaic systems,” In Power Systems Conference and Exposition (PSCE), pp. 1-6, 2011

[6] Dong Cao, Shuai Jiang, Xianhao Yu, and Fang Zheng Peng, "Low-cost semi-Z-source inverter for single-phase photovoltaic systems," IEEE Transactions on Power Electronics, Vol.26, No. 12, pp.3514-3523, 2011.

[7] Engin Ozdemir and Fatih Kavaslar, "A new multifunctional power converter for grid connected residential photovoltaic applications," In Energy Conversion Congress and Exposition, pp. 2650-2656, 2009

[8] Soumyadeep Ray, Madichetty Sreedhar and Abhijit Dasgupta, "ZVCS based high frequency link grid connected SVPWM applied three phase three level diode clamped inverter for photovoltaic applications," In Power and Energy Systems Conference: Towards Sustainable Energy, pp. 1-6, 2014.

[9] Matthias Klatt, Alicia Dorado, Jan Meyer, Peter Schegner, Jürgen Backes, Ran Li, and Dresden–Germany Dresden–Germany Stuttgart–Germany, "Power quality aspects of rural grids with high penetration of micro generation, mainly PV-installations," Proceedings of the 21st International Conference on Electricity Distribution, pp.1-4, 2011.

[10] Chandani M.Chovatia, Narayan P. Gupta, and Preeti N. Gupta, "Power Quality Improvement in a PV Panel connected Grid System using Shunt Active Filter," International Journal of Computer Technology and Electronics Engineering (IJCTEE), Vol.2, No. 4, pp.41-45, August 2012.

[11] A.Hari Prasad, Y.Rajasekhar Reddy and P.V. Kishore, "Photovoltaic Cell as Power Quality conditioner for Grid connected system."International Journal of Scientific and Engineering Research, Vol.2, No.10, pp.1-8, 2011

[12] Riad Kadri, Jean-Paul Gaubert, and Gerard Champenois. "An improved maximum power point tracking for photovoltaic grid-connected inverter based on voltage-oriented control," IEEE Transactions on Industrial Electronics, Vol. 58, No.1, pp. 66-75, 2011

[13] S.A.Lakshmanan, B. S. Rajpourhit, and Amit Jain, "A novel current controlled SVPWM technique for grid connected solar PV system." In PES General Meeting Conference & Exposition, pp.1-5, 2014

[14] Yongheng Yang and Frede Blaabjerg, "Low-Voltage Ride-Through Capability of a Single-Stage Single-Phase Photovoltaic System Connected to the Low-Voltage Grid", International Journal of Photoenergy, pp.1-9, 2013

[15] A.Mahmud, H. Pota and M.J. Hossainm, “Nonlinear Current Control Scheme for a Single-Phase Grid-Connected Photovoltaic System.” IEEE Transactions on Sustainable Energy, Vol.5, No.1, pp.218-27, 2014

[16] Masoud Farhoodnea, Azah Mohamed, Hussain Shareef, and Hadi Zayandehroodi, "Power Quality Analysis of Grid-Connected Photovoltaic Systems in Distribution Networks," Przeglad Elektrotechniczny, pp.208-13, 2013

[17] Rosa A. Mastromauro, Marco Liserre, Tamas Kerekes and Antonio Dell, "A Single-Phase Voltage-Controlled Grid-Connected Photovoltaic System with Power Quality Conditioner Functionality," IEEE Transactions on Industrial electronics, Vol. 56, No. 11, pp. 4436-44, 2009

18] B.N.Alajmi, K.H.Ahmed, G.P. Adam, S.J.Finney, and B.W. Williams, "Modular multilevel inverter with maximum power point tracking for grid connected photovoltaic application," International Symposium on Industrial Electronics, pp. 2057-2062, 2011

[19] F.Mulolani, M. Armstrong, and B. Zahawi, "Modeling and simulation of a grid-connected photovoltaic converter with reactive power compensation," In proceedings of International Symposium on Communication Systems, Networks & Digital Signal Processing, pp. 888-893, 2014

[20] P.Sharma and V.Agarwal,"Maximum Power Extraction from a Partially Shaded PV Array Using Shunt-Series Compensation," IEEE Journal of Photovoltaics, Vol.4, No.4, pp.1128-37, 2014

[21] F.Blaabjerg, R.Teodorescu, M.Liserre and A.Timbus, "Overview of control and grid synchronization for distributed power generation systems," IEEE Transaction on Industrial Electronics, Vol.53, No.5, pp.1398-1409, 2006