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Successful Application of Permanent Magnet Speed Regulation Technology in Power Plant Slurry Circulation Pump

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Abstract: *This paper focuses on the application of the permanent magnet speed regulation transformation of the desulfurization slurry circulating pump in Guangxi Guoneng Nanning Power Generation Co., Ltd. of the national energy group. Through the comprehensive analysis of three schemes of hydraulic coupling speed regulation, frequency conversion speed regulation and permanent magnet speed regulation, the permanent magnet speed regulation scheme is finally selected. During the transformation, the design, manufacture, transportation, installation and commissioning of the equipment were carried out in detail, and the comprehensive benefit analysis of the transformed system was carried out. The results show that the permanent magnet speed regulation transformation of slurry circulating pump has the characteristics of strong operability, high reliability and remarkable energy saving effect. After the transformation, the system operates stably, the power saving rate reaches 33%, the annual power saving is significant, and the transformation workload of the original system is small, and the later maintenance cost is low. This technology has high popularization value in the industrial field.*

Keywords: *Slurry circulating pump, Permanent magnet governor, Energy conservation*

1. Introduction

Nanning Power Generation Co., Ltd. is located in Nanning, the capital of Guangxi Zhuang Autonomous Region, which is located in the regional load center and has significant geographical advantages. Nanning has convenient transportation and developed highway and railway network, which provides extremely convenient conditions for the fuel transportation of the power plant [1]. The power plant mainly burns anthracite and bituminous mixed coal supplied by Guizhou Province, which is transported directly to the plant by railway to ensure the stability and economy of fuel supply. In addition, the water resources around the power plant are sufficient and the engineering geological conditions are good, which can meet the requirements of power plant construction and long-term operation. The basic seismic intensity of the plant area is 6 degrees, which meets the relevant national seismic design standards and provides a reliable geological guarantee for the safe operation of the power plant.

Guoneng Nanning Power Generation Co., Ltd., as an important part of Guangxi Company of State Energy Group, undertakes the important task of regional power supply. With the continuous improvement of national requirements for energy conservation and environmental protection, power plants are committed to reducing energy consumption and pollutant emissions while pursuing efficient power generation. In recent years, with the rapid development of the power industry, desulfurization technology has been widely used in thermal power plants. One of the core equipment of the desulfurization system is the slurry circulating pump, whose main function is to circulate the slurry in the absorption tower to ensure that the sulfur dioxide in the flue gas fully reacts with the slurry, so as to achieve the goal of desulfurization. However, the traditional slurry circulating pump system is usually driven directly by the power frequency motor, which lacks effective means of speed regulation, resulting in high energy consumption. In order to improve the energy utilization efficiency, reduce the auxiliary power consumption rate and meet the requirements of environmental protection, Guoneng Nanning Power Generation Co., Ltd. decided to carry out energy-saving transformation on the desulfurization C slurry circulating pump of # 1 and # 2 units.

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The modified desulfurization C slurry circulating pump of # 1 unit and # 2 unit has a motor power of 1400kW and a rated speed of 1479 rpm. Because the slurry circulating pump system is not equipped with a regulating valve, the pump is fully open after starting, and the operating power is high. Before the transformation, the operating power of the motor was 1121kW (current 124A), and the energy consumption was large. In order to achieve the goal of energy saving, the power plant decided to use permanent magnet speed control technology to transform the slurry circulating pump after considering a variety of speed control methods [2]. The transformation includes the design, manufacture, transportation, installation and commissioning of the equipment until the equipment operates economically and reliably. In the energy-saving reconstruction of slurry circulating pump, permanent magnet speed regulation technology has achieved remarkable energy-saving effect in many domestic thermal power plants, and has accumulated rich application experience.

2. Selection of transformation scheme

In the process of energy-saving transformation of slurry circulating pump in Guoneng Nanning Power Generation Co., Ltd., choosing the appropriate speed control scheme is the key link to achieve the energy-saving goal. At present, the speed regulation methods of high-power high-voltage asynchronous motor mainly include hydraulic coupling speed regulation, variable frequency speed regulation and permanent magnet speed regulation.

2.1 Analysis of speed regulation of hydraulic coupler

As a traditional speed control device, the working principle of hydraulic coupling is based on the basic theory of fluid dynamics. When the motor drives the pump impeller to rotate, the liquid in the pump impeller is thrown to the turbine under the action of centrifugal force to push the turbine to rotate, thus driving the load to operate. The speed ratio between the pump wheel and the turbine can be changed by adjusting the liquid filling amount in the working chamber, so that stepless speed regulation is realized. The hydraulic coupler has excellent starting performance, which can realize the soft start of the motor, effectively reduce the impact of the starting current on the power grid, and reduce the mechanical impact on the load during starting. In addition, the hydraulic coupling also has the overload protection function, when the load increases suddenly, the output speed is automatically reduced through the slip of the liquid, thus playing the role of protecting the equipment [3].

However, the hydraulic coupling speed control system also has some obvious limitations. The hydraulic coupling has a large energy loss in the process of power transmission, especially at low speed, the efficiency is low, which makes its performance in energy saving is not ideal. The maintenance work of hydraulic coupling is more complex, which requires regular replacement of working oil, and is prone to oil seal leakage, bearing wear and other problems, which not only increases the maintenance cost, but also may lead to reduced reliability of equipment operation. The speed regulation range of hydraulic coupling is usually narrow, which is difficult to meet the speed regulation requirements of slurry circulating pump under different working conditions. With the increasing requirements of energy saving and reliability in modern industry, the hydraulic coupling speed control system gradually exposes its deficiencies in efficiency and maintenance, which makes it difficult to adapt to the current development trend of science and technology.

2.2 Analysis of variable frequency speed regulation

Frequency conversion technology is widely used because of its efficient energy-saving effect and wide range of speed regulation. By changing the power supply frequency of the motor, variable frequency speed regulation can realize the precise control of the motor speed. Its core principle is based on the proportional relationship between the motor speed and the power supply frequency. Regulating the power supply frequency of the motor through the frequency converter can realize the stepless speed change of the motor speed, thereby meeting the flow and pressure requirements under different working conditions. Variable frequency speed regulation technology is excellent in energy saving, especially in part load operation, which can significantly reduce the energy consumption of the motor. In addition, the variable frequency speed regulation system also has good dynamic response performance, which can quickly adapt to the changes of the load and ensure the stable operation of the system.

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However, the variable frequency speed regulation technology also faces some challenges in practical application. The initial investment cost of the variable frequency speed regulation system is relatively high, which is mainly due to the price of the frequency converter equipment itself and the related installation and commissioning costs. The harmonic pollution of variable frequency speed regulation system to power grid can not be ignored. The frequency converter will produce a large number of higher harmonics in the operation process, which will interfere with the normal operation of the power grid and affect the performance of other equipment. Therefore, corresponding harmonic suppression measures are needed, which further increases the complexity and cost of the system. The reliability of variable frequency speed regulation system is affected by the quality of power grid to a certain extent. In the case of large voltage fluctuation or harmonic interference in the power grid, the operation of the frequency converter may be disturbed, or even lead to equipment failure. In the slurry circulating pump transformation project of Guoneng Nanning Power Generation Co., Ltd., the implementation of variable frequency speed regulation scheme is limited because the power plant did not reserve the space of the variable frequency room at the beginning of the design. This phenomenon has a certain universality in the transformation project of thermal power plant, which limits the application scope of variable frequency speed regulation technology.

2.3 Analysis of speed regulation of permanent magnet governor

In recent years, as a new speed control method, permanent magnet speed control technology is gradually emerging in the industrial field. The operating principle of the permanent magnet governor is based on the fundamental principles of electromagnetic induction and magnetic field coupling. Its core components include a conductor disk and a permanent magnetic disk. When the motor drives the conductor disc to rotate, the conductor disc cuts the magnetic field of the permanent magnetic disc. According to the law of electromagnetic induction, eddy current is generated in the conductor disc, and then a reverse magnetic field is generated, which interacts with the magnetic field of the permanent magnetic disc to generate torque and drive the load to run. By adjusting the air gap distance between the conductor disk and the permanent magnetic disk, the magnetic field coupling strength can be changed, and then the stepless adjustment of the load speed can be realized.

Permanent magnet governor has many significant advantages. It is simple in structure and does not need complex mechanical connection and fluid medium, thus reducing maintenance workload and fault points. The permanent magnet speed regulator has a wide speed regulation range and can meet the requirements of the slurry circulating pump under different working conditions. The energy-saving effect of permanent magnet speed governor is remarkable, and the unnecessary energy loss is reduced by optimizing the matching between the motor and the load. At the same time, the permanent magnet governor also has good soft start performance, which can effectively reduce the impact of starting current on the power grid and protect the motor and load equipment. In the slurry circulating pump transformation project of Guoneng Nanning Power Generation Co., Ltd., these advantages of permanent magnet governor make it an ideal speed control scheme [4].

Through the comprehensive analysis of hydraulic coupling speed control, variable frequency speed control and permanent magnet governor speed control, combined with the specific conditions and needs of Guoneng Nanning Power Generation Co., Ltd., the permanent magnet governor speed control scheme is finally selected. This choice not only considers the energy-saving effect and reliability, but also takes into account the maintenance cost and implementation difficulty of the system. As a new speed control technology, the application of permanent magnet governor in the transformation of slurry circulating pump provides a new idea and solution for the energy-saving transformation of thermal power plants.

3. Working principle of permanent magnet speed regulation

The principle of permanent magnet drive (see Figure 1) is that the motor drives a conductor disk (driving rotor) to rotate. After the conductor disk cuts the magnetic field on a magnetic disk (driven rotor), eddy current is generated on the conductor disk (driving rotor) according to the Leng magnetic law, and then an opposite magnetic field is generated. The relative action with the magnetic field of the magnetic disk (driven rotor) generates a torque force to drive the magnetic disk (driven rotor). Drive the load at the same time. On the basis of the above, a device for adjusting the distance between the magnetic disk and the conductor disk is added to the permanent magnet speed regulator to control the intensity of the cutting magnetic field so as to achieve the purpose of adjusting the load speed. It can be seen from the

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principle that the structure is simple and reliable, the maintenance is low, the problem of centering between the load and the motor is solved, and it is also a mechanical soft starter.

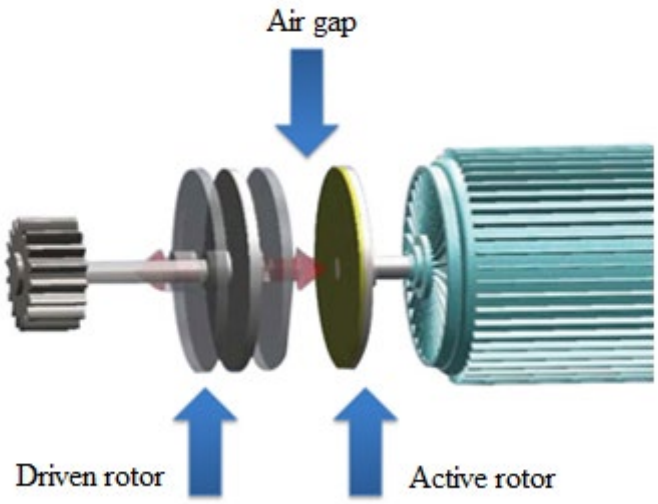

Figure 1. Schematic of a Permanent Magnet Drive

In the permanent magnet speed control system, the adjustment of the air gap is the key link to realize the speed control. When the air gap increases, the magnetic field coupling strength between the conductor disk and the permanent magnetic disk weakens, and the load speed decreases. On the contrary, when the air gap is reduced, the magnetic field coupling strength is enhanced, and the load speed is increased. This regulation method not only realizes stepless speed change, but also avoids the common problems of mechanical wear and energy loss in the traditional speed regulation method. This operating principle of the permanent magnet governor makes it excellent in terms of energy saving and reliability, especially suitable for applications requiring frequent speed regulation, such as slurry circulating pump systems.

The structural design of the permanent magnet governor also provides a guarantee for its efficient operation. Its core components, conductor disk and permanent magnetic disk, are made of special materials and processes to ensure the stability and strength of the magnetic field. The conductor disk is usually made of a metal material with high conductivity to minimize eddy current losses; Permanent magnetic disks are made of high-performance permanent magnetic materials, such as neodymium iron boron, which have high magnetic energy product and high coercivity, and can produce strong magnetic fields in a small volume. In addition, the permanent magnet governor is equipped with an advanced control system, which monitors the change of air gap in real time through sensors, and precisely adjusts the air gap distance through actuators, thus realizing the precise control of load speed.

In practical application, the energy-saving effect of permanent magnet governor is particularly significant. Taking the slurry circulating pump as an example, the traditional speed control method often controls the flow by adjusting the valve. Although this method is simple, it will cause a lot of energy to be wasted in the form of pressure loss [5]. The permanent magnet governor controls the flow by adjusting the motor speed, which avoids unnecessary energy loss and achieves significant energy saving effect. According to the actual test data, the energy consumption of the slurry circulating pump can be reduced by more than 30% after the permanent magnet governor is adopted, which has important economic and environmental significance for large energy consumers such as thermal power plants.

In practical applications, the installation and debugging of the permanent magnet governor is also relatively simple. Taking the slurry circulating pump transformation project of Guoneng Nanning Power Generation Co., Ltd. as an example, the permanent magnet governor is installed between the motor and the load, and the installation can be completed through simple mechanical and electrical connections. In the debugging process, the air gap distance is finely adjusted by the control system, so that the accurate control of the load rotating speed can be realized. This installation and debugging method not only saves time and labor costs, but also reduces the changes to the original system, and improves the compatibility and reliability of the system.

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4. Actual transformation scheme

In the energy-saving reconstruction project of slurry circulating pump of Guoneng Nanning Power Generation Co., Ltd., the application of permanent magnet speed regulation technology requires not only theoretical feasibility analysis, but also practical operation to ensure the feasibility, economy and reliability of the technology.

4.1 Preparation and planning before reconstruction

Before the implementation of the permanent magnet speed regulation transformation of the slurry circulating pump, Guoneng Nanning Power Generation Co., Ltd. has carried out a comprehensive preparatory work to ensure the smooth progress of the transformation process and the realization of the transformation objectives. Firstly, the project team carried out detailed data collection and analysis on the operation parameters of the desulphurization C slurry circulating pump of # 1 unit and # 2 unit, including motor power, speed, flow, head and actual operation conditions. Through the analysis of these data, the performance indicators of the system after transformation are determined, such as energy-saving effect, speed range and system stability.

In terms of technology selection, after many demonstrations and comparisons, the project team finally chose the WF-TW850 horizontal installation oil-cooled permanent magnet speed regulation system produced by Anhui Wofu Permanent Magnet Technology Co., Ltd. The complex environment of industrial field is fully considered in the structural design of the system, which has the characteristics of high reliability and low maintenance. At the same time, the oil cooling mode can effectively reduce the operating temperature of the equipment, prolong the service life of the equipment, and ensure the stability in long-term operation. In order to ensure the smooth progress of the renovation work, the project team also formulated a detailed construction plan and contingency plan. The construction plan includes the time nodes and responsible persons of each link of equipment disassembly, transportation, installation and commissioning. In view of the possible technical problems, equipment failures and safety risks, the contingency plan has formulated corresponding solutions and countermeasures to ensure the safety of personnel and equipment in the process of transformation. In preparation for the renovation, the project team also carried out a comprehensive inspection and optimization of the site's electrical system. Because the permanent magnet speed regulation system needs to be seamlessly connected with the original motor and control system, the laying of high-voltage cables, the upgrading and transformation of control cabinets and the operation interface of DCS (Distributed Control System) are optimized. Through these preparations, it ensures that the modified system can run efficiently under the original control architecture, and lays a solid foundation for the subsequent debugging work.

4.2 Technical implementation in the transformation process

In the process of transformation, technology implementation is the key link to ensure the success of the project. The slurry circulating pump transformation project of Guoneng Nanning Power Generation Co., Ltd. adopts the horizontally installed permanent magnet speed regulation system, which not only saves space, but also facilitates the maintenance and repair of equipment. The specific implementation steps are as follows:

Firstly, the high-voltage motors of the desulphurization C slurry circulating pump of # 1 unit and # 2 unit are lifted out. This process requires precise lifting equipment and professional operators to ensure that the motor is not damaged during the lifting process. At the same time, in order to adapt to the installation of the permanent magnet speed regulation system, the connection part between the motor and the reducer is redesigned and processed to ensure that the permanent magnet speed regulator can be firmly installed between the motor and the load.

Secondly, the installation of permanent magnet speed regulation system is the core link of the whole transformation process. During installation, technicians shall strictly follow the installation manual provided by the equipment manufacturer to ensure that the air gap distance between the conductor disk and the permanent magnet disk meets the design requirements. Because the size of the air gap directly affects the speed regulation performance and energy saving effect, high-precision measuring tools and adjusting devices are used in the installation process to ensure the uniformity and stability of the air gap. At the same time, in order to ensure the heat dissipation performance of the equipment, strict sealing and

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pressure tests have been carried out on the oil cooling system to ensure that there will be no oil leakage in the long-term operation.

In terms of electrical connection, the project team has optimized and adjusted the original high-voltage cable. Because the permanent magnet speed regulation system needs to be electrically connected with the motor and the load, the length and laying path of the cable are re-planned. By reasonably adjusting the length of the cable, the loss of the cable is reduced, and the problem of signal interference caused by the overlong cable is avoided. In addition, the control cable of the electric actuator is laid, and the corresponding control module is added to the DCS operation interface, which realizes the remote monitoring and operation of the permanent magnet speed regulation system.

In the process of transformation, the project team also pays special attention to the compatibility of the original system. Because the slurry circulating pump system plays a key role in the desulfurization process of the power plant, the modification of the original system is minimized in the transformation process. By optimizing the design, the permanent magnet speed control system can achieve seamless docking under the original pipeline layout and electrical architecture, thus reducing the workload and downtime of the transformation. At the same time, in order to ensure the long-term stable operation of the transformed system, the project team has checked and verified the installation accuracy and reliability of the equipment many times to ensure that every link meets the design requirements.

4.3 Commissioning and optimization after transformation

After the transformation, debugging and optimization are the important links to ensure the permanent magnet speed control system to achieve the desired performance. The debugging work mainly includes the test and adjustment of the electrical parameters, mechanical properties and speed control accuracy of the permanent magnet speed control system. Firstly, the electrical parameters of the permanent magnet speed regulation system are tested comprehensively, including the starting current, operating voltage and power factor of the motor. Through the detection of these parameters, we can ensure that the equipment can maintain good electrical performance during operation, while avoiding adverse effects on the power grid.

In the aspect of mechanical performance, the vibration, noise and temperature of the permanent magnet speed regulation system are monitored in real time. Through the vibration sensor and noise detector, the running state of the equipment is evaluated comprehensively. During the commissioning process, technicians fine-tuned the installation accuracy and air gap distance of the equipment according to the monitoring data to ensure that the equipment can run smoothly and reduce mechanical vibration and noise pollution. At the same time, the temperature of the oil cooling system is monitored in real time to ensure that the equipment will not be overheated in long-term operation.

The test of speed control accuracy is one of the key points of debugging work. By changing the load conditions, the speed control range and accuracy of the permanent magnet speed control system are tested comprehensively. The test results show that the permanent magnet speed regulation system can realize stepless speed regulation in the range of 100% ~ 70% rated speed, and the speed regulation accuracy meets the design requirements. During the commissioning process, technicians optimized and adjusted the parameters of the control system to ensure that the equipment can achieve stable speed regulation under different working conditions, while meeting the flow and lift requirements of the slurry circulating pump. During the optimization process, the project team also evaluated the energy saving effect of the system. Through the comparative analysis of the running power of the motor before and after the transformation, the power saving rate of the permanent magnet speed regulation system is calculated to reach 33%. This energy-saving effect not only meets the expectations of the project, but also brings significant economic benefits to the power plant. At the same time, through the long-term operation monitoring of the system, it is found that the permanent magnet speed regulation system has high reliability and low maintenance, which can effectively reduce the operation cost and maintenance workload of the equipment.

Through the detailed implementation of the above three stages, the slurry circulating pump permanent magnet speed regulation transformation project of Guoneng Nanning Power Generation Co., Ltd. has not only achieved success in technology, but also achieved the expected goal in economic and environmental benefits. After retrofit, the system runs stably and the energy saving effect is remarkable, which provides a successful example for the energy saving retrofit of thermal power plants. With the continuous development and application of permanent magnet speed regulation technology, its promotion prospects in the industrial field will be broader.

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5. Benefit analysis after transformation

Slurry circulating pump parameters: model 800DT-A90, rated flow Q = 8904m 3 /H, lift H = 24.1m, pump speed n = 618 rpm, motor power P = 1400kW, motor speed n = 1491rpm, motor rated current I = 153A, Slurry density 1.1 × 10 3 kg/m 3 .

Before the transformation, the operating power of the motor is P = 1121kW, the operating flow is Q = 8904m 3 /H, the lift is H = 24.1m, and there is no regulating valve. The sulfur content in the flue gas at the outlet of the desulfurization tower is basically controlled within 20 mg/Nm 3 and maintained below 15 mg/Nm 3 for a long time, which is far below the national standard and the common standard of 35 mg/Nm 3 in other plants.

Although the desulfurization system is composed of four pumps, the single pump is an independent inlet and outlet pipeline, which has no influence on each other and only affects the total amount of desulfurization. Another condition of the slurry circulating pump is that the static pressure is very high. Take this case as an example: the height difference between the center line of the outlet of the # 1 # 2 unit C slurry circulating pump and the center line of the inlet on the tower is 28.1m, the maximum lift of the pump is 24.1m, and the liquid level in the tower is generally maintained at 10m. Therefore, this kind of pump has two characteristics when adjusting the speed: 1. The speed adjustment range of the pump is not large, about 100% ~ 70% of the rated speed; 2. When adjusting the speed, the flow changes very fast relatively (pressure). These are the characteristics of single pump system and equipment with high static pressure after speed regulation. Therefore, although the speed adjustment range of the slurry circulating pump is not large, the overall energy saving is very considerable due to the rapid change of the flow.

After the transformation, the output speed of the permanent magnet is adjusted to 1220 rpm, the operating current is 83.0 A, the operating power is calculated to be 750kW, and the power saving rate is (1121-750)/1121 = 33%. According to the statistics of the sulfur content in the past six months, it is found that the sulfur content is basically controlled within 20 mg/Nm 3 , which is still a very low value.

At the same time, when the speed of slurry pump of Guoneng Nanning Power Plant is 1200 rpm, check the nozzle (Figure 2), and there is no blockage at all.

Figure 2. Photo of Nozzle Condition

Compared with frequency conversion and hydraulic coupling, the permanent magnet governor is easy to maintain, has high reliability, and reduces the maintenance rate of the slurry circulating pump and the motor. It has incomparable advantages in installation, equipment alignment, vibration and other aspects, and has not done any maintenance so far.

Before the transformation of the slurry circulating pump, the annual power consumption of a single motor was 8.96 million kwh based on the annual operation time of 8000 hours. After the permanent magnet speed regulation was adopted, the annual power saving was 2.95 million kwh based on the power

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saving rate of 33%. Based on the current power generation price of 0.42 yuan/kwh, the power saving of a slurry circulating pump motor was about 1.24 million yuan/year, and the energy-saving effect was remarkable.

6. Conclusion

The slurry circulating pump of # 1 # 2 unit C in Guoneng Nanning Power Generation Co., Ltd. operates well after energy saving transformation of permanent magnet speed regulation. The permanent magnet speed regulation transformation of the slurry circulating pump can ensure that the desulfurization system is in a good operation state, change the situation that the original desulfurization system can only adopt the number of switches to adjust the desulfurization effect to adapt to the low power generation load, and can also obtain a good energy-saving effect, and the workload of the original system transformation is not large, the equipment structure is simple, the failure rate is low, the later maintenance cost is low, the reliability is high, and the service life is long. The occupy area is small and it can operate stably for a long time. At present, there are more than 4000 cases of this product in the transformation of desulfurization system of slurry circulating pump in China, and the use effect is good. Permanent magnet drives have high promotional value in China's metallurgy, petrochemical, mining, power generation, cement, paper pulp, shipping, warships and other industries.

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