Technology: Flywheel Energy Storage

GENERAL DESCRIPTION

Mode of energy intake and output

Power-to-power

Summary of the storage process

Flywheel Energy Storage Systems (FESS) rely on a mechanical working principle: An electric motor is used to spin a rotor of high inertia up to 20,000-50,000 rpm. Electrical energy is thus converted to kinetic energy for storage. For discharging, the motor acts as a generator, braking the rotor to produce electricity.

System Design

Each FESS module has a power electronics module which allows its AC motor-generator to interface with a DC bus that is common to several FESS modules. Power and energy can be chosen independently, a design decision fixed by the size of the electric motor-generator (Ref. 1).

Figure 1: Inside of a FESS module (© STORNETIC)

Note: FESS and large synchronous flywheels

Large synchronous flywheels are also used for energy storage, yet not to be mistaken with FESS. They use very large flywheels with a mass in the order of 100 tonnes. These are directly connected to a synchronous condenser in order to provide grid inertia. Their main advantage is their immediate response, since the energy does not need to pass any power electronics. However, only a small percentage of the energy stored in them can be accessed, given the flywheel is synchronous (Ref. 2).

Focus on provision of power or energy

Power

Suitable fields of application

FESS is used for short-time storage and typically offered with a charging/discharging duration between 20 seconds and 20 minutes. However, one 4-hour duration system is available on the market. FESS is typically positioned between ultracapacitor storage (high cycle life but also very high storage cost) and battery storage, (low storage cost but limited cycle life). Similar to ultracapacitors and battery storages, FESS' response time is in the order of milliseconds and limited only by the power electronics' response speed. Typical applications are:

- Fast frequency regulation in transmission and distribution grids (e.g. instantaneous reserve and primary control power)
- Stabilisation of micro grids and peak shaving
- Balancing of wind energy (schedule compliance) and ramp management
- Recuperation of braking energy in railway vehicles
- Local grid boosting at electric vehicle charging stations

FESS can be used in conjunction with medium and long duration mechanical/thermal/chemical storages to mitigate slow ramp up times of the latter and accelerate storage response.

State of development/commercial availability

Flywheel energy storages are commercially available (TRL 9) but have not yet experienced large-scale commercialisation due to their cost disadvantages in comparison with battery storages (higher investment, lower energy density). Another challenge is the comparably high standby loss in FESS caused by the magnetic drag of the motor-generator. To counteract it, several different types of inertia rotors are under development, which can roughly be differentiated by whether they are made from steel or carbon fibre composites. Composite rotors beat steel when it comes to rotor-mass-specific energy storage, but require substantial safety containment to handle possible rotor failures. Steel designs can greatly reduce the size and weight of the containment unit, thereby also reducing build cost and increasing energy density.

There are five large (>500 kW), commercially operating systems: Two 20 MW-systems by Beacon Power are operated for frequency regulation in the USA. In Germany, a 600 kW storage system from STORNETIC is operated by a large municipal utility company. These are both based on carbon composite rotors. Two 3 MW-systems with steel rotors are operating in the Netherlands.

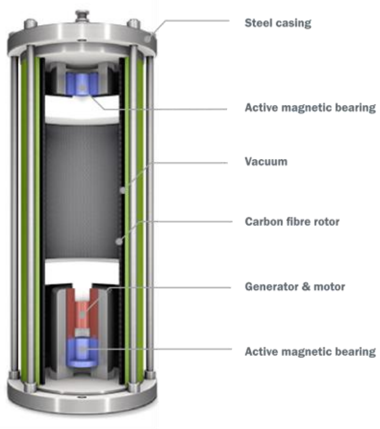

Figure 2: Typical FESS and components (© STORNETIC)

Figure 3: FESS modules in a container (© STORNETIC)

Figure 4: 20 MW storage for frequency regulation in Pennsylvania, USA (© Beacon Power)

TECHNICAL SPECIFICATIONS (EXAMPLE STORNETIC)

Typical/feasible storage size	kWh_{out} 2 to >5,000	kW_{out} 20 to >20,000
System efficiency	80-95 %	
Storage efficiency	80-95 %	
Storage duration	Seconds-hours	
Response time	< 1 s	
Service life (maximum)	Cycles > 100,000	Years > 15
Loss per time in %	approx. 5 % per hour	

ECONOMIC SPECIFICATIONS (EXAMPLE STORNETIC)

Investment cost per kW: approx. 1,000 €

Investment cost per kWh: approx. 6,000 €

Notes

These investments refer to a STORNETIC DuraStore unit (Fig. 1, 3) with a peak power of 600 kW. The system consists of a 40-foot container with 28 flywheel storage units, electronics enclosure, 750 V DC-circuitry, cooling, and a vacuum system. Costs for grid inverter, energy management system, and cooling unit are excluded.

Operating and maintenance cost

Approx. 1-2% of total investment per year

References:

1 Amiryar, E.: A Review of Flywheel Energy Storage System Technologies and Their Applications www.mdpi.com/2076-3417/7/3/286

2 Krull, F.: This way for the right momentum to grid stability www.siemens-energy.com/global/en/home/stories/flywheels-for-electranet-substation.html