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Energy Storage Technologies for Electric Applications

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Abstract. Integration of renewable sources in electrical networks has increased dramatically in recent years. However, the power supplied by renewable energy sources is not as secure and easy to adjust to changes in demand, as the power supplied by traditional power systems. As a result, storage devices are also integrated into the electrical network in order to ensure reliability and quality in the performance of the power system.
This paper presents the current state of development of various storage technologies proposed for use in electric power systems. Thus, characteristic expressions, specific and comparative data (in technical and economic terms) are shown.

Key words: Energy Storage, Flywheel, SMES, Supercapacitors, BESS, PHES, CAES.

1. Introduction

Within the context of distributed generation, new energy sources rely mainly on renewable resources. However, energy production peaks do not always are in accordance to the energy demand. They can have large fluctuations in their daily, seasonal, annual or even multi-annual energy production cycles. Meanwhile, demand may vary throughout the day, week or year. Consequently, an energy reserve is required and energy storage devices can be very useful for an efficient energy management. Storage devices can store energy in off-peak hours and return it to the grid during peak hours.

This energy storage concept can allow a plant design for a fairly constant load operation, below peak demand. This process is known as peak leveling and it reduces significantly the high capital costs of power plants. There are many techniques for energy storage, based on virtually all forms of energy: electrical, mechanical, chemical and thermal. Moreover, storage technologies present different technical and economical criteria, which vary considerably, depending on the specific needs and applications [1]. Thus, these technologies can be divided into four categories, depending on the applications [2]:

1) *Low power applications in remote areas,* mainly to supply transducers and emergency terminals.
2) *Medium power applications in remote areas*, such as individual electrical systems and power supply to villages.
3) *Power-quality applications.*
4) *Network connection application with peak leveling.*

The first three categories are suitable for small scale systems, where energy could be stored as kinetic energy, chemical energy, compressed air, hydrogen, supercapacitors and superconductors.

The fourth category is suitable for large-scale systems, where energy could be stored as gravitational energy in hydraulic systems, thermal energy as latent and sensible heat, chemical energy in batteries or compressed air.

2. Parameters of Storage Technologies

The most relevant parameters that define these storage devices are:

1) *Storage capacity*: defined as the amount of energy available in the storage device after completing the charging cycle. The discharge is often incomplete and therefore, storage capacity is defined based on the total energy stored, W_{st}, which is higher than the useful energy at a particular point of operation, W_{ut}.
2) *Energy available*: determined by the dimensions of the generator-motor system used in the conversion process of stored energy. Available power is usually expressed as a mean value. Besides, a peak value, P_{max}, is often used to represent the maximum power in charging and discharging cycles.

   Moreover, the energy supplied in the discharge, or depth of discharge, is the ratio of energy released in relation to the amount of energy that can be stored. This value is usually indicated as a percentage.
3) *Discharge time*: defined by expression (1), [3].

$$\tau(s) = \frac{W_{st}}{P_{\max}} \qquad (1)$$

where:

$\tau(s)$: Discharge time, in s
W_{st}: Total energy stored, in Wh
P_{max}: Maximum or peak power, in W

4) *Efficiency*: evaluated from the ratio between the energy released and the stored energy. Its value is given by expression (2).

$$\eta = \frac{W_{ut}}{W_{st}} \qquad (2)$$