# Optimal Design of Filter System in Power Supply System of Maglev

Zhang Ruihua, Yan Luguang, Xu Shangang, Sun Guangsheng
The Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing, 100080, China. (Zhang Ruihua, Telephone: +86-10-62529814, E-mail: ruihuazh@mail.iee.ac.cn, Xu Shangang, E-mail: shgxu@mail.iee.ac.cn, Yan Luguang, Telephone: +86-10-62553222, E-mail: lgyan@mail.iee.ac.cn, Sun Guangsheng, +86-10-62616349)

**Key Words:** Maglev, Power Supply System, Reactive Power, Genetic Algorithms

**ABSTRACT** An integrated model combined serial single-tuned filters with high-pass filter is established for optimal design of the filter parameters of Maglev power system. The model can be used in two situations: (1) filter just suppress harmonic current; (2) filter suppress harmonic current and provide reactive power compensation at the same time. Through applying genetic algorithms (GA) to solve these kinds of complex discontinuous optimization problems, the optimal parameters of filter system are obtained, which minimize the total investment cost. Based on improved genetic algorithms (IGA), a practical optimal algorithm for selecting filter capacity values to achieve lowest investment of the filter system is obtained.

**Topic:** 4

## 1 Introduce

In the maglev system, it is converter that supplies power to the vehicle, but the converter will generate harmonic to the power supply system, in order to ensure the power quality of the substation, filter system should be installed. In this paper, the passive filter system is designed, its aim is ensure the harmonic level at the same time the capital invested is minimum. It has meaning on the research and development of the maglev system.

Genetic Algorithm (GA) is a search algorithm based on the conjecture of natural selection and genetics. 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, and from the calculation of the example, 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 a valuable and powerful tool for optimal design of maglev filter system.

## 2 Primary Design of Filter System

The high-speed maglev is a load in the power system, which can be considered as a harmonic current source as showed in figure 1, the harmonic current it generates is 11th and 13th harmonic current mainly, besides, it send 5th and 7th to the power system too [1]. In this paper the filters system we designed include 5th filter, 7th filter and the high-pass filters, Figure 2 is the flow chart of the filters design in detail.

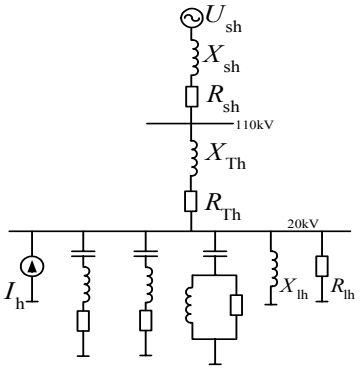


**Fig.1 The schematic diagram of the filter**

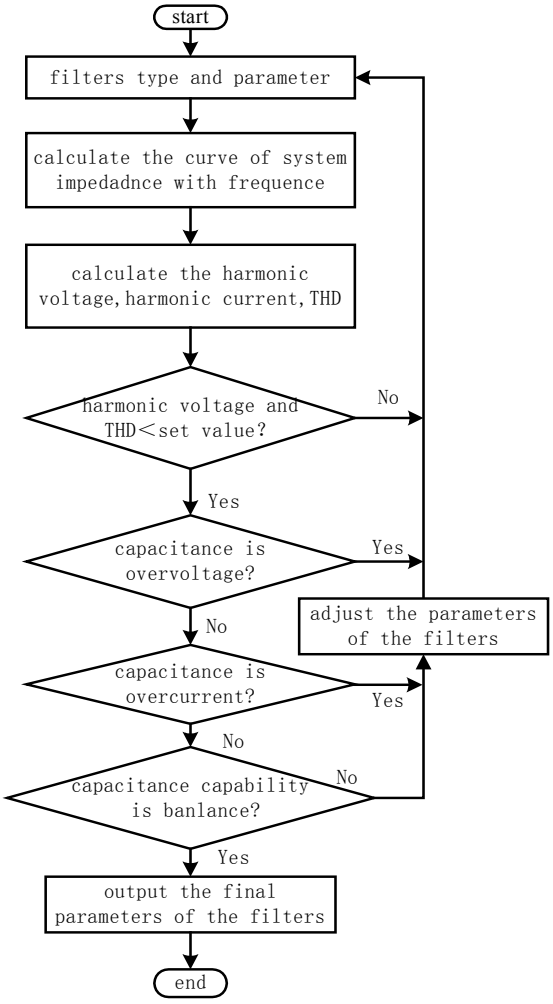


**Fig.2 The flow chart of the filter system design**

# 3 Optimal Design of Filter System

The model which is used in this paper is to optimal the filter system, and as the same time to let the fee of the filters is mini, the model is as following:

Object equation: $\min\left\{K_C\sum Q_C+\sum K_L Q_L+K_R Q_R\right\}$

Constraint equation： $Q_{sgl}+Q_h=Q_{1\Sigma}$

$$HRU_h \le HRU_h GB$$

$$THD_u \le THD_u GB$$

$$I_h \le I_h GB$$

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 filters. $HRU_h$, $HRU_h GB$ 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.

## 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.

## 3.2 Flowchart of Optimal Design of filter system using GA

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 owning cost.

A flow-chart of the optimal parameters of filter system using genetic algorithms is shown in Fig. 3.

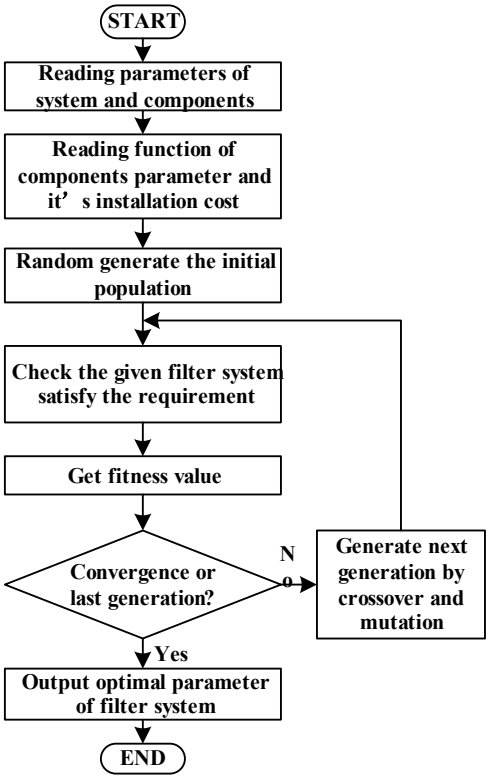


**Fig.3 Flowchart of the optimal parameters of filter system using GA**

### 3.3 the 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 as shown in table 1, and all the reactive power that the passive filter system should create is 6 Mvar, the calculation result of all the parameters is shown in table 2, the filter impedance frequency curve and system impedance frequency curve are showed in fig.4 and fig.5 individual.

**Table 1 the maximum harmonic 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 the calculation result of parameters**

| harmonic order | Bank of capacitors | | reactor（$mH$） | resistance（$\Omega$） |
|---|---|---|---|---|
| | Reactive power (Mvar) | capacitor（$\mu F$） | | |
| $5^{th}$ | 0.547 | 4.37 | 92.84 | 0 |
| $7^{th}$ | 0.428 | 3.42 | 60.47 | 0 |
| $11^{th}$ and the upward | 5.025 | 39.99 | 2.534 | 15.92 |

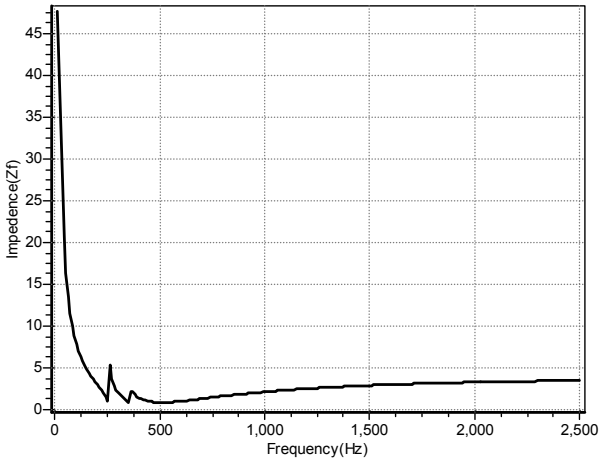


**Fig.4 Filter impedance frequency curve**

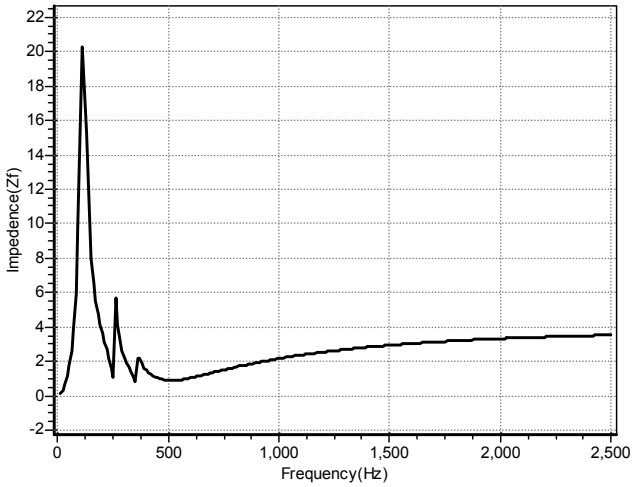


**Fig.5 System impedance frequency curve**

# IV. Conclusion

The passive filter system of the maglev is designed in this paper, based on IGA, a practical optimal algorithm for selecting filter capacity values to achieve lowest investment of the filter system is obtained. From the calculation of the example, we can see that the result is correct and the passive filter can be used in the maglev system.

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