IMPLEMENTATION AND MODELING OF ADAPTIVE FILTER IN UPQC

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Abstract

This paper presents design, modeling and simulation of Unified power quality conditioner system to improve the power quality. Unified power quality conditioner consists of combined series and shunt active power filters for simultaneous compensation of voltage and current. The Unified power quality conditioner system is modeled using the elements of Simulink and it is simulated using MATLAB. A new synchronous-reference- frame based control method and d-q-0 theory is used to improve the power quality at the point of common coupling on power distribution systems under unbalanced and distorted load conditions. The results are analyzed and presented using MATLAB Simulink software.

Keywords: Active Power Filter (APF), Phase Locked Loop (PLL), Power Quality (PQ), Synchronous Reference Frame (SRF), Unified Power-Quality Conditioner (UPQC).

I. INTRODUCTION

UNIFIED POWER - QUALITY CONDITIONER (UPQC) systems were widely studied by many researchers as an eventual method to improve the PQ in electrical distribution systems [3]. The term "power quality" (PQ) has gained significant attention in the past few years. The advancement in the semiconductor device technology has made it possible to realize most of the power electronics based devices/prototypes at commercial platform. As a rule of thumb in all areas of engineering, the proper utilization of the resources that we have in the most efficient way has lead to great development and is the major concern for most engineers in their respective fields. Reactive power compensation is one of the common yet very important issues for power system engineers at transmission as well as at distribution level. It is a well-known fact that a typical distribution network consist of distribution transformer, motor loads, etc., demands reactive power. This load-reactive power demand level is mainly affected by the type of loads present on the network. The capacitor banks have been used to compensate the load-reactive power demand. It is the Simplest and under certain conditions, is a very effective way to compensate the load-reactive power demand. This traditional way has certain major disadvantages, such as fixed compensation, possible Occurrence of resonance condition with nearby loads, switching transient, bulky size, aging effect, etc. [6].

II. UNIFIED POWER-QUALITY CONDITIONER (UPQC)

The UPQC consists of two voltage source inverters connected back to back with each other sharing a common dc link . One inverter is controlled as a variable voltage source in the series Active Power Filter (APF), and the other as a variable current source in the shunt APF.

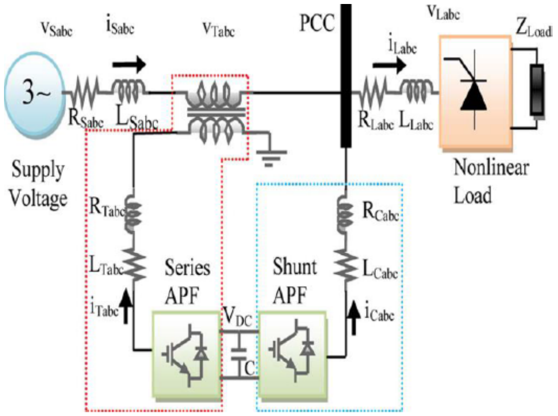


Fig. 1 Configuration of the UPQC

Fig.1 shows the basic configuration of the unified power quality Conditioner. The shunt converter Of the UPQC must be connected as close as possible to the non-linear load, instead of the network side. The UPQC approach is the most powerful compensator for a scenario as depicted in Fig 1, where the supply voltage Vs is itself already unbalanced & distorted & is applied critical load that require high power quality .On the other hand, part of the total load include nonlinear loads that inject a large amount of harmonic current into the network, which should be filtered [1]. In fig1, current i_L represents all nonlinear loads that should be compensated. The shunt active filter of the UPQC can compensate all undesirable current components, including harmonics, imbalances due to negative- and zero sequence components at fundamental frequency, and the load reactive power as well. The same kind of compensation can be performed by the series active filter for the supply voltage, hence, the simultaneous compensation performed by the UPQC guarantees that both the compensated voltage V_L at load terminal and compensated current is that is drawn from the power system become balanced, so that they contains no unbalance from negative- and zero sequence components at fundamental frequency. Moreover, they are sinusoidal and in phase, if the load reactive power is also compensated. Additionally, the shunt active filter has to provide dc link voltage regulation, absorbing or injecting energy from or into the power distribution system, to cover losses in converters, and correct eventual transient compensation errors that lead to undesirable transient power flows into the UPQC. It might be interesting to design UPQC controllers that allow different selections of the compensating functionalities [1].

III. THE UPQC CONTROL STRATEGY

1. Shunt Control Strategy:

The shunt active power filter is provided the current and the reactive power (if the system need) compensation. It acts as a controlled current generator that compensated the load current to force the source currents drained from the network to be sinusoidal, balanced and in phase with the positive-sequence system voltages. The conventional SRF method can be used to extract the harmonics contained in the supply voltages or currents. For current harmonic compensation, the distorted currents are first transferred into two-phase stationary coordinates using $\alpha-\beta$ transformation (same as in $p-q$ theory). After that, the stationary frame quantities are transferred into synchronous rotating frames using cosine and sine functions from the phase-locked loop (PLL). The sine and cosine functions help to maintain the synchronization with supply voltage and current. Similar to the $p-q$ theory, using filters, the harmonics and fundamental components are separated easily and transferred back to the $a-b-c$ frame as reference signals for the filter. The conventional SRF algorithm is also known as $d-q$ method, and it is based on $a-b-c$ to $d-q-0$ transformation (park transformation), which is proposed for active filter Compensation [3]. The instantaneous three-phase currents and voltages are transformed to $\alpha-\beta$ coordinates as shown in equation 1 to 6.

Iso= 13[isa + isb + isc] ..…....eq1
Isα= 23[isa -12 isb - 12isc] ……..eq2
Isβ= 12[isb - isc] …..... eq3
Vso= 13[vsa + vsb + vsc]…... eq4
Vsα= 23[vsa- 12 vsb - 12vsc]……..eq5
Vsβ= 12[vsb - vsc] ……..eq6

The source side instantaneous real and imaginary power components are calculated by using source currents and phase-neutral voltages as given in eq7 and eq8.

P= VsαIsα+VsβIsβ...............eq7
Q= - Vsβ Isα + Vsα Isβ………..eq8

The instantaneous real and imaginary powers include both oscillating and average components. Average components of p and q consist of positive sequence components of source current. The oscillating components of p and q include harmonic and negative sequence components of source currents [2]. In order to reduce neutral current, p is calculated by using average and oscillating components of imaginary power and oscillating component of the real power. These currents are transformed to three-phase system as shown in The reference currents are calculated in order to compensate neutral, harmonic and reactive currents in the load. These reference source current signals are then compared with sensed three-phase source currents, and the errors are processed by hysteresis band PWM controller to generate the required switching signals for the shunt APF.

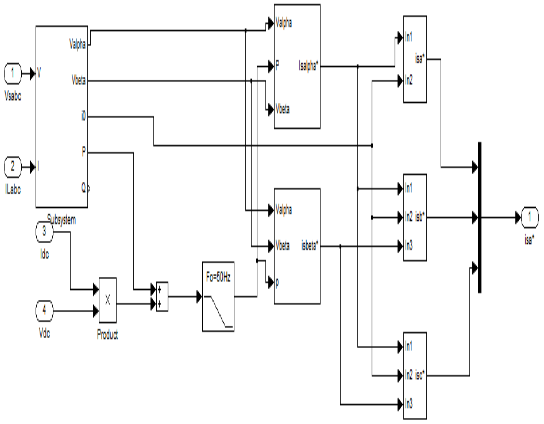


Fig. 2 P−Q theory Simulation

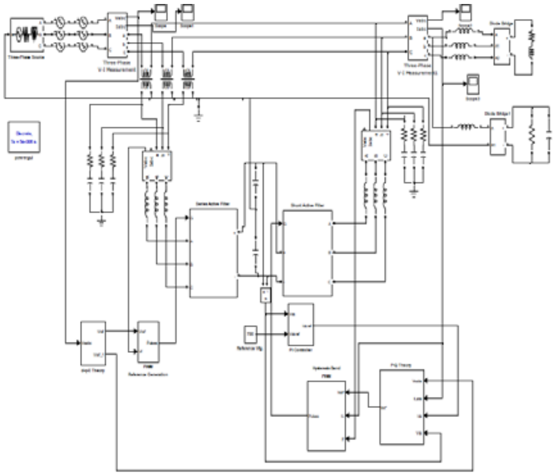


Fig. 3 Simulation Circuit of UPQC

II. Series Control Strategy:

The series active power filter is provided the voltage compensation. It generates the compensation voltage that synthesized by the PWM converter and inserted in series with the supply voltage, to force the voltage of PCC to become sinusoidal and balanced. supply voltages Vsabc are transformed to d-q-0 coordinates.

$Vd = 2/3[Va*\sin wt+Vb*\sin(wt-2\pi/3)+Vc*\sin(wt+2\pi/3)]$

$Vq=2/3[Va*\cos wt+Vb*\cos(wt2\pi/3)+Vc*\cos(wt+2\pi/3)]$ $V0= 1/3 (Va + Vb + Vc)$

The voltage in d axes consists of average and oscillating components of source voltages. The average voltage is calculated by using second order LPF (low pass filter).The load side reference voltages are calculated. The switching signals are assessed by Comparing reference voltages and the load voltages and via sinusoidal PWM controller. Then d-q-0 are transformed to Vsabc coordinates

$Va = [Vd*\sin(wt) + Vq*\cos(wt) + Vo]$

$Vb = [Vd*\sin(wt-2pi/3) + Vq*\cos(wt-2pi/3) + Vo)]$

$Vc = [Vd*\sin(wt+2pi/3) + Vq*\cos(wt+2pi/3) + Vo)]$

These produced three-phase load reference voltages are compared with load line voltages and errors are then processed by sinusoidal PWM controller to generate the required switching signals for series APF IGBT switches.

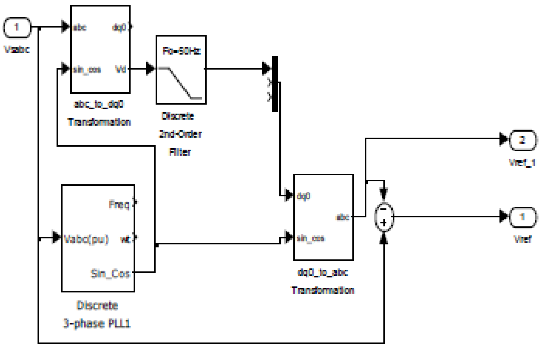


Fig. 4 D-Q-0 Theory Simulation

IV. SIMULATION RESULTS

The harmonics and unbalanced components are compensated in case of unbalanced and distorted current and voltage at the PCC. Simulation results show that the proposed control strategy compensates harmonic components as well as most of the other unbalanced load current distortions. It is shown that the UPQC can compensate the voltage and current problems simultaneously. In this study, the proposed SRF-based control algorithm for the UPQC is evaluated by Matlab/Simulink software under Unbalanced and distorted load-current and source-voltage conditions. The UPQC system parameters used in this study are given in Table I.

	Parameters		Values
Source	Voltage	V_{sabc}	400 Vrms
	Frequency	F	50 Hz
Load	Three phase AC line Inductance	L_{Labc}	5mH
	Single phase AC line Inductance	L_{La1}	5mH
	Three phase DC Inductance	L_{dc3}	10mH
	Three phase DC line Resistance	R_{dc3}	30Ω
	Single phase DC line Capacitance	C_{dc1}	0.24µF
	Single phase DC line Resistance	R_{dc1}	90Ω
DC link	Voltage	V_{DC}	700V
	Two series Capacitor	C_1 ,C_2	2200µF
Shunt Active Filter	AC line Inductance	L_{cabc}	3mH
	Filter Resistance	R_{cabc}	5Ω
	Filter Capacitonce	C_{cabc}	20µF
Series Active Filter	AC line Inductance	L_{tabc}	3mH
	Filter Resistance	R_{tabc}	5Ω
	Filter Capacitonce	C_{tabc}	10µF
	Two series Transformer	S	1 KVA

In the simulation studies, the results are specified before and after the operation of the UPQC system. In addition, when the UPQC system was operated, the load

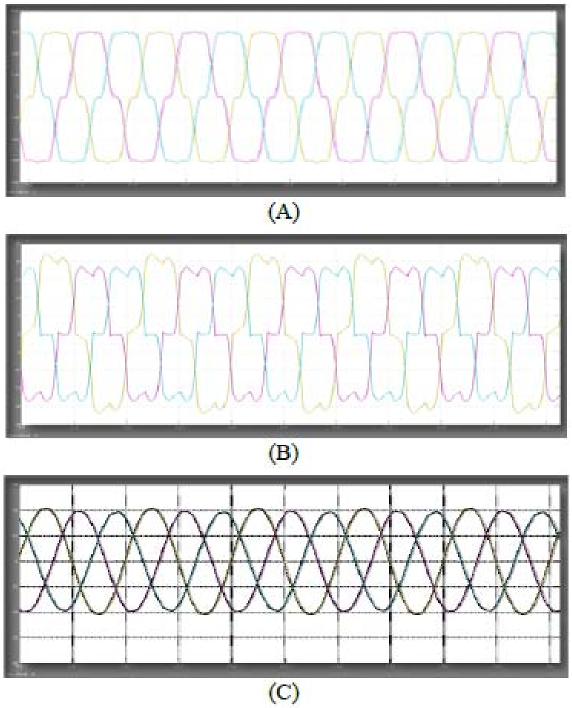


Fig. 5 Simulation Results for Operational Performance of the UPQC System

(a) Source voltage (Vabc),

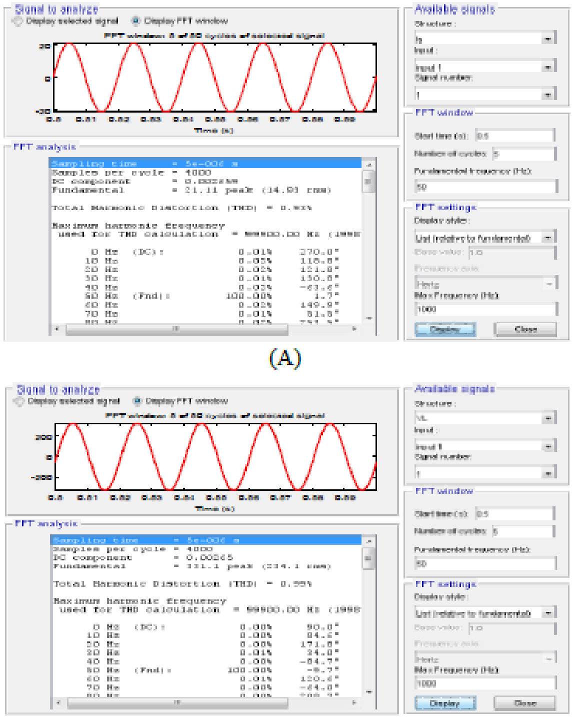
(b) Load current (ILabc),

(c) Source current (Iabc),

d) Load voltage (VLabc),

(e) DC link Voltage (V_{DC})

Before harmonic compensation, the THD of the supply current is 19.33%. The obtained results show that the proposed control technique allows the 4.8% mitigation of all harmonic components as shown in fig. Before compensation, the THD level of the load voltage in phase a was 13.72% and the source current was 19.33%; after compensation, the THD level of the load voltage is approximately 0.99% and the source current is approximately 0.93%.



Structure: Is
Input: Input 1
Signal number: 1
Start time (s): 0.5
Number of cycles: 5
Fundamental frequency (Hz): 50
Display style: List (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz
Max Frequency (Hz): 1000

```
Sampling time       = 5e-006 s
Samples per cycle   = 4000
DC component        = 0.002348
Fundamental         = 21.11 peak (14.93 rms)

Total Harmonic Distortion (THD) = 0.93%

Maximum harmonic frequency
 used for THD calculation  = 99900.00 Hz (1998

     0 Hz   (DC):              0.01%      270.0°
    10 Hz                      0.03%      118.8°
    20 Hz                      0.02%      121.0°
    30 Hz                      0.01%      130.8°
    40 Hz                      0.03%      -63.6°
    50 Hz   (Fnd):           100.00%        1.7°
    60 Hz                      0.02%      149.9°
    70 Hz                      0.01%       81.8°
```

(A)

Structure: VL
Input: Input 1
Signal number: 1
Start time (s): 0.5
Number of cycles: 5
Fundamental frequency (Hz): 50
Display style: List (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz
Max Frequency (Hz): 1000

```
Sampling time       = 5e-006 s
Samples per cycle   = 4000
DC component        = 0.00265
Fundamental         = 331.1 peak (234.1 rms)

Total Harmonic Distortion (THD) = 0.55%

Maximum harmonic frequency
 used for THD calculation  = 99900.00 Hz (1998

     0 Hz   (DC):              0.00%       90.0°
    10 Hz                      0.00%       84.6°
    20 Hz                      0.00%      171.8°
    30 Hz                      0.01%       24.0°
    40 Hz                      0.00%      -84.7°
    50 Hz   (Fnd):           100.00%       -8.7°
    60 Hz                      0.01%      120.6°
    70 Hz                      0.00%      -64.0°
```

(B)

Fig. 6 Simulation Results for FFT Analysis of the UPQC System (a) Source current (Iabc), (b) Load voltage (VLabc),

CONCLUSIONS

The UPQC system is successfully designed and modeled using the circuit elements of simulink. The simulation results show that, when unbalanced and nonlinear load current or unbalanced and distorted mains voltage conditions, the above control algorithms eliminate the impact of distortion and unbalance of load current on the power line, making the power factor unity. Meanwhile, the series APF isolates the loads voltages and source voltage, the shunt APF provides three-phase balanced and rated currents for the loads. The THD in the output is reduced by using UPQC. The scope of this work is the modeling and simulation of UPQC system. The hardware implementation is yet to be done. The simulation can be extended to multi bus system.

ACKNOWLEDGMENTS

I am a indebted forever to my guide Mr.Naveen kumar Mucha Asst. Professor Electrical engineering deportment, MSS,s collage of engineering and technology , Jalna for his continues encouragement, support, ideas, most constructive suggestions, valuable advice and confidence in me. He gave me complete freedom to pursue all my interest and also provided so many exciting direction to explore.

I sincerely thank to all my faculty members of MSS's collage of engineering and technology, Jalna for their continues support.

I sincerely thank Dr. C.M. Sedani, Principal, MSS'S College of Engineering and Technology, Jalna for their continuous encouragement and active interest in my progress that they gave throughout the work.

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