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A Novel Strategy for PV Based UPQC to Reduce Impact of Voltage Sag and Swell in Distribution System

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Abstract

To overcome the limitations in power distribution generation system, which are been compensating by using devices like STATCOM, UPQC and series/shunt compensators etc. In this paper, the design of combined operation of UPQC and PV array is proposed. The proposed system is composed of series and shunt controller, PV array connected to DC link by boost converter which is able to compensate the voltage sag, swell, voltage interruption, harmonics and reactive power in both islanding and interconnected modes. And to improve the performance of iUPQC, in converter design and adopt the features of Five level Cascaded H Bridge Multi Level concept to suppress the harmonics, %THD, voltage, current profile at grid side.The proposed system is able to inject the active power to grid in addition to its ability in improvement of power quality in point of common coupling. Also it can provide a part of sensitive load power during voltage interruption. The simulation carried out by MATLAB/SIMULINK software. The results are verified with conventional model and compared with proposed system model

Keywords—Distributed Generation (DG), Unified power quality conditioner (UPQC), Photovoltaic array (PV), Interconnected mode, Islanding mode, Maximum power point tracking (MPPT), Cascaded H Bridge Multi Level inverter.

I. INTRODUCTION

The Power system faces many problems when distributed generation is added in the already existing system; this is because the power system is not designed with distributed generation in mind. The different types of distributed generation are listed in fig.1. The addition of generation could influence power quality problems, degradation in system reliability, reduction in the efficiency, over voltages and safety issues. On the other side's the power system distribution are well designed which could handle the addition of Generation if there is Proper grounding, transformers and protection is provided. But there are limits to the addition of distributed generations if it goes beyond its limit then it is important to modify and change the already designed distributed system equipment and protection, which could in a result facilitate the integration of new generation. One of the important aspects is that, power electronic devices and sensitive equipment's 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

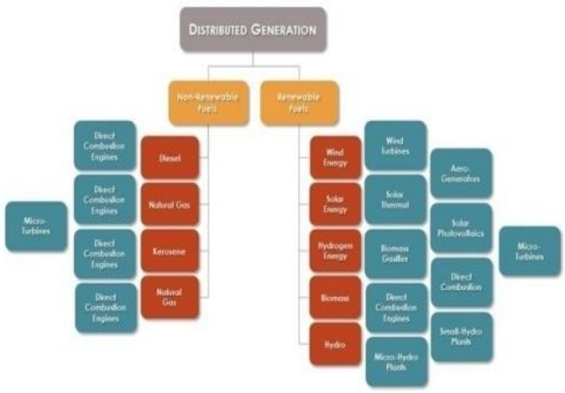

Fig.1Distributed generation Resources in Power system Network

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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 characterized by the amount of stored energy or stand alone supply time. That auxiliary equipment having both "shunt" and "series" converter 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 converters. 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 converters 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. 2 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 carried out by using "MATLAB/SIMULINK" software show that this proposed system operates correctly.

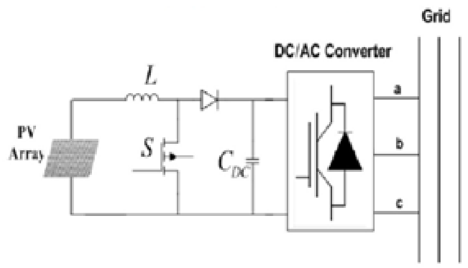

Fig. 2: General structure of grid connected PV systems

This paper organizes:

In section 1, Introduction to DG system, power quality accepts are accomplishing by a new topology called iUPQC for grid system. In section 2, Modeling of PV panel is realized. In section3, The proposed topologies with involving of Cascaded H Bridge Multi Level inverter concept to analysis then performance of grid tied PV based system. In section4, Focusing on MATLAB simulation &verifying with conventional UPQC model with iUPQC proposed model. The simulation is done using MATLAB software. Conclusions are given in last section.

II MODELLING OF PV CELL

Importance of PV: PV systems connected to the low voltage have an important role in distributed generation systems. In order to keep up with the current trends regarding the increase in PV installations, PV systems connected to the low voltage grid have an important role in distributed generation systems. In order to keep up with the current trends regarding the increase in PV

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installations, PV converters should have the following characteristics:

- Low cost, high efficiency
- Small weight and size, due to residential installations
- High reliability to match with that of PV panels
- Be safe for human interaction

The performance of a photovoltaic array is dependent upon sunlight. PV systems are nonlinear power sources whose output power is greatly under effect of two radiation and environment temperature elements. One of the disadvantages of these systems is their low efficiency, because Solar cells rarely operate at their maximum power point. So in order to increase the efficiency, as much power as possible should be extracted from the array. Temperature variation effects on cell voltage and radiation variation effects on cell current.

PV arrays are built up with combined series/parallel combinations of PV solar cells, which are usually represented by a simplified equivalent circuit model such as the one given in Fig.3 and by an equation as in (1).

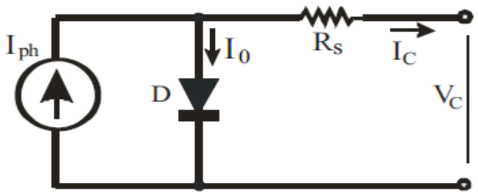

Fig.3 Simplified-equivalent circuit of photovoltaic cell.

The PV cell output voltage is a function of the photocurrent that mainly determined by load current depending on the solar irradiation level during the operation.

$$V_c = \frac{AkT_c}{e} \ln\left(\frac{I_{ph} + I_0 - I_c}{I_0}\right) - R_s I_c \quad (1)$$

Where the symbols are defined as follows:
e: electron charge (1.602 × 10-19 C).
k: Boltzmann constant (1.38 × 10-23 J/^{o}K).
Ic: cell output current, A.
Iph: photocurrent, function of irradiation level and junction temperature (5 A).
I_0: reverse saturation current of diode (0.0002 A).
Rs: series resistance of cell (0.001 Ω).
Tc: reference cell operating temperature (20 °C).
Vc: cell output voltage, V.

In connection of the PV array to grid, a DC/DC converter is applied and is used to adapt the variable voltage of PV with the voltage of grid and extract the maximum power from the array. it is obtained by controlling the duty cycle of DC/DC converter switch. Some methods of finding optimum operation point of solar array are as follow:
1. Mathematically solving the voltage-power equation of solar cell.
2. Algorithm of perturbation and observation (P&O).
3. Incremental conduction method (IncCon).
4. Maximum power point forecasting based on the current method.
5. Maximum power point forecasting based on the voltage method

Perturbation & Observation method is used to achieve the maximum power point. P&O method is one of the most common methods applied to achieve the maximum power point. In P&O method, a short perturbation is created in array's output voltage and then output voltage is measured. If this perturbation causes an increase in output power, then the next perturbation will be applied in this direction, and if it causes reduction, then voltage perturbation will be applied in reverse direction and this process continues till achieving the maximum power point of the array.

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.

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III.PROPOSED TOPOLOGY

One of the comparative structures of the electric power is back to back converter. In respect to controlling structure, these converters may have various operations in compensation. For example, they can operate as series or shunt active filters for synchronous compensating the load current harmonics and voltage oscillation. This is called unified power quality conditioner as shown in fig.4

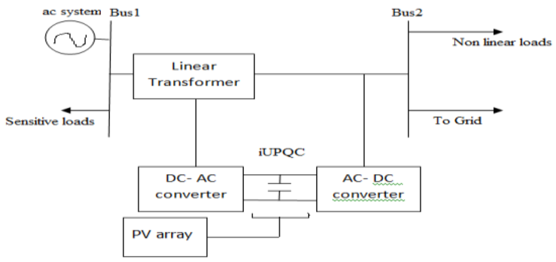

Fig.4 Configuration Of Proposed Upqc With PV

UPQC has two shunt and series voltage Source converters which are as 3-phase 3-wire or 3- phase 4-wire. Shunt converter is connected to point of common coupling (PCC) by shunt transformer and series converter stands between source and coupling point by series transformer. Shunt converter operates as current source and series converter operates as voltage source. The UPQC is a combination of a static compensator and static series compensation. It acts as a shunt compensating and a phase shifting device simultaneously.

Operation of UPQC:

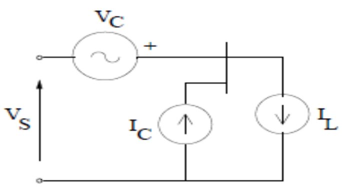

Fig.5 Ideal Equivalent Circuit of UPQC

The operation of a UPQC can be explained from the analysis of the idealized equivalent circuit shown in Fig.5 Here, the series converter is represented by a voltage source VC and the shunt converter is represented by a current source IC. Note that all the currents and voltages are 3 dimensional vectors with phase coordinates. Unlike in the case of a UPFC, the voltages and currents may contain negative and zero sequence components in addition to harmonics. Neglecting losses in the converters, we get the relation

$$(V_L , I_C) + (V_C , I_S) = 0 \qquad (2)$$

Where X,Y Denotes the inner product of two vectors, defined by

$$(X , Y) = \frac{1}{T}\int_0^T X^t (\tau)Y(\tau)d\tau \qquad (3)$$

Let the load current IL and the source voltage VS be decomposed into two
Components given by

$$I_L = I^{1P}{}_L + I^r{}_L \qquad (4)$$

$$V_S = V^{1p}{}_s + V^r{}_S \qquad (5)$$

Where $I^{1p}{}_L$ contains only positive sequence, fundamental frequency components. Similar comments apply to $V^{1p}{}_S$. $I^r{}_L$and $\mathbf{V^r{}_S}$ contain rest of the load current and the source voltage including harmonics. I1pL is not unique and depends on the power factor at the load bus. However, the following relation applies for $\mathbf{I^{1P}{}_L}$

$$P_L = (V_L, I_L) = (V_L, I_L{}^{1p}) \ (6)$$

This implies that $h^{Ir}{}_L$;V_{Li} = 0. Thus, the fundamental frequency, positive sequence component in I_{rL} does not contribute to the active power in the load. To meet the control objectives, the desired load voltages and source currents must contain only positive sequence, fundamental frequency components and

$$P_L = |V_L^* I_S^*|COS\emptyset_l = \left|V_s^{1p} I_s^*\right|cos\emptyset_s \qquad (7)$$

WhereV_L^* and$I_S^*$are the reference quantities for the load bus voltage and the source current respectively. Ál is the power factor angle at the load bus while Ás is the power factor angle at the source bus (input port of UPQC). Note that V_L^*(t) and I_S^*(t) are sinusoidal and balanced. If the reference current I_c^* of the shunt converter and the reference voltage V_c^* of the series converter are chosen as with the constraint

$$\langle V_C^{1P}, I_S^* = 0\rangle \qquad (8)$$

We have,

$$I_c^* = I_L^*,\ V_C^* = -V_S^r + V_C^{1p} \qquad (9)$$

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$$V_L^* = -V_S^{1P} + V_C^{1p} \quad (10)$$

Note that the constraint (11) implies that $V_S^{1p}$is the reactive voltage in quadrature with the desired source current, I_S^*. It is easy to derive that the above equation shows that for the operating conditions assumed, a UPQC can be viewed as a inaction of a DVR and a STATCOM with no active power through the DC link. However, if the magnitude of$V_L^*$is to be controlled, it may not be feasible to achieve this by injecting only reactive voltage. The situation gets complicated if $V_S^{1p}$is not constant, but changes due to system disturbances or fault. To ensure the regulation of the load bus voltage it may be necessary to inject variable active voltage (in phase with the source current). If we express

$$\langle I_{C,}^* V_L^* \rangle \quad (11)$$

$$V_C = V_C^* + \Delta V_C, I_C \quad (12)$$

$$I_S = I_S^* - \Delta I_C, V_L = V_S^{1p} + v_c^{1p} + \Delta V_c \quad (13)$$

$$\langle I_S, \Delta V_C \rangle + \langle V_L, \Delta I_C \rangle = 0 \quad (14)$$

In deriving the above, we assume

$$\langle I_S, V_C^* \rangle = 0 = \langle V_{L,} I_C^* \rangle \quad (15)$$

This implies that both ¢VC and ¢IC are perturbations involving positive sequence, fundamental frequency quantities (say, resulting from symmetric voltage sags).the power balance on the DC side of the shunt and series converter. The perturbation in VC is initiated to ensure that

$$|V_C^* + \Delta V_C + V_S| = |V_L| = constant \quad (16)$$

Thus, the objective of the voltage regulation at the load bus may require exchange of power between the shunt and series converters.

UPQC is able to compensate current's harmonics, to compensate reactive power, voltage distortions and control load flow but cannot compensate voltage interruption because of not having any sources. Common interconnected PV systems structure is as fig.2 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.

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.

Controller Designing

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

A. Shunt converter control

B. Series converter 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 Converter Control:

In this paper, shunt converter 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 converter controlling system should be designed in a way that it would provide the ability of undertaking two above duties.

Shunt converter control calculates the compensation current for current harmonics and reactive power when PV is out of the grid. The power loss caused by converter operation should be considered in this calculation. Also, shunt converter control undertakes the duty of (stabilizing) DC link voltage during series converter operation to compensate voltage distortions. DC link capacitor voltage controlling loop is used here by applying PI controller. Figure 4 shows the circuit block diagram of shunt converter controlling.

A.1. Shunt converter control in Interconnected Mode:

UPQC shunt voltage source converter controlling block diagram to which Synchronous reference frame theory then is applied by extracting the sensitive load currents as **ILA, ILB, and ILC.** 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.

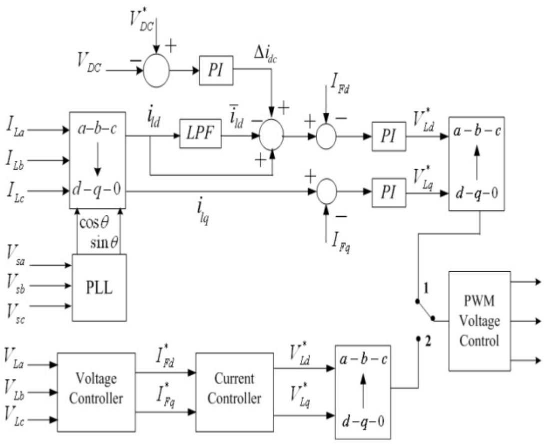

Fig.6 control block diagram of shunt converter

This function is obtained by PLL by taking Source side voltages **VSA, VSB, VSC** as reference, which provides to maintain the synchronism with supply voltage and current.

In the controller they involve the abc-dqo transformation.

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:

$$\mathbf{I}_{ldq0} = \mathbf{T}_{abc}^{dq0}\ \mathbf{I}_{abc} \qquad \mathbf{(17)}$$

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

$$i_d=i_a\cos 0^0+i_b\cos 120^0+i_c\cos 204^0 \qquad (18)$$

$$i_q=i_a\cos 0^0+i_b\cos 120^0+i_c\cos 204^0 \qquad (19)$$

i_q is considered for convinience (20)

$$T_{abc}^{dq0} = \frac{2}{3}\begin{bmatrix} \cos\varphi & \cos\left(\varphi-\frac{2\Pi}{3}\right) & \cos\left(\varphi+\frac{2\Pi}{3}\right) \\ \sin\varphi & \sin\left(\varphi-\frac{2\Pi}{3}\right) & \sin\left(\varphi+\frac{2\Pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \qquad (21)$$

The d-axis and q-axis currents $\mathbf{I}_D$ and $\mathbf{I}_q$ are constant and instantaneous values considered as

$$I_{ld} = \bar{I}_{ld} + \overset{*}{I}_{ld}, \quad I_{lq} = \bar{I}_{lq} + \overset{*}{I}_{lq} \qquad (22)$$

Harmonic currents can be eliminated by low Pass filter. In this case $\mathbf{I_L=I_S+I_C}$ injected by Shunt converter.

The compensation reference currents are considered as:

$$I_{fd}^{*} = \tilde{I}_{ld}\ , \quad I_{fq}^{*} = \tilde{I}_{lq} \qquad (23)$$

As it is shown in fig. 9, the reference currents will transfer to ABC frame by reverse converting the Synchronous reference frame. Resulted reference currents will be compared with shunt converter Output currents ($\mathbf{I_{fa}}$, $\mathbf{I_{fb}}$, $\mathbf{I_{fc}}$) in a PWM current controller (hysteresis type) and required controlling pulses are generated. Applying these signals to shunt converter

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power switches gate, required compensation current is generated by converter.

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 converter control in islanding mode:

In addition to previous duties, shunt converter 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 converter operation will switch from interconnected mode to islanding mode. PV system provides required active power to stabilize load voltage

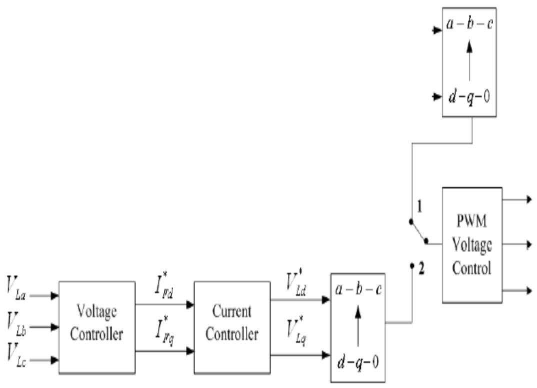

Fig.7: shunt-converter in islanding mode

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:

$$I^*_{fd} = K_{PI}\left(V^*_{Ld} - V_{Ld}\right) - \omega C_P V_{Lq} + I_{Ld} \quad (24)$$

$$I^*_{fd} = K_{PI}\left(V^*_{Ld} - V_{Ld}\right) - \omega C_P V_{Lq} + I_{Ld} \quad (25)$$

$\mathbf{I^*_{fd}, I^*_{fq}}$ 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:

$$V^*_{Id} = K_{PI}\left(I^*_{fd} - I_{fd}\right) - \omega L_f I_{fq} + V_{Ld} \quad (26)$$

$$V^*_{Iq} = K_{PI}\left(I^*_{fq} - I_{fq}\right) + \omega L_f I_{fd} + V_{Lq} \quad (27)$$

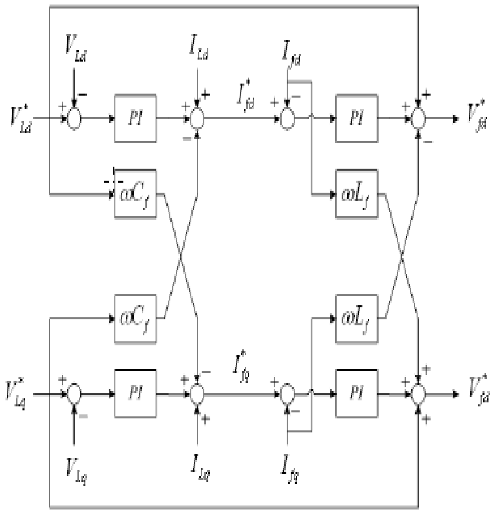

Fig. 8 Controlling block diagram of shunt converter in islanding mode

where $\mathbf{V_{Id}}$ and $\mathbf{V_{Iq}}$ are shunt converter voltage outputs in *d* and *q* axis. Fig. 9 shows the block diagram of shunt converter control based on the above relations to control the shunt converter during voltage interruption and islanding mode.

B. Series Converter Controlling:

The duty of the series converter is to compensate the voltage disturbance in the source side, grid which is due to the fault in the distribution line. Series converter control calculates the voltage reference values which are injected to grid by series converter. In order to control series converter of UPQC, load sinusoidal voltage controlling strategy is proposed as shown in figure Fig.9.

In this condition UPQC, series converter would be controlled in a way that it compensates the whole distortions and helps the voltage of load voltage stay (balanced sinusoidal 3-phase).

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.

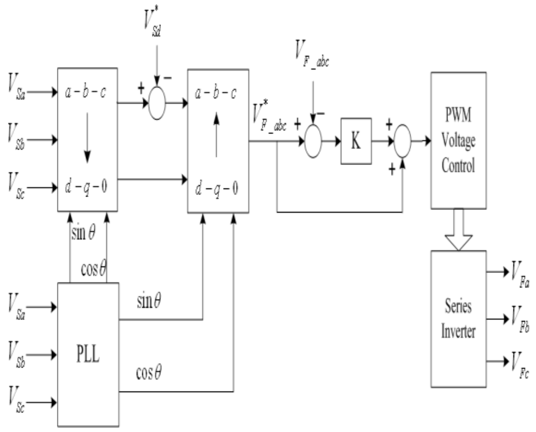

Fig.9 Series converter control block diagram

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 3phase variables and dq variables is known as park's transformation as shown below

$$V^*_{ldq0} = T^{dq0}_{abc} \cdot V^*_{labc} = \begin{bmatrix} V_m \\ 0 \\ 0 \end{bmatrix} \quad \textbf{(28)}$$

in this relation V^*_{labc} is:

$$V^*_{labc} = \begin{bmatrix} V_m \cos(\omega t + \theta) \\ V_m \cos(\omega t + \theta - 120^\circ) \\ V_m \cos(\omega t + \theta + 120^\circ) \end{bmatrix} \quad \textbf{(29)}$$

Where $\mathbf{V_m}$ is desired peak value of load voltage and ($\boldsymbol{\theta}$) is voltage phase angle which is calculated by phase locked loop (PLL). By subtracting the desired value of d-axis phase voltage ($\mathbf{v_{ld}*}$) from $\mathbf{V_{sd}}$, all distortions in d-axis are obtained. Also, the desired value of load phase voltage in q-axis is zero. In other words, $\mathbf{V_{sq}}$ represents total q-axis distortions. So series compensation reference voltage is resulted by relation

$$V^*_{fdq0} = V^*_{ldq0} - V_{sdq0} \quad \textbf{(30)}$$

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 converter 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. Fig. 13 shows the block diagram of series compensator's controlling circuit applying synchronous reference frame method. In order to improve series converter operation, SPWM method is used where the resulted value of subtracting $\mathbf{V^*_{fabc}}$ from $\mathbf{V_{fabc}}$ is multiplied to a constant coefficient and the obtained value is added to $\mathbf{V^*_{fabc}}$. Applying this method distinctively improves operation of series converter.

C. Cascaded H-Bridges Multilevel Inverter:

The concept of multilevel inverters has been introduced since 1975. The term multilevel began with the three-level inverter. Subsequently, several multilevel inverter topologies have been developed. However, the elementary concept of a multilevel inverter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform.

Cascaded H-Bridge concept:

A single-phase structure of an m-level cascaded inverter is illustrated in Figure 16 each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $-V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches, S_1, S_2, S_3, and S_4. To obtain $+V_{dc}$, switches S_1 and S_4 are turned on, whereas $-V_{dc}$ can be obtained by turning on switches S_2 and S_3. By turning on S_1 and S_2 or S_3 and S_4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels m in

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a cascade inverter is defined by m = 2s+1, where s is the number of separate dc sources. An example phase voltage waveform for an 11-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Figure 10.

The phase voltage

$$v_{an} = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5}. \quad \textbf{(31)}$$

$$V(\omega t) = \frac{4V_{dc}}{\pi} \sum_{n} \left[\cos(n\theta_1) + \cos(n\theta_2) + \ldots + \cos(n\theta_s)\right] \frac{\sin(n\omega t)}{n}, \quad \text{where } n = 1, 3, 5, 7, \ldots \quad (32)$$

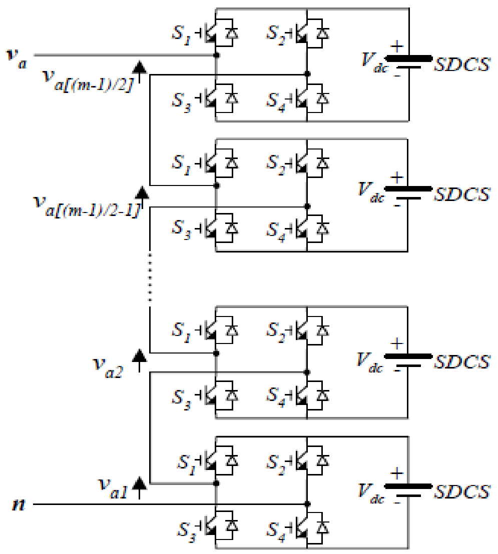

Fig.10 Single-Phase Structure of a Cascaded H-Bridges Multilevel Inverter

4. Simulation results and discussions

In simulation part, power system is modeled as a 3-phase 3-wired system .the previous chapters gives the information about UPQC based PV grid system and with the improved technique that can be developed and implement to verify the performance in aspect of improve the voltage profile of the proposed system.

Whose parameters are regulated for normal condition (25°c temp & sun radiation) Circuit parameters used in simulation are mentioned in table 1.

The proposed Techniques of PV based Grid tied Cascaded H bridge multilevel inverter based iUPQC is implemented in MATLAB/Simulink environment.

Table 1: simulation parameters

Source Phase Voltage (rms)	220v / 50Hz
DC Link voltage	600v
Shunt converter rating	45kVA
Series converter rating	15kVA
Shunt converter Inductance (Lf)	3mH
Shunt converter Capacitance (Cf)	10 µF
Switching Frequency	20kHz
Series converter Inductance (Ls)	3mH
Series converter Capacitance (Cs)	15 µF
Series converter Resistance (Rs)	12 Ω
PV Array Rating	40kw
Switches	IGBTS

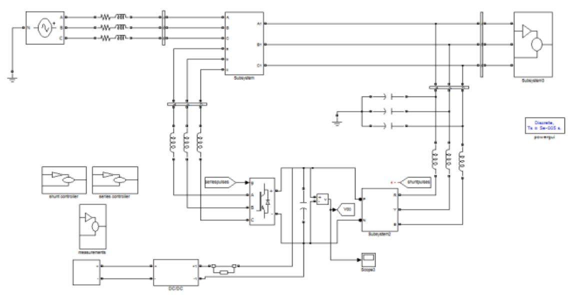

Fig. 11Simulation Block Diagram of PV Based Grid Tied iUPQC System

IUPQC designed with features of series and shunt controllers to inject voltage whenever the voltage sag and swell appear in grid based system it is also connected to the load.

The total proposed simulation block diagram is shown in fig.11

In condition the voltage sag and swell, the voltage will be injected and drop respectively.

In IUPQC consists inverter and rectifier with dc link which performance as like STATCOM.

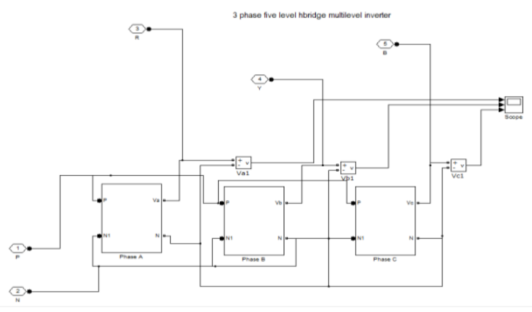

Fig. 12 Simulation Model of 3Phase 5level Cascaded H Bridge Multi Level inverter

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The inverter place a vital role to improve the voltage profile in the grid.

In this thesis designed a 5level cascaded H bridge multiple level inverter as mentioned in previous chapter, it is realized in simulation model as shown in fig 12&13

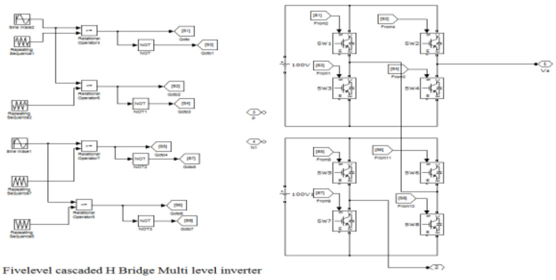

Fig. 13 Internal Structure of 5level Cascaded H Bridge Multi Level inverter

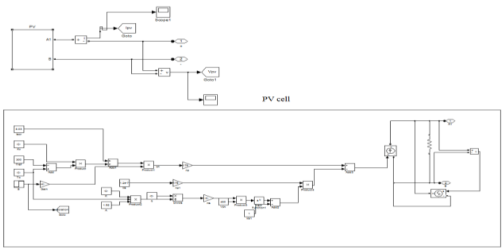

Fig. 14 Simulation Model of PV Cell

Modeling of PV cell in MATLAB environment is shown in fig 14&15

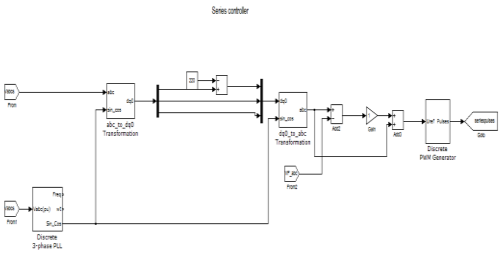

Fig. 15 Mathematical Model of PV Cell

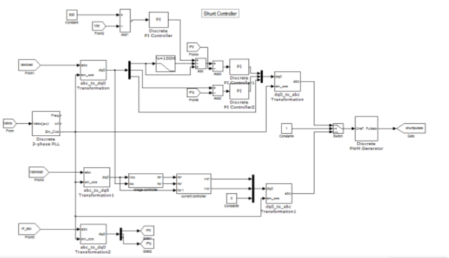

Fig. 16 Internal Structure of Shunt Controller for IUPQC

The shunt controller 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.

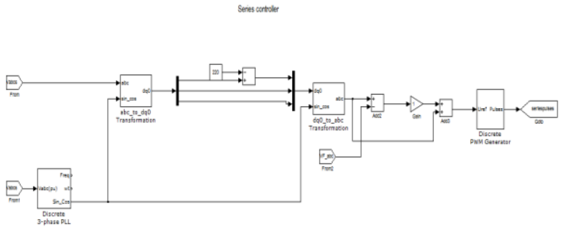

Fig. 17 Internal Structure of Series Controller for IUPQC

The duty of series controller is compensating voltage distortions which are caused by fault in distribution grid. Series controller control calculates the voltage reference values which are injected to grid by series converter.

The series and shunt controllers are used to give a switching pulse pattern for converter which is used in IUPQC to draw stabilized voltage in sag/swell conditions.

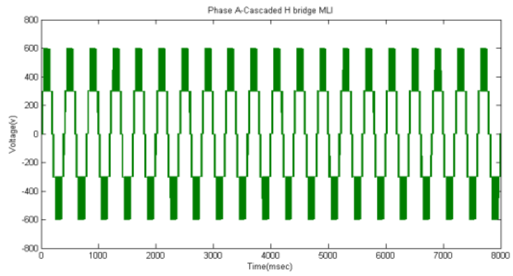

Fig. 18 Output Voltage (Phase A) Of 5level Cascaded H Bridge Multi Level inverter

The Output Voltage of (Phase A) of 3phase 5Level Cascaded H Bridge Multi Level inverter Is Shown In Fig 18

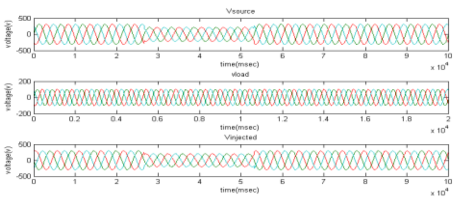

Fig.19 Voltage Profile in Grid Tied Distribution System in Sag Condition

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Source Voltage (V $_{Source}$) B) Load Voltage (V $_{Load}$) C) Injected Voltage (V $_{Injected}$)

In sag condition the grid system gives the voltage profile like as fig 19. This fig gives Source Voltage (V $_{Source}$), Load Voltage (V $_{Load}$), and Injected Voltage (V $_{Injected}$) of a grid system.

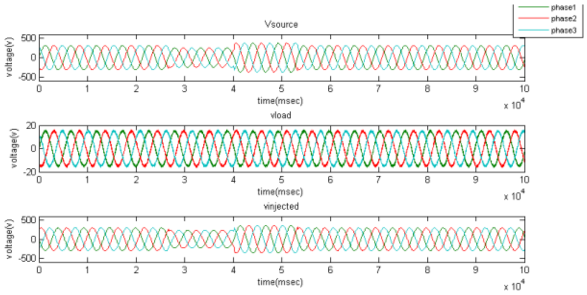

Fig.20 Voltage Profile In Grid Tied Distribution System In Sag/Swell Condition

In sag/swell condition the grid system gives the voltage profile like as fig 20. This fig gives Source Voltage (V $_{Source}$), Load Voltage (V $_{Load}$), and Injected Voltage (V $_{Injected}$) of a grid system.

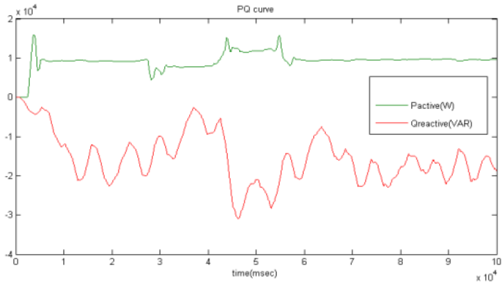

Fig. 21 Curve of Active and Reactive power (PQ Curve) In Voltage Sag Condition

The active and reactive power curves (PQ curves) in sag condition as shown in fig.21

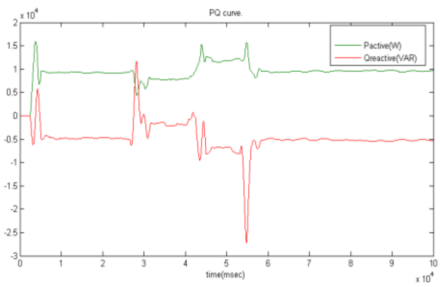

Fig. 22 Curve of Active and Reactive power (PQ Curve) In Voltage Sag/swell Condition

The active and reactive power curves (PQ curves) in sag/swell condition as shown in fig.22

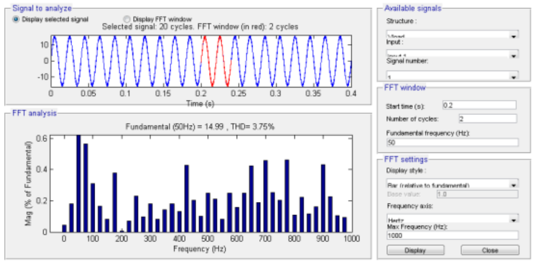

Fig. 23 THD Curve of Load Voltage (V $_{Load}$)

The FFT analysis to derive the percentage THD of V_{Load} of proposed system is shown in fig.23. The percentage THD of V_{Load} is 3.75%.

CONCLUSION

In this paper, the Grid connected DG systems used at present are photovoltaic power wind power, when DG is integrated in the existing power grid, will affect power quality. Issues related with power quality have been analyzed with combined operation of UPQC and PV is explained. The Proposed system is composed of series and shunt converters, 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 converter connection to grid because of applying UPQC shunt converter 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/SIMULINK) software and simulation results confirm that the proposed system operates correctly.

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