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3-Phase Solar PV Incorporated UPQC System Analysis

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ABSTRACT: This paper manages the structure and execution examination of a three-stage single stage sun powered photovoltaic coordinated brought together power quality conditioner (PV-UPQC). The PV-UPQC comprises of a shunt and arrangement associated voltage compensators associated consecutive with basic DC-connect. The shunt compensator plays out the double capacity of extricating power from PV exhibit separated from making up for burden current sounds. An improved synchronous reference casing control dependent on moving normal channel is utilized for extraction of burden dynamic current part for improved execution of the PVUPQC. The arrangement compensator makes up for the lattice side power quality issues, for example, framework voltage droops/swells. The compensator infuses voltage in-stage/out of stage with purpose of basic coupling (PCC) voltage during list and swells conditions individually. The proposed framework consolidates both the advantages of clean vitality age alongside improving force quality. The enduring state and dynamic execution of the framework are assessed by mimicking in Matlab-Simulink under a nonlinear burden. The framework execution is then checked utilizing a downsized research facility model under various unsettling influences, for example, load unbalancing, PCC voltage droops/swells and illumination variety.

KEYWORDS: Power Quality, shunt compensator, series compensator, UPQC, Solar PV, MPPT.

I.INTRODUCTION

This paper manages the structure and execution examination of a three-stage single stage sun powered photovoltaic coordinated brought together power quality conditioner (PV-UPQC). The PV-UPQC comprises of a shunt and arrangement associated voltage compensators associated consecutive with basic DC-connect. The shunt compensator plays out the double capacity of extricating power from PV exhibit separated from making up for burden current sounds. An improved synchronous reference casing control dependent on moving normal channel is utilized for extraction of burden dynamic current part for improved execution of the PVUPQC. The arrangement compensator makes up for the lattice side power quality issues, for example, framework voltage droops/swells. The compensator infuses voltage in-stage/out of stage with purpose of basic coupling (PCC) voltage during list and swells conditions individually. The proposed framework consolidates both the advantages of clean vitality age alongside improving force quality. The enduring stateand dynamic execution of the framework are assessed by mimicking in Matlab-Simulink under a nonlinear burden. The framework execution is then checked utilizing a downsized research facility model under various unsettling influences, for example, load unbalancing, PCC voltage droops/swells and illumination variety. been proposed for use in small apartments and commercial building. A solar photovoltaic system integrated along with dynamic voltage restorer has been proposed in .Compared to shunt and series active power filters, a unified power quality conditioner (UPQC), which has both series and shunt compensators can perform both load voltage regulation and maintain grid current sinusoidal at unity power factor at same time. Integrating PV array along with UPQC, gives the dual benefits of clean energy generation along with universal active. The integration of PV array with UPQC has been reported in . Compared to conventional grid connected inverters, the solar PV integrated UPQC has numerous benefits such as improving power quality of the lattice, shielding basic burdens from matrix side unsettling influences separated from expanding the shortcoming ride through capacity ofConverter during drifters. With the expanded accentuation on dispersed age and smaller scale networks, there is a recharged enthusiasm for UPQC frameworks. Reference signal age is a noteworthy undertaking responsible for PVUPQC. Reference signal age strategies can be extensively partitioned into time-space and recurrence area systems [8]. Time space procedures are ordinarily utilized

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on account of lower computational prerequisites continuously usage. The usually utilized strategies incorporate prompt receptive power hypothesis (p-q hypothesis), synchronous reference outline hypothesis (d-q hypothesis) and quick symmetrical segment hypothesis. The primary issue being used of synchronous reference outline hypothesis based technique is that during burden lopsided condition, twofold consonant part is available in the d-hub current. Because of this, low pass channels with low profile off recurrence is utilized to sift through twofold symphonious part. This out comes in poor powerful execution. In this work, a moving normal channel (MAF) is utilized to channel the d-hub current to acquire basic burden dynamic current. This gives ideal weakening and without decreasing the data transfer capacity of the controller. As of late, MAF has been connected in improving execution of DC-interface controllers just as for network synchronization utilizing stage bolted circle (PLL).

In this paper, the plan and execution investigation of a three stage PV-UPQC are displayed. A MAF based d-q hypothesis based control is utilized to improve the dynamic execution during burden dynamic current extraction. The fundamental focal points of the proposed framework are as per the following,Integration of clean energy generation and power quality improvement, Simultaneous voltage and current quality improvement, Improved load current compensation due to use of MAF in d-q control of PV-UPQC, Stable under various dynamic conditions of voltage sags/swells, load unbalance and irradiation variation.The presentation of the proposed framework is investigated broadly under both dynamic and consistent state conditions utilizing Matlab- Simulink programming. The exhibition is then tentatively checked utilizing a downsized lab model under different conditions experienced in the circulation framework, for example, voltage lists/swells, load unbalance and illumination variety.

II.SYSTEM CONFIGURATION AND DESIGN

The structure of the PV-UPQC is appeared in Fig.1. The PV-UPQC is intended for a three- stage framework. The PVUPQC comprises of shunt and arrangement compensator associated with a typical DC-transport. The shunt compensator is associated at the heap side. The sunlight based PV cluster is straightforwardly incorporated to the DC-connection of UPQC through an invert blocking diode. The arrangement compensator works in voltage control mode and makes up for the network voltage lists/swells. The shunt and arrangement compensators are incorporated to the framework through interfacing inductors. An arrangement infusion transformer is utilized to infuse voltage produced by the arrangement compensator into the lattice. Swell channels are utilized to channel music created because of exchanging activity of converters. The heap utilized is a nonlinear burden comprising of an extension rectifier with a voltage-encouraged burden.

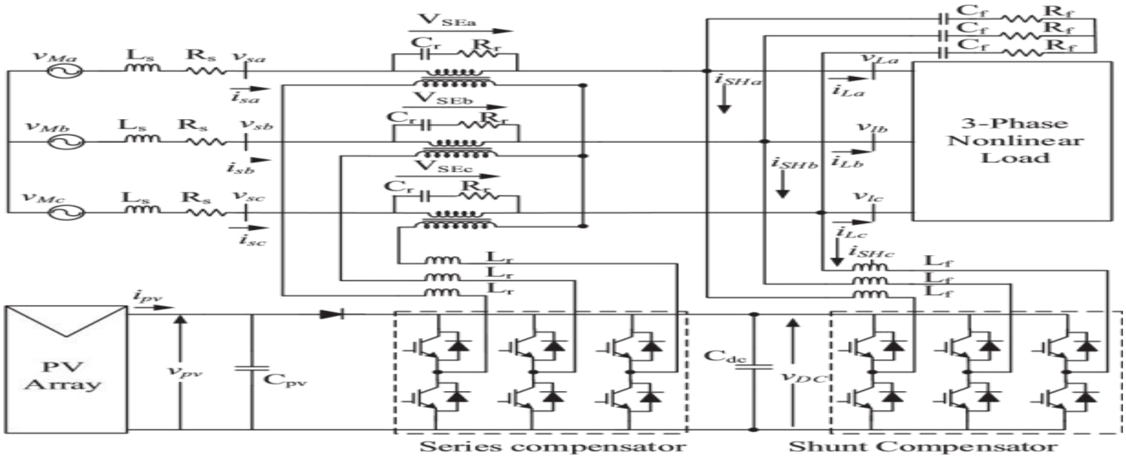

Fig. 1. System Configuration PV-UPQC

III.A. Design of PV-UPQC

The plan strategy for PV-UPQC starts with the best possible estimating of PV exhibit, DC- connect capacitor, DC-Link voltage level and so forth. The shunt compensator is estimated with the end goal that it handles the pinnacle power yield from PV cluster separated from making up for the heap current receptive power and current sounds. As the PV cluster is legitimately coordinated to the DC-connection of UPQC, the PV exhibit is measured with the end goal that the MPP voltage is same as wanted DC link voltage. The rating is with the end goal that, under ostensible conditions, the PV exhibit supplies the heap dynamic power and furthermore feeds control into the matrix. The nitty gritty PV cluster details are given in Appendix A. The other planned segments are the interfacing inductors of arrangement and

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shunt compensators and arrangement infusion transformer of the arrangement compensator. The structure of PV-UPQC is expounded as pursues.

1. Voltage Magnitude of DC-Link: The magnitude of DC link voltage Vdc depends on the depth of modulation used and per-phase voltage of the system. The DC-link voltage magnitude should more than double the peak of per-phase voltage of the three phase system [8] and is given as,

$$V_{dc} = \frac{2\sqrt{2}V_{LL}}{\sqrt{3}m}$$

Where depth of modulation (m) is taken as 1 andVLL is the grid line voltage. For a line voltage of415 V, the required minimum value DC-bus voltage is 677.7 V. The DC-bus voltage is set at 700 V(approx), which is same as the MPPT operating voltage of PV array at STC conditions.

2. DC-Bus Capacitor Rating: The DC-link capacitor is sized based upon power requirement as well as DC-bus voltage level. The energy balance equation for the DC-bus capacitor is given as follows [8],

$$\begin{aligned} C_{dc} &= \frac{3kaV_{ph}I_{sh}t}{0.5 \times (V_{dc}^2 - V_{dc1}^2)} \\ &= \frac{3 \times 0.1 \times 1.5 \times 239.6 \times 34.5 \times 0.03}{0.5 \times (700^2 - 677.79^2)} \\ &= 9.3mF \end{aligned}$$

where Vdc is the average DC-bus voltage, Vdc1 is the lowest required value of DC-bus voltage,a is the overloading factor, Vph is per-phase voltage, t is the minimum time required for attaining steady value after a disturbance, Ish is per-phase current of shunt compensator, k factor considers variation in energy during dynamics.

The minimum required DC-link voltage is Vdc1 =677.69 V as obtained from (2), Vdc = 700 V, Vph=239.60 V,Ish=57.5 A, t= 30 ms, a = 1.2, and for dynamic energy change = 10%, k= 0.1, the value of Cdc is obtained as 9.3 mF.

3. Interfacing Inductor for Shunt Compensator: The interfacing inductor rating of the shunt compensator depends upon the ripple current, the switching frequency and DC-link voltage. The expression for the interfacing inductor is as,

$$\begin{aligned} L_f = \frac{\sqrt{3}mV_{dc}}{12af_{sh}I_{cr,pp}} &= \frac{\sqrt{3} \times 1 \times 700}{12 \times 1.2 \times 10000 \times 6.9} \\ &= 800\mu H \approx 1mH \end{aligned}$$

where m is depth of modulation, a is pu value of maximum overload, fshis the switching frequency,Icr,pp is the inductor ripple current which is taken as 20% of rms phase current of shunt compensator. Here, m=1, a=1.2, fsh=10kHz, Vdc=700V, one gets 800 µH as value. The value chosen is approximated to 1mH.

1.Series Injection Transformer: The PV-UPQC is designed to compensate for a sag/swell of 0.3 pu i.e 71.88 V. Hence, the required voltage to be injection is only 71.88 V which results in low modulation index for the series compensator when the DC-link voltage is 700V. In order to operate the series compensator with minimum harmonics, one keeps modulation index of the series compensator near to unity. Hence a series transformer is used with a turn's ratio,

$$K_{SE} = \frac{V_{VSC}}{V_{SE}} = 3.33 \approx 3$$

The value obtained for KSE is 3.33. The value selected is 3. The rating of series injection transformer is given as,

$$S_{SE} = 3V_{SE}I_{SEsag} = 3 \times 72 \times 46 = 10kVA$$

The current through series VSC is same as grid current. The supply current under sag condition of 0.3 pu is 46 A and hence the VA rating of injection transformer achieved is 10 kVA.

2. Interfacing Inductor of Series Compensator: The rating of interfacing inductorof the series compensator depends on ripple current at swell condition, switching frequency and DClink voltage. Its value is expressed as,

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$$L_r = \frac{\sqrt{3} \times mV_{dc}K_{SE}}{12af_{se}I_r} = \frac{\sqrt{3} \times 1 \times 700 \times 3}{12 \times 1.2 \times 10000 \times 7.1} = 3.6mH$$

Where m is the depth of modulation, a is the pu value of maximum overload, fse is the switching frequency, Ir is the inductor current ripple, which is taken to be 20% of grid current. Here, m=1, a=1.5, fse=10 kHz, Vdc=700 V and 20% ripple current, one gets 3.6 mH as selected value.

IV.CONTROL OF PV-UPQC

The main subsystems of PV-UPQC are the shunt compensator and the series compensator. The shunt compensator compensates for the load power quality problems such as load current harmonics and load reactive power. In case of PVUPQC, the shunt compensator performs the additional function of supplying power from the solar PV array. The shunt compensator extracts power from the PV-array by using a maximum power point tracking (MPPT) algorithm. The series compensator protects the load from the grid side power quality problems such as voltage sags/swells by injecting appropriate voltage in phase with the grid voltage.

A. Control of Shunt Compensator

The shunt compensator extracts the maximum power from the solar PV-array by operating it at its maximum power point. The maximum power point tracking (MPPT) algorithm generates the reference voltage for the DC-link of PV-UPQC. Some of the commonly used MPPT algorithms [28] are Perturb and Observe (P& O) algorithm, incremental conductance algorithm (INC). In this work, (P& O) algorithm is used for implementing MPPT. The DC-link voltage is maintained at the generated reference by using a PI-controller. To perform the load current compensation, the shunt compensator extracts the active fundamental component of the load current. For this work, the shunt compensator is controlled by extracting fundamental active component of load current using SRF technique.

The control structure of shunt compensator is shown in Fig. 2. The load currents are converted to d-q-0 domain using the phase and frequency information obtained from PLL. The PLL input is the PCC voltage. The d-component of the load current (ILd) is filtered to extract DC component (ILdf) which represents the fundamental component in abc frame of reference. To extract DC component without deteriorating the dynamic performance, a moving average filter (MAF) is used to extract the DC component. The transfer function of moving average filter is given as,

$$MAF(s) = \frac{1 - e^{-T_w s}}{T_w s}$$

where Tw is the window length of the moving average filter. As the lowest harmonic present in the d-axis current is double harmonic component, Tw is kept at half of fundamental time period. The MAF has unity DC gain and zero gain integer multiples of window length.

The equivalent current component due to PV array is given as,

$$I_{pvg} = \frac{2}{3}\frac{P_{pv}}{V_s}$$

where Ppv is the PV array power and Vs is the magnitude of the PCC voltage. The reference grid current in d-axis is given as

$$I_{sd}^{*} = I_{Ldf} + I_{loss} - I_{pvg}$$

is converted to abc domain reference grid currents. The reference grid currents are compared with the sensed grid currents in a hysteresis current controller to generate the gating pulses for the shunt converter.

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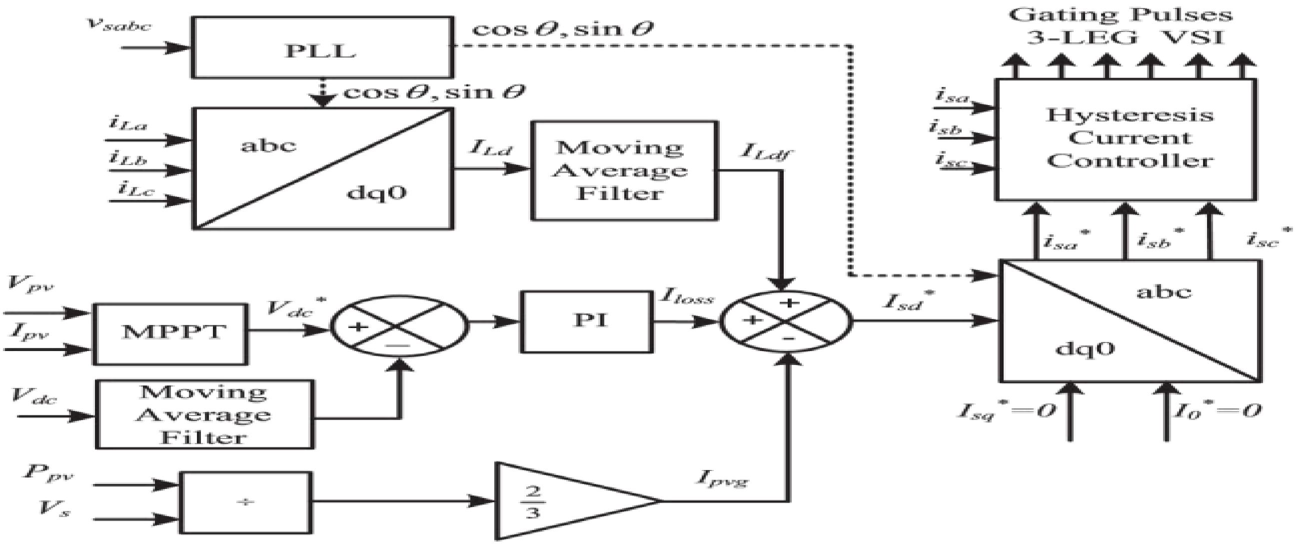

Fig. 2. Control Structure of Shunt Compensator

B. Control of Series Compensator

The control procedure for the arrangement compensator is pre sag pay, in-stage remuneration and vitality ideal pay. A point by point portrayal of different pay systems utilized for control of arrangement compensator is accounted for in [29], [30] In this work, the arrangement compensator infuses voltage in same stage as that of network voltage, which results in least infusion voltage by the arrangement compensator. The control structure of the arrangement compensator is appeared in Fig.3. The essential segment of PCC voltage is extricated utilizing a PLL which is utilized for creating the reference hub in dq-0 space. The reference load voltage is created utilizing the stage and recurrence data of PCC voltage got utilizing PLL. The PCC voltages and burden voltages are changed over into d-q-0 space. As the reference load voltage is to be in stage with the PCC voltage, the pinnacle burden reference voltage is the d-hub segment estimation of burden reference voltage. The q-pivot segment is kept at zero. The distinction between the heap reference voltage and PCC voltage gives the reference voltage for the arrangement compensator. The contrast between burden voltage and PCC voltage gives the genuine arrangement compensator voltages. The distinction among reference and genuine arrangement compensator voltages is passed to PI controllers to produce fitting reference signals. These signs are changed over to abc space and went through heartbeat width balance (PWM) voltage controller to produce fitting gating signals for the arrangement compensator.

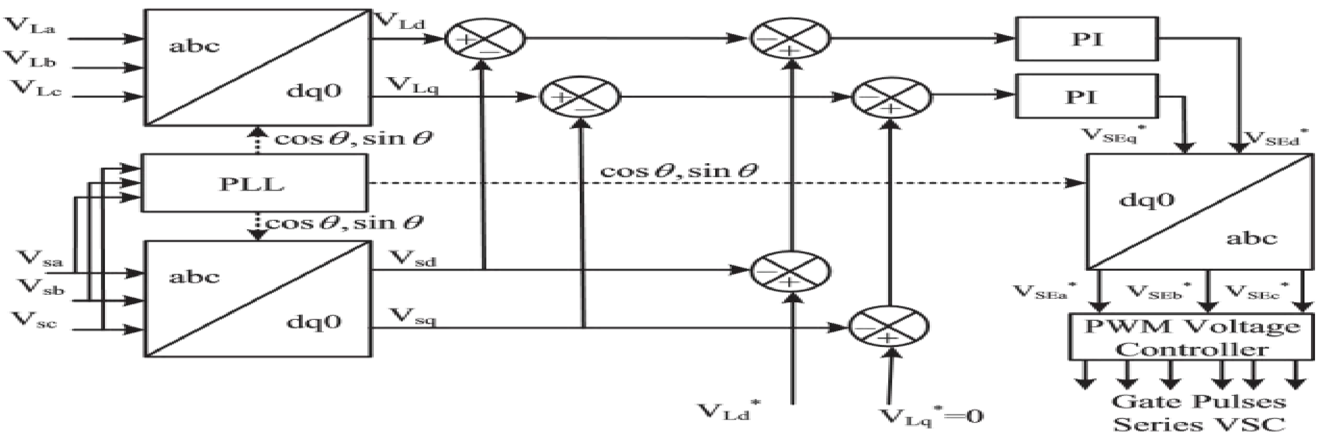

Fig.3.Control Structure of Series Compensator

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V. SIMULATION STUDIES

The steady state and dynamic performances of PV-UPQC are analyzed by simulating the system in Matlab-Simulink software. The load used is a nonlinear load consisting of three phase diode bridge rectifier with R-L load. The solver step size used for the simulation is 1e-6s. The system is subjected to various dynamic conditions such as sag and swells in PCC voltage and PV irradiation variation. The detailed system parameters are given in Appendix.

A. Performance of PV-UPQC at PCC Voltage Fluctuations

The dynamic performance of PV-UPQC under conditions of PCC voltage sags/swells is shown in Fig.4. The irradiation (G) is kept at 1000W/m2. The various sensed signals are PCC voltages (vs), load voltages(vL), series compensator voltages (vSE), DC-link voltage (Vdc), solar PV array current (Ipv), solar PV array power (Ppv), grid currents (iS), load currents(iLa,iLb,iLc), shunt compensator currents (iSHa,iSHb,iSHc). Between 0.7s and 0.75s, there is voltage sag of 0.3pu and from 0.8s to 0.85s there is voltage swell of 0.3pu. The series compensator compensates for the grid voltage under these conditions by injecting a suitable voltage vSE in opposite phase with the grid voltage disturbance to maintain the load voltage at rated voltage condition.

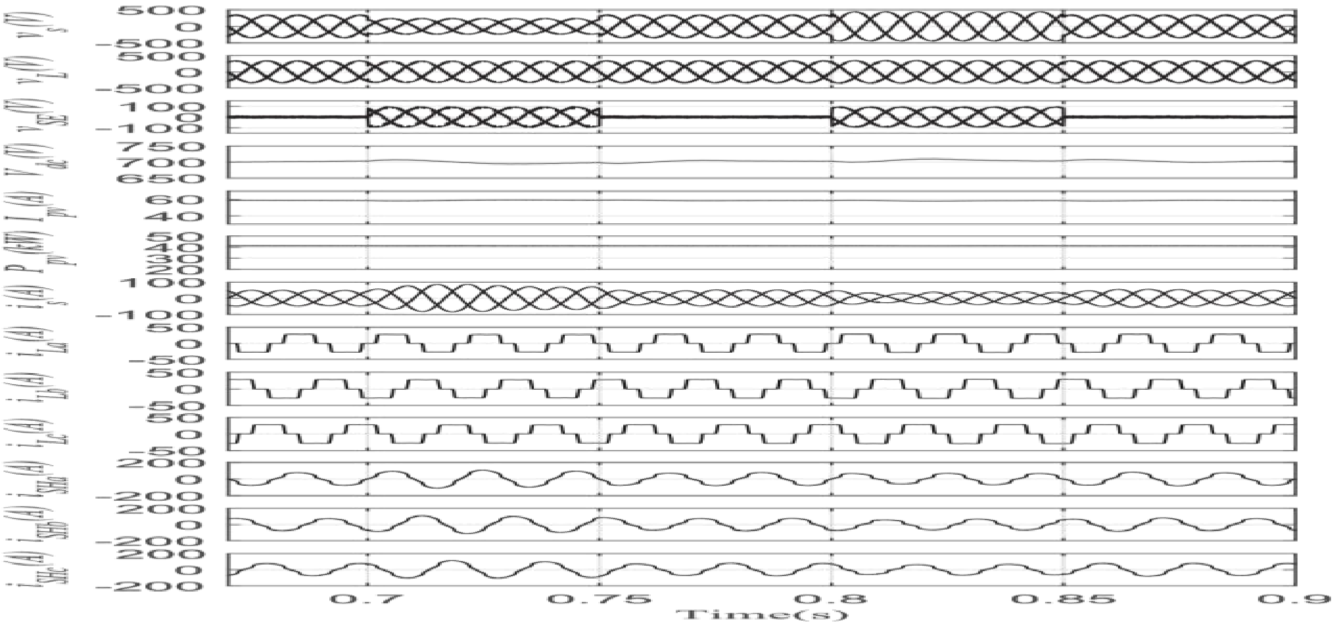

Fig. 4. Performance of PV-UPQC under Voltage Sag and Swell Conditions

B. Performance of PV-UPQC at Load Unbalancing Condition

The dynamic performance of PV-UPQC under load unbalance condition is shown in Fig.5. At t=0.8s, phase 'b' of the load is disconnected. It can be observed that the grid current is sinusoidal and at unity power factor. The current fed into the grid rises leading due to the reduction in the total effective load. The DC-link voltage is also stable and it is maintained near its desired regulated value of 700 V.

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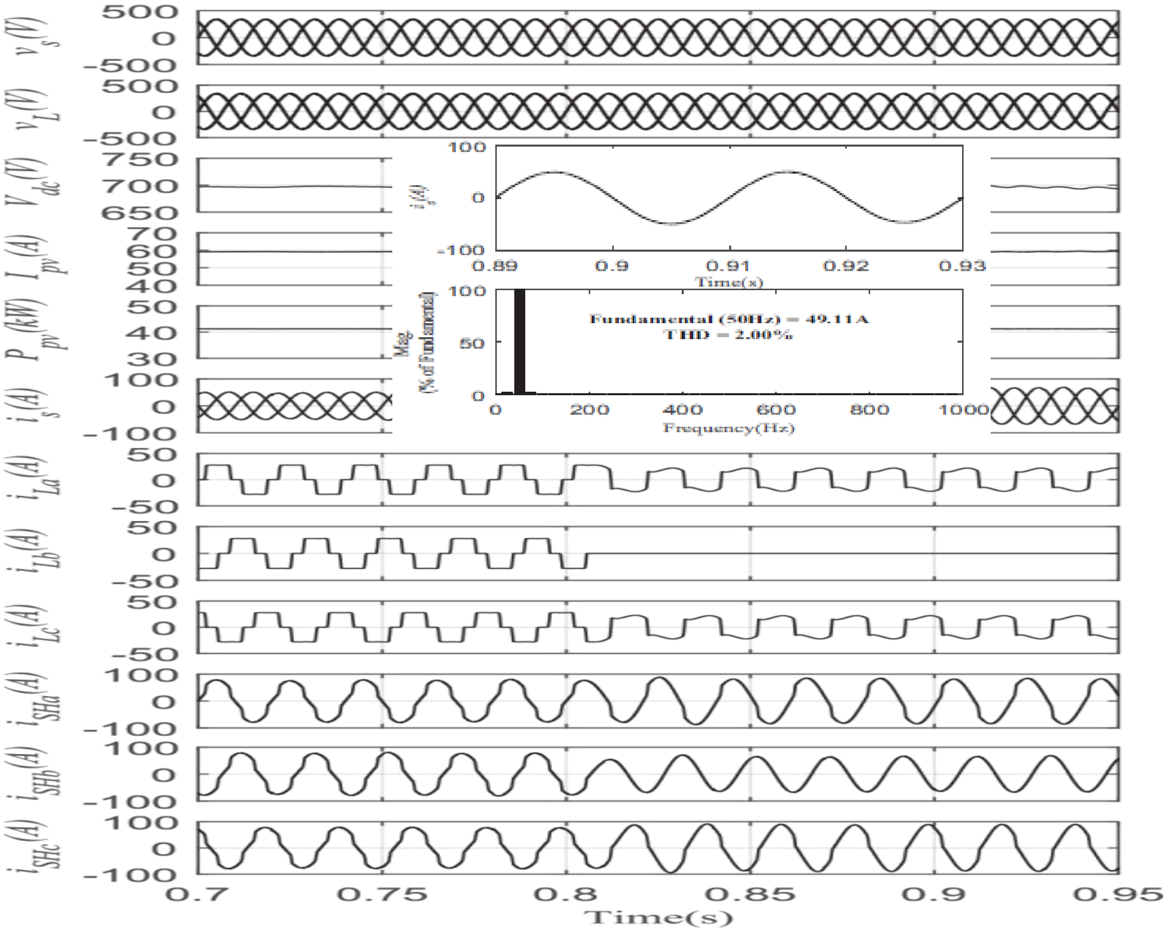

Fig. 6. Performance PV-UPQC at Varying Irradiation Condition

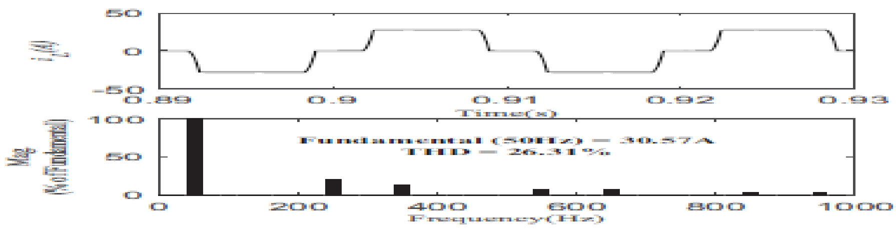

Fig. 7. Load Current Harmonic Spectrum and THD

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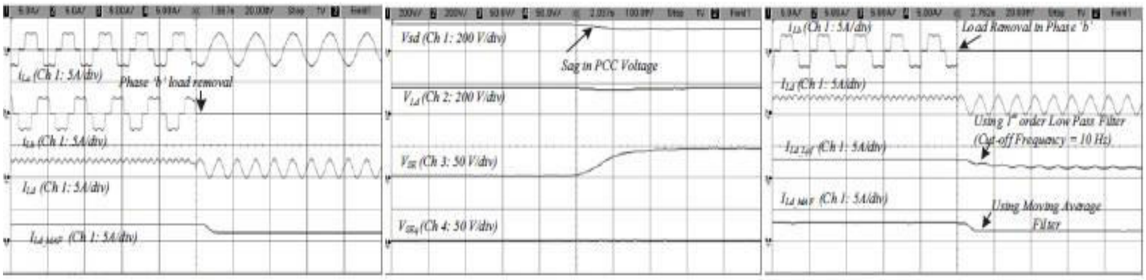
The three phase nonlinear load is realized using a bridge rectifier along with an R-L load. Thecontrol is realized using a dSPACE MicrolabBox DSP controller.

VI.CONCLUSION

The structure and dynamic execution of three- stage PVUPQC have been examined under states of variable light and network voltage hangs/swells. The exhibition of the framework has been approved through experimentation on downsized research facility model. It is seen that PVUPQC mitigates the music brought about by nonlinear burden and keeps up the THD of lattice current under points of confinement of IEEE-519 standard. The framework is observed to be steady under variety of light, voltage hangs/swell and burden unbalance. The presentation of d-q control especially in burden unequal condition has been improved using moving normal channel. It tends to be seen that PV-UPQC is a decent answer for current appropriation framework by coordinating conveyed age with power quality improvement.

TABLE I
PV TRACKING EFFICIENCY

SL.No	$G(W/m^2)$	$V_{mpp}(V)$	$I_{mpp}(A)$	$P_{mpp}(W)$	$V_{pv}(V)$	$I_{pv}(A)$	$P_{pv}(W)$	Efficiency(%)
1	1000	371.6	12.6	4672.3	375.8	12.4	4662.6	99.79
2	900	369.9	11.4	4216.1	369.0	11.4	4206.6	99.78
3	800	368.0	10.1	3738.9	370.1	10.1	3738.1	99.97
4	700	365.8	8.9	3255.6	366.3	8.8	3255.6	99.57
5	600	363.3	7.7	2797.4	361.9	7.7	2786.6	99.61
6	500	360.4	6.5	2342.6	365.0	6.4	2336.0	99.74



(a) Internal Signals of Shunt Compensator (b) Internal Signals of Series Compensator (c) Performance comparison in Load Active Component Extraction

Fig. 14. Salient Internal Signals in PV-UPQC control

REFERENCES

[1] Mountain and P. Szuster, "Solar, solar everywhere:Opportunities and challenges for australia's rooftoppv systems," *IEEE Power and Energy Magazine*,vol. 13, no. 4, pp. 53–60, July 2015.

[2] R.Malekpour,A.Pahwa,A.Malekpour,andB.Natarajan, "Hierarchical architecture for integrationof rooftop pv in smart distribution systems," *IEEETransactions on Smart Grid*, vol. PP, no. 99, pp. 1–1, 2017.

[3] Y.Yang,P.Enjeti,F.Blaabjerg,andH.Wang,"Wide-scale adoption of photovoltaic energy: Gridcode modifications are explored in the distributiongrid," *IEEE Ind. Appl. Mag.*, vol. 21, no. 5, pp. 21–31,Sept 2015.

[4] M. J. E. Alam, K. M. Muttaqi, and D. Sutanto, "Anapproach for online assessment of rooftop solar pvimpactsonlow-voltagedistributionnetworks,"*IEEE Transactions on Sustainable Energy*, vol. 5,no.2, pp. 663–672, April 2014.

[5] J.JayachandranandR.M.Sachithanandam,"Neuralnetwork-basedcontrolalgorithmforDSTATCOMundernonidealsourcevoltageandvaryingloadconditions,"

[6] Parchure,S.J.Tyler,M.A.Peskin,K.Rahimi,R.P.Broadwater,andM.Dilek,"Investigatingpvgeneration induced voltage volatility for customerssharingadistributionservicetransformer,"*IEEETrans.Ind.Appl.*, vol. 53,no.1,pp. 71–79,Jan2017.

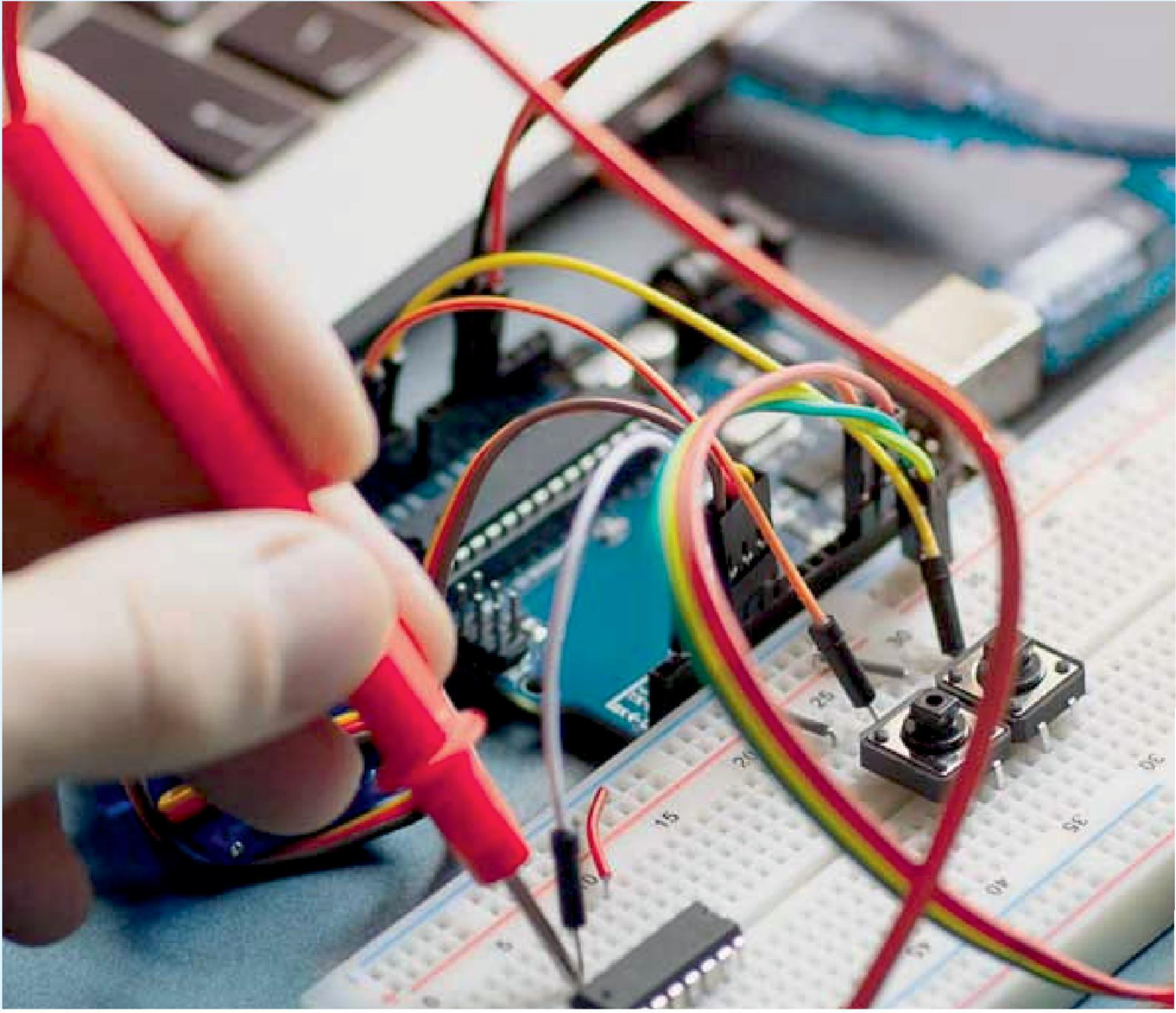
[7] Yao, P. Samadi, V. W. S. Wong, and R. Schober,"Residential demand side management under highpenetrationofrooftopphotovoltaicunits,"*IEEETransactions on Smart Grid*, vol. 7, no. 3, pp. 1597–1608,May 2016.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 8.18|

||Volume 11, Issue 8, August 2022||

|DOI:10.15662/IJAREEIE.2022.1108012 |

[8] Singh,A.ChandraandK.A.Haddad,*PowerQuality:ProblemsandMitigationTechniques*.London:Wiley, 2015.
[9] M. Bollen and I. Guo, *Signal Processing of PowerQualityDisturbances*. Hoboken: Johm Wiley,2006.
[10] P. Jayaprakash, B. Singh, D. Kothari, A. Chandra,andK.Al-Haddad,"Controlofreduced-ratingdynamicvoltagerestorerwithabatteryenergystorage system,"*IEEETrans. Ind. Appl.*, vol.50,no.2, pp. 1295–1303, March 2014.



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