Unified Power Quality Conditioner in a Grid Connected Photo-voltaic System

S.MD.ISHAQ, M.Tech,
Student,
Electrical Power Systems,
Sree Vidyanikethan Engineering College.

W.V.JAHNAVI, M.Tech,
Asst.Professor (S.L),
E.E.E.Department,
Sree Vidyanikethan Engineering College.

T.DEVARAJU, M.E, Ph.D,
Professor, HOD,
E.E.E.Department,
Sree Vidyanikethan Engineering College.

ABSTRACT

In this paper the design of combined operation of UPQC and PV-ARRAY is proposed. The proposed system is composed of series and shunt inverters connected back to back by a dc-link to which pv-array is connected. This system is able to compensate voltage and current related problems both in inter-connected mode and islanding mode by injecting active power to grid. The fundamental aspect is that the power electronic devices (PE) and sensitive equipments (SE) are normally designed to work in non-polluted power system, so they would suffer from malfunctions when supply voltage is not pure sinusoidal. Thus this proposed operating strategy with flexible operation mode improves the power quality of the grid system combining photovoltaic array with a control of UNIFIED POWER QUALITY CONDITIONER.

NOMENCLATURE

I_L	load current
V_L	load voltage
C_F	filter capacitance
I_F	filter current
V_{DC}	Dc voltage
I_S	source current
V_S	source voltage
V_f	filter voltage
Cs	source capacitance
Ls	source inductance
I_{abc}	3-phase instantaneous load current
V_{labc}	3-phase instantaneous load voltages
V_{sabc}	3-phase source voltages
I_{ldq}	Two axis currents
Δi_{dc}	dc link capacitor voltage
Ic	compensating current
PLL	phase locked loop
LPF	low pass filter
P I	proportional plus integral controller
PWM	pulse width modulation
MPPT	maximum power point tracking

I.INTRODUCTION

One of the important aspects is that, power electronic devices and sensitive equipments are designed to work in non-polluted power systems. So, they would suffer from malfunctions when the supply voltage is not pure sinusoidal. As these devices are the most important cause of harmonics, inter harmonics, notches and neutral currents, the power quality should be improved. The solution to PQ problem can be achieved by adding auxiliary individual device with energy storage at its dc-link by PV-array.

This auxiliary equipment has the general name of power conditioners and are mainly characterised by the amount of stored energy or stand alone supply time. That auxiliary equipment having both "shunt" and "series" inverter connected back to back by a dc-link is called the "unified power quality conditioner" (UPQC).

UPQC with PV-ARRAY is greatly studied by several researchers as a basic device to control the power quality. The duty of UPQC is reducing perturbations which affect on the operation of sensitive loads. UPQC is able to compensate voltage sag, swell, voltage and current harmonics using shunt and series inverters.

In spite of this issue, UPQC is able to compensate voltage interruption and active power injection to grid because in its dc-link there is energy storage known as distributed generating (D.G) source.

The attention to distributed generating (DG) sources is increasing day by day. The reason is their important roll they will likely play in the future of power systems (Blaabjerg *et al*, 2004), (Barker and deMello, 2000).Recently, several studies are accomplished in the field of connecting DGs to grid using power electronic converters. Here, grid's interface shunt inverters are considered more where the reason is low sensitiveness of DGs to grid's parameters and DG power transferring facility using this approach. Although DG needs more controls to reduce the problems like grid power quality and reliability, PV energy is one of the distributed generation sources which provides a part of human required energy nowadays and will provide in the future. The greatest share of applying this kind of energy in the future will be its usage in interconnected systems. Nowadays, European countries, has caused interconnected systems development in their countries by choosing supporting policies. In this paper, UPQC and PV combined system has been presented. UPQC introduced in has the ability to compensate voltage sag and swell, harmonics and reactive power.

In fig. 1 the general structure of grid connected PV systems is shown. The advantage of proposed combined system is voltage interruption compensation and active power injection to grid in addition to the mentioned abilities. Also, this proposed system has higher efficiency and functioning ability in compare with other common PVs and causes reduction in system's total cost. Simulation results, using **"MATLAB"** software show that this proposed system operates correctly.

II.SYSTEM DESCRIPTION

UPQC has two shunt and series voltage source inverters which are as 3-phase 3-wire or 3-phase 4-wire. Shunt inverter is connected to point of common coupling (PCC) by shunt transformer and series inverter stands between source and coupling point by series transformer. Shunt inverter operates as current source and series inverter operates as voltage source.
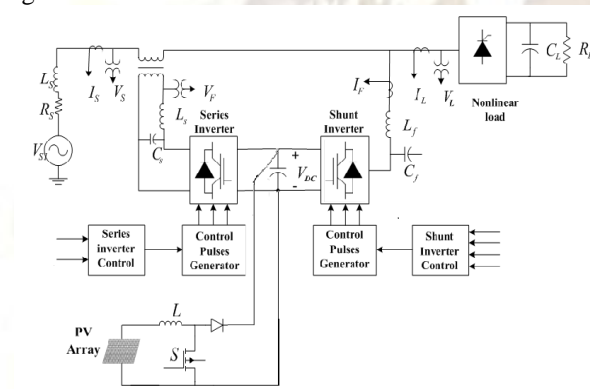

Fig. 1: Configuration of proposed UPQC with PV

UPQC is able to compensate current's harmonics, to compensate reactive power, voltage distortions and can compensate voltage interruption because of having PV-array as a source. Common interconnected PV systems structure is as fig. 1 which is composed of PV array, DC/DC and DC/AC converters.

In this paper a new structure is proposed for UPQC, where PV is connected to DC link in UPQC as energy source.

In this case, UPQC finds the ability of injecting power using PV to sensitive load during source voltage interruption. **Fig. 1** shows the configuration of proposed system. In this proposed system, two Operational modes are studied as follow:

A. Interconnected mode: where PV transfers power to load and source.

B. Islanding mode: where the source voltage is interrupted and PV provides a part of load power separately.

SYSTEM DESIGN:

The controlling design of proposed system is composed of three following parts:

A. Shunt inverter control

B. Series inverter control

C. DC/DC converter

Controlling strategy is designed and applied for two interconnected and islanding modes. In interconnected mode, source and PV provide the load power together while in islanding mode; PV transfers the power to the load lonely. By removing voltage interruption, system returns to interconnected mode.

A. Shunt inverter control:

In this paper, shunt inverter undertakes two main duties. First is compensating both current harmonics generated by nonlinear load and reactive power, second is injecting active power generated by PV system. The shunt inverter controlling system should be designed in a way that it would provide the ability of undertaking two above duties.

Shunt inverter control calculates the compensation current for current harmonics and reactive Power when PV is out of the grid.
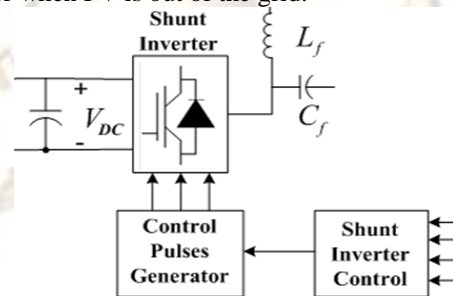

Fig.2: shunt inverter control block

The power loss caused by inverter operation should be considered in this calculation. It has the ability of stabilizing DC-link voltage during shunt inverter operation to compensate voltage distortions. The stabilization is maintained by DC-link capacitor voltage controlling loop in which P.I. controller is applied.

Shunt inverter control consists of the control circuit as shown in figure below:
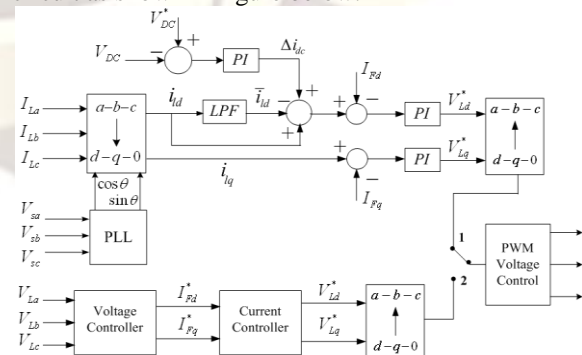

Fig.3: control block diagram of shunt inverter

A.1. Shunt inverter control in Interconnected mode:

Mode-1 of fig.3 shows UPQC shunt voltage source inverter controlling block diagram to which

Synchronous reference frame theory then is applied by extracting the sensitive load currents as I_{LA}, I_{LB}, I_{LC}.

When unbalance condition occurs in each phase the stationary values are changed as +ve, − ve & '0' sequences. So exact analysis is difficult to achieve.

So the measured load currents applying synchronous reference frame conversion method (dq0) or parks transformation are transferred to dq0 frame using sinusoidal functions, i.e., frequency and phase angle of the converted load currents are determined.

This function is obtained by PLL by taking source side voltages V_{SA}, V_{SB}, V_{SC} as reference, which provides to maintain the synchronism with supply voltage and current.
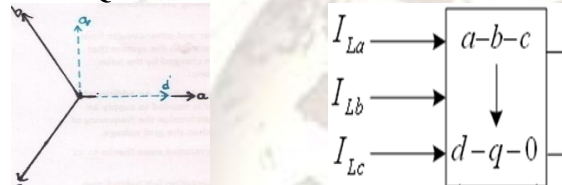
ABC-DQ0 transformation:

Fig.3 (a): abc-dq phasor   Fig.3 (b): abc-dq block

This transformation can be thought of in geometric terms: As the projection of the three phase separate sinusoidal phase quantities on two axes, called the direct (**d**) and quadrature (**q**) axis.

The direct & quadrature axis currents are:

$$I_{ldq0} = T^{dq0}_{abc} I_{abc} \qquad (1)$$

General form of transformation is replacing old variables by a new set of variables:
[New variables] = [transformation matrix] [old Variables]
Where,

$$I_d = i_a \cos 0° + i_b \cos 120° + i_c \cos 240° \qquad (2)$$
$$I_q = i_a \sin 0° + i_b \sin 120° + i_c \sin 240° \qquad (3)$$
$$I_0 \text{ is considered for convinience.} \qquad (4)$$

$$\text{Thus total } T^{abc}_{dq0} = \begin{bmatrix} I_d \\ I_q \\ I_0 \end{bmatrix} \qquad (5)$$

$$= \frac{2}{3} \begin{bmatrix} \cos\theta & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ \sin\theta & \sin(\theta - \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \qquad (6)$$

The d-axis and q-axis currents I_D and I_q are constant and instantaneous values considered as:

$$I_{LD} = \bar{I}_{LD} + \tilde{I}_{LD} \qquad (7)$$

Harmonic currents can be eliminated by low pass filter. In this case $I_L = I_S + I_c$, injected by shunt inverter.

The compensation reference currents are considered as:

$$I^*_{Fd} = \tilde{I}_{Ld}$$
$$I^*_{Fq} = \tilde{I}_{Lq}$$

As it is shown in fig. 3, the reference currents will transfer to ABC frame by reverse converting the Synchronous reference frame. Resulted reference currents will be compared with shunt inverter Output currents (I_{fa}, If_b, Ifc) in a PWM current controller (hysteresis type) and required controlling pulses are generated. Applying these signals to shunt inverter power switches gate, required compensation current is generated by inverter.

NOTE: In machine analysis, for the development of electric torque T_e, requires the interaction between two axis currents which must be in quadrature. Hence, in this transformation it is important to consider this condition.

A.2. shunt inverter control in islanding mode:
In addition to previous duties, shunt inverter control should inject active power of PV system to control when PV is operating. If the voltage interruption occurs at load, that exceeds a threshold value, the inverter operation will switch from interconnected mode to islanding mode. PV system provides required active power to stabilize load voltage.
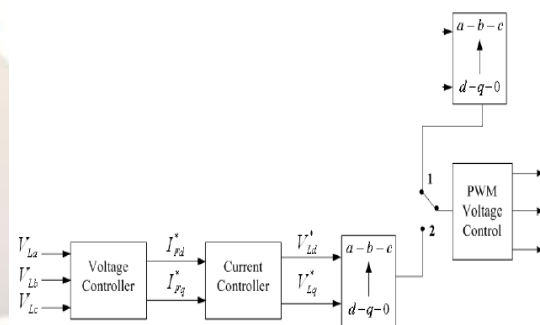

Fig.4: shunt-inverter in islanding mode

In this case, shunt inverter controls output voltage and current in order to inject to load using PI controller as shown below:
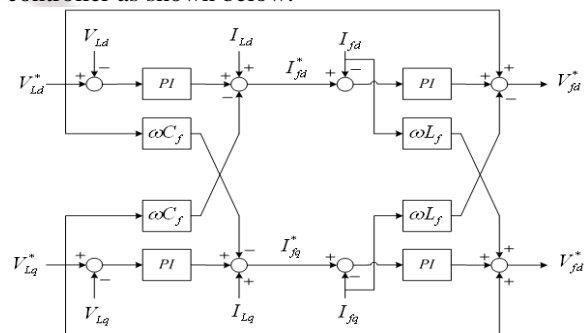
Fig. 4(a): Controlling block diagram of shunt inverter in islanding mode

This reduces steady state error and maintains constant power. In voltage control current is considered as leading (capacitive load) and corresponding d-q currents are obtained as output as shown below:

$$I^*_{fd} = K_{PI}(V^*_{ld} - V_{ld}) - \omega C_f V_{lq} + I_{ld} \quad (8)$$

$$I^*_{fq} = K_{PI}(V^*_{lq} - V_{lq}) - \omega C_f V_{ld} + I_{lq} \quad (9)$$

I^*_{Fd}, I^*_{Fq} currents Are inputs to current controller. In this control considering current lagging (inductive load), the corresponding DQ-voltages are obtained as output as shown below:

$$V^*_{fd} = K_{PI}(I^*_{Fd} - I_{Fd}) - \omega L_F I_{fq} + V_{Ld} \quad (10)$$

$$V^*_{fq} = K_{PI}(I^*_{Fq} - I_{Fq}) - \omega L_F I_{fd} + V_{Lq} \quad (11)$$

Double times the calculation is performed to maintain 's' constant(S = P+JQ), from this maximum distortions are removed and compensating output value is obtained. From the figure.4 these voltages are again transformed to A-B-C sequence and compared with angular waveform in PWM control, and corresponding control pulses are generated. Applying these signals to shunt inverter switch, the corresponding voltage is given to load.

B.Series inverter controlling:

The duty of the series inverter is to compensate the voltage disturbance in the source side, grid which is due to the fault in the distribution line. Series inverter control calculates the voltage reference values which are injected to grid by series inverter. In order to control series inverter of UPQC, load sinusoidal voltage controlling strategy is proposed as shown in figure below:
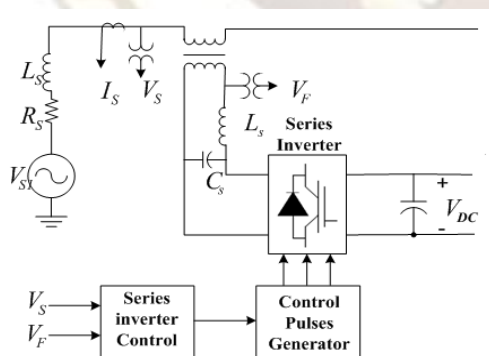

Fig.5: series inverter block diagram

In this condition UPQC, series inverter would be controlled in a way that it compensates the whole

distortions and helps the voltage of load voltage stay (balanced sinusoidal 3-phase).
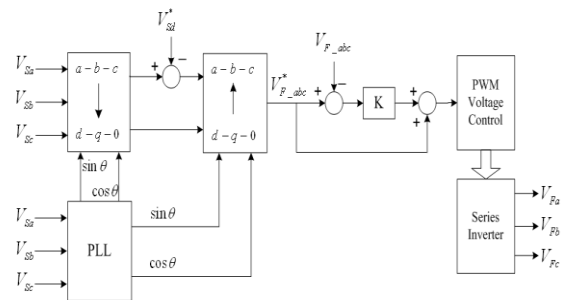

Fig.5 (a): control block diagram of series inverter

In order to reach this aim synchronous reference frame theory is applied. In this method only d-axis component is being controlled i.e., active power component. By compensating the active power component, reactive power component will be compensated automatically.

In this method the desired value of load phase voltage is replaced in d and q-axis. The load voltage should be kept sinusoidal with constant amplitude even if the voltage on system side is disturbed.

At interruption mode the system voltages V_{sa}, V_{sb}, V_{sc} are detected and then transformed to dq0 reference frame and this set of relations in between the 3-ϕ variables and dq variables is known as park's transformation as shown below:
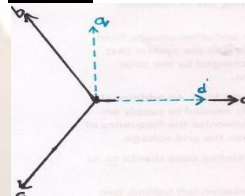
Park's:

Fig.6: phasor of abc-dq

$$V^*_{ldq0} = T^{dq0}_{abc} \cdot V^*_{labc} \quad (11)$$

$$= \begin{bmatrix} \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ \sin(\theta) & \sin(\theta - \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix} \times \begin{bmatrix} V_m \cos(\omega t + \theta) \\ V_m \cos(\omega t + \theta - 120°) \\ V_m \cos(\omega t + \theta + 120°) \end{bmatrix} \quad (12)$$

$$= \begin{bmatrix} V_m \\ 0 \\ 0 \end{bmatrix} \quad (13)$$

This means d-axis of load reference voltage equals "V_M", while q-axis and zero axis of load reference voltage equals zero. Where Vm is desired peak

value of load voltage and (θ) is voltage phase angle which is calculated by phase locked loop (PLL). By

subtracting the desired value of d-axis phase voltage (V^*_{Ld}) from V_{Sd}, all distortions V_{Ld} in d-axis are obtained. Also, the desired value of load phase voltage in q-axis is zero. In other words, V_{Sq} represents total q-axis distortions. So series compensation reference voltage is resulted by relation (14):

$$V^*_{fdq0} = V^*_{ldq0} - V_{sdq0} \tag{14}$$

The above equation of compensation reference voltage is then inversely transformed into a-b-c reference frame as: V^*_{Fabc}

$$V^*_{Fabc} = [T^{abc}_{dq0}]^{-1}[V_{dq0}] \tag{14.1}$$

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & \frac{1}{3} \\ \cos(\theta - \frac{2\pi}{3}) & \sin(\theta - \frac{2\pi}{3}) & \frac{1}{3} \\ \cos(\theta + \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) & \frac{1}{3} \end{bmatrix} \times \begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} \tag{14.2}$$

These voltages are compared with an angular waveform in PWM controller and required controlling pulses (g1... g6) are generated to be applied to series voltage source inverter switches. This corrected method is programmable with a low cost. The other advantage is that the controlling System's calculation time is shortened and so controlling system's response is faster.

Note: In order to improve series inverter operation, SPWM method is used where the resulted value of subtracting V^*_{Fabc} from V_{Fabc} is multiplied to a constant coefficient and the obtained value is added to V^*_{Fabc}. Applying this method distinctively improves operation of series inverter.

C. DC-DC Converter controlling to obtain the Maximum Point Of PV-Array:

At, present Pv systems are not very efficient with only about 12-20% efficiency in their ability to convert sunlight to electrical power.

The efficiency can drop further due to other factors such as:
  (i) Solar panel temperature.
  (ii) Load conditions.

In order to maintain the power derived from the solar panel it is important to operate the panel at its optimal power point. An important consideration in achieving high efficiency in PV power system is to match " PV source and load impedance properly for any weather conditions, thus obtaining maximum power generation".

So in order to increase the efficiency, as much power as possible should be extracted from the array. The possible technique for this is known as "Maximum Power Point Tracking" (MPPT).

SOLAR-ARRAY:
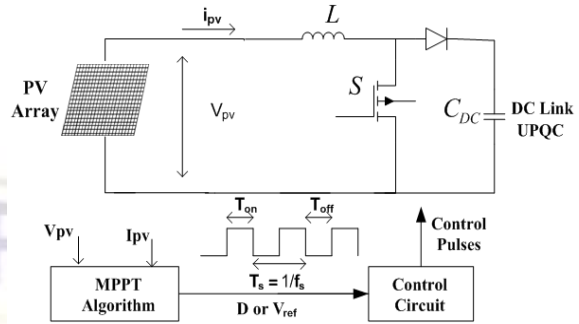The circuit of PV-Array is shown below:

Fig.7: circuit of pv-array

A solar cell basically is a p-n semiconductor junction which is made of several polycrystalline silicon cells. At junction electrons from the sides mix and form a barrier, making it hard for electrons on the N-side to cross to the P-side. Eventually equilibrium is reached, and an electric field separates the sides.

When photon (sun light) hits a solar cell, its energy frees electron-hole pairs. The electric field will send the free electron to the N-side and hole to the P-side. This cause further disruption of electrical neutrality, and if an external current path is provided.

Note: electrons will flow through the path to their original side (p-side) to unite with holes that the electric field sent here, doing work for us along the way.

The electron flow provides the current, and cell electric field causes a voltage.
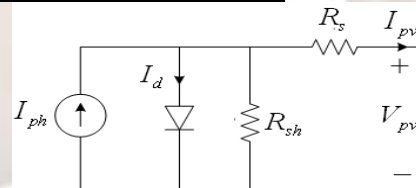
Equivalent circuit of PV-array:

Fig.7 (a): equivalent pv circuit

An equivalent circuit used together with the following set of circuit equations to express a typical current – voltage (I-V) characteristic of pv modules and arrays as shown below:

$$I = I_{ph} - I_d - I_r, \tag{15}$$

$$I_{ph} = I_{sho}\left(\frac{S}{1000}\right) + J_0(T - T_{ref}), \tag{16}$$

$$I_d = I_0\left[\exp\left\{\frac{q(V + R_s I)}{nkT}\right\} - 1\right], \tag{17}$$

$$I_O = I_{d0}\left(\frac{T}{T_{ref}}\right)^3 \exp\left\{\frac{qE_g}{nk}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right\}, \quad (18)$$

$$I_r = \frac{V + R_s I}{R_{sh}}, \quad (19)$$

S   → solar insolation (w/m^2)
T_{ref} → reference temperature (298 k)
T   → cell temperature
Eg   → band gap enargy of the cell semi conductor
K   → boltzman constant
R_S → series resistance
R_{sh} → shutn resistance
N   →diode emission factor
I_{DO} → diode reversal current
I_{Sho} → short circuit current at reference state
J_O → temperature coefficient

From equation (18), Eg and I_{DO} are not independent of each other.

Thus, Eg is calculated using:
$$E_g = m\left(1.16 - 7.02 \times 10^{-4}\frac{T^2}{T - 1108}\right). \quad (20)$$

m→ no cells in series

The method to obtain optimum power point at solar array is algorithm of perturbation and observation (P & O) in Mppt.

PERTURBATION AND OBSERVATION:

This method is used to achieve the maximum power point. According to the structure of MPPT, the required parameters are only voltage (v) and current (I) of pv-modules.
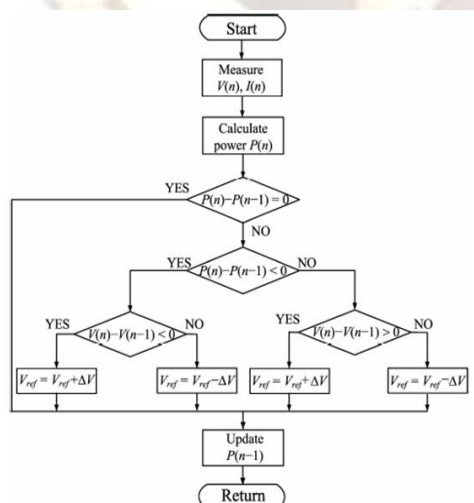
Fig.7(b): MPPT algorithm flow chart

The algorithm reads the value of current and voltage from pv-array module. Power is calculated from the measured voltage and current.

The slope $\left(\frac{dp}{dv}\right)$ of the power can be calculated by consecutive output voltages and output currents and can be expressed as:

$$\frac{dP}{dV}(n) = \frac{P(n) - P(n-1)}{V(n) - V(n-1)}$$

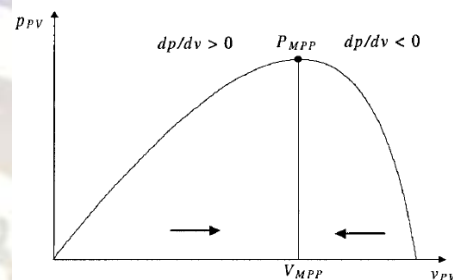where $P(n) = V(n)I(n)$ $\quad$ →(21)

Fig.5: The operating region on the curve

So through this maximising the cyclic process, correspondingly i/p and o/p pulses are generated by the control circuit and given to switch 's', this switch provides the required voltage and also if there is any ripples they are eliminated and pure DC is given to dc link.

Hence at every instant of PV-array we are determining MPP and correspondingly capacitor-DC link's voltage is charged.

The advantage of P&O method is its simple application and its disadvantage is its capability to determine the correct MPP during sudden and fast variation in environmental conditions. Of course, the probability of sudden variations in environmental conditions is very low. As it is seen in fig. 8, the duty cycle of converter switch is determined by measuring voltage and array's current values in specific periods of time and applying maximum power tracking algorithm.

Finally, by applying this type of control with PV-array generation the power quality of the System is improved or will be made more reliable.

RESULTS AND DISCUSSION

In simulation part, power system is modelled as a 3-wired 3-phase system by an RC load with uncontrolled diode rectifier. The PV model applied in simulation is as fig. 6 whose parameters are regulated for normal condition (25°c temp & sun radiation) Circuit parameters used in simulation are located in

table 1. The maximum simulation time is regulated on 600msec. Shunt inverter starts to operate at 100msec and series inverter starts at 200msec.

Table 1: Grid parameters

Source phase voltage (r m s)	220v/50Hz
Dc link voltage	$600v$
Shunt inverter rating	$45kva$
Series inverter rating	$15kva$
Shunt inverter inductance(L_f)	$3mH$
Shunt inverter capacitance(C_f)	$10\mu F$
Switching frequency	20KHz
Series inverter inductance(L_s)	$3mH$
Series inverter capacitance(C_s)	$15\mu F$
Series inverter Resistance(R_s)	12Ω
PV Array Rating	$40Kw$

Nonlinear load's current is illustrated in fig. 8.

Fig. 8: Nonlinear load's current

Active and reactive powers consumed by load are shown in fig. 9. Simulated load consumes $17kW$ active power and $8kVAr$ reactive power. In this part of simulation, it is assumed that the PV array is interconnected to grid and outages after 0.45s of operation. The current, injected by shunt inverter is shown in fig. 10. As it is shown in fig. 10 at the presence of PV, shunt branch injects a high current to grid, a part of which is consumed to feed the load and else is injected to grid. When PV outages, the shunt branch undertakes the duty of compensating current harmonics and current's reactive power.
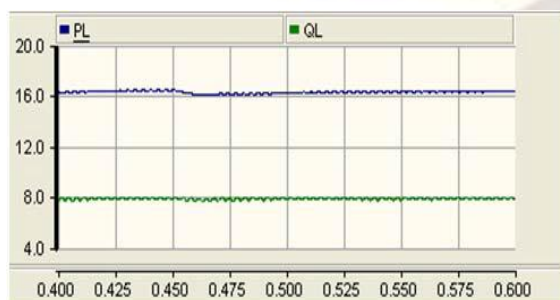

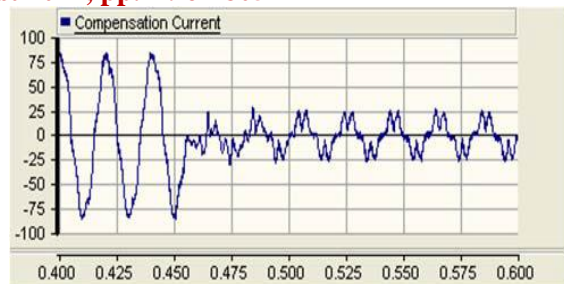**Fig. 9:** Active and reactive power consumed by Nonlinear load

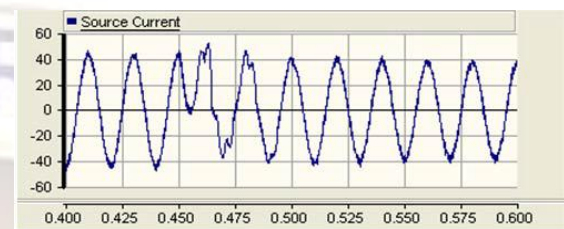**Fig. 10:** Current of shunt inverter injected to grid
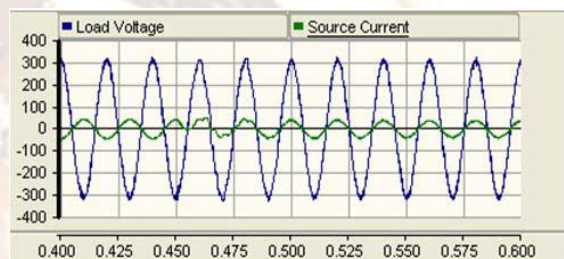

Fig.11: source current

Fig. 12: source current and voltage

Fig. 11 shows the source current and fig. 12 presents the source voltage. At 0.45sec when PV outages, source current returns to sinusoidal mode after passing he transient state. With respect to fig. 12 it can understood that, before PV outages, voltage has 180° phase difference with its current and PV injects current to source in addition to providing load. After PV outages, it is seen that, voltage and current are in same phase and UPQC compensates current harmonics and power factor. Fig. 13 shows the total harmonic distortions (THD) of source and load currents. Shunt inverter has been able to make current's wave form sinusoidal and reduce the THD of load current from 22% to 3%.
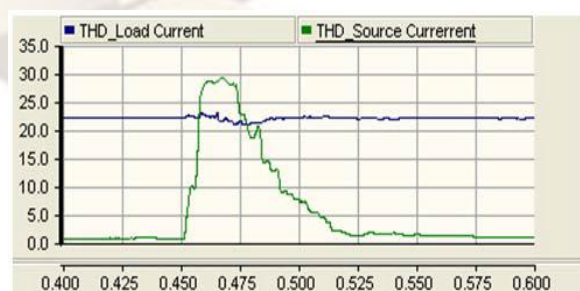

Fig.13 : Load and source current THD

In fig. 14 active and reactive powers injected by shunt inverter are shown. When PV outages, injective reactive power doesn't vary distinctively, while injective active power decreases to a negative value from $37.5kW$. In other words, shunt inverter is not able to inject active power after PV outages and required active power of series inverter is provided through shunt inverter from the grid.
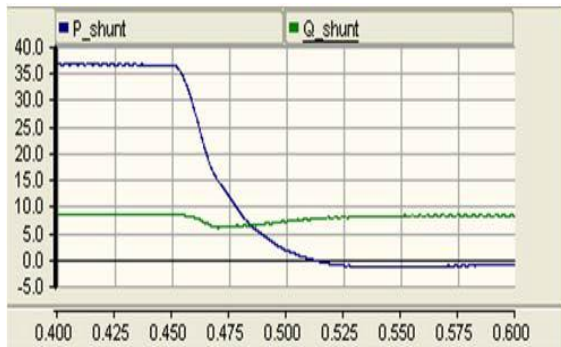

Fig. 14: Active and reactive power injected by shunt inverter

DC link voltage is shown in fig.15 for the above cases. When PV outages, the voltage of DC link decreases and returns to its desired value by correct operation of DC controlling loop. In this part of simulation, by applying voltage sag to the grid side, series inverter's operation is studied to improve voltage sag and it is investigated that how series and shunt inverters inject power to the grid at the presence of PV. Fig.16 source side voltage in which voltage sag has occurred during 0.25 to 0.35 seconds is shown.
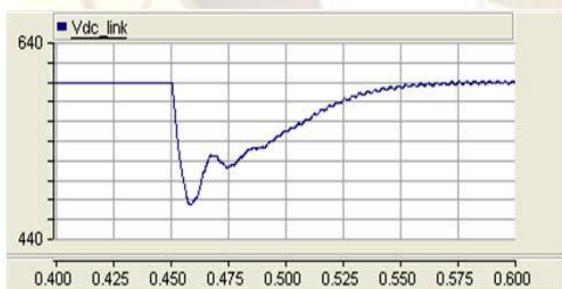

Fig. 15: DC link voltage

Fig. 17 shows the load side voltage and source current. Load voltage is completely compensated and current has 180° phase difference with load voltage. This issue shows the complete compensation of load's reactive power too. The voltage injected by series inverter to compensate the voltage sag is shown in fig. 18. The active power injected by series and shunt inverters during voltage sag occurrence is shown in fig. 19. When voltage sag occurred, share of series inverter in PV's active power transferring and voltage

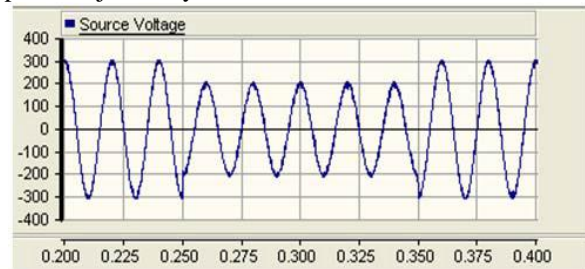sag compensation increases and a part of active power injected by series inverter decreases.

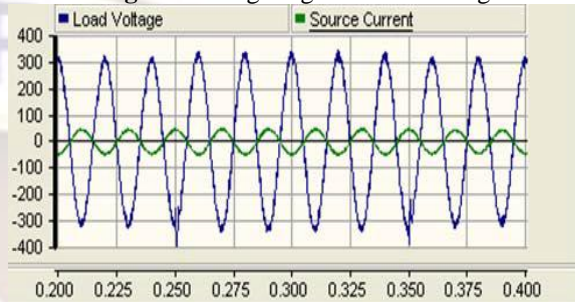
Fig. 16: voltage sag in source voltage

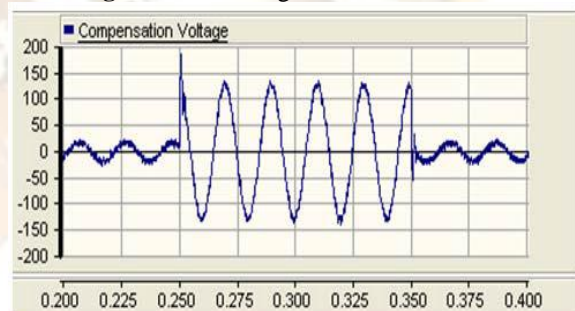**Fig. 17:** load voltage and source current

Fig. 18: voltage injection by series inverter
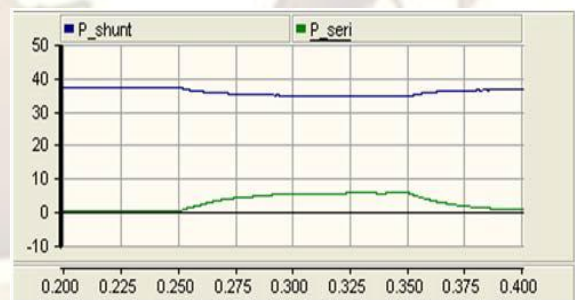

Fig. 19: Active power injected by series and shunt inverters

In the third part of simulation, voltage interruption is applied in the source and the operation of PV system in providing the power which is required by load is studied. In order to do this, a voltage interruption occurs at 0.5 seconds and immediately the power switches parallel with series transformer are closed and so other switches allocated between shunt and series inverters are opened and so isolate shunt inverter from the grid. Controlling algorithm of parallel inverter, switches from interconnected mode to islanding mode. In fig. 20 the source side voltage is shown during voltage interruption occurrence. Fig. 21 shows load current. When interruption occurs,

load current is provided by shunt inverter and PV. The active power injected by shunt inverter to load is shown in fig. 22. As it is seen, during interruption occurrence, the power injected by PV is the function of the load's required power in PV power range off course.
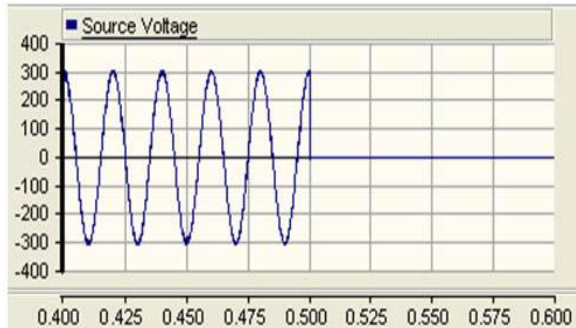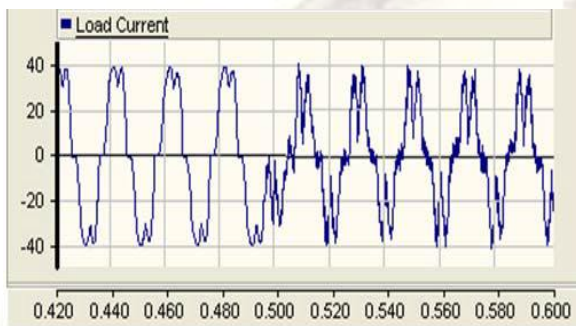

Fig. 20: voltage interruption in source voltage

Fig. 21: load current during voltage interruption oc currence

Fig. 22: active power injected by shunt inverter to load

Conclusion

In this paper, the results of analyzing combined operation of UPQC and PV is explained. The proposed system is composed of series and shunt inverters, PV array and DC/DC converter which can compensate the voltage sag, swell, interruption and reactive power and harmonics in both islanding and interconnected modes. The advantages of proposed system is reducing the expense of PV interface inverter connection to grid because of applying UPQC shunt inverter and also is the ability of compensating the voltage interruption using UPQC because of connecting PV to DC link. In this proposed system, P&O

method is used to achieve the maximum power point of PV array. This proposed system's operation is analyzed using (MATLAB) software and simulation results confirm that the proposed system operates correctly.

REFERENCES

1. M. Siahi,"Design and simulation of UPQC to improve Power Quality and Transfer Power of photovoltaic array to grid". IEEE transaction on basic and applied sciences, 5(3): 662-673, 2011.

2. K. R. Padiyar, "facts controllers in power transmission and distribution", New age international (P) LIMITED, PUBLISHERS,2007.

3. Basu, M., Shyama P. Das, Gopal K. Dubey, 2007. "Comparative evaluation of two models of UPQC for Suitable interface to enhance power quality". J. Electric Power Systems Research, 77: 821-830. Digital Object Identifier(DOI): 10.1016/j.epsr.2006.07.008.

4. Watanable, H., T. Shimizu, G. Kimura, "A novel utility interactive photovoltaic inverter with Generation control circuit". IEEE Industrial Electronics Society, 1998.

5. Akagi, H., Y. Kanazawa and A. Nabae, 2007. "Instantaneous reactive power compensator comprising switching devices without energy storage components". IEEE Trans. Ind.Appl., 20: 625-630. Digital Object Identfier(DOI):10.1109/TPWRD.2005.

6. Akagi, H. and H. Fujita, 1995. "A new power line conditional for harmonic compensation in Power systems". IEEE Transaction on Power Delivery, 10(3): 1570-1575. Digital Object Idetifier (DOI): 10.1109/61.400941.

7. Aredes, M. and E.H. Watanabe, 1995. "New control algorithms for series and shunt three-Phase four-wire active power Filters". IEEE Transaction on Power Delivery, 10: 1649-1656.

8. Barker, P.P. and R.W. de Mello, 2000. "Determining the impact of distributed generation on power systems: Part1-Radial distribution systems". Proceeding of IEEE Power Engineering Society Summer Meeting 1645-1656.

9. Basu, M., Shyama P. Das, Gopal K. Dubey, 2007. "Comparative evaluation of two models of UPQC for suitable interface to en-

hance power quality". J. Electric Power Systems Research, 77: 821-830. Digital Object Identifier(DOI): 10.1016/j.epsr.2006.07.008.

10. Blaabjerg, F., Z. Chen, S.B. Kjaer, 2004. "Power electronics as efficient interface in dispersed power generation systems". IEEE Transaction on Power Electronics. 19(5): 1184-1194. Digital Object Identifier (DOI):10.1109/TPEL.2004.833453.

11. Chen, Y., X. Zha, and J. Wang, 2000. "Unified power quality conditioner (UPQC): The theory, modelling and application. Proceeding of Power System Technology Conference", 3: 1329-1333. Digital Object Identifier (DOI): 10.1109/ICPST.2000.

12. Fujita, H. and H. Akagi, 1998. "The unified power quality conditioner: The integration of series and Shunt active filters". IEEE Transaction on Power Electronics, 13(2): 315-322.Digital Object Identifier (DOI):10.1109/63.662847.

13. Ghosh, A. and G. Ledwich, 2001. "A unified power quality conditioner (UPQC) for simultaneous Voltage and current compensation". Electric Power Systems Research, 59: 55-63. Digital Object Identifier (DOI): 10.1016/ S0378-7796(01)00141-9.

14. Han, B., B. Bae, H. Kim, S. Baek, 2006. "Combined Operation of Unified Power Quality Conditioner With Distributed Generation". IEEE Transaction on Power Delivery, 21: 330-338. Digital Object Identifier (DOI): 10.1109/ TPWRD. 2005.852843.

S.MD.ISHAQ was born in tirupati, India, received the B.Tech(Electrical and Electronics Engineering) degree from the Jawaharlal Nehru technological university, Ananthapur in 2009. Currently pursuing M-Tech in the Dept of Electrical and Electronics Engineering, Sree Vidyanikethan Engineering College, Tirupati, Rangampeta.

W.V.JAHNAVI was born in tirupati, india. She received the B.Tech (Electrical and Electronics Engineering) degree from Sree Kalahasteshwara Institute Of Technology, Kalahasti in 2004 and M.Tech(Electrical Power systems) from Sree Vidyanikethan Engineering College, Tirupati, Rangampeta in the year 2006. She is currently working as Senior Assistant Professor in Sree Vidyanikethan Engineering College since 2006. Her area of interest are power quality improvement, renewable (solar) energy generation sources.

Dr. T.Devaraju received Ph.D from JNTU Anantapur, Andhra Pradesh. Presently he is a professor and Head ,Department of Electrical& Electronic Engineering, Sree Vidyanikethan Engineering College, Tirupati. He obtained his B.E and M.E from Andhra university college of engineering and PSG college of Technology, Coimbatore in 1995 and 1998 respectively. He has about 20 publications in National and International Journals and conferences to his credit. His areas of interest are in power electronic applications to power systems.