Comparative Aspects of Single & Multiple PV Arrays Connected With UPQC

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ABSTRACT
This paper deals with the comparative aspect if single and multiple PV Arrays connected with UPQC. Dynamic model of the UPQC is developed in the MATLAB/SIMULINK environment and the simulation results demonstrating the power quality improvement in the system are presented.

INDEX TERMS:*Photovoltaic Arrays (PV Arrays), UPQC, Energy Storage Devices.*

I. INTRODUCTION

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 compensating the load current harmonics and voltage oscillation [1]. This is called Unified Power Quality Conditioner (UPQC) [2].UPQC is greatly studied by researchers [3-5] as a basic device to control the power quality. The duty of UPQC is to reduce perturbations which affect the operation of sensitive loads. UPQC is able to compensate voltage using shunt and series inverters. In spite of this issue, UPQC is not able to compensate voltage interruption and active power injection to grid, because in its DC link, there is no energy source.The attention to Distributed Generating (DG) sources is increasing day by day. The reason is their important roll they likely play in the future of power system [6-8]. 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 sensitive of DGs to grids parameters and DG power transferring facility using this approach. Although DG needs more controls to reduce the problems like grid power quality and reliability, Photovoltaic array (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 shares of applying this kind of energy in the future will be its usage in interconnect systems.

Nowadays, European countries have shown inter – connected systems development in their countries by choosing supporting policies. In this study, UPQC and PV combined system has been presented. UPQC introduced by Chen et al., [9], it has the ability to compensate voltage sag voltage swell, harmonics and reactive power.A structure has been proposed in [10, 12-15], as shown in Figure 1, where DG sources are connected to a DC link in the UPQC as an energy source.

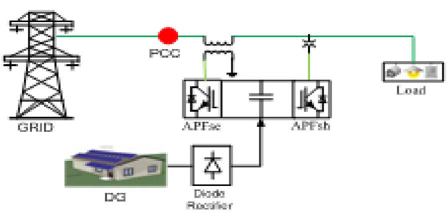

Fig.1.UPQC with DG connected to the DC link

This configuration works both in interconnected and islanded mode (shown in Figure 3.1; 3.2). In Interconnected mode, DG provides power to the source and loads whereas in islanded mode DG (within its power rating) supplies the power to the load only. In Addition, UPQC has the ability to inject power using DG to sensitive loads during source voltage interruption. The advantage of this system is voltage interruption compensation and active power injection to the grid in addition to the other normal UPQC abilities. The system's functionality may be compromised if the DG resources are not sufficient during the voltage interruption conditions. Economical operation of the system can also be achieved by proper controlling of the active power transfer between the supply and DG source through a series APF [16-19].

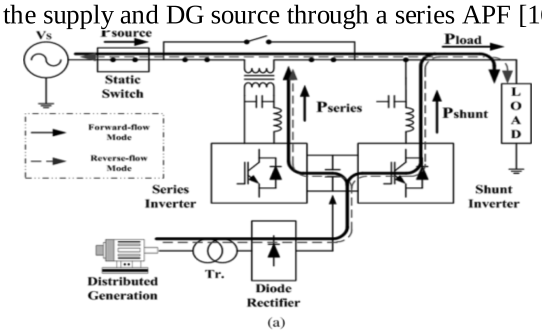

Fig.3 (DG-UPQC) DC- linked System operation concept. (a) Interconnected mode.

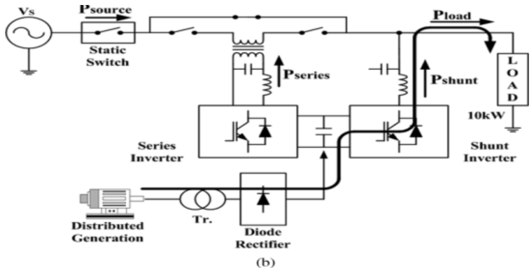

Fig.4. (DG-UPQC) DC- linked System operation concept. (b) Islanding mode

Major advantages of the photovoltaic power are as follows:

- Short lead time to design, install, and start up a new plant.
- Highly modular, hence, the plant economy is not a strong function of size.
- Power output matches very well with peak load demands.
- Static structure, no moving parts, hence, no noise.
- High power capability per unit of weight.
- Longer life with little maintenance because of no moving parts.
- Highly mobile and portable because of light weight.

II. INTRODUCTION TO UPQC WITH PV ARRAYS

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. Hence, UPQC and PV combined system has been presented. UPQC introduced in has the ability to compensate voltage interruption along with voltage sag and swell, harmonics and reactive power [20 -22].Here, PV energy conversion system has high efficiency, low cost and high functionality. In the following figure, converter 1 (PV converter) is responsible to convert the PV energy to the grid as well as to compensate current harmonics and reactive power. The converter 2 (DVR Converter) is responsible to compensate voltage harmonics or voltage sags. Thus, the utilization of two controlled converters makes the system to have the most structure applied as energy conditioner[23].

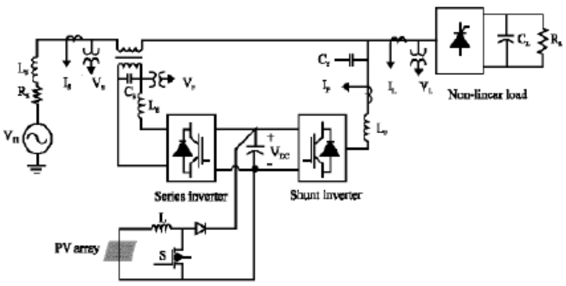

Fig.4. UPQC connected with PV arrays.

III. A.UPQC WITH SINGLE PV ARRAY

In this paper the role of Unified power quality conditioner is the power quality improvement of Distributed networks (PV Arrays). Here, UPQC is integrated with single PV Array and then with multiple PV Arrays. The comparative aspect of UPQC wit single and multiple PV Array is studied with the help of MATLAB SIMULINK models. Figures shown in Fig.5 and Fig.6 represent the circuit models of both UPQC with single and multiple PV Arrays respectively and battery is taken as the energy storage device.In the figure shown single PV array is connected with UPQC. The DC output required by the UPQC is obtained from the PV Array. Since this DC voltage generated by a photovoltaic array varies and is low in magnitude, a step-up DC-DC converter is essential to generate a regulated higher DC voltage. The DC-DC converter is responsible for absorbing power from the photovoltaic array, and therefore should be designed to match photovoltaic array ripple current specifications and should not conduct any negative current into the photovoltaic array. Following figure shows the internal model of the PV Array.

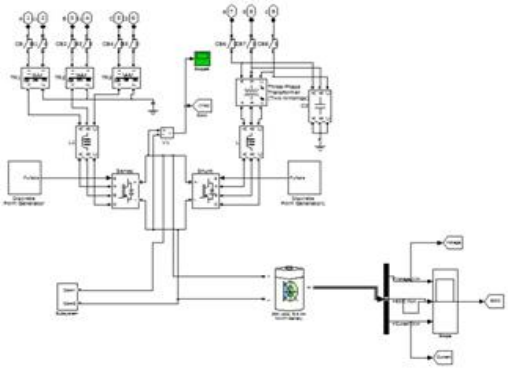

Fig.5. UPQC with single PV Array

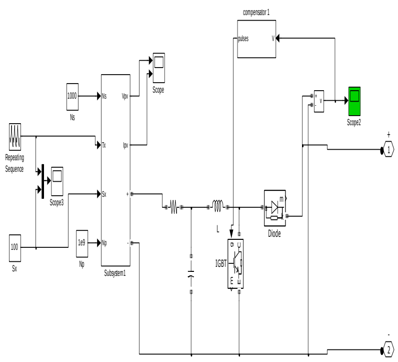

Fig.6. Internal of PV Array

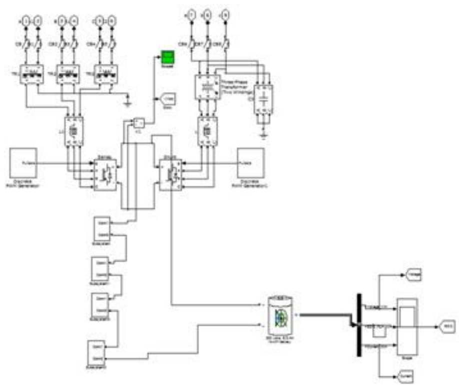

Fig.7. UPQC with multiple PV Arrays

IV. B.UPQC WITH MULTIPLE PV ARRAYS

The multiple input single output (MISO) DC-DC converters is useful for combining several distributed generation sources whose power capacity and/or voltage levels are different to obtain well-regulated higher output voltage [24]. The converter topology used for the combination of DC output of photovoltaic array units is shown in Fig. 8. In the control system of MISO DC-DC converter, the output voltage of converter has been compared with a reference value and the error signal is applied to PI-controller.The output signal of this controller is the one input of PWM switching for adjusting the duty cycle. Here, as an example a Triple-Input Single-Output (TISO) DC-DC converter has been designed and studied.

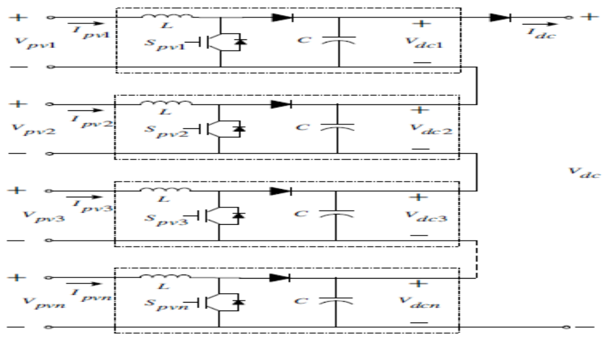

Fig.8. TISO DC - DC Converter

5.2 Control Scheme of the Proposed System

Instantaneous power theory is used to control of the proposed system. This scheme includes Photovoltaic (PV) energy resource to deliver PV power to loads and maintaining DC link voltage as well as other condition tasks. The theory is based on converting three axis parameters into two axes by defining well-known transfer matrix. The active and reactive instantaneous power can be decomposed by DC component and AC harmonic components, which consist of negative sequence component and harmonic component. Following sections provide the shunt and series inverter control strategies.

If shunt inverter is used simultaneously for reactive, negative and harmonic component compensation, the α-β axis current reference is given by the following equation

$$\begin{bmatrix} i^*_{c_\alpha} \\ i^*_{c_\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} -p_{control} \\ -q_{control} \end{bmatrix} \quad (1)$$

When the series converter of the proposed configuration is used simultaneously for reactive, negative and harmonic compensation, the α-β axis voltage reference is given by equation (4).

$$\begin{bmatrix} v^*_{c_\alpha} \\ v^*_{c_\beta} \end{bmatrix} = \frac{1}{i_\alpha^2 + i_\beta^2} \begin{bmatrix} i_\alpha & -i_\beta \\ i_\beta & i_\alpha \end{bmatrix} \begin{bmatrix} -p_{control} \\ -q_{control} \end{bmatrix} \quad (2)$$

When the shunt converter of the proposed configuration is used for the charge control of battery, the active reactive power control is becoming the main issue, and the proposed system still satisfy the compensation demand of load such as negative and harmonic compensation. Then the α-β axis current reference is given by equation (3).

$$\begin{bmatrix} i^*_{c_\alpha} \\ i^*_{c_\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p_{control} + p_{pv} \\ q_{control} \end{bmatrix} \quad (3)$$

Where, p_{pv} is the PV power delivered to local loads by shunt converter. It should be noted that, it is so difficult to compensate reactive power and harmonic current using series converter only and because the signals from converter output terminals must be passed through the filters, the filter design strongly depends on the system parameters like load size and transformer turns ratio.

V. SINGLE LINE DIAGRAM OF TEST SYSTEM

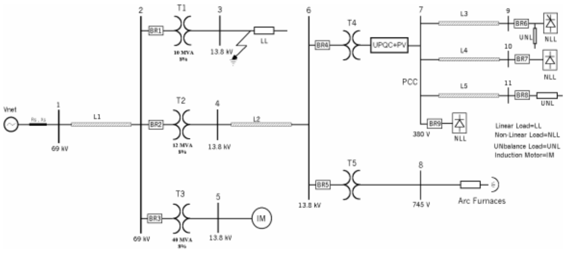

Fig.9. Single line diagram of test system used under consideration

As mentioned earlier this paper focuses on the comparison of UPQC with single PV Array and Multiple PV Arrays with compensation being performed at the distribution voltage level (13.8 kV in this case)[24]. Above designed new UPQC with PV Array models are installed in the secondary side of transformer between bus bars 6 and 7 near the point of common coupling (PCC). Following figures show the single line diagram and MATLAB model of the test system under consideration. Initially working of system is observed for UPQC with single PV Array and then with multiple PV arrays. The effectiveness of the both of UPQC models can be observed form the outputs of the system with UPQC.

VI. SIMULATIONS AND RESULTS

The values for inductance and capacitance are 0.112mH and 138.455 µF respectively for multiple PV arrays. The output voltage of MISO DC-DC converter V_{dc} can be expressed by the following (4):

$$V_{dc} = V_{dc1} + V_{dc2} + V_{dc3} + \ldots\ldots + V_{dcn}$$

$$= \frac{V_{pv1}}{1-D_{pv1}} + \frac{V_{pv2}}{1-D_{pv2}} + \frac{V_{pv3}}{1-D_{pv3}} + \ldots\ldots + \frac{V_{pvn}}{1-D_{pvn}} \quad (4)$$

Where D_{pv1}, D_{pv2}, D_{pv3} and D_{pvn} are the duty cycles of boost converters and V_{dc1}, V_{dc2}, V_{dc3} and V_{dcn} are the output voltages of boost converters.

Following are the outputs obtained for the UPQC with single and multiple PV arrays. And FFT analysis is done to analyze the THD % differences for voltage and current of the system.

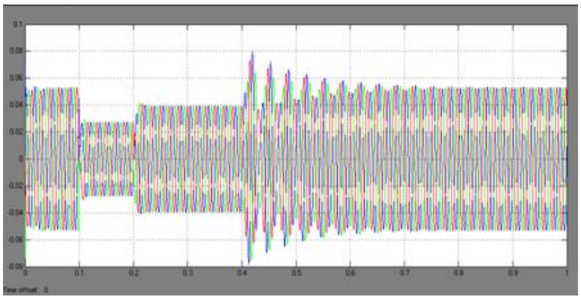

Fig.10. Voltage of the system integrated with UPQC and single PV Array

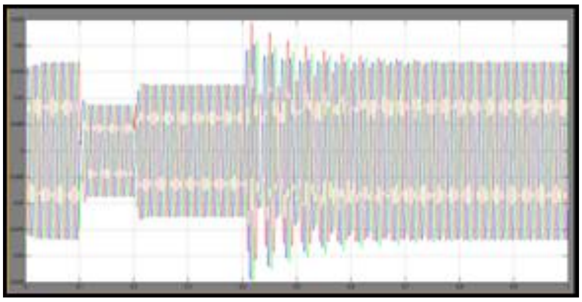

Fig.11. Current of the system integrated with UPQC and single PV Array

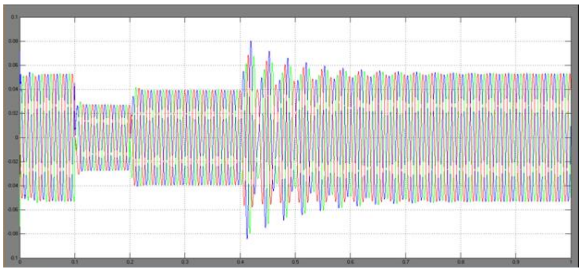

Fig.12. Voltage of the system integrated with UPQC and multiple PV Arrays

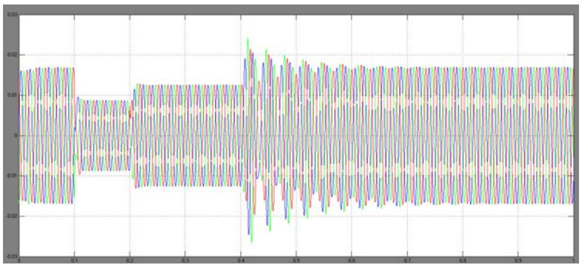

Fig.13. Current of the system integrated with UPQC and multiple PV Arrays

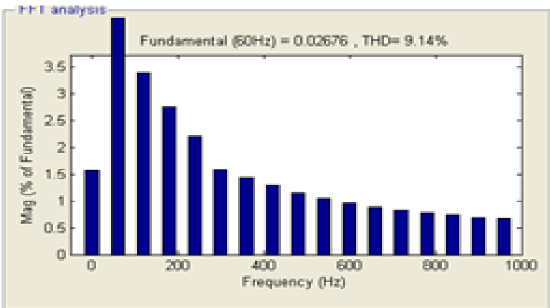

Fig.14. FFT Analysis for voltage of the system integrated with UPQC and single PV Array.

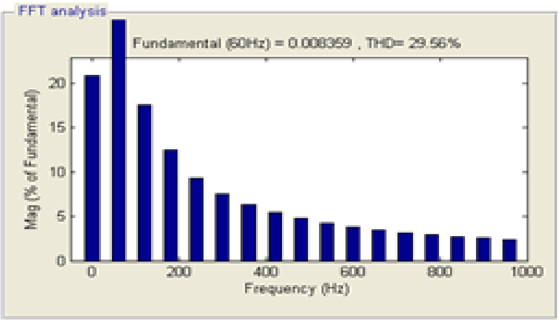

Fig.15. FFT Analysis for current of the system integrated with UPQC and single PV Array.

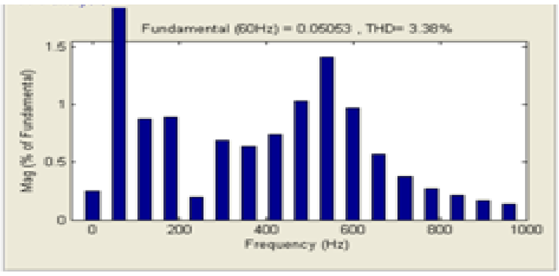

Fig.16. FFT Analysis for voltage of the system integrated with UPQC and multiple PV Arrays.

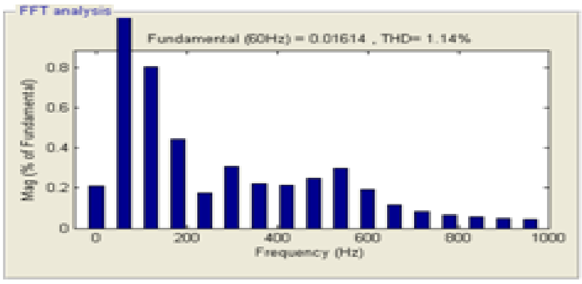

Fig.17. FFT Analysis for current of the system integrated with UPQC and multiple PV Arrays.

Figures 10 & 11 shows greater distortions in voltage and current output of the system integrated with UPQC and single PV arrays as compared to that in figures 13 & 14 outputs of system with multiple PV arrays. It can also be cleared from FFT analysis for the THD% shown in the table below:

TABLE I. FFT ANALYSIS

PV Arrays	Voltage THD%	Current THD%
Single	9.14	29.56
Multiple	3.38	1.14

VII. CONCLUSIONS & FUTURE ASPECTS

This paper proposes the comparative aspect of UPQC model s with single and multiple PV Arrays and the concept of Multi Input Single Output is studied. Results obtained show the effectiveness of the UPQC with multiple PV Arrays over the UPQC with single PV Arrays. The THD% level of the system is reduced in the case of multiple PV arrays. Hence it can be a better option where more accuracy in the system is required and multiple PV arrays can be easily installed. The performance of the proposed system was analyzed using simulations with MATLAB SIMULINK and validates the improvement of the power reliability of the system.

TABLE II. LIST of PARAMETERS USED

Sr. No.	System Quantities	Standards
1	Source	3 phase, 69 kV, 60Hz
2	Inverter parameters	IGBT based, 3-arm, 6-Pulse, Carrier Frequency=2000 Hz, Sample Time=5 µs
3	PI Controller	KP=0.5, Ki=1000 for series control Kp=0.5, Ki=1000 for shunt control, Sample time=50 µs
4	RL load	Active Power = 5kW; Inductive Reactive Power = 2kVAR
5	Transformer 1	Δ\Yg, 69/138kV
6	Transformer 2	Δ\ Δ; 69/138kV
7	Transformer 3	Δ\Yg, 69/138kV
8	Transformer 4	Δ\Yg,138\745kV
9	Motor Load (NLL)	Voltage V_{rms} = 138kV, Frequency = 60Hz

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