Research Review of Flywheel Energy Storage Technology

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Abstract. to study the flywheel energy storage technology, a great number of papers about the researches on and development of high-speed flywheel energy storage system in China and overseas were reviewed and summarized. The technology started early in foreign countries. It developed rapidly and has formed a certain series of products today, while in China, the research on this technology is quite laggard and still in the experimenting stage. Now there is no flywheel energy storage product which can be applied in practice in quantity. Therefore, the research on a new type of efficient and low power consumption energy storage flywheel is of great value and significance today.

1. Introduction
Flywheel energy storage is a complex electromechanical integrated system which involves multidisciplinary knowledge from mechanical structure to electrical control, electronic circuit and materials science, etc., It achieves the function of unlimited times of charging and discharging. Research on flywheel energy storage technology started in the 1950s at overseas and has lasted for many years. The first serialized product prototype of maglev energy storage flywheel came out in the 1970s. Its energy density was up to 93W/m/kg, max linear velocity 880m/s, conversion efficiency over 95%. China’s research in this field is still in its infancy, so carrying out research on a new type of energy storage flywheel with high efficiency and low power consumption has great significance to solving China’s energy problem.

2. Overseas research on flywheel energy storage technology
As a well-known producer and supplier of UPS product, American company Active Power is in the leading position in the field of flywheel energy storage technology [3, 4]. Figure 1 is a prototype model of an energy storage flywheel product of Active Power. A single flywheel weighs about 600 pounds. Its diameter is about 2.5 feet and rated speed with electric drive in vacuum is around 7,700rpm. After power interruption, the flywheel will continue to rotate in inertia, similar to generator turning kinetic energy into electric energy. Each flywheel can provide 250kW power output. Figure 2 is the company’s patented product CleanSource UPS, with single system power larger than 120kW. The parallel system power can cover the range of 250-7,000kW. More modules can be added inside for redundancy or
extension. Intersystem parallel capacity reaches megawatt level and can ensure emergency operation and equipment running in case of power interruption.

**Figure 1.** Active Power’s energy storage flywheel. **Figure 2.** Active Power’s UPS product.

Beacon is another American company which also possesses advanced flywheel energy storage technology. Its customers include wind farm, large data center and semiconductor manufacturer, etc. Figure 3 shows the fourth generation of flywheel product of Beacon. Its max energy storage capacity is about 30kWh, and peak power output is greater than 160kVA. The rated speed of its rotor ranges 8,000-16,000rpm. Its useful life is more than 20 years and designed repeated full-power deep charging and discharging is up to 10,000 times. At 16,000rpm single flywheel can discharge continuously for 15min at 100kW power level [3]. Multiple flywheels in parallel can provide electric power for megawatt-level power consumption equipment.

**Figure 3.** Beacon’s 4th generation flywheel.

**Figure 4.** Japanese superconducting maglev energy storage flywheel.
As Japanese industry developed much earlier, it’s also at an advanced level in the international flywheel energy storage field [4]. For example, Nippon Oil Corporation and a control engineering institute jointly developed an energy storage flywheel for tramcar. It has a cylindrical shape, with a radius of 230mm and weight of 65kg. It is made of lightweight carbon fiber composite material. This type of material has quite high strength-weight ratio, which makes reducing the flywheel rotor weight and improving the flywheel energy ratio possible. The flywheel’s max speed is $3.6 \times 10^4$ r/min, charging and discharging efficiency as high as 85%. In addition, Japanese high-temperature superconducting maglev technology is also at the global leading position. Figure 4 is a model of the superconducting maglev energy storage flywheel jointly proposed by companies like Mitsubishi, Seiko and several universities and institutes.

3. Domestic research on energy storage flywheel
Flywheel battery energy storage technology has been booming in overseas. As an alternative of traditional energy, it is highly competitive and has been put into service in the fields of transportation, energy and aerospace [5]. Being influenced by the boom of this technology in foreign countries, research on the technology is also rising gradually in China. In the recent years, domestic researches on the flywheel technology have been carried out by: the flywheel energy storage laboratory of Tsinghua University, Beijing University of Aeronautics and Astronautics, Nanjing University of Aeronautics and Astronautics and North China Electric Power University, etc. The flywheel energy storage laboratory of Tsinghua University, as the earliest laboratory engaging in the research in China, has laid a theoretical and experimental foundation for China’s later researches on this technology. In 1999, it developed composite material flywheel system with 0.5kWh of energy storage capacity, prototype weighing 8kg, rotor linear velocity up to 650mm/s. North China Electric Power University developed a maglev and oil suspension hybrid energy storage flywheel. The rotor weighs about 330kg. The rotor’s rotational inertia is about $10.4k \cdot m^2$. They successfully completed constant power acceleration and charging/discharging experiments while meeting the relevant technical indicators.

Since 2004, the ship integrated power technology & defense technology laboratory of Naval University of Engineering has been committed to the R&D of medium and large capacity low-speed flywheel energy storage module, to meet the demands of short-term high-power load and power system peaking of ship integrated power system. The flywheel generator they developed has 50MW power, 120MJ energy storage and less than 5,000rpm max speed. The prototype adopts sliding bearing and asynchronous motor/generator. The university is also engaged in the research of maglev high-speed flywheel in recent years, but the motor power is only about 40kW.

Some Chinese companies are engaged in the research of flywheel energy storage system, for example, Beijing Qifeng Power Technology Technology under Yingli Solar. The company is mainly engaged in the research of low-power flywheel energy storage system. At present, the max electric/generated power of the flywheel system completed is only 20kW. Longyan Haidexin Automobile produced maglev flywheel energy storage UPS vehicle using introduced technology, but the whole energy storage system is imported from abroad. Beijing Flywheel Energy Storage Flexibility Institute realized permanent magnet high temperature superconducting levitation on vertical shaft rotating experimental system and then completed permanent magnet unloading and flywheel energy storage experiment with hydrodynamic bearing providing auxiliary support, flywheel weight: 30kg, rotating speed: 30,000rpm. Kinetic Traction Systems acquired American and British flywheel companies, but the core technology of flywheel is still at overseas, and the domestic branch mainly engages in sales and solving problem of connection with the grid. Shenyang Microcontrol New Energy also acquired American flywheel company VYCON, and mainly sells products in China. Beijing Honghui Energy and Huachi Kinetic Energy (Beijing) are now developing high-speed flywheel energy storage system product using different integrated electric/generator technical solutions. The former mainly adopts permanent magnet synchronous motor/generator, while the latter uses homopolar solid rotor hybrid electrically excited/generator structure.
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4. Conclusion

With a lot of researches on high-speed flywheel energy storage system having been carried out at overseas and formed certain series of products to date, such research is still laggard in China today. In particular, problems like network voltage fluctuation and flicker, etc., caused by phenomena like input power high-frequency impulse due to the intermittency, variability and high unpredictability of wind, solar and hydraulic energy are still unsolved. In order to improve the electric energy quality and power supply reliability of new energy power generation in China, the research on developing large-capacity energy storage flywheel which is more efficient and safer and has longer service time than storage battery and super capacitor energy storage device and the related products is absolutely necessary.

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