Optimal Parameters for Filter of Maglev Power Supply System Using Improved Genetic Algorithms

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ABSTRACT: The objective of this paper is to propose a new approach for designing the passive filter systems of magnetic levitation (Maglev) power supply system by using improved genetic algorithms (IGA). The new approach combined serial single-tuned filters with high-pass filter. The model can be used in two situations: (1) filter system just suppress harmonic current. (2) filter system suppress harmonic current and provide reactive power compensation at the same time. Through applying IGA to solve these kinds of complex discontinuous optimization problems, designer can quickly find appropriate parameter values to meet the desired power quality requirement, which minimize the total investment cost. A practical optimal algorithm based on IGA for selecting filter capacity values to achieve lowest investment of the filter system is obtained. Calculation results for a practical system show that the proposed method is valuable and powerful.

1 INTRODUCTION

In Maglev transportation system, it is converter supplies power to the vehicle, but the converter will inject harmonic current into utilities electric systems [1-3]. In order to ensure the power quality of the substation, filter system is needed in Maglev system [4-5]. In this paper, the passive filter system is designed, its aim is ensure the harmonic magnitudes are constrained in the harmonic standards at the same time make the capital investment is minimum. It has positive meaning on the research and development of the Maglev power supply system.

Genetic Algorithm (GA) is a search algorithm based on the conjecture of natural selection and genetics [6-8]. The features of genetic algorithm are different from other search techniques in several aspects. First, the algorithm is a multi-path that searches many peaks in parallel, and hence reducing the possibility of local minimum trapping. Secondly, GA works with a coding of parameters instead of the parameters themselves. The coding of parameter will help the genetic operator to evolve the current state into the next state with minimum computations. Thirdly, GA evaluates the fitness of each string to guide its search instead of the optimization function. Finally, GA explores the search space where the probability of finding improved performance is high.

The optimal filter system model based on IGA is established in this paper. The validity and availability of the developed integrated algorithms are proved by numerical calculation results for the real filter system of Shanghai Maglev Demonstration Line. The proposed method is not only valuable and powerful for optimal design of Maglev filter system, but also has enough requisites to be applied to any power supply system in the characteristics of the nonlinear loads.

2 DESIGNING OF FILTER SYSTEM

Among the several methods used to reduce these harmonic disturbances, the more employed is the tuned passive filter due to their simplicity and economical cost. The filter consists basically of a shunt circuit composed of inductor and capacitor series connection. The inductance (L) and capacitance (C) parameters of a single tuned passive filter are mutually dependent.

The high-speed Maglev is a nonlinear load in power system, it inject harmonic currents of several orders into utilities electric systems [9-10], which can be considered as a harmonic current source as shown in Fig. 1. Experiment studies show that most of voltage and current distortions in Maglev power systems are due to harmonics of fifth, seventh, eleventh and thirteenth orders to power system. In this paper the filters system we designed include 5th filter, 7th filter and high-pass filters. Fig. 1 is the schematic diagram of the filter in detail. Fig. 2 is the main flow chart of the filter system design program.

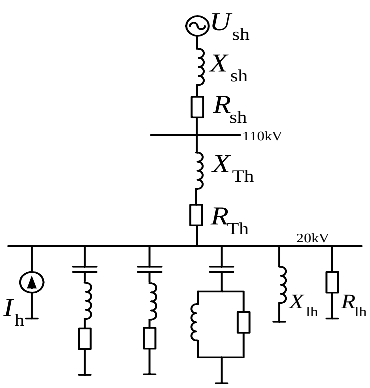

Fig.1 The schematic diagram of the filter

3 PRINCIPLE AND APPLYING PROCESS OF IGA

3.1 Principle of GA

GA is a powerful search algorithm based on the mechanism of natural selection. Unlike conventional search algorithms, it considers many points in the search space simultaneously and then reduces the chance of converging to local optimal. In addition, GA could deal with any kind of problem, even ill-defined, irregular problems.

At the beginning of the structure-GA loop, the population is initialized randomly and evaluated using the fitness function. Then we use one-point crossover and simple mutation to generate the new individuals. Crossover operator provides a mechanism for chromosomes to mix and match attributes through random processes. Mutation is a random alteration of some gene values in a chromosome. Every gene in each chromosome is a candidate for mutation. The selection of crossover and mutation is determined by the crossover and mutation rate respectively. Once the new individuals have been generated, the offspring is selected by the selection scheme. The selection scheme for structure-GA loop is roulette selection method, which selects the offspring according to the fitness. The larger the fitness value, the more opportunities the parents could be selected. After the selection, a new iteration will be carried out until there is no improvement of the best chromosome for several generations. It can be seen that the global optimal value has been found after GA loop is performed.

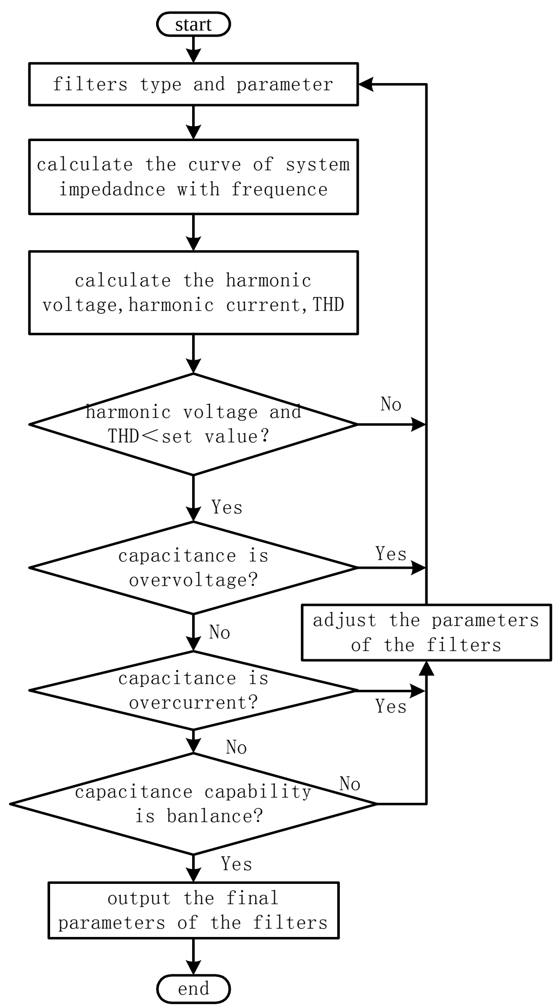

Fig.2 Flow chart of the filter system design

3.2 Applying Process of GA

Applying processes of GA are as following:

(1) Initialization

Choose a colony, then choose a strand or individuals' congregation b_i $(i=1,2,\ldots,n)$. This initialized colony is the hypothesized solutions' gather of problems. Generally strand or individuals' gather b_i is generated in random method. The best solution of the problem will be found through the hypothesized solutions' evolution.

(2) Selection

Based on the fitness function, choose individuals of the next generation. In the process of selection, take the fitness degree as the choosing principle. The fitness function incarnates the mechanism of natural selection, in terms of which the fitness will survive; contrarily the unfitness will be die. Given the objective function f, thus f_{bi} is the fitness value of the individual b_i. Establish the M for the number of times chosen for the next generation individual of b_i, then

$$M = \frac{f_{bi}}{\sum f_{bi}} \qquad (1)$$

From equation (9) we can see that: ① the higher the fitness value of the individual, the larger number of the offspring generated by it. ② the lower fitness value of the individual, the smaller number of the offspring, even it will demise. Thus more adaptive offspring to environment are generated.

(3) Crossover

For individuals selected to propagate, select a same position of two individuals at random to be carried on the exchange in term of the probability P_c. This process reflects the random exchange of information, the purpose of which is to produce new gene combination, then produce new individuals. In the course of crossover, we can carry out one to one or many to many crossovers. For example, having two individuals S_1=100101, S_2=010111, choose their left side 3 to carry on crossover operation, whereupon $S_1' = 010101$, $S_2' = 100111$. Generally speaking, the probability P_c of crossover is taken in the range of 0.25~0.75.

(1) Mutation

According to the principle of the gene mutation of the biology heredity, carry out the mutation to the same positions of some individuals, which mutation probability's value is P_m. When carrying out mutation, negate the bit of the strands, namely change 1 to 0 and change 0 to 1. The mutation probability P_m is in accordance with the biology mutation probability which value is very small, so the P_m's value is very small. For instance, to the individual S=101011 of 1 and 4 genes perform the mutation, then having S'=001111.

The function of the mutation lies in the assurance of not producing the single colony in the calculation that can't evolve. Because when all individuals are the same, crossover can't produce the new individual, which can be generated by the mutation only. That is to say, mutation increases the characteristics of global optimization.

(5) Global optimal convergence

When fitness value of the optimal individual is up to the valve, or the optimal individual and colony's fitness values no longer rise, the iterative process of algorithm converges, and the process of algorithm is over. Otherwise, the new generation colony obtained through the process of selection, crossover and mutation replaces the preceding generation colony, and return to the step (2) to continue to perform the circulation.

Fig. 3 shows the process of GA.

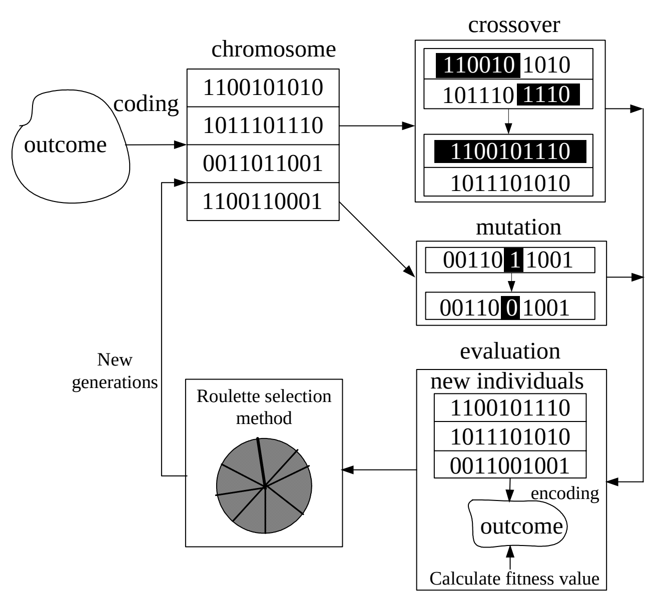

Fig. 3 Implementation procedure of GA

3.3 Improvement of standard GA

This paper make more improvement on standard GA, implemented the IGA in a practical optimal parameters for filter system software using VC++6.0 program language. Main improvement as follows:

1) Optimal individual protection. Make the optimal individual in preceding generation directly as next generation individual. Then protect the optimal individual in every generation. By this way, it is not only get the

optimal value but also get the suboptimal value when the process of algorithm is over.

2) Select the proper size of colony. Select the bigger size of colony only in the beginning of the process of algorithm.

3) Adoption comprehensive convergence criteria. This paper adopts fitness value and rate of fitness value as comprehensive convergence criteria. By this way, it can reduce the time of iterative process, and avoid to obtain the local optimal value after GA loop is performed because of early convergence.

4 OPTIMAL DESIGN OF FILTER SYSTEM

4.1 Objective Function of Optimal Design of Filter System

The model which was used in this paper is to optimal the parameters of filter system, and at the same time the object of the model is to obtain the minimum total cost of the filters system C_{FS}, the object function is as following:

$$C_{FS} = \min\left\{F_C \sum Q_C + \sum F_L Q_L + F_R Q_R\right\} \tag{2}$$

Constraint function：

$$Q_{sgl} + Q_h = Q_{1\Sigma} \tag{3}$$

$$HRU_h \le HRU_h GB \tag{4}$$

$$THD_u \le THD_u GB \tag{5}$$

$$I_h \le I_h GB \tag{6}$$

In this formula, F_C, F_L, F_R is the unit cost of capacitance, inductance and resistance individual, its unit is Yuan/kVar. Q_{sgl}, Q_H is the reactive power which is given by the single tuning filter and the high-pass filter individual, Q_C is the reactive power that be created by all the filters. $Q_{1\Sigma}$ is the total fundamental reactive power that should be created by filter system. HRU_h , $HRU_h GB$ is harmonic voltage percentage composition and corresponding limiting standard. THD_u , $THD_u GB$ is total harmonic voltage distortion and its limiting standard. I_h , $I_h GB$ is the harmonic current and its limiting standard, h is the harmonic order.

4.2 Flowchart of Optimal Design of filter system using IGA

The problem is modeled as the optimization steps in this paper. The proposed method finds the optimal parameters of filter system to minimize the total investment cost.

A flow-chart of the optimal parameters of filter system using IGA is shown in Fig. 4.

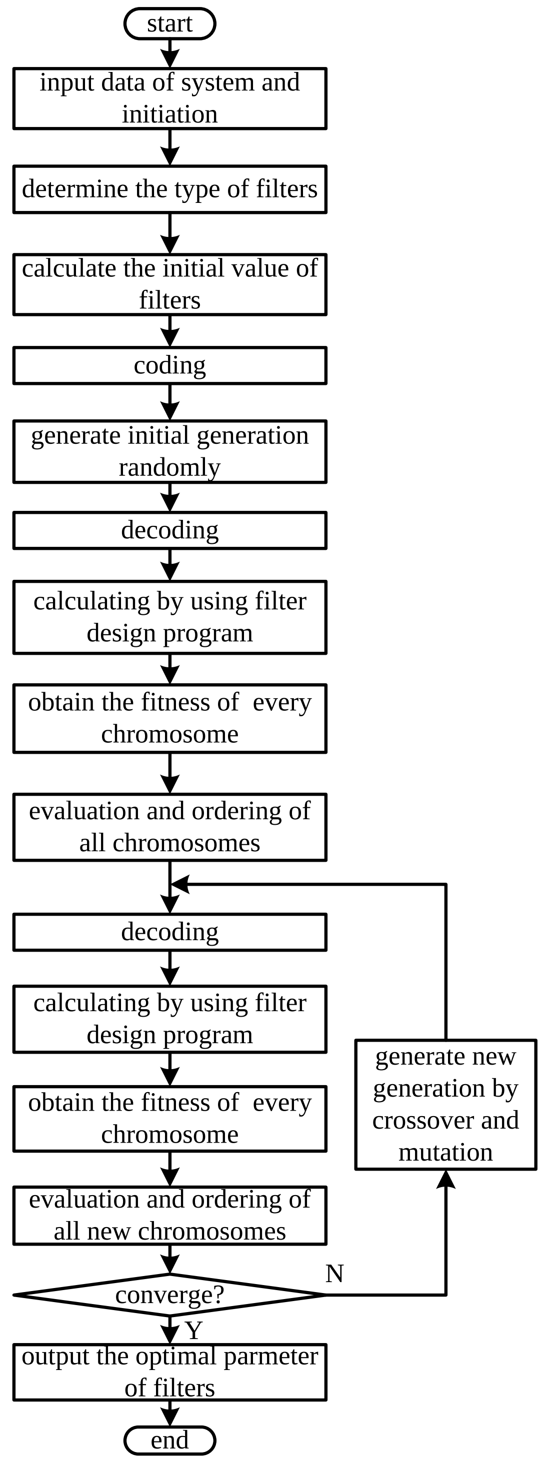

Fig.4 Flowchart of the optimal parameters of filter system using IGA

4.3 Object Function Mapping to Fitness Function

The target of optimal parameters for filter system of Maglev power supply system is finding the minimum total cost of the filters system, but the target of IGA is finding the most adaptive individuals. Therefore, it is needed to convert the minimum problem into maximum problem. Because $C_{\mathrm{FS}}(x)$ is non-negative, construct fitness function $f(x)$ is

$$f(x) = \frac{1}{C_{\mathrm{FS}}(x)} \tag{7}$$

4.4 Optimal Calculation result of the example

To prove the validity and availability of the developed integrated algorithms, we suppose that the maximum harmonic when the Maglev train is running is shown in Table 1. Two different cases are considered:

Case 1: the reactive power generated by the passive filter system is not determined.

Case 2: the reactive power generated by the passive filter system is 6 MVar.

Calculation result of all the parameters of filter is shown in Table 2, Table 3 for the two cases. Table 4 gives out the important parameters of IGA. The filter impedance frequency curve and system impedance frequency curve are showed in Fig. 5 and Fig. 6 individual in case 1. Fig. 7 and Fig. 8 show the filter impedance frequency curve and system impedance frequency curve in case 2.

Table 1. Maximum harmonic data in 20kV side (supposed)

Harmonic order	Harmonic current (A)	Harmonic voltage (%)
5^{th}	7	1.2
7^{th}	5	1.0
11^{th}	22	5.0
13^{th}	16	4.5

Table 2. Calculation result of parameters for filter in case 1

harmonic order	Bank of capacitors		reactor (mH)	resistance (Ω)
	Reactive power (Mvar)	capacitor (μF)		
5^{th}	0.0416	0.330883	1224.86	0
7^{th}	0.0224	0.178006	1161.64	0
11^{th} and above	1.13636	9.04289	11.2045	70.4

Table 3. Calculation result of parameters for filter in case 2

harmonic order	Bank of capacitors		reactor (mH)	resistance (Ω)
	Reactive power (Mvar)	capacitor (μF)		
5^{th}	0.547	4.37	92.84	0
7^{th}	0.428	3.42	60.47	0
11^{th} and above	5.025	39.99	2.534	15.92

Table 4. Important parameters of IGA

Parameters	Population size	Length of chromosome	Mutation rate	Crossover rate	Maximum number of generations
value	20	18	0.05	0.6	50

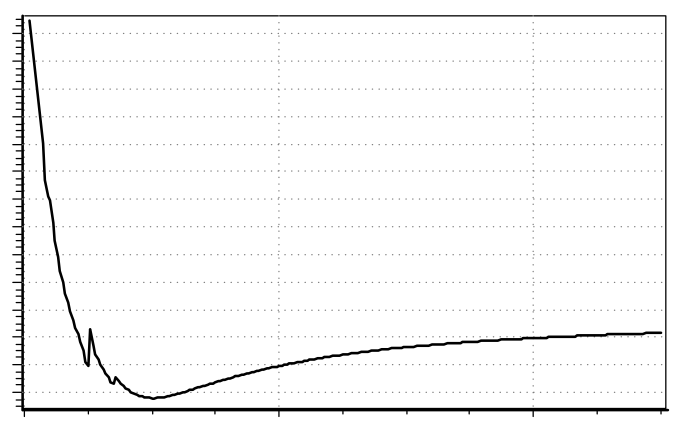

Fig. 5 Filter impedance frequency curve in case 1

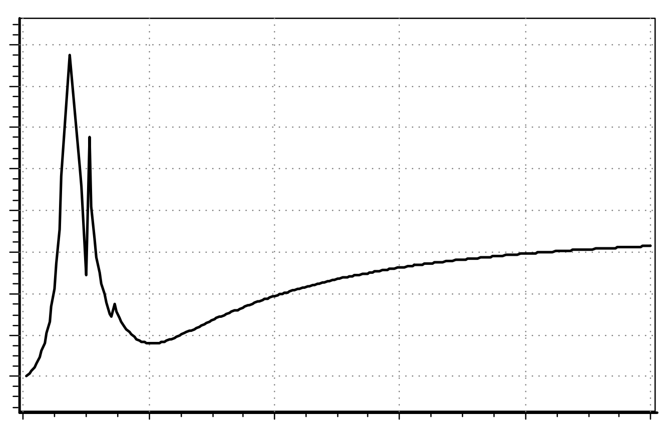

Fig. 6 System impedance frequency curve in case 1

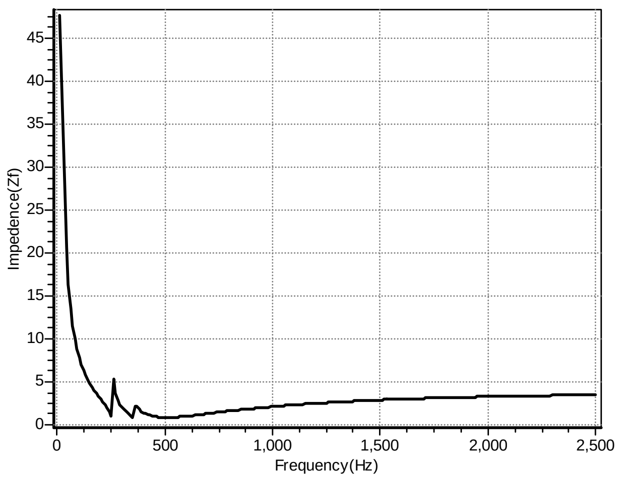

Fig. 7 Filter impedance frequency curve in case 2

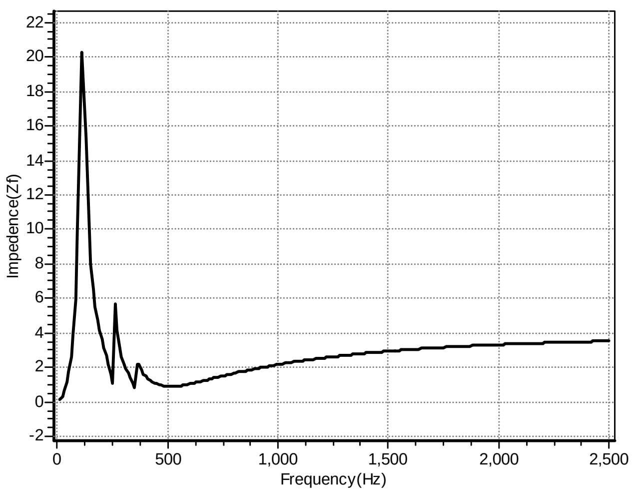

Fig. 8 System impedance frequency curve in case 2

5 CONCLUSIONS

The passive filter system of the Maglev power supply system is designed in this paper. A practical optimal algorithm based on IGA for selecting filter capacity values to achieve lowest investment of the filter system is obtained. The improved genetic algorithm has been adapted very well to the formulated problem. The proposed method has enough requisites to be applied to any power supply system in the characteristics of the nonlinear loads are known in advance. From the calculation of the practical example, we can see that the proposed method is a valuable and powerful tool for optimal design of filter system.

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