

Research on Harmonic Suppression Methods

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Abstract. Harmonics can be very harmful to power electronic equipment. With the widespread use of modern electronic equipment, the generation of harmonics has become more common. These harmonics not only come from non-linear loads but can also be caused by faults or instability in the power system. Therefore, suppressing harmonics is crucial to maintaining the stability and normal operation of the power system. In recent years, experts have studied the harmonic problem, there are a large number of harmonic suppression methods, and the basic idea is divided into two, one is to transform the power electronic equipment itself; the other is to install harmonic compensation devices. In this report, three feasible harmonic suppression methods are selected for these two main ideas, harmonic suppression based on feed-forward compensation, harmonic suppression based on transformer, and harmonic suppression based on filter. For the public to have a clear enough understanding of these methods, the backgrounds of these three methods are introduced, the basic working principles are analyzed, and the effects of harmonic suppression are analyzed and summarized, which will help subsequent researchers sort out research ideas. Finally, according to the current shortcomings of the three methods, including a small range of applications, limitations of harmonic detection technology, and so on, the future development of harmonic suppression methods is prospected.

Keywords: Harmonic suppression; feed-forward compensation; transformers; filters.

1. Introduction

Under today's production industrialization, power electronic equipment is commonly utilized in the power system to provide society with efficient ways to apply electricity, and at the same time, it also generates a large number of harmonics; at the same time, electronic equipment also leads to a large number of harmonics injected into the power grid, so that the voltage sinusoidal waveform distortion, power quality degradation, to the power supply, power equipment have brought about serious harm. Experts pointed out that harmonics will be the biggest pollution of the power supply system in the future. Harmonic suppression can improve the reliability of equipment operation and service life, but also reduces the harmonic pollution of the public power grid, from the harm of harmonics as well as harmonic suppression significance of harmonic suppression of the importance of the study of harmonic suppression is self-evident. For this reason, the state has formulated a variety of laws and regulations for harmonics and requires that harmonics be suppressed at the source to reduce the pollution of the public power grid and provide a reliable power supply guarantee for the increasingly powerful national defense construction. At present, there are various methods for harmonic suppression, but there is a lack of awareness of their feasibility and applicability. To solve this knowledge gap, so that the public has more specific knowledge of several mainstream methods of harmonic suppression, this paper focuses on the three methods of harmonic suppression, based on feed-forward compensation, based on the utilization of transformers, based on the utilization of filters, and analyzes the background, working principle, and effect of each method, and then summarizes the comparison of these three methods and proposes the direction of research on harmonic suppression methods in the future. The research direction of harmonic suppression methods in the future is proposed.

2. Harmonic Suppression Based on Feed-Forward Compensation

It is stated that according to Zhao and Lipo [1], in dual three-phase permanent magnet synchronous motors, very small voltage distortions due to air gap magnetic field distortions and other reasons can generate large distorted voltages, which result in current harmonics. Literature [1] addresses this problem by proposing the exploit of voltage feed-forward based on quasi-proportional harmonic control for harmonic suppression. Literature [2] addresses the current harmonics of permanent magnet synchronous motors and applies the same method to suppress the harmonics as in literature [1], which will be described in the following as an example of a dual three-phase permanent magnet synchronous motor.

2.1. Explanation of Harmonic Suppression Based on Feed-Forward Compensation

Literature [1] proposes the application of coordinate transformation with voltage feed-forward compensation for harmonic suppression. First use the coordinate transformation, quasi-proportional resonant controller for certain control, and then the coordinate system in the AC quantity into DC components, and extracted with a filter, using the synchronous rotation of coordinate change method, the substitution of direct flow to get the compensated voltage, will be superimposed on the feed-forward compensated voltage obtained by adding to the quasi-proportional resonant controller, to improve the effect of harmonic suppression. Finally, Simulink simulation is performed to calculate the feed-forward compensation voltage, which is added to the current loop with the quasi-proportional resonant controller as a double closed-loop control, and the harmonic current waveforms using quasi-proportional resonance control as well as feed-forward control are compared.

2.2. Effectiveness of Harmonic Suppression Based on Feed-Forward Compensation

After simulation, it can be seen from the current waveform graph that the use of quasi-proportional resonance control plays a certain role in suppressing harmonics, but the suppression effect is not satisfactory, and only the higher harmonics have a certain suppression effect; on this basis and then feed-forward control is used after the simulation is carried out again, and it can be seen from the results that the harmonic currents have been well suppressed.

3. Harmonic Suppression Based on Transformer

Transformers are indispensable electrical equipment in power systems and are widely found in power grids at all levels. As a nonlinear device, it not only generates harmonics as a harmonic source but also transmits harmonics generated by other harmonic sources in the system. Therefore, reducing the harmonics generated by the transformer as a harmonic source can largely suppress harmonic pollution and improve power quality.

3.1. Explanation of Harmonic Suppression Based on Transformer

Literature [3] proposed two measures to suppress the third harmonic of the transformer main flux for the third harmonic generated during the operation of power transformers. Literature [4] suggested that transformer harmonic currents can be suppressed by improving the saturation condition of the transformer magnetic circuit.

3.1.1. Reasonable selection of the transformer coupling groups

At present, the commonly used transformer winding coupling groupings in China are Y, yn0 Y, and d11 D, y11 YN, d11 YN, y0 Y, y0, and Y, y0. It has been found that when the Y,y0 coupling group is applied to a three-phase transformer group, the amplitude of the third harmonic potential can reach 50-60% of the amplitude of the fundamental potential, which means that this will generate very dangerous overvoltages in the windings. Therefore, the Y, y0 coupling configuration cannot be applied to a three-phase transformer bank and a triangularly coupled third winding should be attached to it. In addition, literature [3] also suggests the exploit of the Y, d11, and D, y11 coupling group, this

coupling group can make the third harmonic of the excitation current in the closed loop of the triangular coupling group, forming a loop current, which can be effective third harmonic.

3.1.2. Reasonable determination of transformer core

Three core column type three-phase transformer, the third harmonic flux phase, and size are the same. The third harmonic in the core cannot find the return route and must overcome the higher magnetic resistance to flow back, so this transformer has a minimal third harmonic flux. Therefore, the power system more exploit of a three-core column-type transformer can effectively inhibit the generation of harmonics.

3.1.3. Improve the transformer magnetic circuit saturation condition

The transformer magnetic circuit saturation problem mainly depends on the transformer core material and structure. Using a three-dimensional column core structure instead of the traditional flat laminated structure core, can reduce the core loss, and reduce the distortion rate of the excitation current, to implement the purpose of harmonic current suppression; In addition, pay attention to the installation of the transformer, the main body of the oil tank of the upper and lower sections of the pitch should not be too large, so as not to lead to an increase in the leakage of magnetism and increase the harmonic.

3.2. Effectiveness of Harmonic Suppression Based on Transformer

Since the above three methods are active harmonic suppression methods, it is not possible to obtain effective data through simulation to study the harmonic suppression effect, so the effectiveness of the above methods to suppress harmonic current needs to be verified by more experiments in the future.

4. Harmonic Suppression Based on Filter

Harmonics are generated in general by three factors. Firstly, harmonics in the grid itself due to quality problems; secondly, harmonics in the transformer due to its structural principle; and thirdly, harmonics generated by the introduction of variable frequency equipment due to energy-saving. The harmonics generated due to the introduction of inverter equipment are the most serious. Literature [5-7] addresses this problem by proposing the application of suitable power filters as a way to manage harmonics and improve power quality.

4.1. Explanation of Harmonic Suppression Based on Filter

Literature [5] analyzes the system structure and basic principle of an active power filter, which is mainly composed of a harmonic command current operation module, compensation current control module, DC side voltage control module, main circuit, and necessary protection and auxiliary circuits.

Literature [5] points out that, through the harmonic current detection circuit, the harmonic component in the load current is detected as the output compensation command current, the switching tubes in the main circuit of the APF are controlled, and the main circuit generates the compensation current equal in size and opposite in reverse to the harmonic current to flow into the grid, to offset the harmonic currents in the load current, and to accomplish the purpose of suppressing the inflow of the harmonic component into the power grid.

It is worth noting that, in addition to active power filters, literature [7] proposes several methods of applying microwave filters to suppress harmonics, which also have good results. However, since microwave filters are still a niche application, the following section will take active power filters as an example to analyze the effectiveness of the filters in suppressing harmonics.

4.2. Effectiveness of Harmonic Suppression Based on Filter

Literature [6] on this basis, the current control method of active power filter is analyzed, and a dynamic simulation study is made on the shunt-type active power filter based on the space vector compensation current tracking control method, according to the simulation waveform of the active

power filter can be seen, the active power filter can track the sudden change of the load harmonic current promptly, it can be seen that the active power filter has a good dynamic characteristic, it can track the change of the load harmonic current in real-time, and it can effectively inhibit the impact of the sudden change of the load current brought about by the power supply current.

5. Conclusion

This paper analyzes the background, working principle, and effect of the three current harmonic suppression methods, feed-forward compensation-based, transformer-based, and filter-based, which will help subsequent researchers to sort out their research ideas.

Simulation and experimental results show that the feed-forward compensation-based method can effectively realize the decoupling control of the current loop in synchronous motors, which makes the system regulation time shorter, the regulation accuracy higher, and the dynamic and static performance better, and can largely suppress the harmonic current.

As far as the transformer itself is concerned, although it has been effective through the reasonable selection of transformer linkage group, reasonable selection of transformer core, and other methods, these methods are static suppression methods, and there are some limitations in the suppression effect.

The application of filters to suppress harmonics is the most widely used practice. Firstly, it is effective in suppressing harmonics, and secondly, it is suitable for all types of harmonic sources. The application of filters can effectively manage harmonics as well as improve system stability and reliability.

At present, these three methods still have some unresolved problems, and future research on harmonic suppression technology is essential.

The current commonly used harmonic detection methods have some problems in practical application, such as real-time is not guaranteed, when the grid voltage asymmetry detection accuracy will be reduced. In the future, it is necessary to carry out more in-depth research on the harmonic detection methods, to provide better harmonic suppression.

In addition to a series of static harmonic suppression methods such as improving the quality of the power grid itself and making a reasonable choice of transformer-related devices, the harmonic control process still needs some more intelligent processing methods to suppress harmonics dynamically monitored in real-time. How to combine intelligent technology with harmonic detection and suppression, and whether this method can make up for the shortcomings of the existing problems, is one of the important directions for future research.

With the development of technology, there are more and more types of harmonic sources. Although there are many kinds of filters to choose from for various filter sources, it is still a little difficult to realize one-to-one correspondence in practical application from the aspect of economy as well as practicability. Whether it is possible to develop a filter that can suppress a variety of harmonic sources, thus greatly reducing the cost, can be one of the future directions of harmonic suppression research.

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