

Structure and Application of Flywheel Energy Storage-A Simple Perspective

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Abstract: Flywheel energy storage is a new sustainable development technology, which has the advantages of high energy storage density, fast charging and discharging speed, long service life and so on. It breaks through the constraints of traditional chemical fuel cells and stores energy in a physical way. This paper discusses the structure and composition of flywheel energy storage, introduces three kinds of common and practical high-speed motors for flywheel, and three kinds of powerful flywheel magnetic levitation bearings. The development of flywheel energy storage in different industries and the reuse of resources in different situations are introduced. The application of flywheel energy storage technology to achieve energy saving and emission reduction production has a broad market application prospect.

Keywords: Flywheel energy storage, Motors, Magnetic levitation bearing.

1. Introduction

'Along with society's progress, honest electrification degree is higher and higher, people demand for power is more and more big, the global output also increased year by year, non-renewable energy of conventional oil has dried up, at present, countries around the world are vigorously develop renewable energy sources, relying on solar energy, wind energy won rapid development of new energy power generation, however, Because the power generation conditions are completely controlled by the meteorological conditions the power generation is uncertain and intermittent, so it cannot provide stable power for a long time.'[1]The intermittency problem of new energy generation can be solved by the technology of storing electricity with other forms of energy and converting it into electricity at a specific moment. Flywheel energy storage device is a device that uses mechanical power conversion to store energy. It stores electric energy in a physical way instead of the traditional chemical way, which will not cause any pollution.

2. Flywheel Energy Storage Structure

The flywheel body is the core component of the flywheel energy storage system. Its function is to increase the ultimate angular velocity of the stator and reduce the stator load, so as to maximize the storage capacity of the flywheel energy storage system. Generally, it is made of carbon fiber. The characteristics of bearing type system are directly related to the stability, quality and life of flywheel energy storage system. The actual application of flywheel energy storage system generally adopts maglev train technology to reduce the wear of engine stator in operation, so as to reduce bearing loss and improve the quality of energy storage. The switch between the mechanical energy and electricity of the flywheel energy storage device is based on the control system of the electric/generator. The generator integrates a component. During the energy storage period, the operation of the generator drives the generator with external energy, and drives the rotation of the free wheel rotor to a specified speed;

When electricity is generated, the motor acts as a generator, transmitting energy to the outside world, while the speed of the free wheel decreases. Obviously, low loss, high performance generator is the basis of efficient power transmission. The power conversion device is mainly used to increase the sensitivity and controllability of the flywheel energy storage device, so that the output energy conversion (frequency modulation, rectification or constant voltage, etc.) is in line with the load power supply conditions of energy. The main function of the vacuum chamber is to create the maximum vacuum condition and reduce the wind resistance loss in the operation of the fan. Flywheel energy storage system generally consists of three parts: rotor system, bearing system and rotating energy system.

2.1. High speed motor for flywheel

In order to achieve more effective conversion of power and machine energy in the energy storage system, and increase the energy storage capacity of the flywheel energy storage system, it is necessary for the fan used in the flywheel energy storage system to have large rotation efficiency and fast operation efficiency, that is, the stator can accept the high-speed rotating centrifugal force and stable, small rotation loss, high efficiency. 'The motor plays an important role in the flywheel energy storage. The quality of the flywheel is directly related to the efficiency. The common types of motors are induction motor, switch reluctance motor, and permanent magnet synchronous motor.'[2]

2.1.1. Induction motor

The induction motor is different from the conventional motor, the magnetic circuit of the motor needs to be analyzed first. The ring excitation winding is directly connected to the excitation current, and the main magnetic flux generated by the direction of the rotating parts flows through the moving part to the left 0.5 part of the stator. According to the principle of reluctance size, because the stator punch tooth magnetic resistance value is very small, so all the magnetic current flows through the stator rotor teeth, into the air gap size; Some stator slots have large reluctance, and a small amount of flux

passes through the stator slots and flows into the air gap. After the air gap, a large number of magnetic flux into the stator core, again after the stator core rod into the rotor casing, machine flux through, must choose permeability material. The magnetic flux first passes through the housing to the rod center at part right zero point five of the stator, and then most of the magnetic flux passes through the size of the air gap into the rotor teeth at part right zero point five of the stator, and then returns to the closed output circuit of the stator. The magnetic flux direction of the left and right parts of the rotor remains unchanged, so it is called the same pole inductor motor. When the rotor is rotating, the magnetic field of pulse vibration will be formed due to the size of the air gap, and the magnetic field of pulse vibration and the cross-chain of armature winding will form the back electric potential.

2.1.2. Switched reluctance motor

Magnetically suspended switched reluctance motor, through the difference in the construction of magnetic bearing and switched reluctance motor transformer, the suspension torque of magnetic bearing is superimposed on the stator winding of switched reluctance motor through the transformer, and the suspension torque and electromagnetic torque are formed together, so as to complete the suspension and rotation of the motor stator. Arrangement of two groups on the stator centralized transformer, transformer and suspension winding, respectively, by floating transformer form floating force bias field, by controlling the floating transformer magnetic field to improve the original small air gap magnetic effects, through the rotor to a second end small air gap magnetic uneven, formed on the stator radial floating ability, thus improve the stator radial floating.

2.1.3. Permanent magnet synchronous motor

Permanent magnet synchronous motor has good characteristics, no mechanical rectifier and capacitor film, simple structure, small size, safe and reliable working environment, easy to achieve high efficiency, good adaptability to the site, and can carry out positive and negative reversal switching function; But the stator transformer heating up, convenient dispersion; Fast reaction function; The working voltage is not affected by the voltage resistance of the power-related components, and the higher voltage can be used to achieve large capacity easily. Because of its high power density, it can work at great speed, so it has been widely used. But its price is expensive, the permanent magnet is easy to disappear at high temperature, and it needs a long time to maintain.

2.2. Flywheel bearings

Flywheel energy storage has the advantages of fast response and long life, which is very suitable for fast load control in power system, and can play a key role in maintaining the safety and reliability of new power system. 'The key technology of magnetic suspension bearing is one of the core technologies of high speed and heavy engine. In practice, only a maglev train bearing of the overall system may not meet requirements, but in many cases will take two or more than two kinds of bearing together, give full play to the characteristics of various types of bearing industry, under various conditions can adopt different maglev train bearing,

so that the characteristics of the overall system to achieve the optimization.' [3]

2.2.1. Permanent magnet magnetic bearings

The classic superconducting technology, maglev train bearing model, uses a permanent magnet and a high-temperature superconductor in the superconducting state to give it an initial thrust, after which the permanent magnet rotates. Permanent magnetic suspension bearing refers to the use of moving and static two magnetic rings, using the mechanism of opposite-phase attraction between magnets, the same sex mutually exclusive, so that the moving magnetic ring suspended on the static magnetic ring, but can not require the rotation in the six rotational working degrees of freedom are in a stable equilibrium, but must require a dynamic balance in a certain direction.

2.2.2. Superconducting magnetic bearings

When the superconductor is in the superconducting state, it has diamagnetism and magnetic flux pinning. Diamagnetism can be used to achieve the suspension effect, and magnetic flux pinning can provide a pinning force to make the rotor rotate stably. Therefore, the superconducting magnetic levitation system is a non-original self-stable magnetic levitation system.

2.2.3. Electromagnetic magnetic bearings

The bearing of electromagnetic suspension is generally composed of bearing rotor, inductor, control system and electromagnet and other four parts. The electromagnet structure rock bearing rotor is symmetrically arranged in a circle on a degree of freedom, through a corresponding electromagnet structure, and through a corresponding high power amplifier circuit, according to the differential mode to drive the electromagnet. And electromagnetic magnetic floating bearing, including the axial magnetic floating and radial electromagnetic solenoid magnetic axial electromagnetic magnetic floating, floating up and down through two winding magnetic field which is formed by the force balance push of equilibrium state of the driven plate to the suspension, and the radial battery type maglev train is through the balance of the two formed by the winding magnetic force to drive plate.

3. Flywheel Energy Storage Applications

Because of the advantages of fast running speed, low pollution and high safety, subway has become an important life mode chosen by modern people. Because of the large volume of Shanghai metro, speed control braking, stop braking and emergency braking in the process of operation, will produce energy consumption.

Ordinary kowtow type oil suction machine, there is too much power consumption, low daily rate of difficulties. As the development of oil fields gradually enters the middle and late development of high water cut conditions, the water depth of oil fields is further reduced. In order to improve the productivity, it is usually required to use high-load pumping units, and the equipment power, technology input and cost are increased. The development of energy-saving pumping unit is always the key point of technical innovation of oilfield scientists.

3.1. The traffic

High-speed trains have good efficiency, and the traction load has a wide area of power supply system, which is easy to produce power efficiency problems and power failure. At the same time, high speed EMUs are faster, heavier and have higher braking power than ordinary trains. Therefore, the recycling of regenerative braking energy plays a very key role in the operation of power equipment and the reduction of energy consumption.

3.1.1. Flywheel energy storage and rail traffic application opportunities

At present, there are two types of regenerative braking energy use methods for high-speed railway: one is to adjust the running conditions and use the regenerative braking energy formed by a power arm to the braking train for traction locomotive; the other is to use feedback equipment to feedback the regenerative braking energy to the power supply equipment of high-speed railway. However, these two technologies also have disadvantages. 'The former has low utilization rate and poor reliability, and the latter is easy to affect the electrical equipment. Based on this, regenerative braking energy can be stored through storage devices.' [4]

3.1.2. Flywheel energy storage and transportation integration applications

Some characteristics of the flywheel energy storage and completely conform to the rail transportation technology, the quality of the rail transit system, vehicle stops and produce a great brake power, the speed of the flywheel complete electrical energy reserves, vehicle start, reduce the flywheel speed, realize the release of energy, to realize the brakes, power cycle and use, to save energy and improve economic sense.

3.2. The industry

The application scope of wheel energy storage technology in oilfield engineering technology is relatively small, mainly including the use of flywheel energy storage to assist drilling lifting technology, the use of flywheel energy storage is helpful to achieve the load peak regulation of the bit, so as to achieve the goal of stable work of the bit.

3.2.1. Flywheel assists drilling power boost

Drilling work is also a major operation in oil field exploitation. The overall driving equipment of a drilling rig is generally composed of multiple engines. During the drilling operation, the diesel unit is subjected to unbalanced mutation load. 'On the other hand, the mutation of output power may cause great changes in generator voltage and equipment operating frequency. In addition, the back electromotive force generated by the impact load during operation will also damage the generator set, resulting in instantaneous transient torque impact, and ultimately greatly reduce the service life of the generator set.' [5] On the one hand, this kind of sudden load phenomenon can be overcome by using load peak regulation design, so as to ensure stable and safe operation in unit operation. On the other hand, it can improve the efficiency of the unit, so as to achieve energy saving and emission reduction production. During the drilling process of the traditional drilling kinetic energy lifting device, the deadweight potential energy of the cutting tool and the traveling vehicle control system converted to the braking device will be consumed because it is not available. The new

flywheel assisted drilling kinetic energy improvement control system. In the drilling condition, the gravity potential energy of the drill string and the control system of the traveling car is converted into alternating current after the inverter of the DC electric appliance and the inverter, and then drives the permanent magnet synchronous motor or the free wheel to accelerate, and the electric energy is converted into flywheel electric energy and stored. In the drilling condition, the wing wheel slows down and releases energy, and through the inverter and the drive DC motor, the drilling rig provides the maximum load to the driving unit, so as to reduce the power generation installation energy in the control system, and carry out energy circulation and use.

4. Conclusion

Flywheel energy storage system can complete the conversion of mechanical energy and electric energy, so as to greatly improve the system energy utilization rate, reduce the system energy consumption, so as to achieve energy-saving production, and has a huge market use prospect. At present, the advancement of this technology also requires technological breakthroughs in flywheel materials, bearings, motors, charging and discharging, and control.

1. Flywheel not only the main energy storage component of the control system, but also the core of the system, which needs to have high specific stiffness characteristics. At the present stage, the structural parameter optimization analysis and charge and discharge evaluation experiments of metal and composite flywheels have been carried out. Although the two have their own characteristics, they have not been applied in practical engineering, so it is necessary to continue the research on metal flywheel energy storage system materials.

2. Type bearing in flywheel energy storage system, the general use of multi-bearing element drive, its applications are mainly rolling bearings, electromagnetic bearings and high temperature superconducting maglev train bearings and other bearing forms. The speed of flywheel bearings used in engineering generally ranges from 15,000 to 30,000 R /min. Considering its speed and safety, it is recommended to use high-speed superconducting maglev train bearings. However, the bearing of high-speed superconducting maglev train with large capacity level above 100 kW H still needs to be further studied and matched, and put forward the scientific and technological guarantee for its application development.

3. In the electric energy storage system, because the motor mode is in the bilateral variable speed working mode, that is, to realize the two states of operation and power switching, it is necessary to adopt high speed stator structure and electromagnetic distribution adjustment to reduce power consumption. Compared with asynchronous motor, permanent magnet motor, low reluctance motor and other characteristics, permanent magnet motor is more conducive to flywheel energy storage system. However, the new motor and its internal structure optimization still need a breakthrough in key technologies to ensure that it can operate in a long period and efficiently in engineering practice.

In recent years, flywheel energy storage materials have been preliminarily used in urban subways in China, and have reached the corresponding development maturity. However, the application of flywheel energy storage technology in petrochemical engineering technology is still in the research and exploration stage, although the field scale research and application has not been carried out. Compared with other

energy-saving methods, the motor structure of flywheel energy storage technology has better system reliability, lower cost, prolong service life, safety and non-toxic characteristics, and has the advantages of technology promotion. The wide application of flywheel energy storage technology can reduce the energy demand and carbon dioxide emissions of petrochemical products, and has great economic use value.

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