Grenze International Journal of Engineering and Technology, July 2017

UPQC in Alleviation of PQ issues with Islanding and Reconnection for Micro-grid Applications

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***Abstract*—Due to Immense employment of electronics equipment/gadgets quality of power has turned into essential and important factor. The conventional devices or equipment is not sufficient to increase the power quality. The UPQC is the modern method to improving the quality of power & furthermore it attends simultaneously voltage deformity and current deformity. In this paper new FACTs (flexible Alternating current Transmission) circuit termed as UPQC (unified power quality conditioner) is designed and developed to recompose the voltage and current imperfections. The two different controlling method are implemented. The sag as well as swells of voltage along with current harmonic compensation are shown. The micro-grids are interconnection of renewable resources available at distribution end. Micro -grids can be regulated in three different forms, they are grid connected mode, autonomous mode & micro generation mode .The battery system is conceited to DC-link for supplying real power in the micro-grid. The new controlling method is employed for the integration and control of quality in distribution generation based micro-grid system.**

***Index Terms*— Unified Power Quality Conditioner, Flexible AC Transmission, power quality. Islanding, Detection, Synchronous reconnection, Distribution Generation.**

I. INTRODUCTION

The nature of electric supply has a serious impact due to more usage of electronics gadgets. Electric power customers must be fed with smooth uninterrupted or undistorted supply at desired magnitude and frequency. As well as the consumers should draw harmonics free current [1]. Many researchers has been done based on effective improvement of quality. For the complication arising in quality of power, UPQC is found powerful tool. UPQC is apt and sufficient to attend supply disturbance like swelling of voltage, sagging of voltage flickering of voltage, harmonics of voltage, harmonics of current.
The metonym of UPQC is “universal active power line conditioner”, “universal power quality conditioner” and “universal active power filter”. The APFs of shunt and series are cascaded through the same link of dc capacitor. The series APF is coupled through series transformer to transmission line. The APF which is in

Grenze ID: 01.GIJET.3.3.77

series prevents the source end disturbances of voltage from entering into the load end to make the load voltage at desired magnitude and frequency [2]. Whereas the APF in shunt is connected in parallel across the load controls the problems related to current at the load side and makes the current from the source purely sinusoidal [3]. In this manuscript two different controlling methods are employed for series and shunt APF. This paper effort has been made to reduce the THD-total harmonics distortion. Comparing paper [5], the distortion is minimized by using SPWM controller and Hysteresis controller.

The major issues in successful placement and integration of unified power quality conditioner (UPQC) in a distributed generation (DG)-based grid connected micro-grid (μ-G) system are

a) Control complexity for active power transfer;

b) Ability to compensate non-active power during the islanded mode; and

c) Difficulty in the capacity embellishment in a modular way [1].

For a smooth transfer of power in between the grid-connected system and islanded mode, various operational changes are presented, such as switching between the voltage and current control mode, robustness against the islanding detection and reconnection delays and method and else more. Clearly, these further increase the control complication of the micro-grid systems. To widen the operational flexibility and to enhance the quality of power at grid connected micro-grid systems, a new controlling scheme placement and integration technique of UPQC have been proposed in [3], which is termed as UPQC-μG.

II. Control Strategy

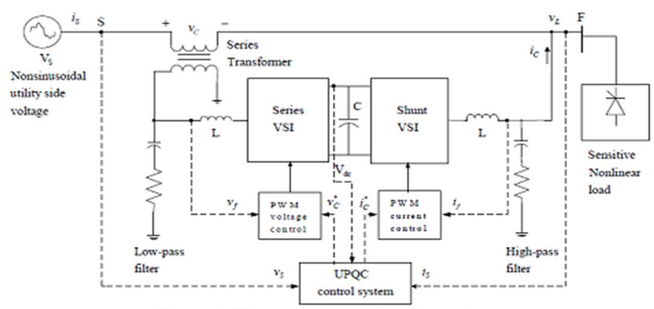

Figure 1: Diagram of UPQC representation.

The configuration of UPQC is shown in figure 1. The UPQC consists 2 voltage source inverters connected with same dc link capacitor. The voltage associated issues such as sagging of voltage, swelling of voltage, flickering and voltage harmonics are composed by series inverter attached to the line in series. The current associated issues like current harmonics taken care by shunt inverter attached to the transmission line. The DC link capacitor joins the shunt APF and series APF together and facilitates for sharing active power among two inverter.

A. Control Strategy I

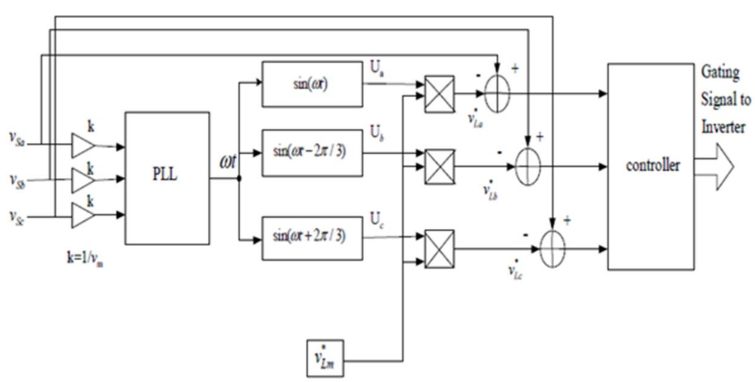

Figure 2: Control block diagram of series APF.

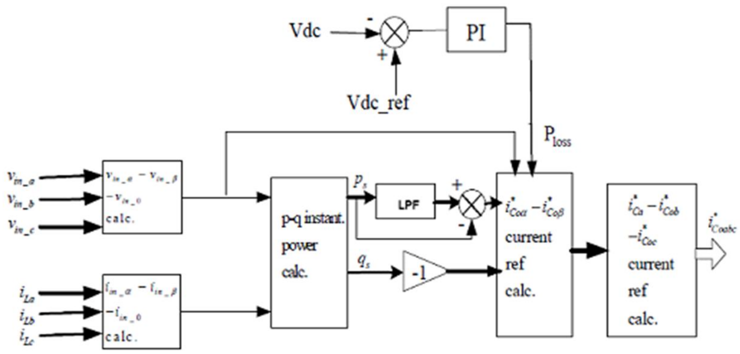

Figure 3: Control block diagram of shunt APF

The controlling of series filter is made by simple algorithm. The UVT-unit vector template approach is implemented in the paper as the controlling method [4]. From the distorted supply unit vector template (UVT) is taken. The extraction process is shown in Figure 2. The major objective here is to make load voltage completely sinusoidal. To carry this procedure the voltage opposite to distortion will be generated and it get cancels with the distorted wave, the resultant voltage will be desired voltage with exact magnitude required at load side, the load voltage will be compared with the load reference voltage and it gives error voltage signal, this signal will be fed into controller, this SPWM/hysteresis controller gives the required gating pulse to maintain power quality.

B. Control strategy II

In the shunt active power filter employs the Instantaneous reactive power theory or p-q theory [3], to generate the reference signals. The equation (a) and the equation (b) are employed to transverse the three phase currents and voltages to α- -γ co-ordinates [3]. The shunt APF control scheme is shown in figure 3.

$$\begin{bmatrix} V_{i\_0} \\ V_{i\_\alpha} \\ V_{i\_\beta} \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & 3/\sqrt{2} & -3/\sqrt{2} \end{bmatrix} \begin{bmatrix} V_{i\_a} \\ V_{i\_b} \\ V_{i\_c} \end{bmatrix} \quad \ldots(a)$$

$$\begin{bmatrix} I_{i\_0} \\ I_{i\_\alpha} \\ I_{i\_\beta} \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & 3/\sqrt{2} & -3/\sqrt{2} \end{bmatrix} \begin{bmatrix} V_{i\_a} \\ V_{i\_b} \\ V_{i\_c} \end{bmatrix} \quad \ldots(b)$$

$$\begin{bmatrix} P_0 \\ P_s \\ q_s \end{bmatrix} = \begin{bmatrix} V_{i\_0} & 0 & 0 \\ 0 & V_{i\_0} & 0 \\ 0 & 0 & V_{i\_0} \end{bmatrix} \begin{bmatrix} I_0 \\ I_{i\_\alpha} \\ I_{i\_\beta} \end{bmatrix} \quad \ldots(c)$$

The equation c depicts the computation of real power [P].
ps=real power
qs=imaginary power.
The equation below shows the presences of average and oscillating components of instantaneous power.

$$Ps = \overline{Ps} + \widetilde{ps} \;,\; qs = \overline{qs} + \widetilde{qs} \quad \ldots(d)$$

For the power reference and current reference total imaginary power and oscillating real power are considered and used in equation (e).

$$\begin{bmatrix} I^*_{c\alpha} \\ I^*_{c\beta} \end{bmatrix} = \frac{1}{v_{i\_\alpha} + v_{i\_\beta}} \begin{bmatrix} V_{i\_\alpha} & -V_{i\_\beta} \\ V_{i\_\beta} & V_{i\_\alpha} \end{bmatrix} \begin{bmatrix} -P_s + P_{loss} \\ -q_s \end{bmatrix} \quad \ldots(e)$$

The compensating current (Icα, Icβ) which are in α-β co-ordinate are converted into a-b-c again using the equation (f).

III. SIMULATION RESULTS

MATLAB/SIMULINK is implemented to simulate the model designed in the paper. To add the nonlinear load the three phase diode bridge is implemented in model of Simulink. The Simulink result for sag and swell of voltage along with current harmonics are presented.

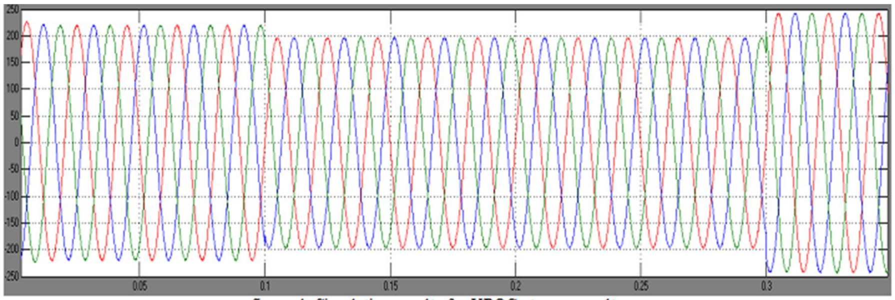

figure 4: Simulation results for UPQC at source voltage.

In the above graph, it is shown that the voltage till the 0.1s is normal. From 0.1s to 0.3s the voltage sag is seen, after 0.3s voltage swell is seen

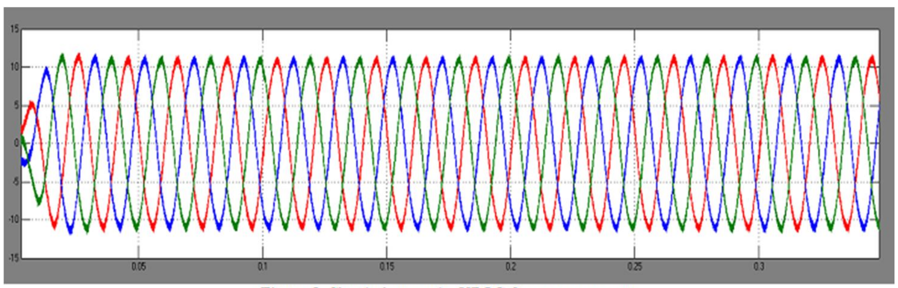

Figure 5: Simulation results UPQC for source current

In the above graph the source current is shown, the source current will not have any distortion, the current harmonics problem occurs at load side, that is current harmonics is seen in load current.

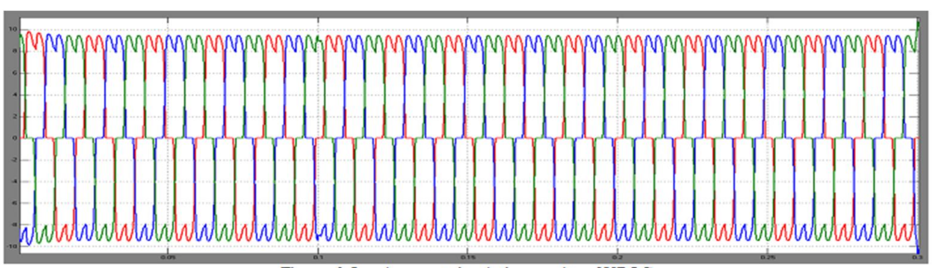

Figure 6: Load current simulation results of UPQC

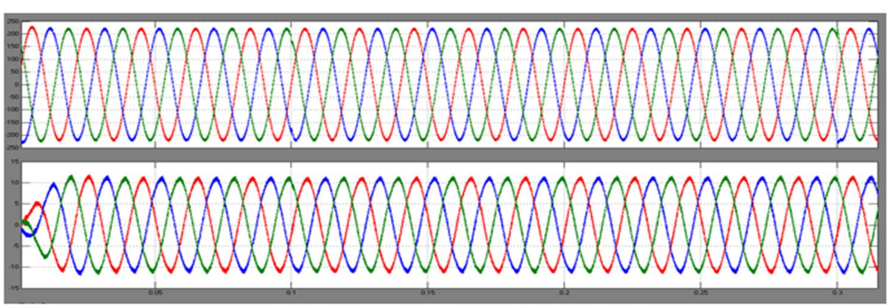

Figure 7: a) Voltage at the grid without any distortion.
b) Current at the grid without any harmonics.

The graphs shown above is the grid voltage and current when UPQC is connected to it.

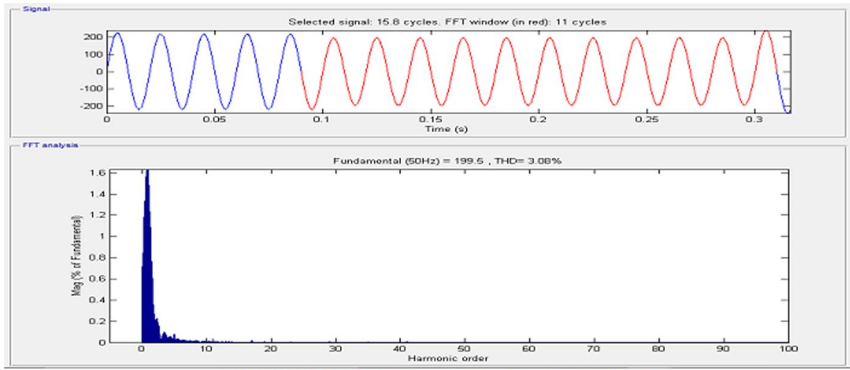

Figure 8: Total harmonics distortion analysis of source voltage

The distortion value of the source voltage is appearing as 3.08% for 11 cycles from the start time of 0.09s.

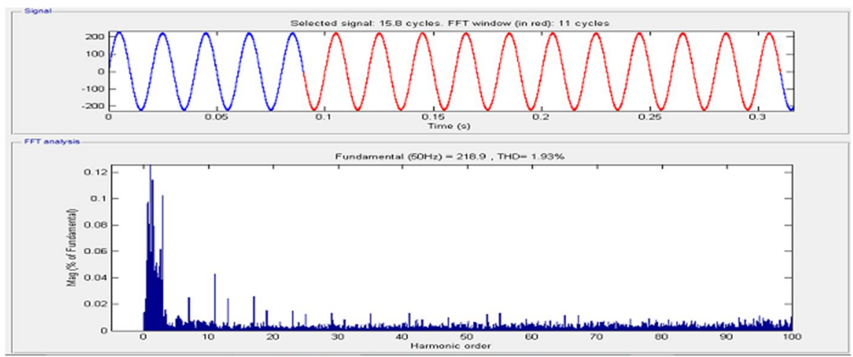

Figure 9: Total harmonic distortion analysis of line voltage

The distortion value of load voltage is 1.93% for 11cycles from the start time of 0.09 s. hence the THD of line voltage is lesser than the source voltage and it's proved that UPQC has improved the power quality.

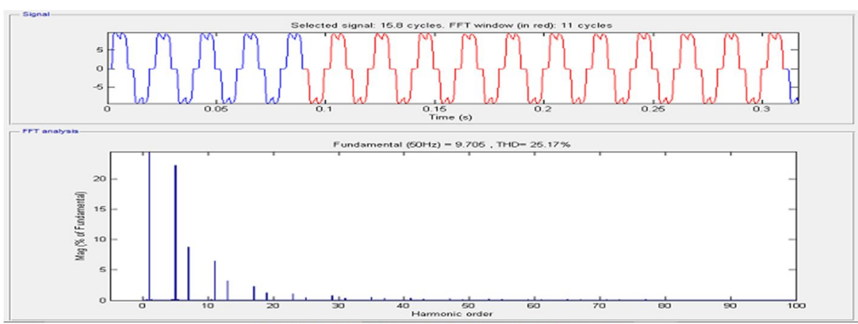

Figure 10: Total harmonic distortion of load current

The Distortion value of load current is 25.17% of 11cycles from the start time of 0.09 s.

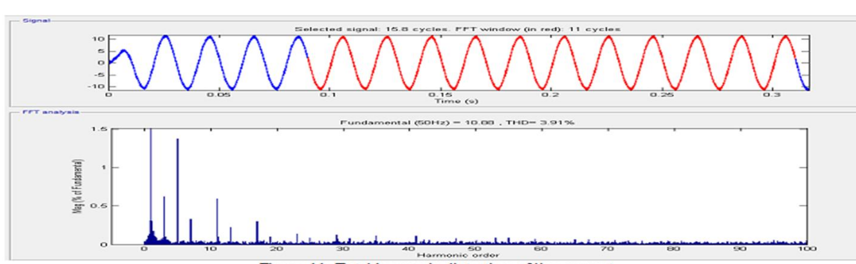

Figure 11: Total harmonic distortion of line current.

The distortion value of line voltage is 3.91% for 11cycles from the start time of 0.09 s. Hence the THD of line current is lesser than the source current and it's proved that UPQC has improved the power quality.

III. MICROGRID

The Integration technique of the proposed UPQC micro grid –IR to a grid connected and DG integrated micro grid system is presented in Fig 12 (a). S1 and S2 are the breaker switches that are used to island and reconnect the micro grid system to the grid as directed by the secondary control of the UPQC micro grid –IR. The working principle during the interconnected and islanded mode for this configuration is shown in the Fig 1(b, c). The operation of UPQC micro grid- IR can be divided into two modes.

A. Interconnected mode

In this mode, as shown in Fig 12(b):
1. The DG source delivers only the fundamental active power to the grid, storage and load.
2. The APFsh compensates the reactive power and harmonic power (QH) of the non-linear load to keep the THD at the PCC within the IEEE standard limit.
3. Voltage-sag or swell/interruption can be compensated by the active power from the grid/storage through the APFse. DG converter does not sense any kind of voltage disturbance at the PCC and hence remains connected in any condition.
4. If the voltage interruption/black out occurs, UPQC sends a signal within a pre-set time to the DG converter to be islanded.

B. Islanded mode

In this case, as shown in Fig 12(c):
1. The APFse is disconnected during the grid failure and DG converter remains connected to maintain the voltage at PCC.
2. The APFsh still compensates the non-active power of the non-linear load to maintain undistorted current at PCC for other linear loads.
3. Therefore, DG converter (with storage) delivers only the active power and hence does not need to be disconnected from the system.
4. The APFse is reconnected once the grid power is available.

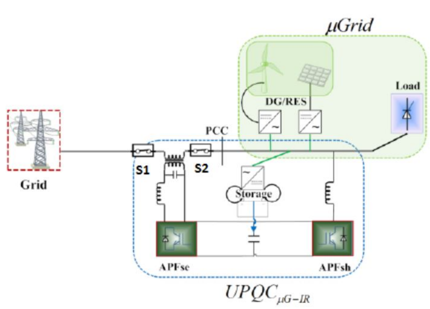

Figure-12(a): Shows Integration Technique of UPQCμG-IR

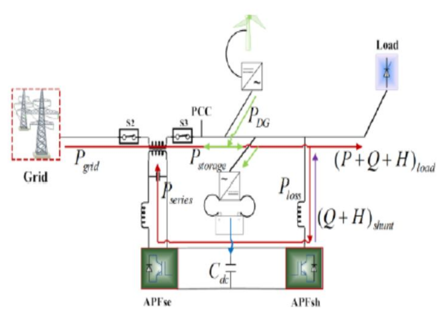

Figure 12(b): Working principle in Interconnected Mode

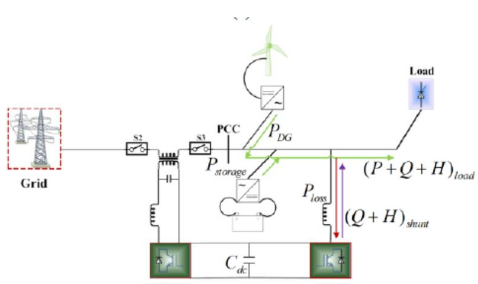

Fig 12 (c) Working Principle in Islanded Mode

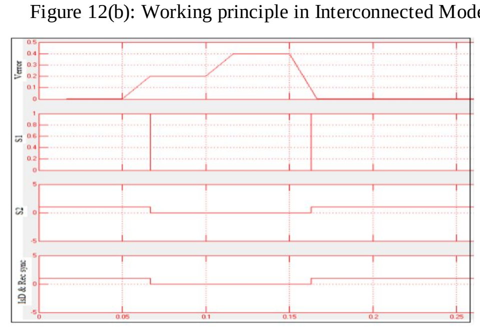

Figure 13 (a): Switching positions during the islanding operation

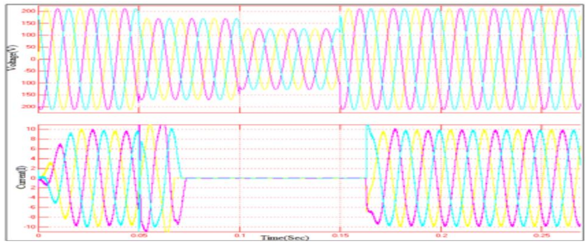

Figure13 (b): Voltage and current waveforms at Θ_s=20 degree

IV. CONCLUSION

This paper recommends a controlling algorithm for UPQC based on SPWM voltage and current controller. The UPQC model is developed and simulated. It is observed from obtained results through simulation that the supply side sag/swell of voltage with the load side current harmonics are easily evicted successfully.
This paper presents the integration and controlling of islanding and reconnection design technique in the grid connected micro grid condition. The performance with off-line simulation has been obtained. The results depicts that the UPQC ugrid-IR can recompose the voltage and current deformities at the PCC (point of common couple) during the interconnected mode.

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