Renewable and Sustainable Energy Reviews 16 (2012) 274–283

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

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

Overview of energy storage systems for storing electricity from renewable energy sources in Saudi Arabia

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ARTICLE INFO

Article history:
Received 22 May 2011
Accepted 7 July 2011
Available online 23 September 2011

Keywords:
Electrical energy storage
Renewable energy
Energy management
Solar
Wind
Storage battery

ABSTRACT

Renewable power (photovoltaic, solar thermal or wind) is inherently intermittent and fluctuating. If renewable power has to become a major source of base-load dispatchable power, electricity storage systems of multi-MW capacity and multi-hours duration are indispensable. An overview of the advanced energy storage systems to store electrical energy generated by renewable energy sources is presented along with climatic conditions and supply demand situation of power in Saudi Arabia. Based on the review, battery features needed for the storage of electricity generated from renewable energy sources are: low cost, high efficiency, long cycle life, mature technology, withstand high ambient temperatures, large power and energy capacities and environmentally benign. Although there are various commercially available electrical energy storage systems (EESS), no single storage system meets all the requirements for an ideal EESS. Each EESS has a suitable application range.

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Contents

1. Introduction

Energy storage has long been recognized as a means of reducing petroleum demand and air pollution problems. Presently, the development of efficient and environmentally safe energy storage systems is an important and urgent issue to save our society from potentially serious damage due to various pollutants in the atmosphere. Demand for new energy storage systems is increasing for applications such as remote area power supply systems (like offshore platforms, telecommunication installations), stressed electricity supply systems, emergency back-up, as well as mobile applications. The supply of electric power to remote areas is becoming more attractive due to advancements in the photovoltaic (PV) technologies, concentrated solar thermal power systems (CSP) and wind power generation systems along with the development of advanced storage batteries. The wind power technology is commercially developed and efficient multi megawatt sized turbines are available. Moreover, the wind power is being utilized in many countries and today the total global wind power installed capacity surpassed 150 GW.

The use of batteries as portable electrical power source has increased and to some extent technology has not been able to

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1364-0321/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2011.07.153

keep pace with the demands. Longer lifetime and higher volumetric energy densities are needed for electric vehicles while electricity from renewable sources and load leveling applications are more sensitive to cost than to the gravimetric or volumetric energy densities. Computers, other electronic equipment and defense industries require higher reliability, safety and shelf life whereas the space stations are demanding enormous amounts of power storage capacity in a small volume and weight. The ideal high energy density battery has to meet many of the above demands and efforts are being made to cope with these stringent requirements. Throughout the world, therefore, enormous effort and funding is currently being diverted for the development of suitable battery systems for these applications. Lee and Gushee [1] stated that massive electricity storage is the critical technology needed by the renewable power if it is to become a major source of base load dispatchable power. They indicated that energy storage systems (EES) cost constitute about 30% of the total renewable power supply system cost. According to recent estimates electricity storage association (ESA) and KEMA, Inc. reported that more than 100,000 incremental jobs will be created by 2020 (a 10-year period) in energy storage sector, if investors received the proposed investment tax credit currently being debated in Congress based on Storage Act 2009 (S. 1091) [2].

This paper presents the climatic conditions and supply demand situation of power in Saudi Arabia. Subsequently, the assessment of different electric energy storage systems (EESS) for storing electricity generated from renewable energy sources was performed and suitable EESS based on various available technologies and economics has been identified.

2. Climatic conditions in Saudi Arabia

Usually batteries are used to store the energy produced by solar or wind to assure continuous supply 24/7. The batteries are very sensitive to weather conditions (temperature, relative humidity, barometric pressure, wind speed, etc.) and need to be evaluated both for efficiency and for working life degradation in the harsh environment of Saudi Arabia. Among all the weather parameters, temperature and relative humidity are very critical for battery efficiency and working life and hence should be considered while selecting a battery for energy storage purpose.

Saudi Arabia has a desert climate characterized by extreme heat during the day, an abrupt drop in temperature at night, and slight, erratic rainfall. Because of the influence of a subtropical high-pressure system and the many fluctuations in elevation, there is considerable variation in temperature and humidity. The two main extremes in climate are felt between the coastal lands and the interior.

Temperatures are different in each part of the country. Particularly in the central area and the north, the temperatures can be very high. From June through August, midday temperatures in the desert can soar to 50 °C (122 F) or more. The south has moderate temperatures, which can go as low as 10 °C (50 F) during the summer in the mountains of Sarawat in Asir. Along the coastal regions of the Red Sea and the Persian Gulf, the desert temperature is moderated by the proximity of these large bodies of water. Temperatures seldom rise above 38 °C, but the relative humidity is usually more than 85% and frequently 100% for extended periods. This combination produces a hot mist during the day and a warm fog at night. A uniform climate prevails in Najd, Al Qasim Province, and the great deserts. The average summer temperature is 45 °C, but readings of up to 54 °C are common. The heat becomes intense shortly after sunrise and lasts until sunset, followed by comparatively cool nights.

During the winter, the temperatures are moderate in general, but turning cold at night sometimes descending below freezing especially in mountainous areas of the west and along the northern border. Torrential rains fall along the Red Sea coast during March and April. In Najd, AL-Qasim Province, in the winter, the temperature seldom drops below 0 °C, but the almost total absence of humidity and the high wind-chill factor make a bitterly cold atmosphere. In the spring and autumn, temperatures average 29 °C.

The entire year's rainfall may consist of one or two torrential outbursts that flood the wadis and then rapidly disappear into the soil to be trapped above the layers of impervious rock. This is sufficient, however, to sustain forage growth. Although the average rainfall is 100 mm per year, whole regions may not experience rainfall for several years. When such droughts occur, as they did in the north in 1957 and 1958, affected areas may become incapable of sustaining either livestock or agriculture. The region of Asir is subject to Indian Ocean monsoons, usually occurring between October and March. An average of 300 mm of rainfall occurs during this period which is about 60% of the annual total. Additionally, in Asir and the southern Hijaz, condensation caused by the higher mountain slopes contributes to the total rainfall.

Prevailing winds are from the north, and, when they blow, coastal areas become bearable in the summer and even pleasant in winter. A southerly wind is accompanied invariably by an increase in temperature and humidity and by a particular kind of storm known in the gulf area as a kauf. In late spring and early summer, a strong northwesterly wind, the shamal, blows; it is particularly severe in eastern Arabia and continues for almost 3 months. The shamal produces sandstorms and dust storms that can decrease visibility to a few meters.

The mean maximum and minimum values of temperature over a period of 35 years, i.e. from 1970 to 2006 are summarized in Table 1. The long-term mean temperature was found to vary between a minimum of 18.6 °C at Abha and a maximum of 30.2 °C at Gizan. On the other hand the extreme maximum temperature varied between 34.1 °C and 51 °C corresponding to Abha and Qaisumah stations, respectively. So, any energy storage system being considered for Saudi Arabia should have a tolerance of withstanding a maximum temperature of about 50–55 °C and minimum temperature of −10 °C. The contour maps of mean, maximum and minimum temperatures; mean relative humidity; mean barometric pressure; mean and maximum wind speeds; and maximum rain fall over Saudi Arabia are shown in Figs. A.1–A.8, respectively.

3. Supply demand situation of power in Saudi Arabia

The electric energy in the Kingdom of Saudi Arabia is provided mainly by the Saudi Electricity Company (SEC), SEC is divided in four operating areas, namely the Eastern, Central, Western and Southern operating Areas. The residential and commercial loads represent more than 60% of the SEC total load. A large portion of the loads is mainly from air conditioner, therefore, reducing the use of energy at the peak hours and build at off-peak hours, look like a viable option.

To study the viability, the hourly load data for SEC four operating areas for the year 2006 were obtained. In this paper preliminary assessment is conducted for the Central Operating Area (COA). COA was chosen for the assessment as the load in COA is mostly residential and commercial and the difference between the daily peak and minimum load is quite large. The peak load recorded in the year 2006 was 9725 MW and occurred in the month of July, the total annual energy was 52,794 GWh. The minimum load recorded was 2133 MW and occurred in the month of January. The value of peak to minimum ratio for COA is 4.56 and the annual load factor is 0.62. Fig. 1 shows the peak day load for COA, the maximum load during the day was 9725 MW and it occurred at 1400 h on July 1, 2006. The minimum load for the day was 7290 MW and the average load for the day was 8169 MW. It can be seen from Fig. 1 that the load

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