Electrical Power and Energy Systems 61 (2014) 421–428

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Iron redox battery as electrical energy storage system in the Spanish energetic framework

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ARTICLE INFO

Article history:
Received 16 January 2014
Received in revised form 27 March 2014
Accepted 28 March 2014

Keywords:
Electrical energy storage
Renewable energy
Economic assessment

ABSTRACT

The energy storage technologies will play a crucial role in the near future under the use of efficient electric energy sources and renewable energies such as wind and solar energy. This sort of energy usually suffers from intermittent problems in distributed generation systems. To overcome this problem, electricity storage systems provide solutions to improve dispatchability and reliability. The different electrochemical storage systems are presented when considering their applications and comparing advantages and disadvantages. Based on this description and the possible applications of each technology, a particular case is considered in the framework of the Spanish energetic system. An iron redox battery (one of the most promising technologies) is analyzed from an economic point of view determining important aspects as the payback of the investment or the IRR.

Introduction

General scope

The energy situation in Europe is determined by measures to reduce the CO_2 emissions and the dependence on fossil fuels from other countries. For these reasons, the energy production from renewable sources becomes especially important. However, the large energy distribution leads to a benefit for the renewable energy which will be unviable without an appropriate storage capacity system.

The produced energy from renewable sources has the advantage of not emitting CO_2 to the atmosphere. Renewable energy allows managers to use local energy sources and to reduce the energy dependency on foreign energy sources, especially fossil fuels, which are mostly imported to Spain and the European Union [1]. Therefore, one of the main objectives of European Authorities is to increase the use of renewable sources in energy production. On March 9, 2007, the Spring European Council, with the support of the European Parliament and the Member States agreed that at least 20% of its energy consumption must be produced with renewable energy sources by [2]. Nevertheless, the energy situation of each specific European country must be taken into account. The European Council also adopted a commitment to reduce by at least 20% its greenhouse effect gases emissions to achieve energy savings of 20%. Furthermore, biofuels reach 10% within fuels consumed in the EU transport. In this sense, Spain was encouraged to reduce exactly 20% of its energy consumption.

Renewable energy integration in the whole energy system

It is recognized that the energy production and consumption as known nowadays is not sustainable. It means that, fossil fuels could be finished in the long term besides the threat which supposes its use for the environment, mainly due to greenhouse effect gases emissions and its impact on climate change [3,4]. This is why, industrialized countries are supporting and legislating new technologies to ensure that their energy will be sustainable in the future. This sustainability aims to maintain the economical growth of the country while increasing energy security and environmental protection.

The renewable energy sources and its application, especially to produce electricity, have been supported by all the Governments of Spain. In 2011 the Renewable Energy Plan 2011–2020 (or 20-20-20 package) was published to indicate the commitment of the Spanish Government to cover at least 20% of total primary energy consumption by renewable energy sources in 2010 [5].

Nevertheless, it is still a long way to reach the target rates set in 2020 regarding the proportion of renewable energy in final energy consumption. The power sector has to greater contribute to achieve this goal in the case of Spain [7]. According to recent studies carried out by the Spanish Government, 40% of renewable energy source is required in the power (electricity) sector to reach

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http://dx.doi.org/10.1016/j.ijepes.2014.03.067
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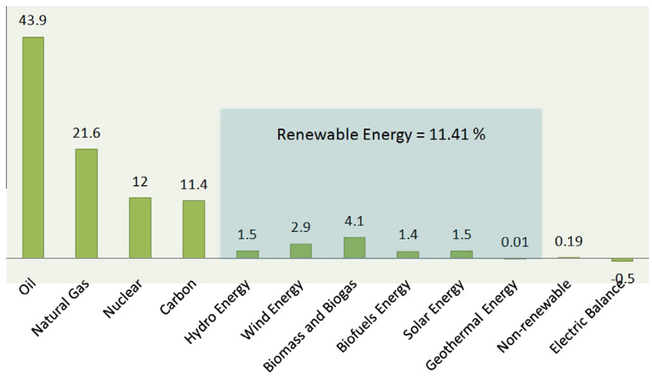

Fig. 1. Primary energy sources, the case of Spain. Adapted from (IDAE [6]).

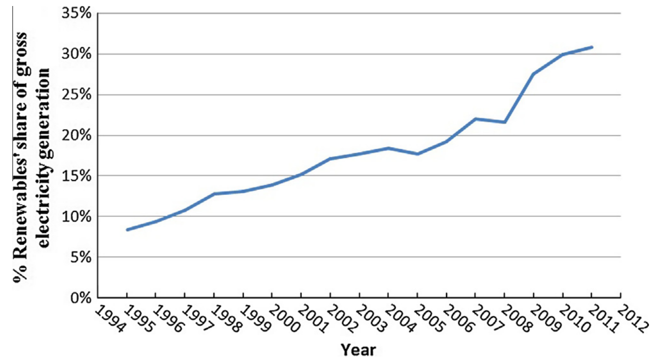

Fig. 2. Renewables' share of gross electricity generation. *Source:* ForoNuclear.org [15].

a renewable energy integration of 20% in the whole system. To achieve this desirable goal is not easy. While fossil fuels can be easily transported and can perform as energy stores, most of renewable energy sources cannot be stored or transported without being converted first to electricity [8]. This is why, energy storage strategies and technologies are necessary to contribute to sustainable development [9]. It is necessary to store energy when it is produced by renewable sources (such solar and wind power) to be consumed when required. Nowadays, there are many storage systems [10]. However, its industrial implementation and regulations [11] are still being under development. It is very important to have a positive balance between benefits obtained from the use of storage systems compared with the economical investment [12]. In this contribution a simplified analysis about one of these new storage devices is presented: the Electro-Chemical Energy Storage Semi-Redox Iron Flow. The aim of the study is to quantify the functionality and the economical viability of the storage device in the Spanish energy scope (see Fig. 1).

The need to store energy

The uncontrollable nature of some renewable energy sources leads to increase the difficulties to safely operate power systems. This kind of energy will represent a significant percentage of the power installed capacity in the future. Electricity generation from renewable sources does not firmly contribute to the power supply warranty. Nevertheless, it contributes to cover the power demands in terms of annual energy supply. This lack of power guaranteed is a problem for the operation of the power system because it requires a stable power generation. Additionally, there are problems associated with the particular renewable energy generation and problems of network congestion in areas with high consumption and low generation rates, due to the saturation of the transmission lines.

The extent of regenerative electricity involving a disparity between power production and consumption can lead to the loss of electricity produced if the presence of electricity storage systems is not ensured. Every country has its own necessities of storage systems related to the precedence of the energy in the national system, as the case of Japan [13] or Saudi Arabia [14,4]. The growing of renewable energy in Spain [15] is considered in all the forecasted scenarios (Fig. 2).

Electricity storage systems

Worldwide electrical grid storage capacity is about at 127 GW and it increasing each year [16]. Electric Energy Store Systems (EES) are crucial for future developments in national energy grids [17]. In general, an energy storage system is more than ever a necessity [18,19] and many different sorts of devices can be applied to storage electricity [20,21]. This necessity increases as the use of renewable energy gets more important in national balances of electricity [22]. Economic implications of these devices attract great interest in recent times [23,24].

Two categories of EES can be considered related to their applications [25]: Energy Management applications (long-duration discharge applied to decouple generation and consumption of electric energy), and Power Management Applications (short duration discharge applied to deliver power in real time).

Energy Management applications involve different scales of time, since daily up to several times per month along a year (long duration storage up to hours or more). Power Management Applications involve short-duration with a big number of discharges over a year involved (short fractions of time up to some minutes).

An overview on the more efficient electrochemical storage systems batteries

Electrochemical batteries are one of the most used technologies for store energy [26].They are very convenient for many sort of uses and adaptable to grid necessities providing very good efficiency, in some cases up to 95%. Different technologies have been developed in the recent years [14]: Lead-acid batteries, Sodium/Sulfur batteries and Flow batteries, Nickel–Cadmium and Lithium Ion. Apart of them, the Iron flow battery will be presented in this article as one of the most interesting ones based on economic and technological factors. A short description of the general types of batteries is provided (see Fig. 3).

Lead-acid batteries

These are the oldest and most mature battery technology currently in use. These battery cells consist of spongy lead anode and lead acid cathode immersed in a dilute sulfuric acid electrolyte, using lead as the current collector [27].

Sodium/Sulfur batteries

Sodium/Sulfur (Na/S) batteries are based on a high-temperature electrochemical reaction between sodium and sulfur separated by a beta alumina ceramic electrolyte. The active materials in a Na/S battery are molten sulfur as the positive electrode and molten sodium as the negative one [28].

Nickel Cadmium batteries

Nickel Cadmium (NiCad) batteries are a rechargeable batteries using nickel oxide hydroxide and metallic cadmium as electrodes. Sealed Ni-Cd batteries require no maintenance, as described on [29].