Research on Power System Harmonic Suppression Method of Active Filter

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Abstract. The active filter has different connection methods, and the methods used are also various. With the deepening of research, more novel filtering methods are proposed and applied, which enhances the efficiency and rapidity of filtering. At present, China has made great progress in harmonic suppression. In the face of the fact that harmonic problems are becoming more and more serious, the research of filtering technology and the popularization and application of filtering equipment are urgently needed.

1. Introduction
The rapid advancement of the power sector in recent years has promoted the development of related industries. Different types of electrical products have emerged, which has guaranteed the daily use of electricity, and the research and design of electrical devices has become more mature[1-3] While bringing great progress, the development of the power industry, especially the power electronics industry, has made the power industry face many new problems. The increase of harmonics is a big problem, and the power loss is also increased. Harmonic pollution also affects the user's power quality. From this point of view, the problems caused by non-fundamental components need to be solved as soon as possible.

2. APF topology
The topology of the APF consists of a harmonic detection module and a harmonic suppression module. The principle is to generate corresponding reverse compensation components according to the harmonic components in the real-time detected power grid, and compensate the harmonic components in the power grid, so that the power grid can only provide the fundamental component, and the purpose of filtering out harmonics can be realized.

However, it is worth noting that this filtering only filters out the harmonics in the grid to the greatest extent. Due to the differences in the APF method, the principles and devices used in each method cannot be completely filtered out. The harmonics in the grid can only be filtered out approximation.

PWM is a common component in harmonic suppression. The popularization and application of PWM control circuit has improved the efficiency and effect of active filters. According to the result of the measurement of the current component, the ratio of the fundamental component to the non-fundamental component, the pulse width modulator generates a corresponding pulse signal to control
the action of the IGBT device of the three-phase bridge, so that the output of the three-phase bridge corresponds to the non-fundamental component. The amount of current changed, filtering out the non-fundamental components of the grid.

The inverter circuit module is basically a three-phase bridge inverter. The IGBT is widely used due to its good switching characteristics and service life. In the APF inverter circuit, the switching element generally uses IGBT components. With the turn-on and turn-off of the IGBT, the amount of current output by the inductor changes correspondingly to the measured non-fundamental component current, compensating for the non-fundamental current obtained by the decomposition in the power grid, and ensuring the normal operation of the power grid.

The DC control module is generally composed of a corresponding capacitor inductor. The capacitor can eliminate the ripple of the DC voltage, ensure the stability of the DC voltage, and the inductor can ensure the continuous current transmission in the circuit.

The APF is divided into a parallel APF and a tandem APF, and the following are analyzed separately.

Figure 1. Topology of series active power filter

Figure 1 shows the structure of a tandem APF. The series active power filter is connected in series in the power grid and can be considered as a controlled voltage source to compensate the harmonic source of the voltage source. The series control system first detects a non-fundamental component that does not change according to a sinusoidal law from the grid current, and then controls the pulse width modulator signal generator to control the voltage associated with the non-fundamental component to compensate for the harmonic voltage in the grid. Compared with the parallel APF, the series APF will cause more power consumption, and the protection measures are relatively complicated. Special treatment is required in the input and subsequent maintenance, so the use of the series active power filter is used. There are fewer situations.

Figure 2. Topology of shunt active power filter

Figure 2 shows the structure of a parallel APF. The APF is connected in parallel to the grid and can be viewed as a controlled current source. After detecting the harmonic current in the power grid, the parallel APF will input the current in the opposite direction to the harmonic current of the grid in real time to the grid, thereby filtering out the higher harmonics. And the parallel active power filter has a variety of filtering methods, including current method and voltage method. The current method has
three kinds of instantaneous value hysteresis current control method, triangular wave comparison method and time-limited current method. Therefore, it is currently widely used in the use of filtering.

3. Parallel active filter working principle

Among various types of APF, the parallel APF has been widely used due to its superior advantages and various control methods. Figure 3 is a block diagram of a parallel APF:

![Figure 3. Topology of shunt active filter](image)

In the parallel type APF, the main circuit is mostly a voltage source type three-phase inverter. The main circuit can be in the form of a single main circuit or a superimposed main circuit. In the form of a single voltage source type main circuit. The figure below shows the equivalent circuit of a shunt active power filter. In Fig. 3, \(u_d(t)\) is the AC power supply voltage; \(u_c(t)\) is the DC side capacitor voltage of the parallel active power filter main circuit; \(i_{sn}\) is the harmonic compensation current of the parallel active power filter; \(L\) and \(R\) are Equivalent inductance and resistance.

![Figure 4. Block diagram of shunt active power filter](image)

According to Figure 4, you can get:

\[
L \frac{di_{sn}(t)}{dt} + Ri_{sn}(t) = u_c(t) - u_s(t)
\]  (1)
Usually R is small, formula (1) can be written as:

$$L \frac{di_{sn}(t)}{dt} \approx u_c(t) - u_s(t)$$  \hspace{1cm} (2)

It can be seen from the formula (2) that the filtered current $i_{sn}$ of the non-fundamental component is related to the parallel APF main circuit $u_c(t)$ and $u_s(t)$, and the larger the difference between the two is, the larger the $i_{sn}$ is.

Assuming that the three-phase power supply is balanced, the sum of the three-phase power supply voltage $u_{a0} + u_{b0} + u_{c0} = 0$ and the three-phase power supply current $i_{a0} + i_{b0} + i_{c0} = 0$, so that the following differential equation can be given:

$$\begin{align*}
L \frac{di_{sa}}{dt} &= u_{sa} + K_a U_c \\
L \frac{di_{sb}}{dt} &= u_{sb} + K_b U_c \\
L \frac{di_{sc}}{dt} &= u_{sc} + K_c U_c
\end{align*}$$  \hspace{1cm} (3)

In equation (3), $K_a$, $K_b$, $K_c$ - switching coefficients are shown in the table below. As can be seen from the table, $0_{ba} = 0_{bc} = 0_{ca}$ of the same mode;

4. Current tracking control

Figure 5 shows the principle of the instantaneous value hysteresis comparison method. $i_c$ is the compensation current of the non-fundamental component, that is, the current signal output by the APF. This electrical quantity is obtained after the voltage and current transformer, that is, the same current as the three-phase power grid. It contains the sum of the non-fundamental component current or the non-fundamental component current and the reactive component that needs to be filtered out; their full name should be $i_{ref}$, which is the reference amount set for the current to be filtered, generally the standard 50 Hz fundamental wave. The component may also be a non-fundamental component after detection.

![Figure 5. Instantaneous value hysteresis comparison method schematic](image)

In principle, $i_c$ and $i_r$ are compared in the measurement comparator. The final difference signal $\Delta i_c$, $\Delta i_r$ is used as the input electrical quantity of HBC. Compared with the upper and lower limits of the fixed loop width of HBC, the hysteresis comparator HBC will generate a PWM signal, which is used as a control terminal input signal for controlling the three-phase bridge, and the controller three-phase...
bridge power switch tube is turned on or off to track the reference current in real time for filtering. If the compensation current \( i_c \) is greater than \( i_{ref} \) at the rising edge of the sampling pulse, the PWM output will be a positive pulse, thereby controlling the switching element of the active filter, so that the compensation current is reduced; if \( i_c \) is less than \( i_{ref} \), the PWM pulse is 0, control The active filter (APF) inverter switch increases the compensation current. In this way, the waveform adjusted by the active filter will approach the sine wave, thereby filtering out the higher harmonics and achieving the purpose of effective filtering.

In the instantaneous value hysteresis comparison method, the determination of the hysteresis width (H) is to be specifically analyzed. The determination of the loop width is related to the capacity and number of harmonics. If H is too large, the switching frequency and loss of the switching device will be reduced, but the corresponding current tracking error will increase to a large extent; if H is too small, the tracking error of the current will decrease and the switching frequency of the switching element will increase. As a result, the loss is greatly increased, and the life of the switching frequency is reduced.

In summary, in addition to the simple tracking circuit structure, this method can effectively filter the harmonics of the active filter input, so that the entire output current is sinusoidal, reducing the interference of higher harmonics and causing The electromagnetic pollution achieves the purpose of active filtering, but this method is affected by the switching frequency of the switching element, and in the case of a fixed hysteresis loop, a large requirement is imposed on the switching frequency. However, if the method of tracking the amount of compensation is used, the circuit will be complicated, and the economical efficiency of the active filter will not be met.

5. Conclusion

Another important part of the study of active filters is the active filter control aspect. In the process of filtering out the non-fundamental components in the circuit, the effect of the APF is to measure the corresponding electrical quantity by the voltage and current measuring device, and to filter the fundamental component and the non-fundamental component, and to filter the harmonics. Part of the corresponding processing to ensure the stability of the fundamental current in the power grid. At present, there are many methods for effectively filtering out the components of the fundamental wave component. The commonly used hysteresis control filter is unless the fundamental component method is used.

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