

# Power Quality Improvement of Hybrid Power system based microgrid using UPQC

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## **Abstract:**

The advance use of power electronic devices introduces harmonics in the supply system which creates a problem in the quality of power delivered. Good Power Quality is very much important for our day-to-day use of appliances in both industrial and domestic sectors. Researchers have tried and implemented many useful technologies for removing all the voltage and current related harmonic occurrence problems which in turn improves the quality of power delivered to the power system. The prime focus of this thesis is the implementation of control strategies like SRF theory and instantaneous power (p-q) for the operation of Unified Power Quality Conditioner (UPQC) which is one of the recent technologies that includes both series and shunt active power filter operating at the same time and thereby improves all the current and voltage related problem like voltage sag/swell, flicker, etc. at the same time and helps in reduction of Total Harmonic Distortion (THD).

In this work it is shown via MATLAB simulation how UPQC model can be used to decrease the % THD in source voltage, source current and load voltage waveforms created due to non-linear/sensitive loads usage.

*Keywords: Renewable energy sources, Power quality, Harmonic analysis, Synchronization, Voltage control, UPQC, MATLAB.*

## **1. Introduction**

In the present scenario non-linear loads have become extremely important and people are becoming dependent on it. Few of these non-linear loads are televisions, printing and fax machines, rectifiers, inverters, speed drives, AC, etc. Harmonics are introduced in the lines due to the extensive use of these loads in our everyday purpose. The stability of any electrical devices

depends on its voltage and current waveforms. If the fundamental waveform is sinusoidal, and its harmonics are sinusoidal too then these harmonics occurs in integral multiples of the fundamental waveform. Due to this harmonic distortion created by nonlinear loads several problems are caused in the appliances used in our purpose like: motor getting overheated, increase in several types of losses, permanent damage of equipment in the worst case, high error in meter reading, etc. Hence removal of these harmonics or harmonic mitigation from voltage and current waveforms are of great concern for electrical engineers. Due to the harmonic's introduction in the lines by the nonlinear loads other problems of concern are voltage swell, voltage sag, flicker occurring in voltage, etc and thereby disturbing the overall power supply.

In older days passive filters using tuned LC components were in very much use for improvement of power quality by removing voltage and current harmonics. But due to its high cost, resonance problems, large size and many more these filters are not in much use in the present days. All these problems are now improved by the use of active power filters (APF) and more advanced hybrid filters using several new technologies. Series Active Filter is utilized for mitigation of voltage quality problems and Shunt Active Filter (SAF) is helpful for removing the disturbances present in the current waveforms.

## **2. Introduction to UPQC**

The Unified Power Quality Conditioner is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and/or critical load. It is a type of hybrid APF and is the only versatile device which can mitigate several power quality problems related with voltage and current simultaneously therefore is multi functioning devices that

compensate various voltage disturbances of the power supply, to correct voltage fluctuations and to prevent harmonic load current from entering the power system. Fig. 2.1 shows the system configuration of a single-phase UPQC. Unified Power Quality Conditioner (UPQC) consists of two IGBT based Voltage source converters (VSC), one shunt and one series cascaded by a common DC bus. The shunt converter is connected in parallel to the load. It provides VAR support to the load and supply harmonic currents. Whenever the supply voltage undergoes sag then series converter injects suitable voltage with supply. Thus, UPQC improves the power quality by preventing load current harmonics and by correcting the input power factor.

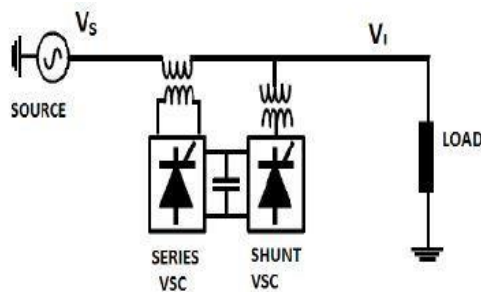


Figure 1: Block diagram of UPQC

The main components of a UPQC are series and shunt power converters, DC capacitors, low-pass and high-pass passive filters, and series and shunt transformers:

### 2.1 Equivalent circuit

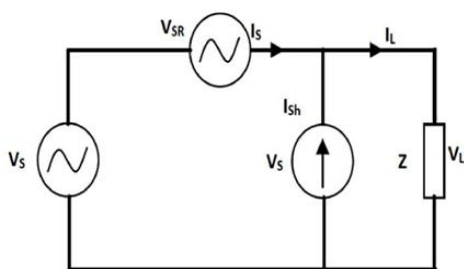


Figure 2: equivalent circuit for UPQC

In this circuit,

$V_S$  represents the voltage at power supply  
 $V_{SR}$  is the series-APF for voltage compensation,  
 $V_L$  represents the load voltage and  
 $I_{sh}$  is the shunt-APF for current and  $V_{SR}$  compensation.

Due to the voltage Distortion, the system may

contain negative phase sequence and harmonic components. In general, the source voltage in Figure 2.2 can be expressed as:

$$V_s + V_{sr} = V_L \quad (2.1)$$

To obtain a balance sinusoidal load voltage with fixed amplitude  $V$ , the output voltages of the series-APF should be given by:

$$V_{sr} = (V - V_{1P}) \sin(\omega t + \theta_{1P}) - V_{Ln} \left( \sum_{K=2}^{\infty} V_K(t) \right) \quad (2.2)$$

where,  $V_{1P}$ : positive sequence voltage amplitude  
 fundamental frequency

$\theta_{1P}$ : initial phase of voltage for positive sequence

$V_{Ln}$ : negative sequence component

The shunt-APF acts as a controlled current source and its output components should include harmonic, reactive and negative-sequence components in order to compensate these quantities in the load current, when the output current of shunt APF  $i_{sh}$  is kept to be equal to the component of the load as given in the following equation:

$$i_L = I_{1P} \cos(\omega t + \theta_{1P}) \sin \phi_{1P} + i_{Ln} + \sum_{K=2}^{\infty} i_{LK} \quad (2.3)$$

$$\phi_{1P} = \phi_{1P} - \theta_{1P} \quad (2.4)$$

where,  $\phi_{1P}$ : initial phase of current for positive sequence

As seen from the above equations that the harmonic, reactive and negative sequence current is not flowing into the power source. Therefore, the terminal source current is harmonic-free sinusoid and has the same phase angle as the phase voltage at the load terminal

$$i_s = i_L - i_{sh} \\ = I_{1P} \sin(\omega t - \theta_{1P}) \cos \phi_{1P} \quad (2.5)$$

## 3. Control Strategy for UPQC:

### 3.1 d-q transformation:

Both active and reactive power is controlled by controlling magnitude and phase of converter voltage with line voltage, because we know that the active power flow from leading to lagging voltage and reactive power from higher to lower voltage. D-q transformation controls both the power independently by controlling phase and magnitude.

According to d-q theory three phase system is converted into equivalent two-phase system known as stationary reference frame. These then converted into synchronous reference frame. In synchronous reference frame active and reactive power current control independently. The three phases to d-q and vice versa transformation is discussed later. Dc bus voltage and line current is controlled by outer loop and inner loop respectively. The instantaneous power of the line is:

$$p = v_R I_R + v_Y I_Y + v_B I_B \quad (3.1)$$

The reactive voltage is eliminated at any instant without changing  $p$ . In three phase circuit voltage and current is expressed as space vector. Three phases R, Y and B displaced by  $2\pi/3$  from each other shown in Figure 3.

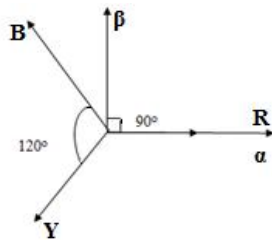


Figure 3: Vector Representation of R, Y, B (Frame Transformation abc to  $\alpha\beta$ )

The space vector instantaneous voltage and current is expressed as instantaneous voltage and current:

$$v = [v_R \quad v_Y \quad v_B] \\ I = [I_R \quad I_Y \quad I_B] \quad \dots (3.2)$$

Instantaneous voltage and current is converted into  $\alpha, \beta$  by using Clarke transformation:

$$\begin{bmatrix} v_\alpha \\ v_\beta \\ v_0 \end{bmatrix} = T \begin{bmatrix} v_R \\ v_Y \\ v_B \end{bmatrix} \quad \dots (3.3)$$

$$\begin{bmatrix} I_\alpha \\ I_\beta \\ I_0 \end{bmatrix} = T \begin{bmatrix} I_R \\ I_Y \\ I_B \end{bmatrix} \quad \dots (3.4)$$

Where Transformation Matrix

$$T = \sqrt{2/3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \quad \dots (3.5)$$

In balanced three-phase three-wire system zero sequence current is not present and it is also eliminated using star delta transformer. The reference frame  $\alpha, \beta$  is converted into d-q reference frame shown in Figure 4.

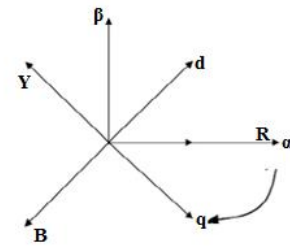


Figure 4:  $\alpha\beta$  to dq Transformation

$$\begin{bmatrix} v_d \\ v_q \end{bmatrix} = T \begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} \quad \dots (3.6)$$

$$\begin{bmatrix} \cos \omega_r & -\sin \omega_r \\ \sin \omega_r & \cos \omega_r \end{bmatrix} \quad \dots (3.7)$$

Where,  $\omega_r$  = angular velocity of d-q reference frame shown in Figure 4. The current is also obtained similarly using transformation matrix  $T$ .

#### 4. Simulation Model

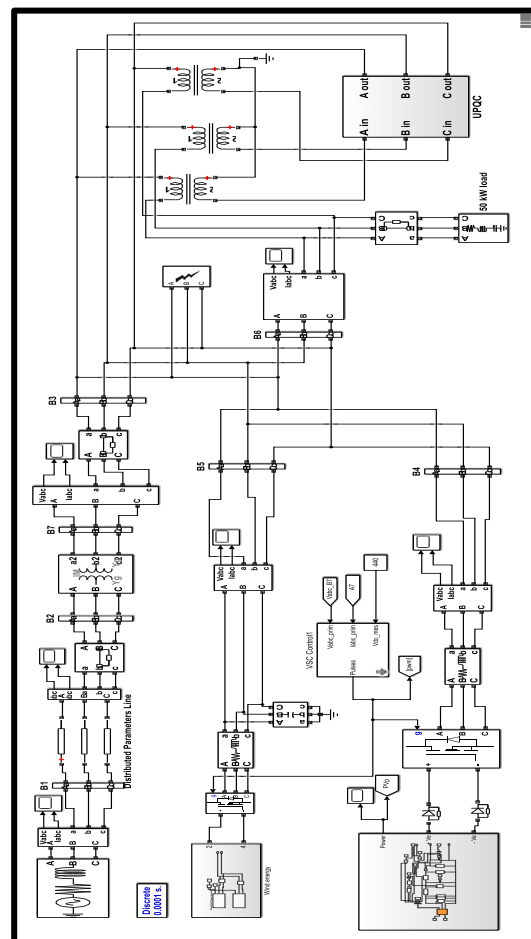


Fig 5 Simulation model with UPSC

#### 4.1 SIMULINK result for LLLG fault case

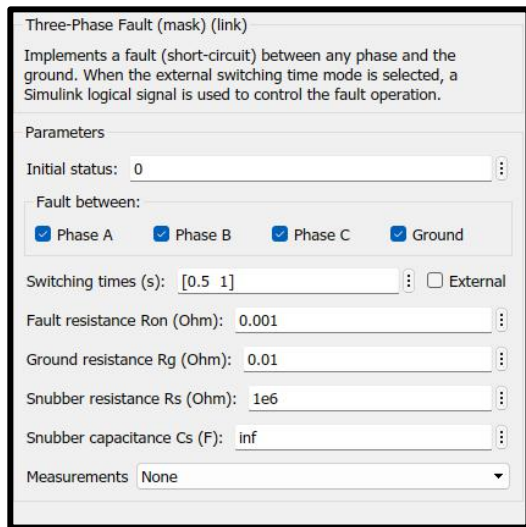


Fig 6 Three phase fault parameters for LLLG fault

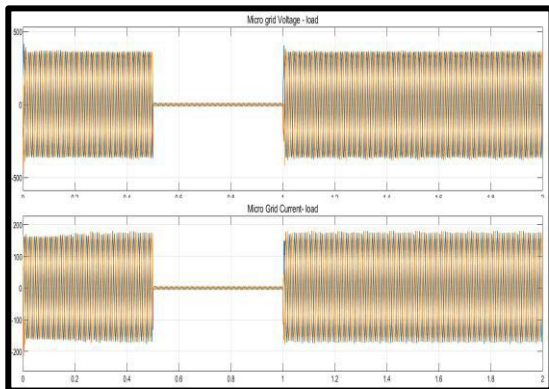


Fig 7 Voltage and current waveform of Micro Grid for LLLG fault

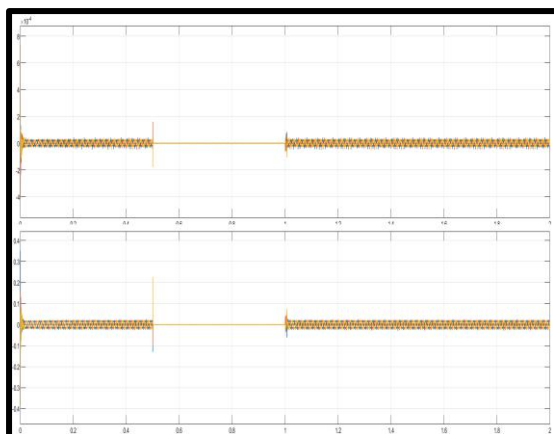


Fig 8 Voltage and current waveform of Along UPQC for LLLG fault

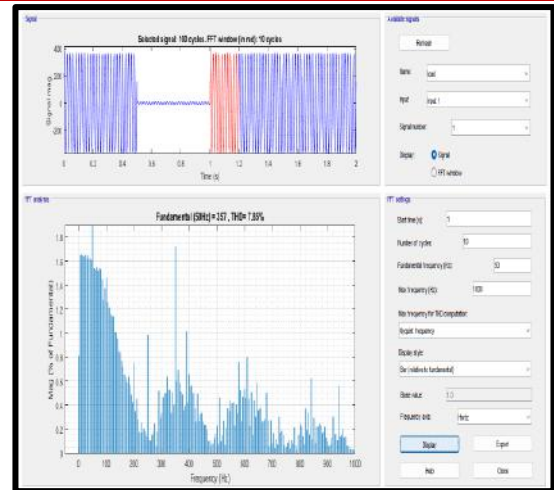


Fig 9 THD for LLLG fault

#### 4.2 SIMULINK result for LLL fault case

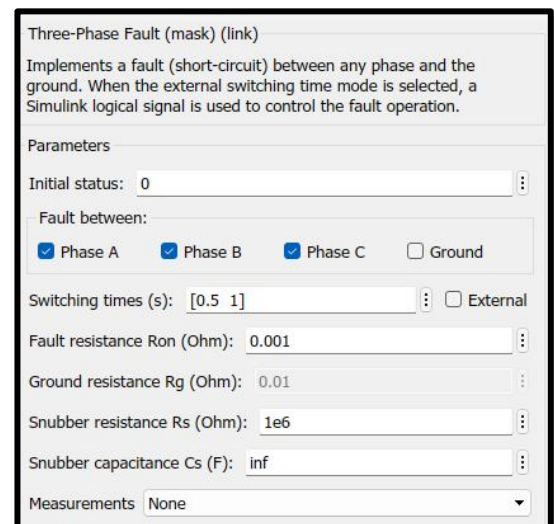


Fig 10 Three phase fault parameters for LLL fault

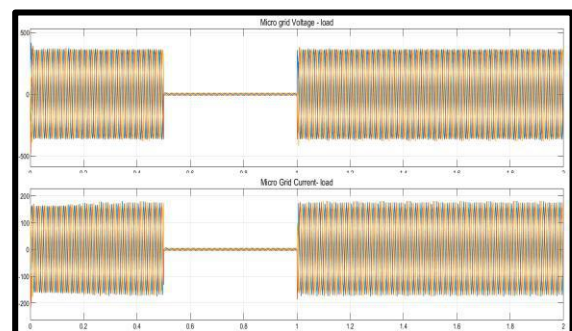


Fig 11 Voltage and current waveform of Micro Grid for LLL fault

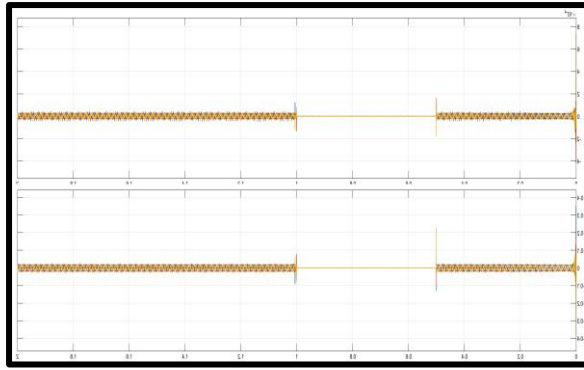


Fig 12 Voltage and current waveform of Along UPQC for LLL fault

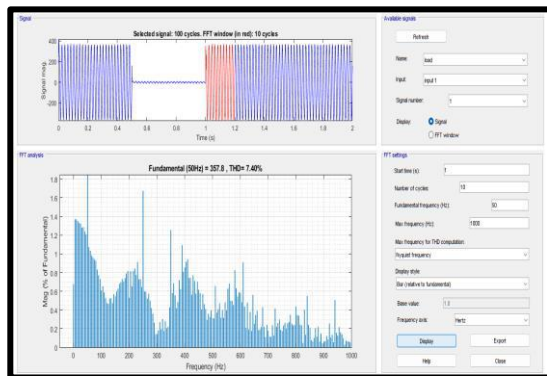


Fig 13 THD for LLL fault

## 5. CONCLUSION

This thesis describes an improved control strategy for the operation of UPQC system. The UPQC model is simulated in MATLAB using instantaneous power theory. Shunt part of UPQC removes all the current related harmonic problems in the system and series connected APF of UPQC system removes all voltage harmonics which comes up due to the use of nonlinear load. The overall THD is now improved in the system which is clearly observed from the waveforms. The value of THD is found to be near about 7.5 %.

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