Key technical parameters of a new distributed physical energy storage system

Xiaoming Zheng¹*, Xuxia Li¹, Xiaoxue Su¹, Jia Li¹, Yang Yu², Xiaojun Song¹

¹ Economic and Electrical Research Institute of Shanxi Electrical Power Company of SGCC, Taiyuan, Shanxi, 030002, China
² North China Electric Power University, Baoding, Hebei, 071003, China
*zhengxiaoming@sx.sgcc.com.cn
*Corresponding author’s e-mail: ysuzhxm@126.com

Abstract. The energy storage technology is one of the advanced technologies to solve the problems of modern power system, and also an indispensable key technology for the construction of smart city power grid. A mechanical elastic energy storage (MEES) technology is proposed in this context. As a new physical energy storage technology, the MEES is still in the principle verification stage compared with other physical energy storage technologies researched and developed for many years. In this paper, the MEES system is introduced from the composition, the principle of energy storage/ power generation, and the key technical parameters of energy storage. The advantages and disadvantages of MEES system are pointed out, and the future development direction of the MEES technology is clear.

1. Introduction

With the development of energy internet, big data and other information technology, demand response technology will be the inevitable trend of distribution network operation and development. The user side resources will show high penetration in the grid connection of distributed generation, which will bring challenges to the control operation of distribution network. As a fast response resource, energy storage technology can improve the reliability and ensure the quality of power supply. It plays an increasingly important role in the stable operation of power grid. Energy storage technology is one of the cutting-edge technologies to solve many problems in modern power system, and it is also an indispensable key technology to build smart grid and support the development of the new energy.

According to different classification standards, energy storage technology can be divided into different types. According to the major function, it can be divided into power and energy type. According to the form of energy storage, it can be divided into four categories, including physical energy storage, electrochemical energy storage, electromagnetic energy storage and phase change energy storage. Physical energy storage mainly includes flywheel energy storage (FES), pumping energy storage (PES), compressed air energy storage (CAES), etc.

At present, the main physical energy storage technologies have their own characteristics and shortcomings. The FES has static loss and needs strong support of high magnetic levitation technology and vacuum technology. Small scale CAES system is generally used in some special fields, but its efficiency is not high. Large scale CAES system need special geographical environment to build gas storage chambers, such as salt caverns, rock caves, abandoned mines, etc., which greatly limits the application scope of the CAES. The development of the PES is relatively mature, but it needs to build...
two reservoirs and dams. The site selection is difficult, and the construction period is long (generally about 7-15 years), so the initial investment is large. From the application of existing energy storage technology, it is still difficult to meet the demand of power system, so it is imperative to explore and develop new energy storage technology.

The MEES [5] is a new type of power type physical energy storage technology. The medium of energy storage is large-scale spiral torsion spring [6] (STS), and the energy storage form is elastic potential energy. In this paper, the composition of the MEES system, the operation mode of energy storage system and the key technical indicators are introduced in detail.

2. Composition of the MEES system
As can be seen from Fig.1, The MEES system includes energy storage control system, linked energy storage tank group, logic protection and monitoring control system, power generation control system from. The function of energy storage control system is to convert electric energy into elastic potential energy and store it in linked energy storage tank through permanent magnet synchronous motor (PMSM). The generation control system converts the elastic potential energy stored in the in linked energy storage tank into electric energy through permanent magnet synchronous generator (PMSG). As the energy storage part of the MEES system, the linked energy storage tank is composed of multi-level single energy storage tanks in series. Each single energy storage tank is parallel and fixed with multiple (Spiral Torsion Spring, STS). The logic protection system is responsible for the action logic judgment of energy storage and power generation. The monitoring and control system is responsible for monitoring the operation status of each part of the whole system, setting the operation parameters, issuing the control instructions, and displaying the curve of the energy storage and generation in real time.

3. Operation principle of the MEES system
As shown in Fig.1, during the energy storage process of the MEES system, the electromagnetic brake at the power generation side is braked, and the electromagnetic brake at the energy storage side is opened, so the PMSM drives the linked energy storage tank group to rotate. As shown in Fig.2, the STS fixed in the energy storage box is gradually tightened, and the electric energy is converted into elastic potential energy storage. In the process of power generation, the electromagnetic brake at the energy storage side is braked, the electromagnetic brake at the power generation side is opened, and the STS drives PMSG to generate electricity, and the elastic potential energy is converted into electric energy.

Fig.1 Structural schematic diagram for the MEES

Fig.2 Operating schematic diagram of the mechanical elastic energy storage box
4. Key index analysis of the MEES and mainstream physical energy storage technology

As a new type of physical energy storage technology, the MEES technology is still in the prototype verification stage compared with other physical energy storage technologies which have been researched and developed for many years, so it has great potential to be tapped. According to the results achieved so far, some key parameters are compared with the mainstream physical energy storage technology, as shown in Fig. 3(a)-(d).

4.1. Mass and energy density

In Fig. 3(a), the mass and energy density of several physical energy storage technologies are compared. The same as the power and capacity of the MEES, the mass and energy density also mainly depend on the performance of the energy storage materials. The most effective way is to develop energy storage materials with low quality and high modulus. At the same time, the bulk energy density can be improved by optimizing the mechanical structure of the storage tank, so as to improve the space utilization rate of the energy storage box as much as possible.

4.2. Efficiency and recycling times

In Fig. 3(b), the operational efficiency and the number of cycles of different physical energy storage technologies are compared. The main factors affecting the MEES efficiency are the mechanical transmission loss of the linked energy storage tank group and the loss of electronic components in the process of charging and discharging. In the experimental stage, the efficiency of the MEES is about 80%. With the further optimization of the mechanical structure of the energy storage tank, the improvement of machining accuracy and the further reduction of mechanical transmission friction, the MEES efficiency is expected to be further improved. If the energy storage material of the MEES is fiber composite material, the number of cycles can be more than 60000, which has obvious advantages compared with other physical energy storage technologies.
4.3. **Investment and operating costs**

In Fig.3(c), the investment and operation costs of main physical energy storage technologies are compared. The MEES is still in the research and development stage. According to the different energy storage materials, the MEES technology is about 150-500 US dollars per kW and 2000-12000 US dollars per kWh. It can be seen that the MEES has obvious advantages in power investment cost.

4.4. **Self-discharge rate**

It can be seen from Fig.3(d) that the MEES has a very low self-discharge rate, which is the most prominent feature compared with other energy storage technologies. So the MEES has outstanding advantages in some occasions where energy demand is not much but long-term hot standby is required.

5. **Conclusion**

In this paper, the MEES system is introduced from the aspects of composition, operation mode and key indicators. Compared with the traditional physical energy storage method, the MEES system has its own advantages, but also has many shortcomings. The next research will focus on the further optimization of energy storage materials and mechanical structure to make it more competitive.

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