Magnetic Control Reactor Application Effect in Metro Power Supply System Research

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Keywords: Magnetic control reactor, Subway power supply system, Chengdu metro 17

Abstract: This paper introduces the method of reactive power compensation, introduces the characteristics of the MCR, and analyzes the compensation strategy of the MCR of Chengdu Metro Line 17. Taking the actual application effect of the project as an example, through testing and analysis, it is proved that the MCR has a good compensation effect and application prospect.

1. Introduction

Urban rail transit with a large number of high and low voltage cable connected to the power system, cable to produce a large number of capacitive reactive power. And the longer the cable length, the greater the capacitive reactive power. Subway vehicles are inductive loads, which can offset part of the capacitive reactive power of the cables during the subway operation. However, after the shutdown of the subway, a large number of cables will produce capacitive reactive power back to the power grid, which will have a great impact on the harmonics and power factor of the power grid. According to the provisions of the relevant national standards of grid load power factor, harmonic, negative sequence, voltage fluctuation, and so on and so forth must be within the prescribed scope, if can't meet the requirements, will be fine.

Take Chengdu Metro 17 as an example, the power supply system of this line is composed of traction power supply system and power lighting system, which adopts centralized power supply mode. The traction power supply system adopts 110/27.5kV two-stage voltage power supply, and the power lighting power supply system adopts 110/35kV two-stage voltage power supply. According to the daily average data at the initial stage of subway operation, the daily active power of subway is about 300,000 kWh, and the capacitive reactive power of 110kV external power cable is about 800,000 kVar. The reactive power measurement is far greater than the active power measurement, and the power factor is far below 0.9, which will generate a large number of punitive electricity charges. Therefore, it is very important to compensate the subway power supply system for reactive power.

2. Methods Analysis of Reactive Power Compensation

Reactive power compensation device can be divided into fixed compensation device and dynamic compensation device according to the compensation mode. According to inductive and capacitive, it can be divided into inductive compensation device, capacitive compensation device and bipolar compensation device. The reactive power of the subway power supply system is constantly changing over time, so it is necessary to carefully calculate the compensation requirements of capacitive reactive power and inductive reactive power, and then rationally configure the compensation device. Generally, dynamic reactive power compensation device is used for reactive power compensation to ensure that the reactive power of the power supply system can be effectively compensated in time under the circumstances of changes.

The existing dynamic reactive power compensation devices mainly include TCR, SVG and MCR. TCR dynamic reactive power compensation device is difficult to be used in high voltage power system because of its high cost and harmonic problem. SVG dynamic reactive power compensation device under the existing technical conditions of high production cost, reliability can

  DOI: 10.25236/mmmce.2021.010

not be guaranteed, SVG is generally low voltage, small capacity reactive power compensation, generally used in 35kV power supply system for reactive power compensation; MCR type dynamic reactive power compensation device has the advantages of small volume, low cost, small amount of harmonic generated during operation, and work in high voltage, which can be compensated in 35kV, 110kV and other different voltage levels.

The first phase of Chengdu Metro 17 is located in the outer circle of Chengdu. The power source point is relatively far from the subway line, and the capacitive reactive power of the outer power supply line is relatively large. The traction power supply system of Chengdu Metro 17 adopts the first AC power supply system design in China. The power supply system of the whole main station is divided into traction power supply and conventional power supply. The traction power supply system adopts 110/27.5kV two-stage voltage power supply, and the conventional power supply system adopts 110/35kV two-stage voltage power supply.

According to the centralized power supply mode of Chengdu Metro. In the traditional SVG compensation technology, the capacity of 110kV power transformer must be increased to compensate the reactive power of traction load. Because the capacitive reactive power of the external power supply line is large, a large amount of reactive power is fed back from 35kV to 110kV system, which easily leads to system voltage fluctuation. In order to reduce the capacity of 110kV power transformer and reduce the construction cost of SVG, the scheme of setting magnetocontrolled reactor on 110kV side for reactive power compensation came into being.

3. Characteristics of MCR

Magnetically controlled reactor has the advantages of continuous regulation of perceptual reactive power, small harmonics, wide application range of voltage, low loss, high reliability, maintenance free, small occupation area and so on. It can quickly compensate system reactive power, keep the power factor at a higher level, improve the quality of power supply, improve economic benefits, and meet the requirements of complex and changeable power system. Because the magnetic reactor can quickly and smoothly adjust the inductive reactive power, it can better compensate the voltage and frequency disturbance caused by the rapid fluctuating load such as rail transit on the power grid.

CR is composed of reactor body, DC excitation regulating unit cabinet, local controller, master controller and monitoring upper computer. In general, MCR reactor and capacitor bank are used together. MCR reactor and capacitor bank are used as terminal equipment for reactive power compensation of the system. MCR provides adjustable inductive reactive power to the system, while capacitor bank provides capacitive reactive power of fixed capacity. Chengdu Metro 17 adopts the combined compensation mode of MCR+SVG. MCR mainly compensates inductive reactive power, while SVG regulates capacitive reactive power.

(1)MCR reactor body

The structure of the magnetron reactor adopts the technology of stereo valve, the design technology of autocoupled DC excitation circuit and the design technology of new iron core. Solve the problems of large loss, high temperature rise and large noise; In the design process of the magnetron reactor, the design method of electric field-circuit combination is adopted, which greatly reduces the loss of the magnetron reactor, and the MCR body is hung on the compensation network in a △ type way.

(2)Excitation device

The excitation device is responsible for providing the excitation current of the MCR to realize the increase and decrease of the MCR capacity. The excitation current loop is based on the principle of single-phase half-bridge thyristor rectifier circuit, and the thyristor is used as a switching device, which can withstand high voltage and large current and has high stability.

(3)Control system

It is developed based on DSP, a high speed digital signal processing chip. The instantaneous reactive power algorithm and the closed-loop control algorithm based on learning idea are used to realize the optimal control of the magnetron reactor. Real-time acquisition of reactor voltage and current signals; Perfect anti-interference control, safe and reliable.

4. Analysis of Compensation Strategy for MCR

The working mode of the MCR has two modes: fixed compensation and automatic compensation. According to the needs of the system, it can be operated in one way. SVG dynamic reactive power compensation device can also be optional between fixed compensation and automatic compensation. The reactive power compensation of Chengdu Metro 17 adopts the combination of the MCR on the 110kV side and the SVG device on the 35kV side. For this reason, the compensation methods of the two kinds of equipment are as follows:

①MCR fixed compensation +SVG automatic compensation

Compensation strategy: according to the set inductive reactive power compensation value of the magnetron reactor, the closed-loop control mode is adopted and the constant inductive reactive power output is continuously calculated and controlled by referring to the voltage and current signals at the inlet side of the magnetron reactor. The SVG compensation device takes the voltage and current signals of the 110kV input line of the main substation as the reference, takes the set power factor or reactive power compensation value as the control target, and adopts the open-loop control method to adjust the compensation output at any time to achieve the set power factor or reactive power compensation value. In this compensation mode, the target of the MCR can be undercompensated or overcompensated.SVG will automatically output capacitive or inductive reactive power within the rated capacity range to balance the reactive power of the system, and finally achieve the set compensation goal.

②MCR automatic compensation +SVG fixed compensation

Compensation strategy: SVG compensation device adopts closed-loop control mode according to the set value, and continuously calculates and controls the output constant reactive power with reference to the voltage and current signals on the line side of SVG equipment. MCR takes the voltage and current signals of the 110kV input line of the main substation as reference, takes the set power factor or reactive power compensation value as the control target, and adopts the open-loop control method to adjust the compensation output from time to time to achieve the set power factor or reactive power compensation value.

③MCR automatic compensation +SVG automatic compensation.

Compensation strategy: MCR and SVG equipment take the incoming line voltage and current of the main substation as the reference for calculation, and continuously and dynamically output reactive power to make the incoming line reactive power reach the set compensation target value.

5. Compensation Effect of MCR

In the actual operation, after debugging verification. Because the reference points of the automatic compensation mode of the magnetoreactor and SVG are both on the input side of the 110kV power supply, if the two sets of equipment are in the automatic compensation situation, the system will be oscillated, the compensation effect cannot be achieved, and even the fault exit of the compensation equipment will be caused. The former two compensation operation modes are actually adopted in the field. The actual operating data of reactive power compensation of the main substation of Chengdu Metro 17 Phase I is as follows:

Serial number	Name of the substation	Device Operation Mode	Normal operation monthly average power factor	Note
1	Yong yi main substation	(1#MCR:Fixed compensation +15.6Mvar)+(1#SVG:Automatic compensation±5.0Mvar)	⩾0.95	
2		(2#MCR:Fixed compensation +10.5Mvar)+(2#SVG:Automatic compensation±5.0Mvar)		

3	WU tong miao main substation	(1#MCR:Fixed compensation +8.5Mvar)+(1#SVG:Automatic compensation±5.0Mvar)	⩾0.95	
4		(1#MCR:Automatic compensation)+(1#SVG:Fixed compensation -1.1Mvar)		

Note:+capacitive reactive power,-capacitive reactive power.

According to the test, the inductive reactive power drift of the actual output of the magnetoreactor is great after the excitation Angle is set according to the compensation capacity due to the influence of the temperature of the device and the system voltage during the fixed compensation operation. There is a drift of about -0.5 to +0.5 MVAR. Because of the combined use of the magnetoreactor and SVG, the drift of the magnetoreactor in the fixed compensation mode can be compensated by the SVG in the automatic compensation mode. According to the monthly electricity meter reading data of State Grid Corporation, the power factors of both 110kV lines of Yongyi main substation are greater than 0.95, meeting the design requirements.

When the MCR is automatically compensated, the operation of the 2#MCR in the Wutongmiao main substation is counted and the reactive power of the system is set as 0.15mVar. According to the actual output of daily observation, the dynamic compensation error of the MCR controller is less than 0.1mVar. According to the monthly power meter reading data of State Grid Corporation, the power factor of the 2# 110kV line in the Wutongmiao main substation is greater than 0.95. Also meet the design requirements.

To sum up, there is a certain data drift in the fixed compensation output of the MCR, and SVG is needed for dynamic compensation adjustment, so that the power factor of the system can reach a better level in the end. When the MCR automatically compensates the output, although the compensation error also exists, the power factor can also reach a better level by comprehensive monthly electric quantity calculation.

6. Compensation Disadvantages of MCR

MCR has many advantages in application, but in the construction and operation of Chengdu Metro 17, it also highlights some shortcomings of it.

(1) Large volume of equipment, transportation and installation difficulties

The volume of MCR is similar to that of oil-immersed transformer, and it is a larger equipment with heavier weight. Therefore, it is relatively difficult to transfer and install MCR. Subway projects are limited by occupation area, and equipment is usually installed indoors, which also increases the difficulty of the installation and maintenance of the MCR.

(2) The noise and heat of equipment operation are large

The MCR generates a large amount of heat during operation. According to the traditional way of natural ventilation oil circulation can not meet the cooling needs, so MCR body design oil pump. After the power is sent to the reactor, the oil pump is always turned on, so that the insulating oil in the reactor body is always in a forced circulation state, so as to promote the heat emission of the reactor body. Due to indoor installation, a strong exhaust system is usually provided on the wall of the equipment room to promote indoor and outdoor air circulation. For this reason, the noise in the reactor room is larger and the indoor temperature is generally higher, which causes some discomfort to the daily inspection of the maintenance personnel on duty in the substation.

(3) The compensation accuracy is low

The minimum adjustable range of MCR is 0.1mVar (100kVar), whether it is dynamic compensation or static compensation. Compared with the adjustment accuracy of 0.01 mVar of SVG dynamic reactive power compensation device, the compensation accuracy of the MCR is too low. In addition, due to the influence of the control strategy of the equipment itself, there is a certain drift phenomenon in the fixed compensation operation of the MCR. The drift of 0.1MVar will lead to unstable power factor when the active power of the system is small.

(4) The MCR compensation function does not switch flexibly

MCR compensation mode has two operating modes: fixed compensation mode and automatic compensation mode. When switching from one mode to another compensation mode during actual operation, MCR must be shut down before switching. When MCR is running, mode switching will result in a malfunction shutdown, which is not flexible enough compared to SVG.

7. Conclusion

With the rapid development of urban rail transit construction, especially the metro main substation with a long power supply distance, the capacitive reactive power of the external power cable needs large capacity compensation equipment to compensate the reactive power. The MCR can adjust the compensation capacity according to the power point length, which is more flexible than the fixed reactor compensation. The magnetic reactor in the main substation of the subway power supply system is generally installed at the voltage level of 110kV. Compared with the SVG dynamic compensation method, the design capacity of the power transformer can be reduced and the construction cost of SVG equipment can also be saved. Therefore, MCR has a good application prospect in rail transit industry.

In the subway power supply system, the power load is: cable (capacitive) + power equipment (inductive) + lighting equipment (resistive) + traction equipment (inductive). According to the power source assessment, the capacitive reactive power of the metro power supply system is relatively large, and the inductive reactive power needs to be compensated. If only from the power factor compensation effect, MCR alone for dynamic compensation, basically can meet the power factor values required by the specification, can omit the configuration of SVG equipment, greatly reducing the initial construction cost of the project.

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