Identification of UPQC Signal with Optimized Fuzzy-PSO Algorithm

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Abstract

Unified power quality conditioners (UPQCs) can overcome current and voltage harmonics which affects the load when compensating the reactive power. This paper proposes a unified power quality conditioner (UPQC), which aims to combining shunt-active and series active filters. The main purpose of using UPQC is to reduction of voltage Imbalance, reactive power, negative-sequence current and harmonics. The Proposed system is simulated with series and shunt inverters which can eliminate the sag, swell and Unbalanced Voltage harmonics and reduction of reactive power losses. PI controller is used to stabilize DC link Voltage and balance the active power between the shunt and series inverters. The proposed technology is analyzed using MATLAB/SIMULINK software.

Index Terms—Unified power quality conditioner, Particle swarm optimization, Fuzzy control, Harmonic measurement

I.INTRODUCTION

Distortion of sinusoidal voltage and current waveforms caused by harmonics is one of the major power quality concerns in the electric power industry. Static power converters and other nonlinear loads are the culprits of these distortions. Considerable efforts have been made in recent years to improve the management of harmonic distortion in power systems. Nowadays, there are a wide range of power electronic applications in utility such as static var compensator (SVC), static synchronous series compensator (SSSC), static compensator (STATCOM), static generator (SG), unified power flow controller (UPFC), active filter (AF) and so on[1-4]. Considering the current researches makes it possible forecasting much more developments of power electronics utilization in the utility during the 21st century. The unified power quality conditioner (UPQC) is expected to be one of the most important systems to overcome the power quality problems of distribution systems [5-7]. Towards an excellent performance UPQC device, accurate and real-time signal detection is much important. Instantaneous reactive power theory based on vectortransformation is widely applied in active filter. A series of improvement detecting method is also followed [8-12]. Aiming at the flaw of many times coordinate alternation and precision of low pass filter, signal detection algorithm based on PSOFUZZY for reactive power and harmonic current is proposed in this paper[13-15]. The Particle Swarm Optimization technique (PSO), which refines its search by attracting the particles to positions with good solutions, has ever since turned out to be a competitor in the field of numerical optimization. The PSO can generate high-quality solutions within shorter computation time and have more stable convergence characteristic than other stochastic methods. In this article, Improved Particle Swarm Optimization is used to tune the parameters of fuzzy Controller.

II. OVERVIEW OF UPQC-S CONCEPT

At distribution level UPQC is the most attractive solution to compensating many power Quality problems. The term active power filter (APF) is a widely used in the area of electric power quality improvement. APF s have the ability to mitigate some of the major power quality problems effectively. The UPQC is one of the APF family members where shunt and series APF functionalities are integrated together to achieve superior control over several power quality problems simultaneously. The system configuration of a UPQC is shown in fig.1.

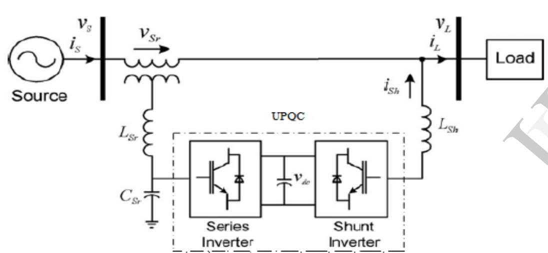


Fig. 1 System Configuration of a UPQC

The UPQC is a combination of series active filter and shunt active filter linked through a common DC link capacitor. Series active filter and shunt active filter compensate the power quality problems of the source voltages and load currents, respectively. In order to improve the power quality of the system, UPQC has to inject required amount of Volt Ampere (VA) into the distribution system. For cost effectiveness, the VA loading of the UPQC need to be minimized[3]. Mainly three significant control approaches for UPQC can be found to control the sag on the system: 1) active power control approach in which an in-phase voltage is injected through series inverter , popularly known as UPQC-P; 2) reactive power control approach in which a quadrature voltage is injected, known as UPQC-Q; and 3) a minimum VA loading approach in which a series voltage is injected at a certain angle, which is known as VAmin. The VA loading in UPQC-VAmin is determined on the basis of voltage sag, may not be at optimal value. The voltage sag/swell on the system is one of the most important power quality problems in distribution. In the paper [9], the authors have proposed a concept of power angle control (PAC) of UPQC. The PAC concept suggests that with proper control of series inverter voltage the series inverter successfully supports part of the load reactive power demand, and thus reduces the required VA rating of the shunt inverter. In this paper, the concept of PAC of UPQC is further extended for voltage swell and sag conditions. This modified approach is utilized to compensate voltage sag/swell while sharing the load reactive power between series and shunt inverters. Since the series inverter of UPQC in this case delivers both active and reactive powers, it is given the name UPQC-S (S for complex power). The series inverter of the UPQC-S is controlled using a Particle Swarm Optimization based fuzzy logic controller. Here PSO is used as an optimization technique to find the optimum value of reactive power with different constraints..

III. SIGNAL DETECTION

Principle of PSO-FUZZY signal detection algorithm is shown in Figure2.

A. Harmonic signal detection algorithm in parallel

According to the integral of standard sine voltage *ra u* multiplied by the sum of fundamental reactive current *q i* and harmonic current *h i* in a cycle is zero, that is,

$$\int_0^T u_a(i_q + i_h)dt = 0$$

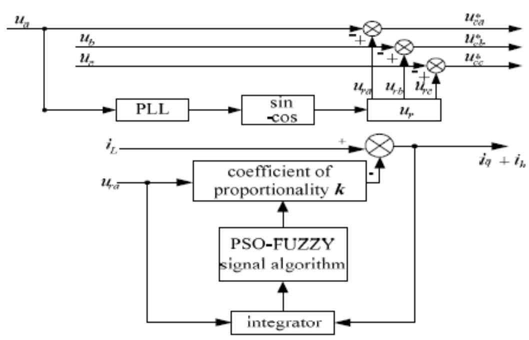


Figure 2. Principle of PSO-FUZZY signal algorithm

Load current *L i* contains fundamental reactive current *p i* , fundamental reactive current *q i* and harmonic current *h i* , that is,

$i_L - i_p = i_p - i_h$

Then

$$\int_0^T u_{ra}(i_q + i_h)dt = \int_0^T u_{ra}(i_L - i_p)dt$$
$$= \int_0^T u_{ra} i_L dt - \int_0^T u_{ra} i_p dt = 0$$

As a result of *p i* has the same frequency and the same phase with *a u* , enable *p a i* □□*ku* , *k* is proportionality factor, then

$$\int_0^T u_{ra} i_L dt - \int_0^T u_{ra} i_p dt$$
$$= \int_0^T u_{ra} i_L dt - k\int_0^T {u_{ra}}^2 i_p dt = 0$$

$$k = \int_0^T u_{ra} i_L dt \Big/ \int_0^T {u_{ra}}^2 i_p dt = 0$$

$$\int_0^T u_{ra}(i_q + i_h)dt = \int_0^T u_{ra} i_L dt - k\int_0^T {u_{ra}}^2 i_p dt = 0$$

Harmonic signal detection algorithm in parallel can derive from above, the principle is that: Calculate $\int_0^T u_{ra}(i_q + i_h)dt$ by integrator. When output of integrator is greater than zero, *k* is increased by PSO-FUZZY controller. When output of integrator is less than zero, *k* is decreased by PSO-FUZZY controller. The output of integrator tends to zero by repeated adjustments. The output of circuit at this time is $i_q + i_h$, that is, the sum of fundamental reactive current and harmonic currents. Figure 3 shows the principle of PSO-FUZZY controller

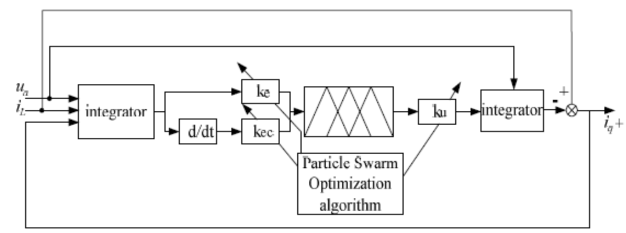


Figure 3. Principle of PSO-FUZZY controller

B. Voltage signal detection algorithm in series

Sinusoidal signal cosine signal which is as the same voltage with *a u* by the phase-locked loop (PLL) and A sine table. A further available with the base voltage signal, that is, the standard sinusoidal voltage.

$u_{ra} = 220\sqrt{2}\mathrm{Cos}(\omega t + \theta)$

And for the same reason, we can get *rb u* , *rc u* 。 According to the (7), voltage compensation of inverter in series is get

$$\begin{cases} u_{ca}^* = u_{ra} - u_a = V_N \mathrm{Cos}(\omega t + \theta) - u_a \\ u_{ab}^* = u_{rb} - u_b = V_N \mathrm{Cos}(\omega t + \theta) - u_b \\ u_{bc}^* = u_{rc} - u_c = V_N \mathrm{Cos}(\omega t + \theta) - u_c \end{cases}$$

IV. PARTICLE SWARM OPTIMIZATION-FUZZY CONTROLLER

A. Particle Swarm Algorithm

Particle Swarm Optimization algorithm, originally proposed by Kennedy and Eberhart, is an evolutionary computation technique inspired by social behavior of a flock of birds andinsect swarms [9][10]. In PSO, each particle is treated as apoint in a *d*-dimensional space, where the *i*th particle isrepresented as ***X****i*(*t*)=(*Xi1*(*t*), *Xi2*(*t*),…, *Xid*(*t*)), the best previousposition (the position giving the best fitness value) of the *i*thparticle is recorded and represented as ***P****i*(*t*)=(*Pi1*(*t*), *Pi2*(*t*),…, *Pid*(*t*)), the index of the best particle among all the particles in the population is represented as ***P****g*(*t*)=(*Pg1*(*t*), *Pg2*(*t*),…, *Pgd*(*t*)), the velocity of the position change for *i*th particle isrepresented as ***V****i*(*t*)=(*Vi1*(*t*), *Vi2*(*t*),…, *Vid*(*t*)). The particles are manipulated according to the following equation

$$V_{id}(t+1) = \omega V_{id}(t) + C_1 r_1 \left(\left(P_{id}(t) - X_{ik}(t) \right) \right) + C_1 r_1 \left(\left(P_{id}(t) - X_{ik}(t) \right) \right)$$

$$X_{id}(t+1) = X_{id}(t) + V_{id}(t+1)$$

$$\omega = \omega_{max} - k * k * \frac{\omega_{max} - \omega_{min}}{k_{max}}$$

Where, *c*1 and *c*2 are the cognitive and the social velocity, respectively; *r*1 and *r*2 are two random functions in the range [0, 1]; according to equation (11), *ω* which introduced as inertia factor can dynamically adjust the velocity over time; kmax is the total cycle index, k is the cycle index of current computation. Equation (9) is used to calculate the particle's new velocity according to its previous velocity and the distances of its current position from its individual extreme value *p*Best and global extreme value *g*Best. Then the particle flies toward a new position according to equation (10). The performance of each particle is measured according to a pre-defined fitness function, which is related to the problem to be solved.

B. Particle Swarm Optimization-Fuzzy Controller

In the process of UPQC operation, PSO renews 3parameters of fuzzy controller in time as follows:

1) Firstly, divides entire solution space into some area, and assign a random initial value to speed and location of everyarea, T. The individual extreme value *p*Best is initial location value now. The global extreme value *g*Best isindividual extreme value which makes error minimal in somearea. The area number at the same time, owing individualextreme value is recorded down.

2) Velocity ***V****i(t+1)* of particle i is calculated by (9).

3) Positioning vector *Xi(t+1)* of particle *i* is updated by(10).

4) If fitness function is better than before, the positioning vector *p*Best is set to *g*Best.

5) By the same token, if the iteration reaches to the pre-determined one, then stop. Particle position is the optimum value of e k , ec k and u k in Fuzzy controllerOtherwise, go to step 2).

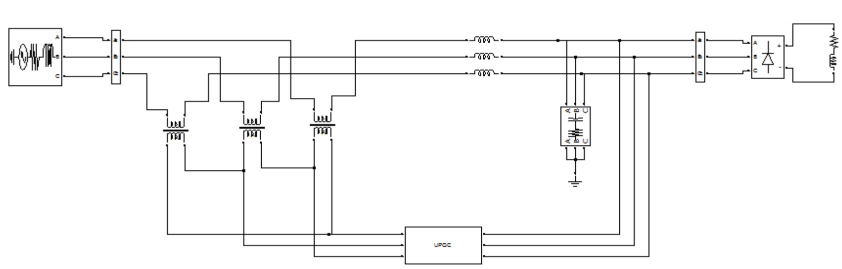


Fig: 4 Simulation Model

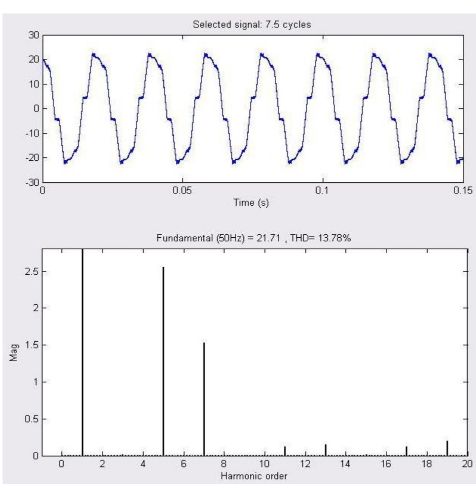
V. SIMULATION RESULT

Under the same parameters and conditions of system, MATLAB simulation analysis on proposed PSO-FUZZYsignal detection algorithm contrast to which on based on thetheory of instantaneous reactive ip-iq method. Systemsimulation model is shown in Figure 4. System parameters is shown in Table 1.

TABLE I. PARAMETERS OF UPQC

Circuit Parameters	Value
DC bus capacitor C_{dc}	2200 uF
Line inductance	0.4 mH
Line resistance	0.5Ω
Switching ripple inductor in series	5 mH
Switching ripple capacitor in series	10 uF
Leakage inductance equivalent resistance in series	1Ω
Switching ripple inductor in parallel	3 mH
Switching ripple capacitor in parallel	30 uF
Leakage inductance equivalent resistance in parallel	1Ω

PSO algorithm is realized by S-function program, the parameter settings are as follows: a total of 50 stocks, each particle dimension are 3, c1 = c2 = 2, ωmax = 0.95, ωmin = 0.1. Simulation waveforms and spectrum of system with Nonlinear load without compensation are shown in figure 5 (a)、 (b).



(a) supply current of A phase (A) and spectrum (THD=13.78%)

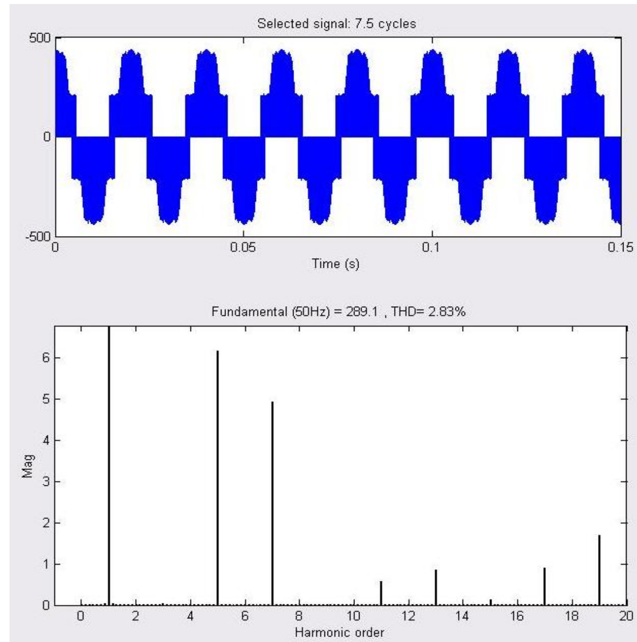
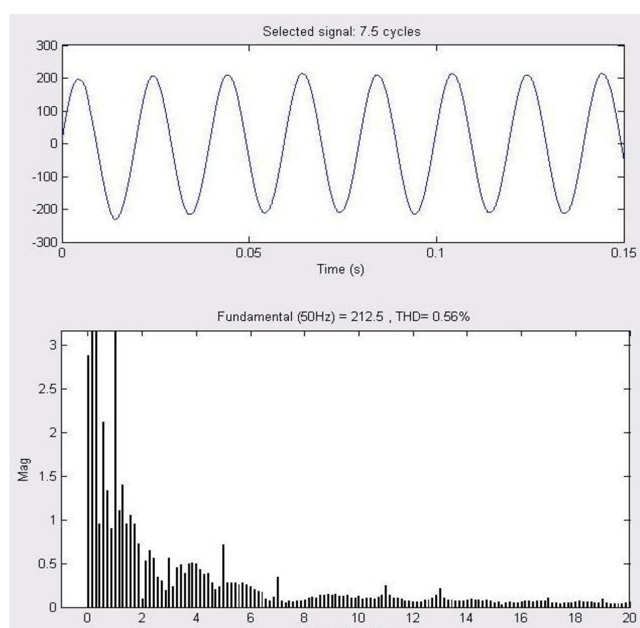


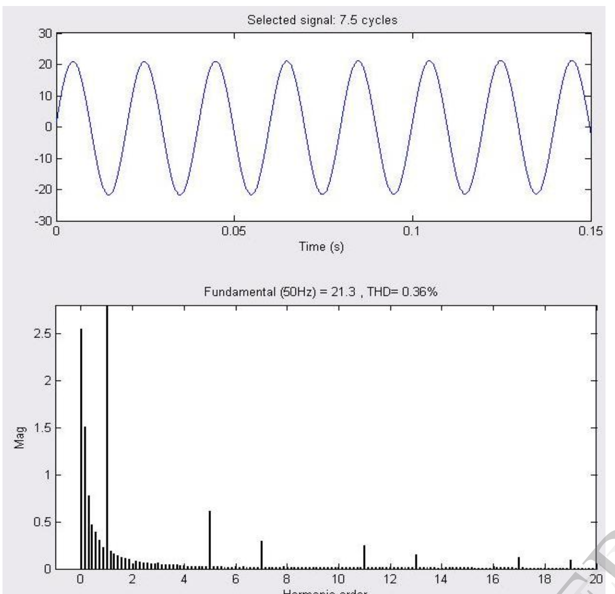
Figure 5. Simulation waveforms without compensation

Simulation waveforms and spectrum of system with ip-iq method are shown in figure 6 (a)、(b).

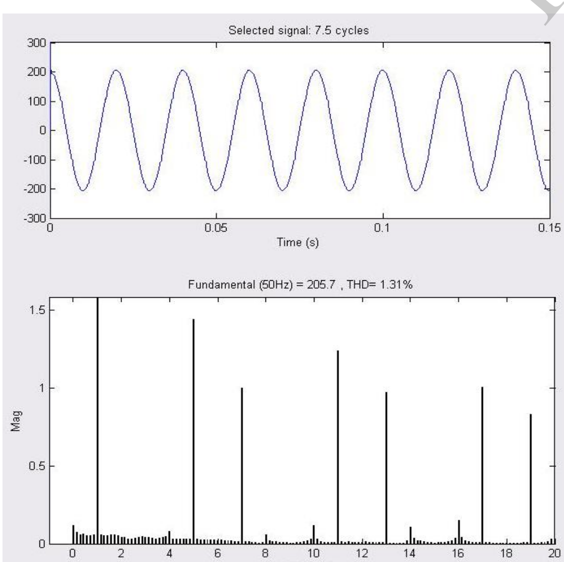


(b) load voltage (V) and spectrum (THD=0.56)

Figure 6. Simulation waveforms with ip-iq compensation Simulation waveforms and spectrum of system with PSOFUZZY signal detection method without voltage sag are shown in figure 7 (a)、(b).



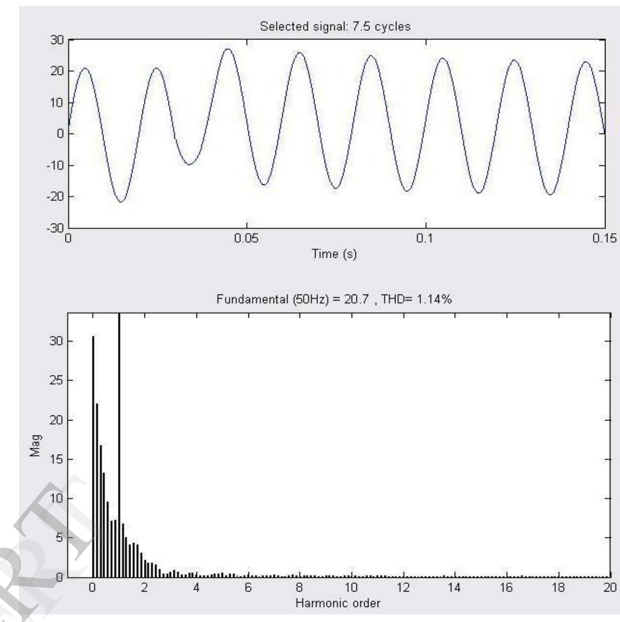
(a) supply current of A phase (A) and spectrum (THD=0.36%)



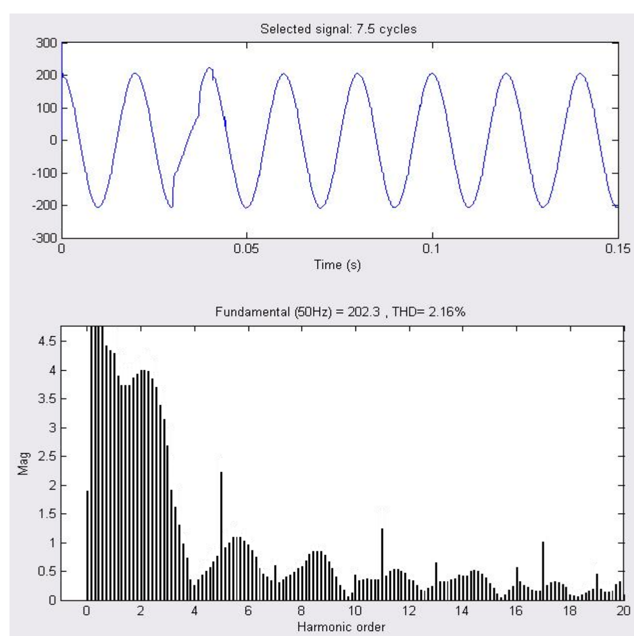
(b) load voltage (V) and spectrum (THD=1.31)

Figure 7. Simulation waveforms with PSO-FUZZY compensation

Simulation waveforms and spectrum of system with PSOFUZZY signal detection method with voltage sag at 0.3s~0.35s are shown in figure 8 (a)、(b).



(a) supply current of A phase (A) and spectrum (THD=1.14%)



(b) Load voltage (V) and spectrum (THD=2.16)

Figure 8. Simulation waveforms with PSO-FUZZY compensation with voltage sag

CONCLUSION

The proposed PSO-Fuzzy identification algorithm verified and proved that can reduce the harmonics in UPQC caused by non linear load and also adjust load power from fluctuation through loads. It's generally purifies adopted vector variations and low pass filter signal. The calculations are comprised very shortly with optimized results. Reactive power compensation is improved as compared with traditional and proposed technology. PSO-FUZZY algorithm is very efficient method which will increases performance of UPQC Device and reduce power losses , harmonic eliminations.

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