# Research on Power Factor Correction Technology of Three-phase Bridge Rectifier Based on Electromagnetic Theory

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**Keywords:** Power factor correction circuit; Electromagnetic interference; Three-phase bridge rectification; Harmonics

**Abstract:** With the development of power electronics technology, the power quality of AC power supply system has attracted more and more attention. The traditional rectifier widely adopts diode uncontrolled rectifier and thyristor phase controlled rectifier circuit, which injects a lot of harmonic and reactive power into the power grid, resulting in serious pollution. It has become a research hotspot to improve the power factor at the power grid side and reduce the harmonic of input current. Power factor correction technology is a powerful measure to reduce the harmonic pollution caused by electrical equipment to the power grid and improve the power factor. This paper analyzes the working principle of unity power factor three-phase bridge rectifier circuit. This rectifier topology can be divided into two parts: power factor compensation network and conventional rectifier network. On this basis, an accurate mathematical model for the rectifier circuit is established.

## 1. Introduction

With the progress of science and technology, more and more electronic devices are applied to industry, commerce, civil, aviation, public utilities, military and other fields [1]. Most electronic devices need to obtain DC voltage by rectifying and filtering the input AC voltage [2]. Three phase secondary rectifier resistance welding machine has been paid more and more attention in the welding system, but its problems such as low power factor, many harmonic components and serious electromagnetic interference of three-phase input power supply need to be solved urgently [3]. If a large number of current harmonic components are injected into the power grid, on the one hand, it will improve the harmonic noise level in the power grid and cause harmonic "pollution" of the power grid. On the other hand, it will produce "secondary effect", that is, the current flows through the line impedance to form harmonic voltage drop, which in turn will distort the power grid voltage; When these effects are serious, they will cause circuit failure and damage substation equipment [4]. In the three-phase circuit, the superposition of three-phase harmonic current flowing through the neutral line will damage the neutral line due to overcurrent. In addition to increasing additional loss, harmonics will also produce additional harmonic torque to the motor, causing mechanical vibration and affecting the normal operation of the motor [5]. Because the conventional measuring instrument is designed according to its working under sinusoidal voltage and sinusoidal current, the measurement of non sinusoidal voltage or current will produce additional errors and affect the measurement accuracy; The harmonic current in the power line will interfere with the communication line through electric field coupling, magnetic field coupling or common ground coupling [6].

The purpose of anti-electromagnetic interference design of power factor correction circuit is mainly to replace the integration of multiple functional modules with a brand-new functional integrated design circuit module, so as to reduce the number of circuit stages, filter out electromagnetic noise interference signals in power factor correction circuit and finally achieve the purpose of electromagnetic compatibility [7]. At present, people pay more and more attention to the high energy and low consumption of the circuit itself when applying the rectifier circuit conversion technology in the circuit. In engineering, due to the mature application of the power factor correction circuit control technology, the conversion of electric energy can basically be similar to [8]. From the input of the whole power factor correction circuit, in order to better filter out some

  DOI: 10.25236/icmmct.2022.037

harmonic currents at the input of the circuit, we must improve the working efficiency of the circuit system [9]. For electronic equipment, different levels of electromagnetic interference will have different effects on the whole system, but if the electromagnetic interference is serious, it will cause damage to electronic equipment, so people must attach great importance to it [10]. With the rapid development of various electronic devices and electromagnetic interference testing technology, the testing technology and general filter circuit for electromagnetic signal interference have developed quite maturely, and can also solve most electromagnetic signal interference problems [11]. However, for some circuits with relatively small power level, especially some power switch circuits, the technology of applying electromagnetic interference filters at the power supply side is not very mature because the load of the circuit does not require high elimination of electromagnetic interference signals in the circuit [12]. This paper attempts to discuss the design method of applying anti-electromagnetic interference technology in power supply circuit.。

## 2. Main circuit analysis

### 2.1. Analysis of the main circuit of three-phase bridge rectifier

Generally, the power consumed by three-phase load is generally supplied by diode rectifier bridge, and then supplied to the load through inverter. However, this method injects a large amount of harmonic current into the power grid. This chapter will give a new topology and control circuit to reduce the current total harmonic distortion of three-phase rectifier inverter circuit and improve the power factor. Three bidirectional switches are connected across the AC side and DC side of the conventional three-phase bridge rectifier to form a three-phase bridge rectifier circuit with unity power factor. Well control the on-off of the switch. When the input current is intermittent, provide another path for the input current, so that the input current can meet the requirements of sine wave. Firstly, this chapter re analyzes the working principle of this rectifier circuit, and divides the unit power factor three-phase bridge rectifier into two parts: power factor compensation network and conventional rectifier network. According to its working principle, an accurate mathematical model is established for this rectifier circuit. The main circuit structure of three-phase high power factor rectifier is shown in Figure 1. The rectifier bridge is composed of six fully controlled devices. The inductor isolates the power grid from the AC side of the rectifier. At the same time, it also has the function of filtering, which can filter out the high-frequency harmonics generated by the switching devices due to on and off. The output of the rectifier is connected with a DC capacitor to stabilize the DC output voltage. The main circuit adopts fully controlled devices. In order to realize the sinusoidal current and unit power factor operation, it is necessary to track the grid voltage in real time to control the opening and closing of switching devices. Therefore, this control method is more complex than thyristor rectification.

It can be seen from Figure 1 that the main circuit uses 6 switches. If no effective control measures are taken, problems such as large switching loss and large switching stress of the circuit will occur, which will bring extra burden to the power factor correction. Therefore, under the goal of realizing power factor correction, if the number of switches and switching losses can be effectively reduced, the circuit will have a more concise control effect. Compared with the power factor correction circuit realized by hysteresis control method in parallel 6 switch tubes in the rectifier bridge circuit, a DC/DC switching converter is connected between the rectifier and the load, and the Boost secondary circuit is introduced to make the power factor correction circuit. Hysteresis control has more concise and superior control effect. The circuit uses double closed-loop feedback technology to make the input current track the input voltage waveform, so that the input current waveform is also close to a sine wave, and the purpose of improving the power factor is achieved. The control idea of this circuit is: the AC input voltage is filtered and then rectified, and the obtained rectified waveform is subjected to DC/DC conversion. Through hysteresis control, the waveform of the current at the input terminal can approximately track the voltage waveform at the input terminal, and the input current is obtained. sinusoidal while obtaining a stable output voltage value.

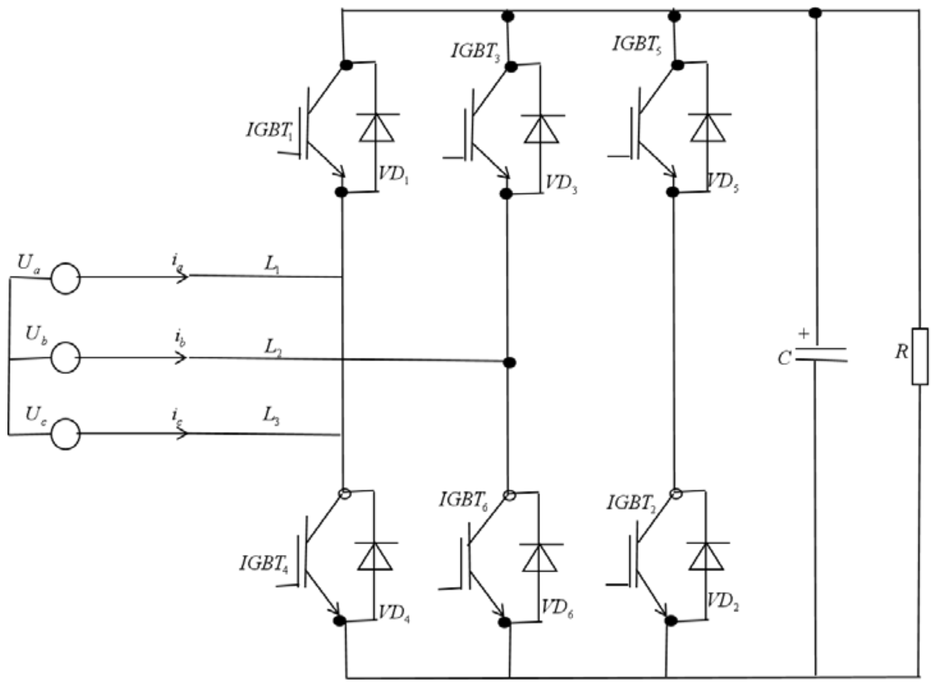


Figure 1 Main circuit structure of three-phase bridge rectifier

## 2.2. Main circuit structure of converter

The traditional three-phase single-stage power factor correction circuit generally has the characteristic of higher DC bus voltage. In order to obtain better power factor correction effect, it is usually necessary to increase the boost ratio (circuit based on boost structure), which leads to higher voltage stress of the system switch tube. A new three-phase single-stage active power factor correction converter is proposed by referring to the structural characteristics and working principles of full-bridge phase shift circuit and Boost PFC circuit and combining with active clamping technology. In this structure, two full bridges are connected in series and an active clamp circuit is used, which greatly reduces the voltage stress of the switch tube.

In the traditional three-phase power factor correction circuit, due to the high voltage of the switch tube, it is necessary to select IGBT as the switching device, and the improvement of the system switching frequency is restricted due to the characteristics of the IGBT itself. General power MOSFETs have a low withstand voltage and are difficult to meet the requirements. The converter uses a full-bridge series structure to reduce the voltage stress of the switching tube, so MOSFET can be selected as the switching device, which is beneficial to improve the switching frequency and the efficiency of the system. There are two windings on the primary side of the high-frequency transformer of the converter, and the number of turns is exactly the same, so the bus voltage of the two bridge arms of the full bridge can be balanced by using the high-frequency transformer. The currents in the two windings of the primary side of the transformer are equal. When the bus voltage of the two bridge arms is different, the energy provided by the bridge arm with relatively high voltage to the load through the transformer increases, and the bus voltage will decrease relatively; The energy provided by the arm to the load through the transformer is reduced, and the busbar voltage is relatively increased, so that the energy balance between the two windings is realized, so the busbar voltage of the two bridge arms is exactly the same. Although the converter uses a large number of switches, it reduces the voltage stress of the switches, so switching devices with relatively low voltage stress of the switches can be selected; the active clamp circuit is used to absorb the voltage spikes generated by the leakage inductance of the transformer, The voltage stress of the switch tube is reduced; all power switch tubes can realize soft switching, which reduces the switching loss and helps to improve the efficiency of the system; the structure does not contain a neutral wire, which is suitable for a three-phase three-wire system; suitable for high-power applications occasion.

## 3. Anti electromagnetic interference design of power factor correction circuit

### 3.1. Filter design

The design of the electromagnetic compatibility circuit working in the power factor correction circuit is the same as that of other types of circuits. It has to deal with the noise interference caused by the high-frequency conversion of electronic devices, and in most cases, these interference noises are also is an unavoidable problem. The use of common mode and differential mode interference filter components in the power factor correction circuit can better filter out the harmonics of the interference. However, because the filter itself also has certain side effects, such as adding a filter to the power factor correction circuit In the future, it may have an obvious effect on filtering out the harmonics in the circuit, but due to the characteristics of various electronic components, under certain circumstances, it will have the opposite effect on improving the power factor of the circuit, that is to say, the electromagnetic interference filter is added. In the power factor correction circuit, the phenomenon of mutual influence may occur, as shown in Figure 2 below.

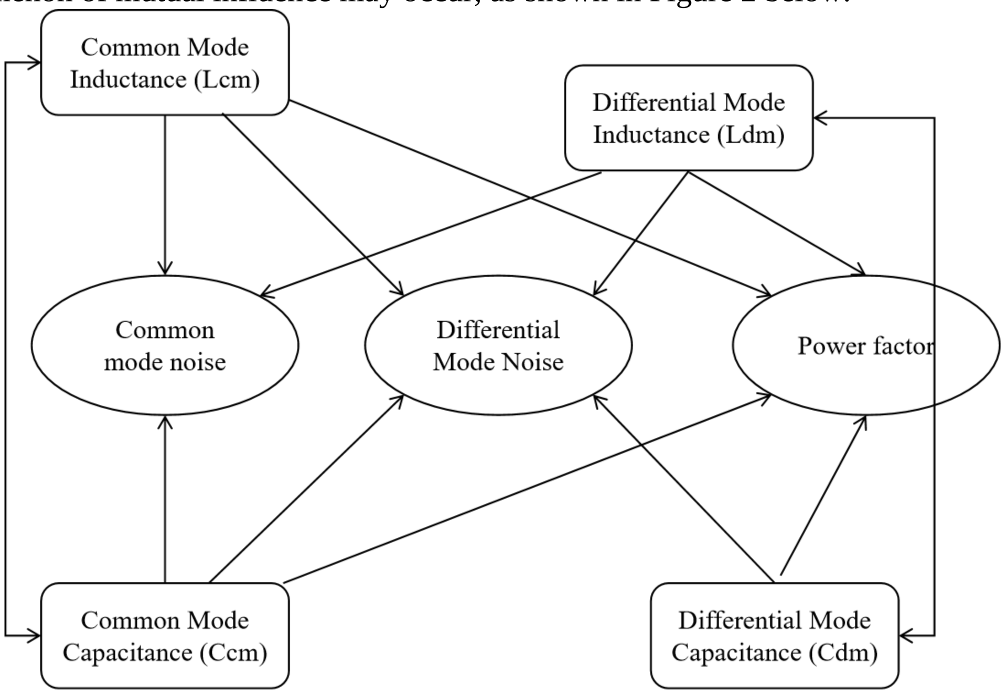


Figure 2 Interaction diagram of power factor correction circuit and anti-electromagnetic interference circuit

The electromagnetic interference filter is generally used to eliminate the interference signal at the AC end of the circuit. If the energy of the interference signal generated in the switching circuit is small, we generally use the leakage inductance of the common mode coil as the differential mode inductance of the electromagnetic interference filter to design the type of filtering, this type of filter can only be regarded as general performance. However, if a high-performance EMI filter is encountered, a magnetic coil is required to surround the filter, which will result in an oversized filter. In circuits with smaller power levels, the utilization of electronic devices is low, and it is difficult to achieve circuits with special requirements for circuit board size. When designing the anti-electromagnetic interference of the power factor correction circuit, it is necessary to consider a series of problems. After the differential mode filter inductor is moved to the DC end of the power factor correction circuit, it will cause certain negative effects on the total harmonic distortion rate of the power factor correction circuit. Therefore, considering the relationship between the electromagnetic interference filter and the various electronic components in the power factor correction circuit, the differential mode filter in the circuit can be directly moved to the DC terminal and integrated with the power factor correction circuit. When choosing a differential mode filter core, it must be noted that the core of the filter is generally a core with a low initial permeability and an open air gap. For the inductance value in the circuit, if the differential mode inductance value if it is too large, it will have a certain negative impact on the total harmonic distortion of the power factor correction circuit. If the value of the differential mode inductance is too small, the circuit will not reach the filtering standard. In the same way, for the capacitance value of the circuit, if the capacitance value is too large, it will affect the power factor of the power factor correction circuit. It has a great impact on the working safety of the circuit. If the capacitance value is too small, the working frequency of the filter will be shifted, and the requirements of the circuit will not be met.

### 3.2. Power factor correction technology

In order to effectively improve the power factor of the rectifier bridge, it is necessary to improve its phase shift factor and reduce its current harmonics. Therefore, in order to improve the power factor of the rectifier bridge and reduce the apparent power absorbed by the rectifier bridge from the power grid, there are two ways: ① providing advanced reactive current to the power grid to compensate for the lagging reactive current of the rectifier bridge ② reducing the demand for lagging reactive current from the load side and reducing harmonic current. The lagging reactive current represents the inductance of the power system itself and the components used in the power system. The lagging reactive current can not be completely eliminated, but it can be reduced by using low reactive current equipment, devices and components. In practice, there is no device that consumes advanced reactive current, so in order to generate advanced reactive current, a specific device must be added to the power system. The simplest method is to install capacitor banks in the power system, and the power factor can be improved by selecting the correct capacitor banks. The classification of power factor correction and harmonic reduction technologies is shown in Figure 3.

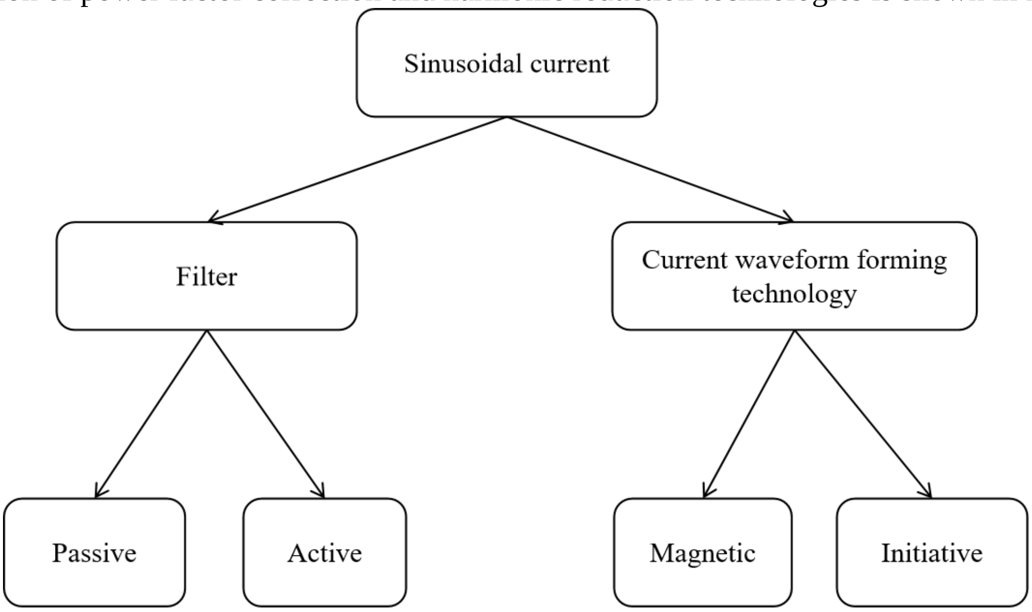


Figure 3 Classification of power factor correction and harmonic reduction techniques

In addition to using capacitor banks, synchronous motors can also be used for reactive power compensation. Synchronous motors used for reactive power compensation are generally called synchronous modulators. The synchronous condenser operates in the state of motor, but without mechanical load. Normally, the synchronous motor absorbs the lagging reactive current from the power grid. However, the synchronous motor working under over excitation absorbs the leading reactive current from the power grid. It is a synchronous motor that only provides reactive power to the power grid. Therefore, by adjusting the excitation current of synchronous motor, it can work in the area of lag, lead and unit power factor, so as to maintain the power factor of power grid at a certain level. Reducing the reactive current and harmonic current absorbed from the power grid from the load side is the focus of this research work. The vast majority of electronic devices will use rectifier circuits to absorb energy from the power grid. However, rectifier is a nonlinear load and produces a large number of harmonic currents. In order to achieve high power factor, the power supply current of the power grid should be close to sinusoidal, and the phase shift between the corresponding voltage and current should be close to 0. In the three-phase rectifier system, the phase shift factor of diode bridge rectifier is almost 1. Using modern control methods to actively control the three-phase rectifier can synchronize the supply current with the corresponding voltage. Therefore, the main task of power factor correction for the three-phase rectifier is to reduce the harmonic current.

## 4. Conclusions

In the design of power supply circuit, the power correction factor circuit is relatively widely used, because the power quality problems it brings are getting more and more attention and attention in the development and application of electronic technology. The power factor correction circuit can increase the power factor of the input terminal by nearly, thus greatly reducing the harmonics of the input terminal current. In this paper, the low power factor of three-phase bridge rectifier is analyzed, and the correction of power factor is completed by introducing the Boost secondary circuit with hysteresis control. Compared with the traditional power factor correction method of three-phase bridge rectifier circuit, this circuit also has the advantages of simple structure, easy control, small number of switches, low cost and fast current dynamic response, etc., which has great use value in practical application.

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