Renewable and Sustainable Energy Reviews 33 (2014) 532–545

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

A review of available methods and development on energy storage; technology update

T.M.I. Mahlia [a,b,*], T.J. Saktisahdan [a], A. Jannifar [c], M.H. Hasan [c], H.S.C. Matseelar [c]

[a] Department of Mechanical Engineering, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia
[b] Department of Mechanical Engineering, Syiah Kuala University, Banda Aceh 23111, Indonesia
[c] Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 10 January 2013
Received in revised form
29 December 2013
Accepted 31 January 2014
Available online 12 March 2014

Keywords:
Energy storage
Electricity
Energy savings
Renewable energy

ABSTRACT

Energy storage becomes a key element in achieving goals in energy sustainability that lead to energy and cost savings. This paper discusses various types of energy storage including compressed air energy storage (CAES), flywheel energy storage (FES), pumped hydro energy storage (PHES), battery energy storage (BES), flow battery energy storage (FBES), superconducting magnetic energy storage (SMES), super capacitor energy storage (SCES), hydrogen energy storage, synthetic fuels, and thermal energy storage (TES) with additional information about the recent update of the technology. In the final part of this paper, the comparison and barriers to deploying the technologies are also given in order to give a better view about the energy storage technique.

Contents

* Corresponding author at: Department of Mechanical Engineering, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia. Tel.: +60 3 8928 7221; fax: +60 3 038 921 7296.
E-mail addresses: i_mahlia@hotmail.com, indra@uniten.edu.my (T.M.I. Mahlia).

http://dx.doi.org/10.1016/j.rser.2014.01.068
1364-0321

1. Introduction

Energy and environment have been forecasted to become two of the most challenging and major issues of the world in the future [1–4]. According to British Petroleum, fuel consumption was growing significantly in the last 30 years from 6630 Mtoe in 1980 to almost double which reach 11,630 Mtoe in 2009 [5]. On the other hand, the total CO_2 gas emissions increased massively from 9.396 million metric tons in 1960 to 32.083 million metric tons in 2008 [6]. For the past few decades, efforts have been made in order to innovate and create new technologies to alleviate environmental problems, energy shortages and reducing the high cost of new power plants. Many research and scientific works have been done to identify and implement the most suitable technology to rectify some of the problems [7–12]. Furthermore, the need for storing the energy waste from a variety of industrial, commercial or domestic processes and minimizing the loss of energy has a very significant impact to the world. In this respect, energy storage technology has attracted attention from researchers due to its capability in reducing energy consumption, costs and may be used as a substitute of another energy source [13].

2. Energy storage

2.1. Current status of energy storage

The drive of becoming the world leader in the clean energy industry has seen some competitive efforts between the researchers to increase energy efficiency, reduce greenhouse gas emission and promoting a cleaner and more sustainable energy generation. Certain types of energy storage such as pumped-storage hydroelectricity are one of the oldest ESS technologies that have been employed in the electricity grid.

To gain a better view of the world's energy storage scenario, a comparative estimation of current installed capacity of worldwide energy storage plant is shown in Fig. 1 [14].

Electricity transmission and contribution sector (power quality and energy management) and transport sector are the potential areas where energy storage system (ESS) can be fully utilized [15]. ESS enhances the existing power plant and at the same time prevents expensive upgrades [16]. ESS could act as a regulator that manages the fluctuations of electricity from renewable energy resources which has prevented their market penetration. With the introduction of ESS, renewable energy sources can be used to aid the transition for a newer and cleaner energy generation technology. However, a number of reasons such as high capital cost and lack of experience hinder the commercialization of ESS. Yet, the use of ESS is expected to rise in the near future due to renewable energy and power quality is becoming increasingly important [15].

Various characteristics of different technologies pertaining to energy storage devices have enabled them to be used for different types of applications depending on the application's specific parameters. Parameters such as energy and power density, response time, cost and economies scale, lifetime, monitoring and control equipment, efficiency and operating constraint are the factors of choosing the most suitable type of technology [17].

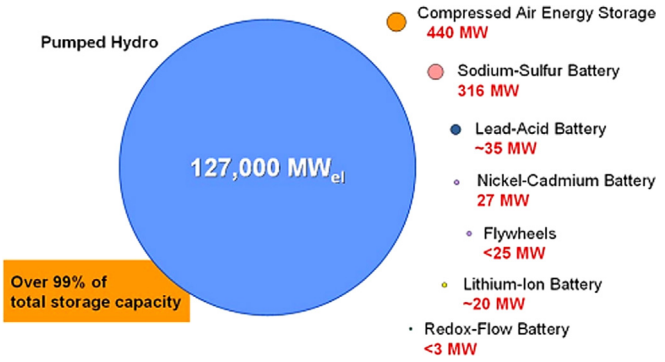

Fig. 1. Worldwide installed storage capacity for electrical energy [14].

2.2. Energy storage and GHGs reduction

As described in the previous section, ESS technologies can be used for Power Quality or Energy Management purposes. Electrical energy storage technologies become a key device to increase the efficiency of electrical utilization due to the capability to produce electricity reserve. According to the report from the International Energy Agency, it is predicted that the world's electricity consumption increase significantly from 14,781 billion kWh in 2003 to 21,699 in 2015 and 30,116 billion kWh in 2030 to 65% of energy supplies coming from fossil fuel. As a result, GHG emission from energy industry will increase about 55% between 2004 and 2030 with oil and coal as the main contributor of global CO_2 emission

Fig. 2. CAES plant in Huntorf, Germany.

Fig. 3. CAES plant in McIntosh, Alabama.