Overview of Energy Storage Technologies and a Short-term Storage Application for Wind Turbines

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ABSTRACT

The spreading of renewables has become stronger due to the increased air pollution. On the other hand, the penetration of renewable energy technologies causes major problems to the stability of the grid. Along with the fluctuations of the renewable energy technologies production, storage is important for power and voltage smoothing. Thus, storage technologies have gained an increased attention considering the distributed generation. This paper presents an up to date comprehensive overview of energy storage technologies. It incorporates characteristics and functionalities of each storage technology, as well as their advantages and drawbacks compared with other storage technologies. A demonstration of a short-term energy storage application in a grid-connected small wind turbine is given. The circuit is operated at the maximum power point (MPP), succeeding its connection and synchronization with the low-voltage grid. It also utilizes the energy generated by the wind turbine when a fault appears for a short period of time, through the supercapacitor.

KEY WORDS: Renewable energy sources; energy storage; grid; wind turbine; supercapacitors.

INTRODUCTION

In March 2007, the European Council set some goals for 2020 to face the problems of the environment: the reduction of 20% of total energy consumption, the 20% contribution of Renewable Energies to total energy production and the 20% reduction of Greenhouse gases below 1990 emissions (20-20-20 targets). Therefore, the development of the Renewable Energy Sources (RES) is more than a necessity.

Wind energy is one of the most important and promising renewable energy sources. It is also a mature, clean and competitive resource. Wind turbine is the technology that converts the wind energy into rotational mechanical energy and then into electricity. Wind farms can be installed both onshore and offshore. Important advantages of the offshore installation are the ability to use larger wind turbines and larger power plants than in onshore, and the presence of strong and powerful offshore wind speeds. The main drawbacks of the offshore wind farms are the high installation and connection to the grid cost and the maintenance requirements. A common disadvantage of wind energy is that the wind behaves in a stochastic and not deterministic manner.

Therefore, the electric power generated by wind turbines is ‘erratic’, a fact that leads to problems in the stability and reliability of the network. When a fault appears on the grid side, wind farms should stay connected producing electricity for a short period of time. Then, energy storage is a very important factor to store the trapped energy (Daoud, Massoud, Abdel-khalik et al., 2015; Díaz-González, Sumper, Gomis-Bellmunt et al., 2012; Spro, Mo, Merz et al., 2015).

In the next section is given an up to date comprehensive overview of the current energy storage technologies. The review deals with the characteristics and functionalities of each storage technology, as well as their advantages and drawbacks compared with other storage technologies. Particular attention is given to Pumped Hydro Storage, Compressed Air Energy Storage, Batteries, Hydrogen Storage, Thermal Storage, Concentrated Solar Power, Superconducting Magnetic Energy Storage, Flywheel and Supercapacitors. The review is given for both onshore and offshore applications, albeit some of the technologies are not suitable for offshore applications (for further information see Díaz-González, Sumper, Gomis-Bellmunt et al., 2012).

Following the energy storage overview, a short-term storage application for wind turbines is presented, where a supercapacitor (suitable for both offshore and onshore applications) is employed.

ENERGY STORAGE

The penetration of renewable energy technologies creates major problems to the stability of the system. On the other hand, the utility grid is necessary when the on-site generation is greater than the loads of the building, so that the excess energy can be exported to the grid. Moreover, due to the fluctuations of the energy production of renewable energy technologies, storage is important for power and voltage smoothing. Thus, storage technologies have gained attention in recent years because of the distributed generation.

We can categorize the storage technologies by storage duration (long-term, short-term storage), by the kind of storage (electrical, mechanical, chemical, thermal, etc.) or by other criteria like capital cost, capacity, efficiency, environmental impact, and so forth. Fig. 1 shows a classification of Electrical Energy Storage (EES) technologies by the form of stored energy.