Design of an Active Power Filter using Genetic Algorithm Technique

T. NARONGRIT, K-L. AREERAK* and K-N. AREERAK
Power Quality Research Unit, School of Electrical Engineering
Institute of Engineering, Suranaree University of Technology
Nakhon Ratchasima, 30000
THAILAND
*corresponding author: kongpol@sut.ac.th

Abstract: This paper deals with the active power filter design controlled by using hysteresis technique. The genetic algorithm is used to design the controllers to minimize the %THD of the source current. The results are compared with that designed from Ingram and Round approach. The simulation results confirm that the genetic algorithm can provide the minimum %THD of the source current compared with the Ingram and Round method. The %THD also follows the IEEE std.519-1992. The design of the active power filter based on the genetic algorithm is flexible and can improve the performance of the filter.

Keywords: genetic algorithm, hysteresis control, harmonic elimination, active power filter

1 Introduction

![Fig.1 The power system considered](image)

Power systems connected nonlinear loads can generate the harmonics into the systems. Theses harmonics cause a lot of disadvantages such as loss in transmission lines and electric devices, protective device failures, and short-life electronic equipments in the system [1]. Therefore, it is very important to reduce or eliminate the harmonics in the system. It is well known that the harmonic elimination via an active power filter (APF) [2] as shown in Fig.1 provides higher efficiency and more flexible compared with a passive power filter. In Fig.1, the three-phase bridge rectifier feeding resistive and inductive loads (R=3.37 kΩ and L=19.8 H) behaves as a nonlinear load into the power systems. An instantaneous reactive power theory (PQ method) [3] is used for a harmonic detection to calculate the reference currents for the active power filter. The APF is then controlled by a hysteresis method [4].
There are many approaches for the APF design using an artificial intelligence (AI) technique such as adaptive tabu search (ATS) [5], particle swarm optimization (PSO) [6], and genetic algorithm (GA) [7]. In this paper, the GA is used to search the appropriate parameters of the APF to minimize the %THD of the source current \(i_s\) after compensation. According to Fig.1, the APF parameters for GA searching are the DC bus voltage \(V_{dc}\), the filter inductance \(L_f\), and the hysteresis band \((HB)\). The results of the APF design via GA are presented in this paper and are also compared with that designed from Ingram and Round approach [8].

The paper is structured as follows. The overview of compensating current control using the hysteresis method is addressed in section 2. The APF design using the Ingram and Round method and GA is fully presented in section 3 and section 4, respectively. The simulation results of the harmonic elimination including discussion are presented in section 5. Finally, section 6 concludes the advantages of GA approach to design the active power filter.

## 2 Control of compensating current using hysteresis method

![Hysteresis Band](image)

The compensating current control using the hysteresis approach is shown in Fig.2. According to Fig.2, the hysteresis band \((HB)\) is the possible boundary of compensating current \((i_c)\). This current swings between upper and lower hysteresis limits. The compensating current can be increased or decreased depending on the pattern switch of IGBT inside the APF. For example, when IGBT turns on, \(i_c\) will be increased. It is continually increased until reaching the upper hysteresis limit. At this state, IGBT will be automatically turned off to decrease the compensating current. If the current falls down to the lower limit, IGBT will be automatically turned on again to increase the compensating current. Therefore, the compensating current swings inside \(HB\) following the reference current \(i_c^*\). The reference current can be identified by PQ harmonic detection as shown in Fig.1. Note that the upper and lower hysterisis limits are controlled by the hysteresis band.

### 3 The APF design using Ingram and Round method

In 1997, D.M.E. Ingram and S.D. Round presented the APF design controlled by hysteresis method. The details are explained as follows:

**Step 1:** Calculate the maximum value of \(\frac{di_c}{dt}\) by:

\[
i_{h(max)}(t) = A \sin(2\pi ft)
\]

\[
\max(\frac{di_c}{dt}) = A2\pi f
\]

where

- \(i_{h(max)}(t)\) is the maximum current for each harmonic component
- \(A\) is the amplitude of the harmonic current
- \(f\) is the frequency of the harmonic current

**Step 2:** Determine \(L_f\) by:

\[
L_{f(max)} = \frac{V_{dc} - V_i}{\max(\frac{di_c}{dt})}
\]

where \(V_i\) is the maximum source voltage.

Note that the maximum value of \(\frac{di_c}{dt}\) is from Step 1 and \(V_{dc}\) should be always designed higher than \(V_i\).

**Step 3:** Determine \(HB\) by:

\[
HB = \frac{2V_{dc}}{9L_f f_{sw}}
\]

where \(f_{sw}\) is the switching frequency.
4 The APF design using GA approach

4.1 The review of GA

In Fig. 3, there are three main processes for GA method. The first is ‘selection’. This process will select the population in the searched system to be the parent for the next generation. The second process is ‘genetic operation’ to search the better solutions for each generation by using the crossover and mutation techniques. The final process is ‘replacement’. The offspring from the genetic operation process will replace the previous population in which it may replace the whole of population or some part of population depending on the conditions in the algorithm.

4.2 The APF design using GA

In section 2, the APF is controlled by using hysteresis method. In this paper, the GA is applied to determine the appropriate APF parameters. The parameters for searching are DC bus voltage ($V_{dc}$), the inductor filter ($L_f$), and the hysteresis band ($HB$). The block diagram to explain how to search the parameters of APF using GA method is depicted in Fig. 4. It can be seen in Fig. 4 that GA will search the APF parameters in which %THD of the compensated current on supply side is defined as the cost value for GA tuning. This value can be determined from the objective function as shown in Fig. 4. The GA will try to search the best APF parameters to achieve the minimum %THD also following on the IEEE std. 519-1992.

According to Fig. 4, the steps of searching APF parameters by using GA are as follows:

Step 1: Define the boundary of parameters. In this paper, the upper and lower limits of $V_{dc}$, $L_f$, and $HB$ are set to 312-700 V, 0-10 H, and 0-0.02 A, respectively.

Step 2: Define the population encoding scheme for GA. In this paper, the chromosomes for the population encoding scheme are set to be the real value [11].

Step 3: Set the population size equals to 40 chromosomes.

Step 4: Define the initial population by random within the search space of parameters.

Step 5: Define the maximum number of generation for searching, here is set to 1000.

Step 6: Define the selection process, here set to roulette. The uniform mutation (probability = 0.06), the single-point crossover (probability = 0.7), and the whole population replacement are selected. Note that the more details of GA can be found in [12].
The parameter values of APF from GA search compared with Ingram and Round method are given in Table 1. In addition, the results in Fig.5 also show the convergence of GA for this problem.

5 Simulation results and discussion

The simulation results of the system in Fig.1 with the APF parameters from GA searching are depicted in Fig.6. It can be seen that the source current after compensation ($i_{sa}$) is nearly sinusoidal waveform. %THD of this current is equal to 0.9885% that is satisfied under IEEE Std. 519-1992, while %THD before compensation is 25.45%. The simulation results for Ingram and Round method are illustrated in Fig.7. From Fig.7, the source current after compensation is nearly sinusoidal waveform the same as the results in Fig.6. However, %THD for this method is 1.5019% that is greater than the one from GA method (0.9885%). Hence, GA method can provide the smaller %THD compared with Ingram and Round method. The results show that GA approach is very useful and more convenient for APF design.

<table>
<thead>
<tr>
<th>APF parameters</th>
<th>APF design method</th>
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<tbody>
<tr>
<td></td>
<td>GA</td>
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<tr>
<td>$V_{dc}$ (V)</td>
<td>620</td>
</tr>
<tr>
<td>$L_f$ (H)</td>
<td>0.39</td>
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<tr>
<td>HB (A)</td>
<td>0.00043</td>
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<td>%THD before compensation</td>
<td>25.45 %</td>
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<tr>
<td>%THD after compensation</td>
<td>0.9885 %</td>
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</tbody>
</table>

6 Conclusion

This paper presents the application of GA for the design of APF controlled by hysteresis method. The results confirm that GA can provide the minimum %THD of the source current after compensation. In addition, %THD is also satisfied under IEEE Std. 519-1992. Moreover, the mathematical model of APF is not necessary for GA approach. Hence, the GA approach for APF design is very useful and flexible.

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References


