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Characterisation of electrical energy storage technologies

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ABSTRACT

In the current situation with the unprecedented deployment of clean technologies for electricity generation, it is natural to expect that storage will play an important role in electricity networks. This paper provides a qualitative methodology to select the appropriate technology or mix of technologies for different applications. The multiple comparisons according to different characteristics distinguish this paper from others about energy storage systems.

Firstly, the different technologies available for energy storage, as discussed in the literature, are described and compared. The characteristics of the technologies are explained, including their current availability. In order to gain a better perspective, availability is cross-compared with maturity level. Moreover, information such as ratings, energy density, durability and costs is provided in table and graphic format for a straightforward comparison. Additionally, the different electric grid applications of energy storage technologies are described and categorised. For each of the categories, we describe the available technologies, both mature and potential. Finally, methods for connecting storage technologies are discussed.

1. Introduction to the structure of the electricity sector

The European electricity sector is getting ready for a challenging evolution, which will happen at several levels. By way of example, 95% of the increase in primary energy consumption between 2005 and 2030 in Europe will be supplied by renewable energy sources (RES). Moreover, the total electricity expected to be generated from renewables will more than double over this period. After 2030, the deployment of renewable energy sources in Europe is expected to accelerate, in order to offset the reduction of between 80 and 95% in greenhouse gas emissions by 2050, decided by the EU Member States (EU-27) [1]. Nevertheless, the deployment of RES in the EU-27 is already increasing steadily as can be seen from Fig. 1. Similarly, around the world other countries are evaluating their potential of reaching challenging goals of RES deployment, especially after the Fukushima accident [2–5].

In this situation, electrical energy storage can play a pivotal role in the EU-27 grid, providing several services for the network in order to balance and smooth variations in both load and generation. With the increased deployment of renewables, where storage can act as a buffer to offset the effects of the intermittency of some natural power sources such as wind and solar, this capability gains even more in importance [6–8]. Moreover, the energy storage technologies associated with renewable energy sources have the capacity to change the role of the latter from energy supplier to power producer [9]. Using data from a recent survey by the JRC [10], the proportional investment in storage systems in Europe is shown in Fig. 2. The actual figures are confidential.

However, market players are confronted with some questions, for example regarding the limited price difference for the final consumer between peak and valley hours or the lack of experience in the commercial deployment of some of the technologies. This applies even to technologies that seem, theoretically at least, to be cost-effective. In fact, an EU-27 regulatory framework, covering not only power supply, but also energy supply and ancillary services, would be advantageous for the deployment of storage technologies.

Actually, one of the reasons why large investments on storage are not attractive from the economic point of view is due to the insufficient remuneration of ancillary services such as balancing services and payments for reserves.

Independently of these considerations, the ability of storage technologies to act as a 'shock absorber' for the electricity infrastructure, thus enhancing its efficiency, reliability and security, is an

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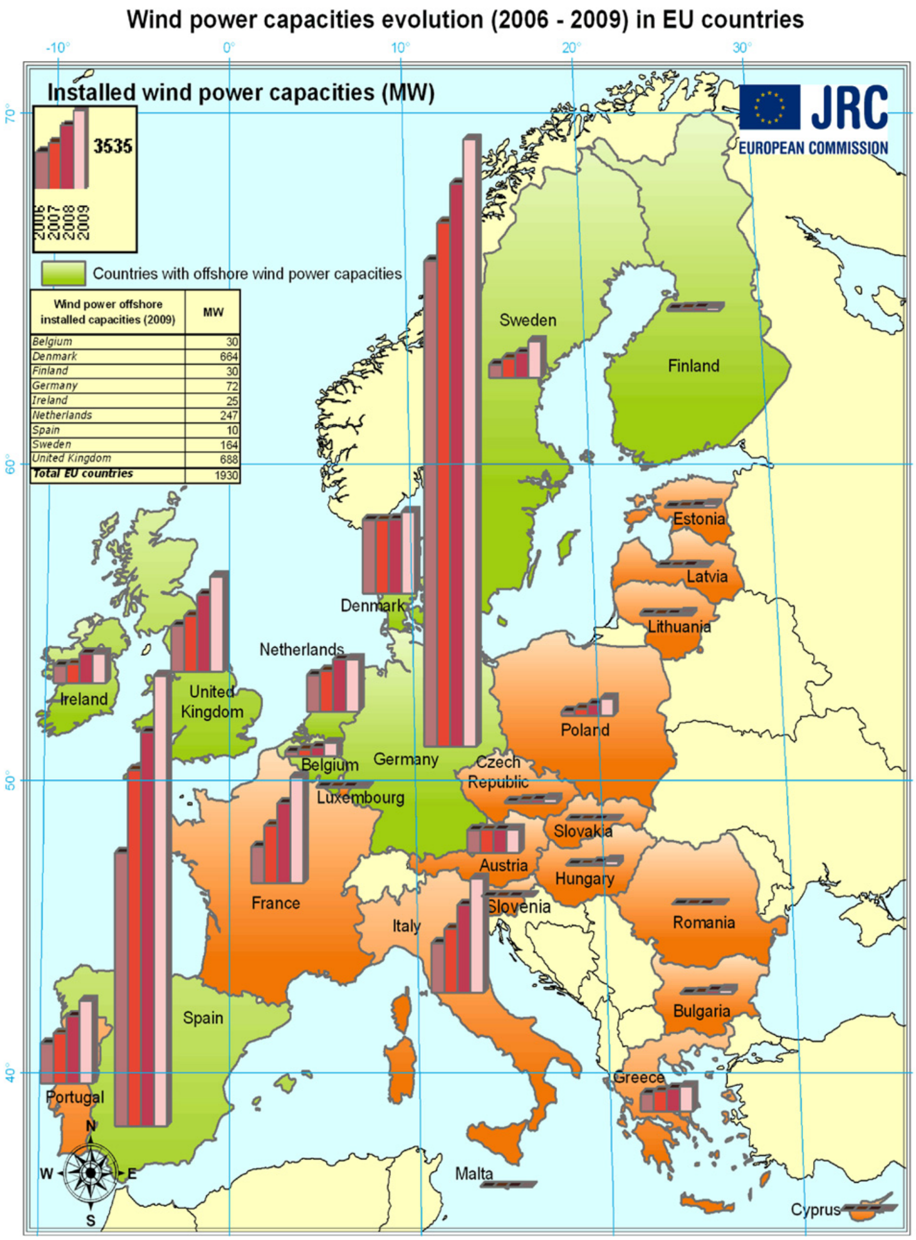

Fig. 1. Evolution of wind power capacities in the EU-27 countries.

important asset for the future electricity network: 'by maintaining even a relatively modest amount of reserves, storage facilities – big and small – will have a positive impact on the market' [11]. This positive impact can take the form of dampening the volatility of electricity market prices, increasing the efficiency of the market, fostering quantification of the value of ancillary services [12], and even improving security in the case of conflicts. In the retail energy sector, storage can reduce energy costs through peak shaving, while improving the quality of power, enhancing service reliability and avoiding spillage of renewable electricity. In countries with large variable renewable generation it happens that during valley hours, renewable generation can be spilled if no storage is used. The quantification of avoided CO_2 emissions because of the use of storage for this purpose should be checked in order to value additionally storage investments.

Moreover, storage technologies have a high deployment potential particularly in markets with an increasing cost difference between peak and valley hours. Integrating storage to ensure a profitable utilisation factor is therefore an important issue [13].

In order to complement the data gathered from the literature on the different technologies, we carried out a survey of manufacturers. In this survey, we requested average values for full cycle efficiency, durability (time and cycling), power and energy rating. The information collected was then incorporated in Table 1.

2. Technologies

2.1. Pumped hydroelectric energy storage (PHES)

For this storage method, two water reservoirs at different heights are used. In charging mode, the water is pumped from the lower to the upper reservoir. In discharging mode, the water flows from the upper into the lower reservoir, driving the reversible turbines and producing electricity. This is the most common