

OPTIMIZATION OF PARAMETERS OF THE UNIFIED POWER QUALITY CONDITIONER USING GENETIC ALGORITHM METHOD

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Abstract. This paper presents a novel technique of optimization of parameters of the UPQC using Genetic Algorithm (GA) method that takes curves of bode as a basis. The choice of the parameters of the shunt active filter is determined by the ratio of its generated current to the harmonic current, while the choice of the parameters of the series active filter is determined by the ratio of its generated voltage to the harmonic voltage. The total impedance of the whole system without load shows that a phenomenon of resonance could appear. To overcome the problem of resonance and widen the pass band, the Genetic Algorithm method was used. Simulation results are presented to validate the proposed method.

Keywords: UPQC, Shunt Active Filter, Series Active Filter, Harmonic, THD, GA.

1. Introduction

The electric power industry in the 21st century will see dramatic changes in both its control and communication infrastructure. These changes are the result of mainly three factors: 1) the push toward a deregulated industry, 2) the development of more efficient and/or less polluting energy resources that are cost competitive with traditional power generation sources, and 3) the continued electrification and integration of information technology into most facets of our everyday lives has resulted in a need for a better reliability and improved power quality than the existing power grid can supply. In this context and with the progress of electronics component technology some efficient solutions as the unified power quality conditioner (UPQC) [1] are used. It consists of combined series and shunt active filters [2-8] for simultaneous compensation of voltage and current.

The UPQC can compensate not only harmonic currents and unbalances of a non-linear load, but also voltage harmonics and unbalances of the power supply, which improves the power quality offered for other harmonic sensitive loads. There are also different custom power devices such as dynamic voltage restorer (DVR), which improves the quality of power supply, distribution static compensator (DSTATCOM), which compensates current unbalance and harmonics of non-linear loads, and combined SVC with DSTATCOM, which generates reactive power and compensates load current simultaneously.

The main objective of this work is the improvement of the performances of UPQC with respect to the variation of the frequency. In order to achieve this goal, we present in this paper, a new method based on GA which allows the determination of the optimized parameters and consequently an optimal operating point of the system, a wide pass band with a unity gain of both the ratio of the compensating voltage to the voltage generated by the series PWM converter and the ratio of the compensating current to the current generated by the shunt PWM converter, and a no load normal total impedance, in other words without resonance. The results given by the GA method is compared with the results given by the classical method, which uses iterative calculations under certain conditions to find the optimal parameters that satisfy all constraints. The GA method seems to be more efficient and gives better results. Therefore, the following presented results are interesting and confirm the efficiency of the proposed new method.

2. Parameters of the power circuit

The equivalent circuit of UPQC that has been considered in this study is presented in Figure 1. In this figure the primary side is the network side and the secondary side is the PWM converter side.

The parameters involved in this analysis are:

- Turn ratio of series and shunt transformers of the UPQC;

- Commutation reactors L_f and L_s ;
- High-pass filters C_f and R_f for the shunt active filter, C_s and R_s for the series active filter.

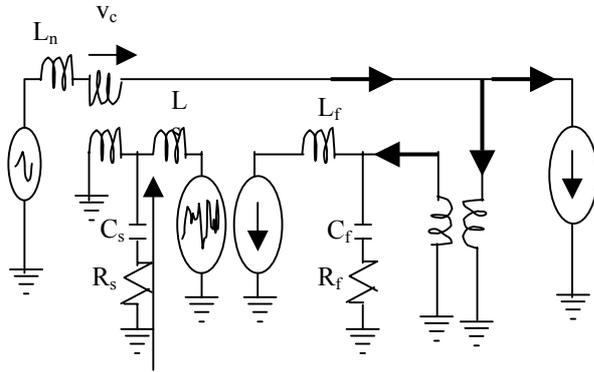


Figure 1. UPQC principle in single device

The turn ratio of the transformers is fixed and is 1:2 for series single-phase transformer and 2:1 for the shunt three-phase transformer. The series PWM converter is modeled as voltage source, while the shunt PWM converter as current source. Harmonic generating load is modeled as generic current source.

The equivalent network inductance L_n is 0.8 mH. According to Figure 1, the high-pass filter impedance of the shunt PWM converter referred to the primary is

$$Z_{1f} = \left(\frac{2}{1}\right)^2 \left(R_f + \frac{1}{j\omega C_f}\right). \quad (1)$$

Z_{1f} in series with the network reactor impedance referred to the secondary of the series single-phase transformer is given by

$$Z_{2ns} = \left(\frac{2}{1}\right)^2 (Z_{1f} + j\omega L_n). \quad (2)$$

Z_{2ns} parallel with the high-pass filter impedance of the series PWM converter is given by

$$Z_{11s} = \frac{Z_{2ns} \left(R_s + \frac{1}{j\omega C_s}\right)}{Z_{2ns} + \left(R_s + \frac{1}{j\omega C_s}\right)}. \quad (3)$$

The ratio of V_1 to V_2 is

$$\frac{V_1}{V_2} = \frac{Z_{11s}}{Z_{11s} + j\omega L_s}. \quad (4)$$

The impedance of the series PWM converter referred to the primary is

$$Z_{1s} = \left(\frac{1}{2}\right)^2 \frac{j\omega L_s \left(R_s + \frac{1}{j\omega C_s}\right)}{j\omega L_s + \left(R_s + \frac{1}{j\omega C_s}\right)}. \quad (5)$$

Z_{1s} in series with the network impedance referred to the secondary of the shunt three-phase transformer

$$Z_{2nf} = \left(\frac{1}{2}\right)^2 (Z_{1s} + j\omega L_n). \quad (6)$$

The ratio of I_1 to I_2 is

$$\frac{I_1}{I_2} = \frac{\left(R_f + \frac{1}{j\omega C_f}\right)}{Z_{2nf} + \left(R_f + \frac{1}{j\omega C_f}\right)}. \quad (7)$$

The total impedance Z_r connected to the power supply, when there is no load is

$$Z_r = j\omega L_n + Z_{1s} + Z_{1f}. \quad (8)$$

3. Optimization by genetic algorithm

The basic principles of Genetic Algorithm (GA) were first proposed by Holland [9]. It is inspired by the mechanism of natural selection where stronger individuals would likely be the winners in a competing environment. In this approach, the variables are represented as genes on a chromosome. GAs feature a group of candidate solutions (population) on the response surface. Through natural selection and the genetic operators, mutation and recombination, chromosomes with better fitness are found. Natural selection guarantees the recombination operator, the GA combines genes from two parent chromosomes to form two chromosomes (children) that have a high probability of having better fitness than their parents. Mutation allows new areas of the response surface to be explored. GAs offer a generational improvement in the fitness of the chromosomes and after many generations will create chromosomes containing the optimized variable settings. The main operations of the genetic algorithm are [10]: the selection, the crossover and the mutation.

Table 1 displays GA parameters.

Table 1. GA parameters

Parameter	Value
Population size	10
Selection	Roulette
Mutation rate	0.001
Crossover rate	0.6
Generation number	50
Tolerance	10^{-6}

4. Simulation and discussion

Table 2 displays five cases of the parameters for the power circuit of UPQC. The first four cases are obtained using the classical iterative method. The last

case (case 5) is obtained using genetic algorithm method (GA).

Table 2. Parameters for the power circuit of UPQC

Cases	1	2	3	4	5
Rf(Ω)	1	3	3	2.5	10
Lf(mH)	2	0.5	0.5	0.5	0.5
Cf(μF)	140	60	60	30	70
Rs(Ω)	30	10	3	5	15
Ls(mH)	2	0.5	0.2	0.5	0.4
Cs(μF)	10	60	60	6	100

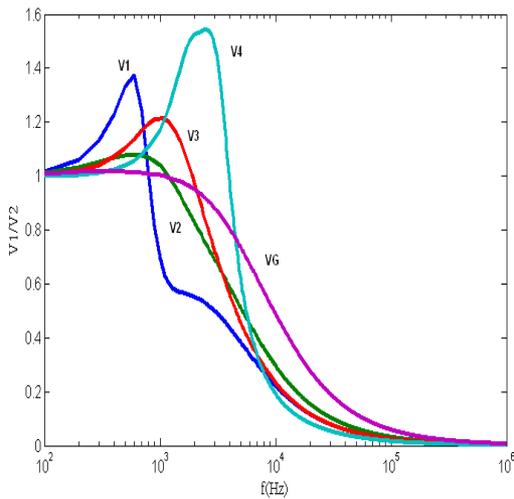


Figure 2. $\|V_1/V_2\|$ versus frequency

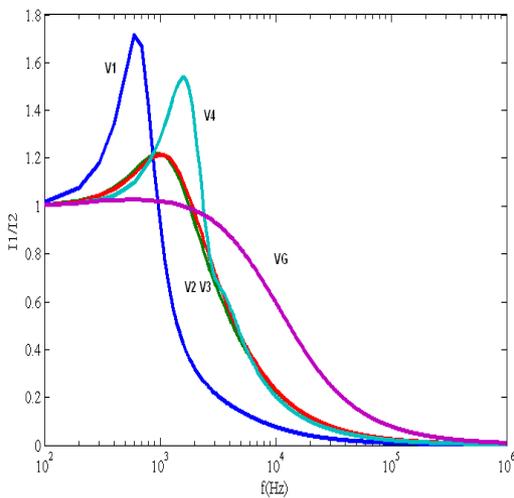


Figure 3. $\|I_1/I_2\|$ versus frequency

Figure 2 presents the amplitude ratio of the compensating voltage of the series active filter to the voltage generated by the series PWM converter as a function of frequency. The curves V_2 and V_3 corresponding to cases 2 and 3, show a better approximation to unity gain up to 1 kHz then decrease rapidly up to 10 kHz and extenuate approximately to zero at 100 kHz, therefore, they present a better configuration than curves V_1 and V_4 . The case 5 whose data are optimized by the genetic algorithm and represented by the

curve V_6 shows almost a unity gain for a wide passing band that exceeds 1 kHz then decreases rapidly from 10 kHz to 100 kHz. So, the case 5 represents the best possible configuration of the system. The amplitude ratio of the compensating current of the shunt active filter to the current generated by the shunt PWM converter as a function of frequency given by Figure 3 behaves in the same manner as the amplitude ratio of voltages described above. The V_6 curve that interprets the configuration given by optimization based on the genetic algorithm shows the best possible configuration of the system.

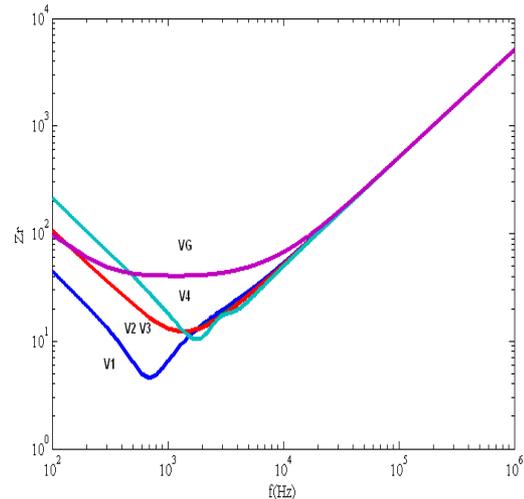


Figure 4. The total impedance $\|Z_r\|$ versus frequency

The total impedance Z_r connected to the power supply, when there is no load as a function of frequency is showed in Figure 4. It shows at what range of frequency the system presents low impedance, where resonance can appear. At this range of frequency the series active filter should be able to generate compensating voltage against the harmonic currents, enhancing the overall system stability. Once more, the curves V_2 and V_3 corresponding to cases 2 and 3, present a better configuration than curves V_1 and V_4 . But as expected, the V_6 curve that represents case 5 which its parameters are optimized using the genetic algorithm shows the best possible configuration of the system.

5. Conclusions

The Unified Power Quality Conditioner (UPQC) is a device expected to solve almost all power problems. It takes advantages of series and shunt active power filters to compensate the distortions of both source voltages and load currents. UPQC has a complicated structure that uses several elements working together, that's why we need rigorous choice of its parameters. A new method based on GA has been proposed in this paper.

The simulation results have shown the important effect of the frequency change on the filtering

characteristics and the no load total system impedance. Therefore, judicious choice of UPQC parameters is necessary. The optimized parameters given by table 2 case 5 and presented by the curves VG show the effectiveness of the proposed method which allow a wider pass band of unity gain for the ratio of amplitudes of currents and voltages and a normal total impedance. Finally, the parameters optimized by GA give to UPQC a better stability.

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