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# Particle Swarm Optimization and Genetic Algorithm based Power Quality Improvement

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## 1. INTRODUCTION

The term 'power quality' [1-2] refers to the purity of the voltage and current wave-form, and a power quality disturbance is a deviation from the pure sinusoidal form. Harmonics superimposed on the fundamental are one cause of such deviations. Power quality problems [1-2] like voltage harmonics, voltage flickers, voltage sags and voltage swells, current harmonics, current unbalance, reactive current etc. are studied.Conventionally passive L-C filters [3] were used to reduce harmonics and capacitors were employed to improve the power factor of the AC loads. However, the demerits of passive filters are fixed compensation, large size and resonance. The increased severity of harmonic pollution in the power networks has attracted the attention of power electronics to develop the dynamic and adjustable solutions to the power quality problems, generally known as active filters [3]. Classification of active power filters [3-4] based on converter type, topology, and the number of phases are presented.Active power filters use power electronic switches such as Thyristors, MOSFET'S, IGBT'S etc. They use 3-phase inverters for generating compensating signals which are controlled by gate pulses generated by pulse width modulated controller[5].Unified Power Quality Conditioner [6, 9] which is a combination of series active power filter and shunt active power filter ,is used to mitigate voltage and current harmonics. The compensating principle of UPQC and its steady state analysis [1] is studied. The control techniques PI,PSO and GA are studied and applied in this work and compared with performance of FUZZY and ANN controllers [1, 7, 8and 9]... The theory about optimization techniques is studied and their applications to UPQC [11,12] is also studied.

## HARMONICS:

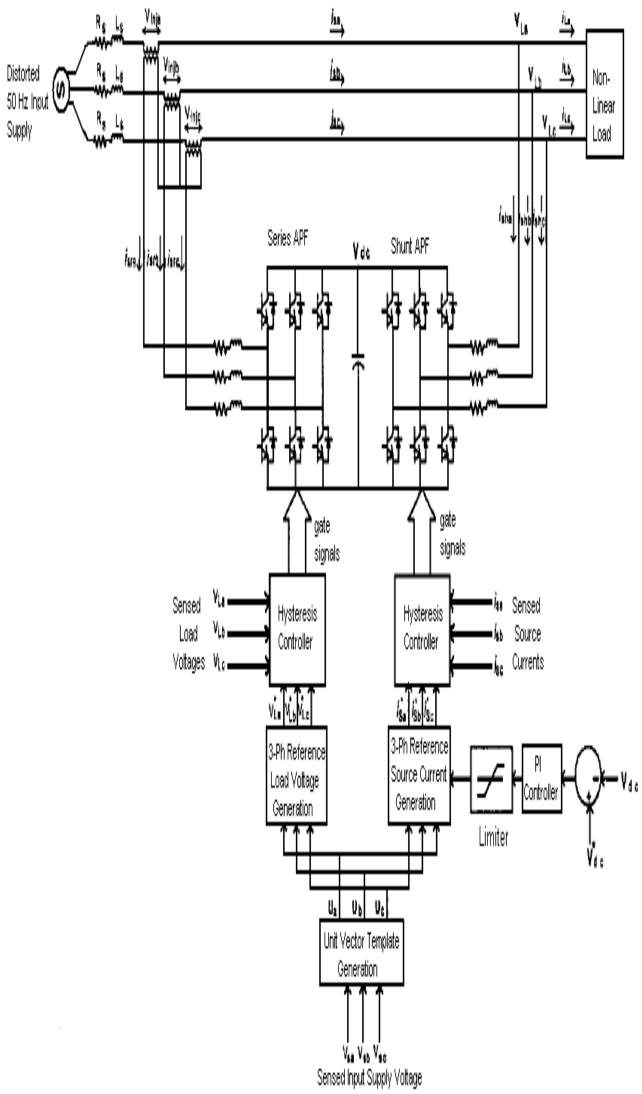
Distortions in the voltage or current wave causes harmonics due to electronic devices power system harmonics are integral multiples of fundamental power system frequency. These harmonics are created by nonlinear devices connected to power system. Frequency deviation is +0.1 or -0.1Hz under normal sometimes +0.2 or -0.2Hz.

## 2. TOTAL HARMONIC DISTORTION (THD)

It is measure of closeness in shape between a waveform and fundamental component and is given by the ratio of sum of squares of RMS values of all harmonic components to the RMS value of fundamental component.
Total Harmonic Distortion(THD)=IH/IF
Where IH=sqrt(I22+I32+____+In2)
In is RMS value of nth harmonic
IF is RMS value of fundamental component

## 3. UPQC CONTROLLER

Fig 1: General power circuit configuration of UPQC.



This system consists of a PAF and a SAF. The control circuit of UPQC generates the reference compensating currents and Voltages of PAF and SAF in instantaneous and simultaneous manner, respectively.

## 4.OPTIMIZATION TECHNIQUES

## a.GENETIC ALGORITHM

### Step 1:Encoding

Here we have 26 values that are to be

encoded. So a binary string is used.

To convert any integers to a binary string, go on dividing the integer by 2 (like LCM), if it leaves a remainder, then it is encoded as 1 otherwise 0.

Xi = xiL+[ {(xiU- xiL) / (2n-1)}*( decoded value of string)]

**Table 1: Values for selection operation**

| Pop | $X_1$ | $X_2$ | $X_3$ | $p_i$ | A | B | C | D | E |
|---|---|---|---|---|---|---|---|---|---|
| **1** | .5 | .5 | .25 | .0 | .832 | .032 | .056 | 1 | 1 |
| **2** | .59 | .58 | .37 | .0 | .91 | .067 | .124 | 4 | 2 |
| **3** | .68 | .66 | .49 | .0 | .962 | .104 | .789 | 2 | 1 |
| **4** | .79 | .74 | .61 | .0 | 1.04 | .144 | .396 | 1 | 1 |
| **5** | .88 | .82 | .73 | .0 | .962 | .181 | .475 | 1 | 3 |
| **6** | .98 | .9 | .85 | .0 | .988 | .219 | .555 | 1 | 1 |
| **7** | 1.07 | .98 | .97 | .0 | 1.04 | .259 | .129 | 4 | 2 |
| **8** | 1.17 | 1.06 | 1.0 | .0 | 1.066 | .3 | .365 | 1 | 1 |
| **9** | 1.26 | 1.14 | 1.2 | .0 | 1.118 | .343 | .289 | 8 | 3 |
| **10** | 1.36 | 1.22 | 1.3 | .0 | 1.04 | .383 | .891 | 2 | 2 |
| **11** | 1.46 | 1.3 | 1.4 | .0 | 1.04 | .423 | .467 | 1 | 3 |
| **12** | 1.56 | 1.38 | 1.5 | .0 | 1.066 | .464 | .587 | 1 | 1 |
| **13** | 1.65 | 1.46 | 1.6 | .0 | 1.118 | .507 | .645 | 1 | 1 |
| **14** | 1.74 | 1.54 | 1.8 | .0 | 1.17 | .552 | .729 | 1 | 9 |
| **15** | 1.84 | 1.62 | 1.9 | .0 | 1.118 | .595 | .144 | 4 | 2 |
| **16** | 1.94 | 1.7 | 2.0 | .0 | 1.066 | .636 | .169 | 5 | 1 |
| **17** | 2.03 | 1.78 | 2.1 | .0 | 1.04 | .676 | .196 | 6 | 1 |
| **18** | 2.13 | 1.86 | 2.2 | .0 | .988 | .714 | .225 | 7 | 2 |
| **19** | 2.22 | 1.94 | 2.4 | .0 | .988 | .752 | .256 | 7 | 2 |
| **20** | 2.32 | 2.02 | 2.5 | .0 | 1.04 | .792 | .289 | 8 | 3 |
| **21** | 2.42 | 2.1 | 2.6 | .0 | 1.066 | .833 | .985 | 2 | 1 |
| **22** | 2.51 | 2.18 | 2.7 | .0 | 1.066 | .874 | .867 | 2 | 1 |
| **23** | 2.61 | 2.26 | 2.8 | .0 | 1.118 | .917 | .478 | 1 | 3 |
| **24** | 2.70 | 2.34 | 3.0 | .0 | 1.066 | .958 | .999 | 2 | 1 |
| **25** | 2.8 | 2.42 | 3.1 | .0 | 1.04 | .998 | .298 | 8 | 3 |
| | | | | | | | | | |
| **26** | 2.9 | 2.5 | 3 | | 1.0 | 1.0 | .87 | 2 | 2 |

### Step2: Reproduction

The selection operator used here is Roulette-wheel selection in which a string is selected from the mating pool with a probability proportional to the fitness. Thus, $i^{th}$string in the population is selected with a probability proportional to $F_i$, where $F_i$ is the fitness value for $i^{th}$ string. The probability of the ith selected string is

$$P_i = \frac{F_i}{\sum_{j=1}^{n} F_j}$$

Where n is the population size, n= 26
Where $p_i$ = Probability in the ith iteration
A = Expected Count
B = Cumulative Probability
C = Random number between 0-1
D = String Number
E = the count in the mating pool
A = n * $p_i$$B_i$ = $\mathbf{p_i + p_{i-1}}$

## b.DEVELOPMENT OF OBJECTIVE FUNCTION:

Objective function is developed using curve fitting tool i.e., ***'sftool' in MATLAB.***to which input values(Kp,Ki) and output (error) should be given in the form of arrays.

**Step3: cross over:**

Thirdly, the position values are swapped between twostrings following the cross-site which is the midpointof selected strings.

## 5. PARTICLE SWARM OPTIMIZATION

In computer science, **particle swarm optimization** (**PSO**) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO optimizes a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position and is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions.

A Program is written naming ***fitness*** taking the overall objective function. This ***fitness*** is linked to another program named ***PSO.*** This PSO program consists of population size (26) and number of iterations (50); the numbers of iterations are taken as 50 because the more the no: of iterations, the more is the chance of getting the best solution. This PSO is executed and after running the given no: of iterations the result is shown in the command window.

The current position corresponds to the values of kp and ki and fitness function corresponds to the error in DC link .

## 6. SIMULINK MODELLING OF UPQC

## 6.1. INTRODUCTION

The SimPower Systems Matlab/Simulink based simulation model of proposed load without UPQC is shown in Fig 6.1. The SimPower Systems Matlab/Simulink based simulation model of proposed UPQC is shown in Fig 6.2& Fig 6.3. The load is realized by using a diode bridge rectifier followed by an R load and RL load. The distortion in the supply voltage is introduced by connecting a 3rd (10% of the fundamental input) and 5th (1% of fundamental input) harmonic voltage sources in series with the utility voltage. Both the series and shunt APF's are realized by six Thyristor switches each, sharing a common dc link and controlled with PSO based PI, GA based PI and are shown in figures.

The ratings of source, load and DC capacitor are given below.

**Table 2: Ratings**

| | |
|---|---|
| Source<br>Source:3-ф, 440v, 50Hz, with harmonic content | |
| | |
| Load | 150Ω,12mH |
| DC link capacitance | 1µF |
| Line inductance | 1mh |
| Sample time | 0.16sec |

## 7. GA BASED UPQC MODEL:

The parameters of PI controller are obtained by running GA such that the DC link voltage is maintained constant.

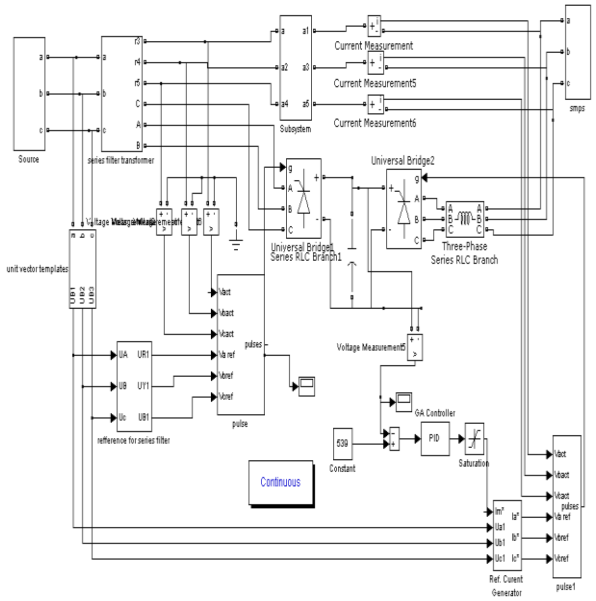



**Fig 2:SIMULINK model of UPQC with GA based PI control**

## 8. PSO BASED UPQC MODEL

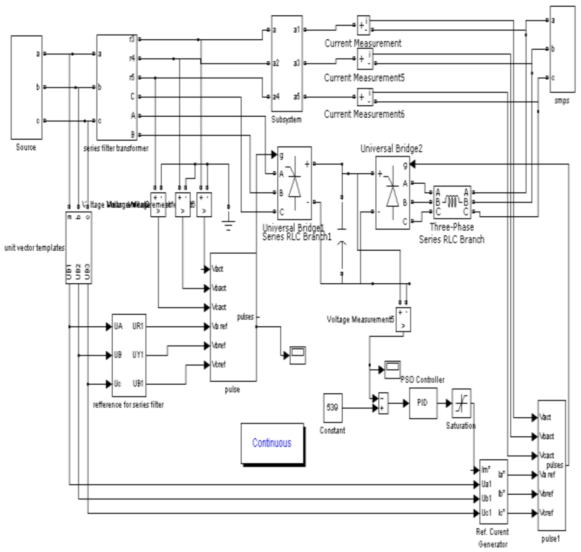
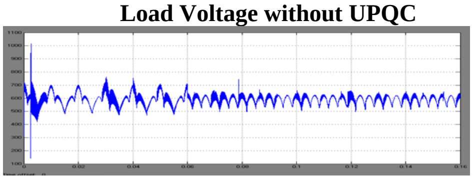



**Fig 3:SIMULINK model of UPQC with PSO based PI control**

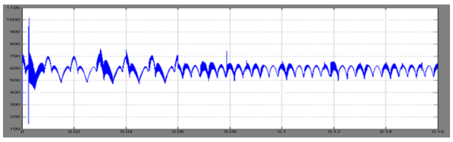
## 9. SIMULATION RESULTS

**Graph 1:LOAD VOLTAGE**

**Load Voltage without UPQC**

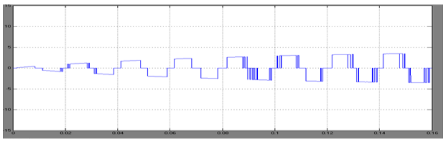


**Load Voltage of UPQC with PSO based PI**

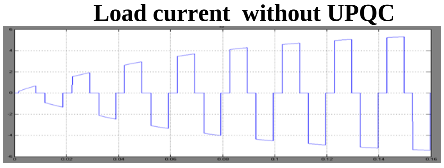


**Load Voltage of UPQC with GA based PI**

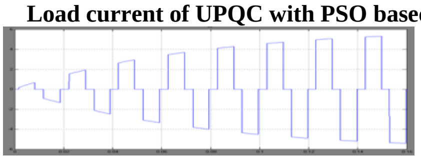
**Graph 2:LOAD CURRENT**



**Load current without UPQC**

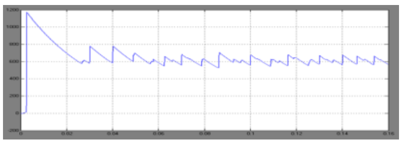


**Load current of UPQC with PSO based PI**

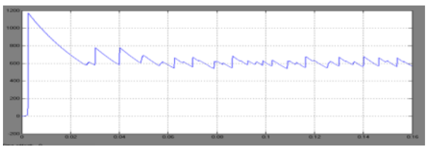


**Load current of UPQC with GA based PI**

**Graph 3:DC LINK VOLTAGE**



**DC link voltage of UPQC with PSO based PI**



**DC link voltage of UPQC with GA based PI**

**Table 3: Comparison of total harmonic distortion (FUZZY,ANN results are taken from ref. paper 13)**

| THD | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ORDER/ of THD | W/o UPQC (VS) | W/o UPQC (IS) | WITHUPQCPSOP | WITH UPQC PSO PI (IS) | WITH UPQC GA PI (VS) | WITH UPQC GA PI (IS) | WITH UPQC FUZZY (V | WITH UPQC FUZZY (IS | WITH UPQC ANN (VS) | WITH UPQC ANN (IS) |
| 3rd & 5th | 10.28 | 45.01 | 9.98 | 14.65 | 9.98 | 14.65 | 10.02 | 15.37 | 10.0 | 15.35 |

**Table 4: Results for THD for different loads for 3rd&5th harmonics**

| HARMONIC ORDER/THD | WITHOUT UPQC (Vs) | WITHOUT UPQC(Is) | WITH UPQC PSO PI(Vs) | WITH UPQC PSO PI (Is) | WITH UPQC GA PI(Vs) | WITH UPQC GA PI (Is) |
|---|---|---|---|---|---|---|
| 150 Ω,12mH | 10.28 | 45.01 | 9.98 | 14.65 | 9.98 | 14.65 |
| 100 Ω,10mH | 10.28 | 45.82 | 9.98 | 16.81 | 9.98 | 16.81 |
| 80 Ω,8mH | 10.29 | 46.21 | 9.99 | 19.76 | 9.99 | 19.76 |

## 10. CONCLUSIONS

D-STATCOM and UPQC can enhance power quality in the distribution system. Based on the power quality problem at the load or at the distribution system, there is a choice to choose particular custom power device with specific compensation. Unified Power Quality Conditioner (UPQC) is the combination of series and shunt APF, which compensates supply voltage and load current imperfections in the distribution system.

A simple control technique based on unit vector templates generation is proposed for UPQC. Proposed model has been simulated in MATLAB. The simulation results show that the input voltage harmonics and current harmonics caused by non-linear load can be compensated effectively by the proposed control strategy. A suitable mathematical model of the UPQC has been developed with different controllers (PSO based PI, GA based PI) to maintain DC link voltage constant.

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