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THREE-PHASE SINGLE STAGE SOLAR PV INTEGRATED UPQC

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ABSTRACT

A fractional open circuit algorithm-based solar PV (photovoltaic) integrated UPQC (unified power quality conditioner) is proposed in this research, and its performance is evaluated.Matlab Simulink is used to simulate steady-state and dynamic settings.software.Shunt and series voltage sources are used in UPQC.A dc link connects two converters (VSC) back to back.in common.The shunt compensator has two functions: It draws power from a solar PV array and supplies current.compensation, whereas a series compensator provides voltage compensation compensation through voltage injection (in phase/out of phase) during voltage, the grid via the point of common connection sags/swells. Single-stage fractional open circuit algorithmThe topology is used to collect power from a PV array. Fractional The open circuit algorithm is not only simple to implement but also effective. provides smoothness and oscillation.

Keywords - Maximum power point tracking (MPPT), power quality(PQ), photo-voltaic (PV), Unified Power Quality Conditioner (UPQC), Fractional Open Circuit Voltage(FOCV), Dynamic Voltage Restorer(DVR), Moving Average Filter(MAF), Total Harmonic Distortion(THD), Series active power filter(SAPF), Parallel active power filter(PAPF).

1. INTRODUCTION

Power quality concerns and problems appear to be the result of the increased use of solid state semiconductor devices, switched mode power supply (SMPS), adjustable speed drives, and so on.The introduction and widespread usage of power electronic products and electronic loads enhanced the penetration of nonsinusoidal currents into the power system. Power quality concerns can cause equipment malfunctions, false activation of electronic switches, data loss and memory malfunctions in sensitive equipment such as computers, programmable logic devices, protection and relaying equipment, and so on. It also accelerates the deterioration of transformers, cables, and other transmission equipment. If this failing occurs in biomedical equipment, the situation will be even worse. According to the history of the power system, power quality is a two-pronged issue in which electronic instruments play both villian and victim. Despite their high efficiency, power electronic devices draw current in bursts and modify the electricity that flows through them. As a result, the output returned to the grid is distorted. As a result, utilities are being obliged to spend more money on filters and capacitors to 'clean' this 'dirty' power. Another key issue that power system engineers are emphasising is the necessity for renewable energy generation. The primary option for this is to install rooftop solar panels in both business buildings and modest apartments.However, the intermittent nature of solar photovoltaic systems can cause voltage quality issues, particularly in older distribution systems. When both of these scenarios are considered, it is evident that there is a great demand for a system that can contribute clean energy to the power system while also improving power quality. Many studies have been conducted in the subject of active power filtering to address power quality issues. The disadvantage of active shunt power filtering was that it introduced reactive power into the system. It also cannot perform voltage compensation at PCC and current compensation (to keep the grid current at unity power factor) at the same time. DVRs and STATCOM devices were invented. opened a new chapter in the realm of PQ mitigation. The first DSTATCOM installation was at a saw mill in British Columbia.Canada's Columbia. A solar photovoltaic system with DVR was installed.suggested in [19].Multifunctional single and three phase There were also single stage solar energy conversion technologies. proposed[4]-[8]. FACTS stands for Flexible AC Transmission System.gadgets have been adjusted in order to be served indistribution networks, as well as through changing UPFC (Unified Power Distribution). Flow Controller), the UPQC was introduced in 1998. Such Different PQ phenomena can be compensated for via solutions. In [10]-[12] The usage of PV integration to the grid results in of the UPQC. A comparison of major MPPT technologies [20] discusses this. DVRs and STATCOM devices were invented.opened a new chapter in the realm of PQ mitigation. The first DSTATCOM installation was at a saw mill in British Columbia.Canada's Columbia. A solar photovoltaic system with DVR was installed suggested in [19].Multifunctional single and three phase There were also single stage solar energy conversion technologies. proposed[4]-[8]. FACTS stands for Flexible AC Transmission System gadgets have been adjusted in order to be served in distribution networks, as well as through changing UPFC (Unified Power Distribution). The creation of reference signals is critical in the UPQC control methodology. It is possible to use either time domain or frequency domain techniques[3]. Time domain-based approaches are commonly used for real-time implementations since they require less processing time. In this study, a time domain strategy based on synchronous reference (d-q theory) frame theory[13] is applied. This method will produce double harmonic components in the d-axis component of current under unbalanced load conditions. A low pass filter with a very low cut off frequency will be employed to filter out these undesired signals. The use of standard LPF will result in lower dynamic performance. As a result, MAF (movig average filter) is employed in this paper to filter out the double harmonic components of d-axis current[14]. MAF can give maximal attenuation while maintaining bandwidth[15]. The performance of PLL in grid synchronisation is also increased by using MAF[16],[17]. The MAF is distinguished by being a simple-to-implement filter capable of rejecting frequency components that are multiples of the cutoff frequency. The purpose of this research is to develop and simulate a three phase single stage solar PV integrated UPQC using d-q theory based control. MAF is also utilised to improve dynamic performance during active current load extraction. One of the important features of this system is the simultaneous control of voltage and current quality enhancement, and it is stable under various dynamic conditions such as voltage sags or swells, unbalanced loads, and so on. The suggested system is modelled with Matlab Simulink software and its features are investigated under dynamic and steady-state settings. The goal of this study is to design and simulate a three-phase single-stage solar PV integrated UPQC based on d-q theory. MAF is also used to improve dynamic performance when extracting active current loads.The simultaneous control of voltage and current quality enhancement is an essential feature of this system, and it is stable under various dynamic conditions such as voltage sags or swells, unbalanced loads, and so on. The proposed system is modelled using Matlab Simulink software, and its characteristics are explored in both dynamic and steady-state situations.

2. BASIC TOPOLOGY AND DESIGN

Figure 1 depicts the fundamental topology of the proposed system's power circuit, which is built for a three-phase grid. PV-UPQC's power circuit includes shunt and series compensators (essentially voltage source converters), also known as series active power filters (SAPF) and parallel active power filters (PAPF), which are linked by a DC link capacitor (which works as a dc bus). The shunt compensator is connected to the load side, whereas the series compensator is connected to the grid side via an injection transformer in each phase, which injects the voltage produced by the series compensator into the grid. The PV array is directly connected to the dc bus via a diode, which inhibits power transfer in the opposite way. The series compensator, which is in voltage control mode, compensates for sags or swells in the grid side voltage. Interconnecting inductors are installed between the grid and both converters. The switching action of the converters might produce harmonics in the system, which are removed by the RC ripple filters. A bridge rectifier with an RL load is linked to the load side and serves as a nonlinear load. PV-UPQC design includes PV module selection and sizing, MPPT algorithm selection, dc-link capacitor design, and dc-link voltage level selection. The next step is to develop interfacing inductors, injection transformers, and ripple filters[3]. Because the MPP voltage must be equal to the DC link voltage, the size of the PV module is determined by the DC link voltage. The shunt compensator should be sized so that it can handle the maximum power output of the PV array while also compensating for reactive power and load current harmonics. [1] describes the design of parameters for a single stage PV-UPQC. The ripple filters are chosen based on [3].

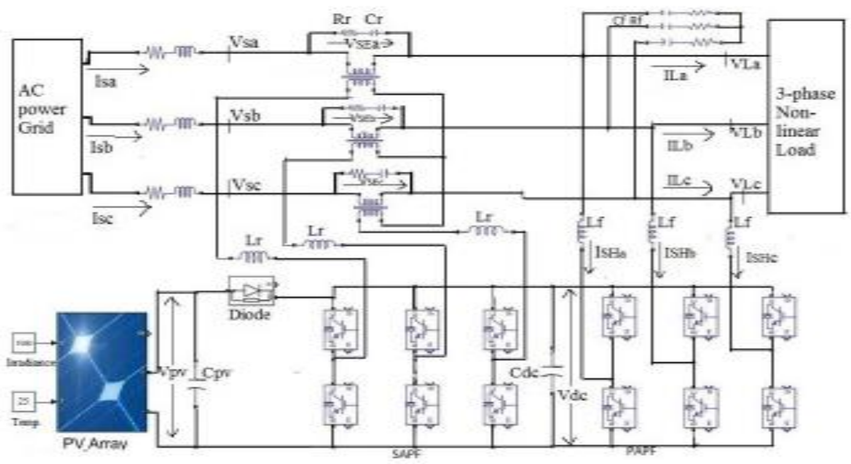

Fig. 1. Basic Topology

Fig.1

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Control Algorithm for Shunt APF

The magnitude of reference is provided by the MPPT algorithm. The voltage for the PV-UPQC's dc-bus. The fractional open circuit voltage algorithm is chosen and implemented in this paper. for tracking maximum power from solar cell. This is one of them. one of the most basic algorithms and ideal for because we only need to calculate Vdc reference in our scenario MPPT is used. Maximum power voltage of a PV module The point is always linearly related to the open circuit. voltage of that module under various irradiance and temperature conditions levels. This fundamental theory underpins the fractional open circuit voltage-based algorithm. To trigger the boost converter in a two-stage conversion topology, the duty ratio must be calculated. As a result, one of the advantages of the proposed system is that we can avoid using a converter section entirely without sacrificing effectiveness and efficiency. A proportional integral (PI) controller is used to keep the voltage across the DC link capacitor constant at 700V.The Ziegler-Nichols tuning method is used to calculate the values of Kp and Kd. The shunt converter must extract the fundamental active component of current in the load side in order to function as a load current compensator. Control of the shunt compensator is accomplished by extracting this fundamental component using the SRF (Synchronous reference frame) technique.Figure 2 depicts the block diagram representation of the control structure used in this paper. The phase and frequency of voltage at the point of common coupling are measured using a phase locked loop and used to convert load currents to the d-q-0 domain. The obtained d axis component (ILd) is filtered using an LPF to obtain the pure dc component (ILdf). In this paper, a moving average filter (MAF) is used instead of a standard LPF to improve performance. Figure 4 depicts a block diagram representation of MAF. The MPPT (FOCV) reference value of Vdc is compared to the filtered value of the sensed dc-link voltage. The error signal is then sent to a PI controller, which is responsible for maintaining constant voltage on the DC bus.

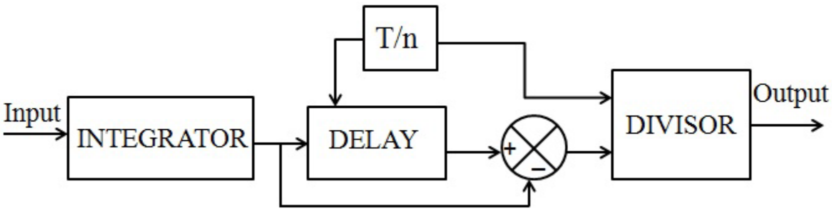

Fig. 2. Block diagram representation of MAF

Equivalent value of current due to photo-voltaic module can be calculated using the below equation

$$I_{pvg} = \frac{2P_{pv}}{3V_s} \qquad (1)$$

where Ppv is the power of the PV module and V is the PCC voltage magnitude. The d-axis component of reference grid current is given by

$$I*_{sd} = I_{Ldf} + I_{loss} - I_{pvg} \qquad (2)$$

I_sd is converted to grid currents in abc domain reference frame. The reference grid currents are then compared with the measured grid currents using hysteresis controller and obtained the gate pulses for triggering the shunt VSC circuit.

Control Algorithm for Series APF

[14] describes various compensation topologies for series converters.In this paper, the voltage injected by the Series APF and the grid voltage are in the same phase, allowing the voltage injection to the grid to be minimised. Figure 5 depicts the control method for the series converter circuit. A phase locked loop is used to obtain the reference axis signals in the d-q-0 domain to obtain the fundamental component of voltage at PCC. The phase and frequency of grid voltage are measured with the help of a PLL. The voltages at the PCC and the voltages at the load side are converted into the rotating reference frame.

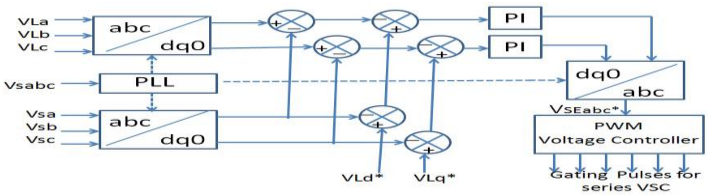

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Fig. 3. Control for series compensator

The quadrature axis component value is assumed to be zero[3]. The difference between the voltage at the common coupling point and the load reference voltage determines the reference voltage for the series compensator. The actual value of SAPF voltages is determined by the difference between load voltage and voltage at PCC. The difference in reference and actual SAPF voltages is then fed into proportional integral controllers to generate appropriate reference signals. These signals are converted to a three-phase stationary reference frame and routed through a pulse-width modulation (PWM) voltage controller to generate appropriate gating pulses for the series VSC circuit.

3. CONTROL OF PV-UPQC

The primary subsystems in the simulation and modelling of the proposed system are shunt and series active power filters, as well as their control circuitry and FOCV-based MPPT algorithm. Shunt VSC or PAPF injects current into the system, compensating for current harmonics on the load side and maintaining the sinusoidal current waveform, ensuring unity power factor. Series VSC or SAPF reduces voltage harmonics and injects power into the grid to cancel out the effect of grid voltage sag or swell. During a sag in grid voltage, the voltage injected from SAPF will be in phase with the grid voltage; but, during a swell condition, the voltage injected from SAPF will be out of phase.

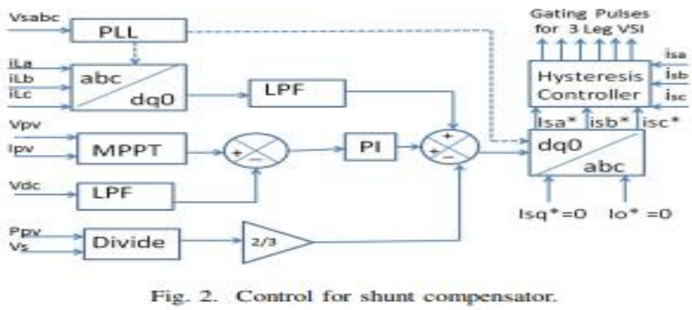

Fig 4. Control for shunt compensator

4. SIMULATION RESULTS

The modelling and analysis of the FOCV-based PV integrated UPQC are carried out in MATLAB using SimPower system tools. As nonlinear load, a three-phase diode bridge rectifier with RL load is used.

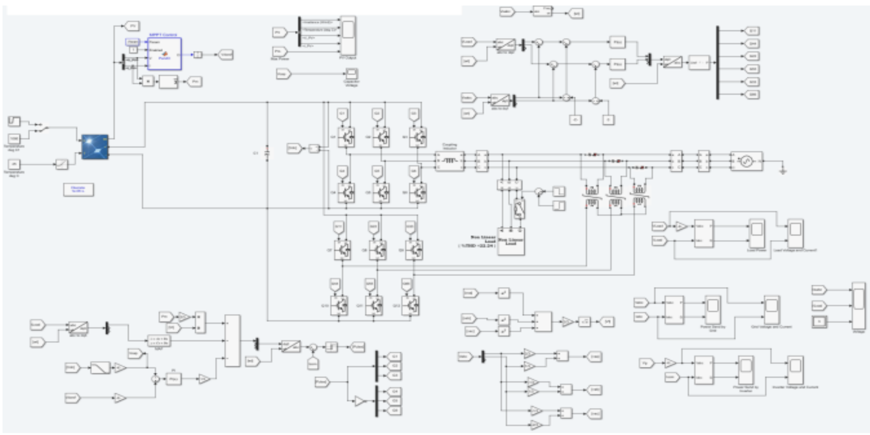

Fig.5 Simulation model

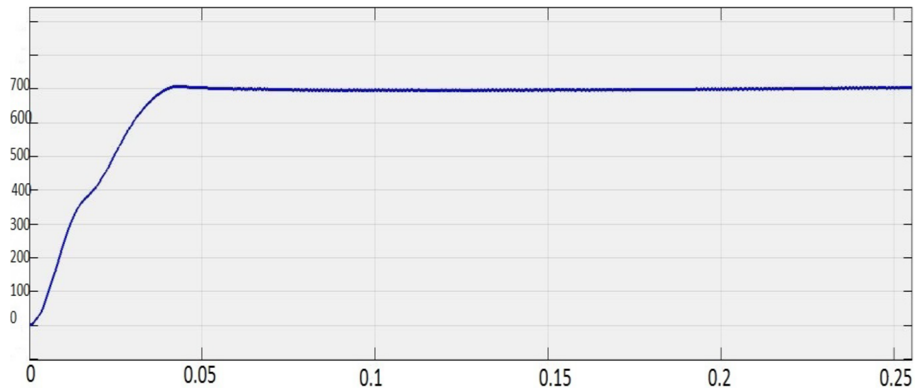

Fig. 6. DC link voltage=700v

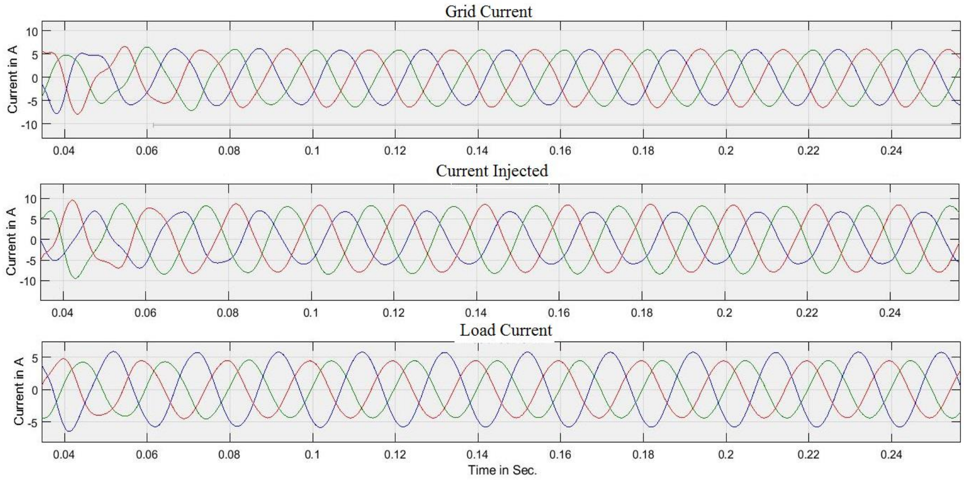

Fig. 7. Current compensation waveforms

The dynamic performance of the system is shown during PCC voltage sags and swells. The irradiation value was kept at 1000W/m2 and the temperature was kept at 45°C. The voltage across the dc bus Vdc is kept constant (700V) thanks to the PV panel and shunt controller. A 1.2pu swell is applied to the grid voltage over a time interval of 0.2sec. to 0.3sec., and the series compensator provides an out-of-phase voltage to cancel the effect, so the load voltage remains constant (Fig.9). During the sag(0.8 pu) condition (voltage sag applied at 0.2sec. to 0.3sec.), voltage is injected from the series compensator to the grid that is in phase with the grid voltage and keeps the load voltage at 1pu. Figure 7 depicts the current waveforms under unbalanced load. The shunt compensator maintains a constant level of grid current. Matlab tools were used to analyse the harmonic spectrum and measure the THD of input and output signals.

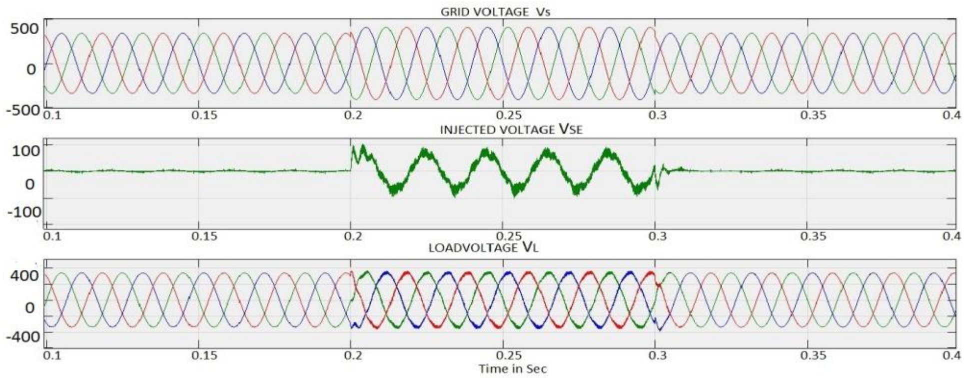

Fig. 8. Voltage compensation waveforms a)input gird voltage: 0.2pu swell is applied between 0.2sec and 0.3 sec b) Compensating voltage injected from VSC phase A c) Improved load voltage

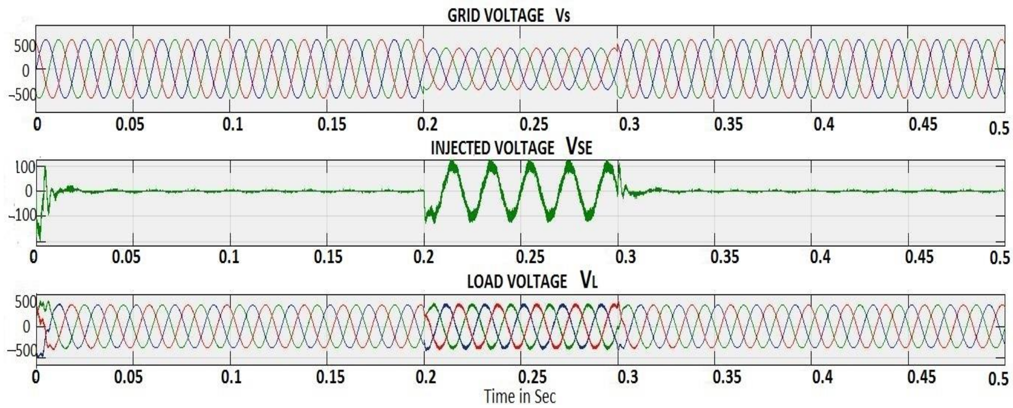

Fig. 9. Voltage compensation waveforms a)input gird voltage: 0.3pu swell is applied between 0.2sec and 0.3 sec b) Compensating voltage injected from VSC phase A c) Improved load voltage

The THD value should be less than 5%, according to "IEEE-519-1992," which defines the requirements for harmonics control in electric power systems. While analysing the proposed system, it was discovered that the THD of the load voltage is approximately 2.84% and that of the grid current is 1.18%, which meets the IEEE THD limits.

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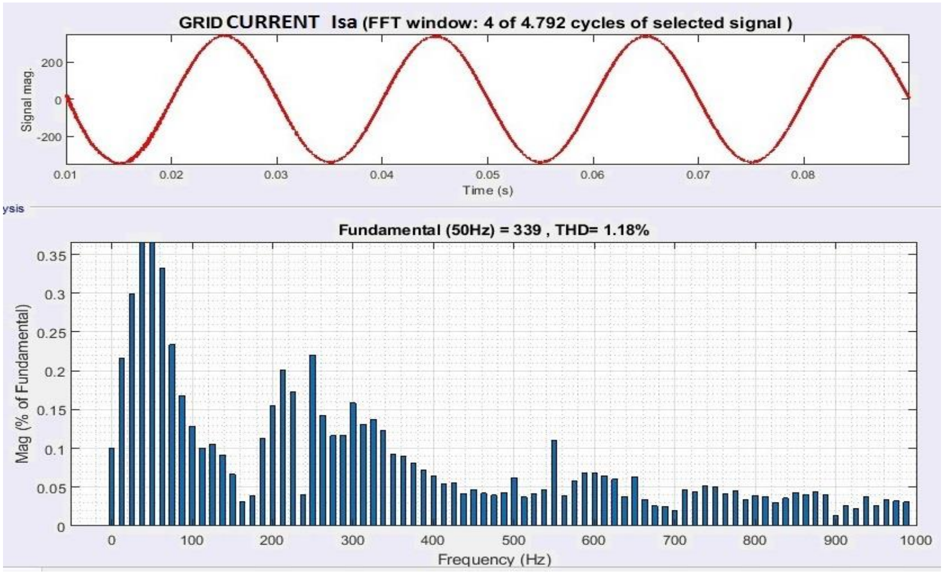

Fig. 10. Grid Current THD = 1.18 %

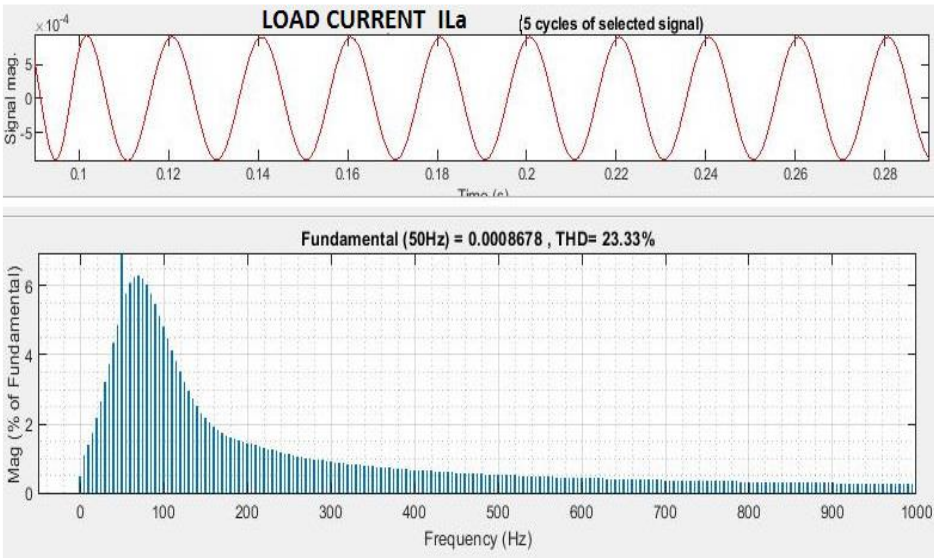

Fig. 11. Load current THD =23.33%

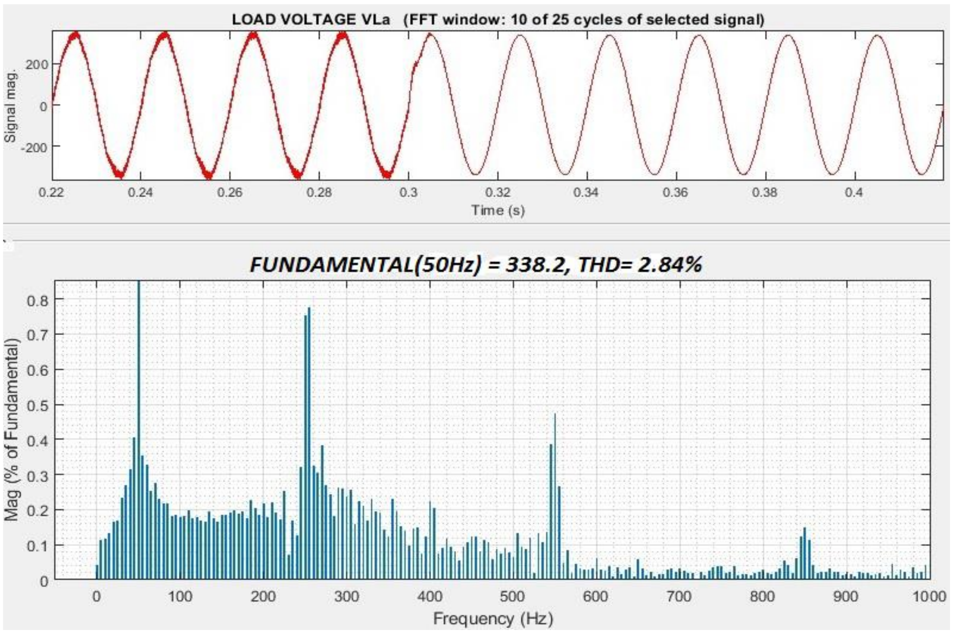

Fig. 12. Load Voltage THD =2.84%

5. CONCLUSION

The three phase solar photovoltaic system integrating UPQC was constructed and tested using Matlab software under various scenarios of grid voltage sags and swells and unbalanced load, and the system was determined to be stable under these conditions. The fractional open circuit voltage technique was used to obtain the maximum power from the PV. The THD values of grid current and load voltages are within the IEEE standard limits. . This solar PV integrated UPQC is a promising system for the current electric power distribution system, since it can incorporate renewable energy generation while improving power quality.

6. FUTURE SCOPE

Despite the fact that the FOCV algorithm is the simplest of all and provides smooth and faster responses without oscillation, measuring Voc was a hurdle that was overcome by incorporating a pilot cell. Pilot cell was replaced by semi-pilot cell to improve accuracy and reduce power loss [22],[23]. During normal operation, it will function as a component of the PV array, contributing to electricity generation. Voc is calculated by unplugging the semi-pilot cell from the PV array. Because of this practise, the outcome is unaffected. For the best results, the FOCV method employed in this research can be replaced with more advanced FOCV algorithms.

7. REFERENCES

[1] Sachin Devassy , Member, IEEE, and Bhim Singh , Fellow, IEEE , Design and Performance Analysis of Three-Phase Solar PV Integrated UPQC Fig. 12. Load Voltage THD =2.84% IEEE Trans. on Power Electronics, Feb. 2018.

[2] Srgio Augusto Oliveira da Silva ; Fernando Alves Negro, Single-Phase to Three-Phase Unified Power Quality Conditioner Applied in Single-Wire Earth Return Electric Power Distribution Grids, IEEE Transactions on Power Electronics,2018 Vol. 33 , Issue: 5

[3] B. Singh, A. Chandra, and K. A. Haddad, Power Quality: Problems and Mitigation Techniques. Hoboken, NJ, USA: Wiley, 2015.

[4] B. Singh, C. Jain, and S. Goel, ILST control algorithm of single-stage dual purpose grid connected solar PV system, IEEE Trans. Power Electron., vol. 29, no. 10, pp. 53475357, Oct. 2014.

[5] I. Hussain, R. K. Agarwal, and B. Singh, Three-phase single-stage grid tied solar PV ECS using PLL-less fast CTF control technique, IET Power Electron., vol. 10, no. 2, pp. 178188, 2017.

[6] B. Singh, Y. Singh, I. Hussain, and S. Mishra, Single-phase solar gridinterfaced system with active filtering using adaptive linear combiner filterbased control scheme, IET Gener., Transm. Distrib., vol. 11, no. 8, pp. 19761984, 2017.

[7] T.-F. Wu, H.-S. Nien, C.-L. Shen, and T.-M. Chen, A single-phase inverter system for PV power injection and active power filtering with nonlinear inductor consideration, IEEE Trans. Ind. Appl., vol. 41, no. 4, pp. 1075 1083, Jul. 2005.

[8] A. Javadi, A. Hamadi, L. Woodward, and K. Al-Haddad, Experimental investigation on a hybrid series active power compensator to improve power quality of typical households, IEEE Trans. Ind. Electron., vol. 63, no. 8, pp. 48494859, Aug. 2016.

[9] A. M. Rauf and V. Khadkikar, Integrated photovoltaic and dynamic voltage restorer system configuration, IEEE Trans. Sustain. Energy, vol. 6, no. 2, pp. 400410, Apr. 2015.

[10] S. Devassy and B. Singh, Design and performance analysis of threephase solar PV integrated UPQC, in Proc. 2016 IEEE 6th Int. Conf. Power Syst., Mar. 2016.

[11] K. Palanisamy, D. Kothari, M. K. Mishra, S. Meikandashivam, and I. J. Raglend, Effective utilization of unified power quality conditioner for interconnecting PV modules with grid using power angle control method, Int. J. Elect. Power Energy Syst., vol. 48, 2013.

[12] S. Devassy and B. Singh, Modified p-q theory based control of solar PV integrated UPQC-S, in IEEE Trans. Ind. Appl., vol. 53, no. 5, Sept./Oct. 2017, doi: 10.1109/TIA.2017.2714138.

[13] S. K. Khadem, M. Basu, and M. F. Conlon, Intelligent islanding and seamless reconnection technique for microgrid with UPQC, IEEE J. Emerg. Sel. Topics Power Electron., vol. 3, no. 2, pp. 483492, Jun. 2015.

[14] P. C. Loh, J. M. Guerrero, T. L. Lee, and M. Chandorkar, Advanced control architectures for intelligent microgrids; Part II: Power quality, energy storage, and ac/dc microgrids, IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 12631270, Apr. 2013.

[15] B. Singh and J. Solanki, A comparison of control algorithms for dstatcom, IEEE Trans. Ind. Electron., vol. 56, no. 7, Jul. 2009.

[16] C. Jain, B. Singh, S. Goel, A. Chandra, and K. Al-Haddad, A multifunctional grid-tied solar energy conversion system with ANF-based control approach, IEEE Trans. Ind. Appl., vol. 52, no. 5, Sep. 2016.

[17] J. M. Guerrero, S. Golestan, M. Ramezani, and M. Monfared, dq-frame cascaded delayed signal cancellation-based PLL: Analysis, design, and comparison with moving average filter-based PLL, IEEE Trans. Power Electron., vol. 30, no. 3, Mar. 2015.

[18] R. Pea-Alzola, D. Campos-Gaona, P. F. Ksiazek, and M. Ordonez, Dclink control filtering options for torque ripple reduction in low-power wind turbines, IEEE Trans. Power Electron., vol. 32, no. 6, pp. 48124826, Jun. 2017.

[19] M. Ramezani, S. Golestan, J. M. Guerrero, F. D. Freijedo, and M. Monfared, Moving average filter based phase-locked loops: Performance analysis and design guidelines, IEEE Transactions on Power Electronics, vol. 29, no. 6, Jun. 2014.

[20] R. Pradhan and B. Subudhi , A comparative study on maximum power point tracking techniques for photovoltaic power systems, IEEE Trans. Sustain. Energy, vol. 4, no. 1, Jan. 2013.

[21] S. Devassy and B. Singh, Design and performance analysis of threephase solar PV integrated UPQC, in Proc. 2016 IEEE 6th Int. Conf. Power Syst., Mar. 2016.

[22] R. Shkoury ; D. Baimel ; L. Elbaz ; S. Tapuchi ; N. Baimel, Novel optimized method for maximum power point tracking in PV systems using Fractional Open Circuit Voltage technique, 2016 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), June 2016

[23] Eenisha Suresh and Bharath K R , Design and Implementation of Improved Fractional Open Circuit Voltage Based Maximum Power Point Tracking Algorithm for Photovoltaic Applications, International Journal of Renewable Energy Research, Vol.7, No.3, 2017.