Renewable Energy 76 (2015) 375–380

Contents lists available at ScienceDirect

Renewable Energy

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

Review

Potential of lithium-ion batteries in renewable energy

Boucar Diouf [a], Ramchandra Pode [b, *]

[a] Kyung Hee University, Department of Information Display, 26 Kyunghee-daero, Dongdaemun-gu, Seoul 130-701, South Korea
[b] Kyung Hee University, Department of Physics, 26 Kyunghee-daero, Dongdaemun-gu, Seoul 130-701, South Korea

ARTICLE INFO

Article history:
Received 6 March 2014
Accepted 18 November 2014
Available online 5 December 2014

Keywords:
Battery
Lithium-ion
Renewable energy
Electric car
Cost
Safety

ABSTRACT

The potential of lithium ion (Li-ion) batteries to be the major energy storage in off-grid renewable energy is presented. Longer lifespan than other technologies along with higher energy and power densities are the most favorable attributes of Li-ion batteries. The Li-ion can be the battery of first choice for energy storage. Nevertheless, Li-ion batteries to be fully adopted in the renewable energy sector need a price reduction that most likely will be due to the mass production. The progress in Li-ion batteries needs to be carried further to match enough energy and power densities for the electric vehicle. We present the electric vehicle sector as the driving force of Li-ion batteries in renewable energies. We believe that the development of the electric vehicle industry could be the driving force for the renewable sector making Li-ion batteries more affordable as a benefit of mass production. In the development of Li-ion technology, the electric automobile will be accompanied by other sectors such as grid storage, consumer electronics, the electric bike, military or other medical applications. We present the incomparable advantages of Li-ion batteries over other technologies even if some challenges are still to overcome for a wider usage in stationary energy storage.

1. Introduction

Photovoltaic energy is continuously proving itself efficient throughout the world. The technology had known tremendous evolution along with a huge price drop making it more and more affordable. The evolution in photovoltaic (PV) energy can be attributed to the development of the individual different parts of a standalone solar system and the expansion of grid-tie systems. Nevertheless the energy storage that largely remains based on lead-acid batteries has not known much change in the last decades. In fact the price of solar panels has considerably dropped even if the technology is still in general made of mono or polycrystalline wafer based silicone solar cells. The thin film solar panels are acquiring more and more importance but are yet to be major players in the market. The lighting technology has considerably changed from incandescent lamps to highly efficient light emitting diode (LED) lamps with a price continuously decreasing as described by Haitz's law [1]. It is the same for charge controllers and inverters in general. The weak point remains the lead-acid battery, mainly because of its shorter lifespan, especially in comparison with the other components of an off-grid system. The battery technology has undergone a lot of evolution but the photovoltaic industry still uses largely lead acid batteries because of initial cost reasons and controlled recycling. Historically, valve regulated lead acid (VRLA) batteries have had a few superior technical traits, in addition to their extremely low cost, that have kept them in the lead of the overall battery market.

In a standalone PV system the lifespan of the solar panel is more than 25 years and at least 50,000 h for the LED (about 15 years) [2]. In order to improve the longevity of such a system, the lifetime of the battery should level up from the bottom to match that of the LED lamps by reaching the 15 years target, about 5000 cycles at 80% depth of discharge.

Lithium-ion (Li-ion) is a fairly new comer in the battery technology [3–7]. Li-ion and VRLA battery markets are expected to grow over the next several years, but Li-ion is certainly to overtake VRLA in some areas as when mass, lifespan or power density is critical. Lithium based batteries with their technical characteristics have the potential to revolutionize the photovoltaic (PV) industry and renewable energies in general, provide they are affordable for common systems. The current photovoltaic market is not profitable enough to boost a new battery technology expensive to develop otherwise. The development of parallel industries as the electric automobile sector [3,8], the electric bike, especially in China [9–13],

* Corresponding author. Tel.: +82 10 5169 3510; fax: +82 2 957 8408.
E-mail addresses: diouf@khu.ac.kr (B. Diouf), rbpode@khu.ac.kr (R. Pode).

http://dx.doi.org/10.1016/j.renene.2014.11.058
0960-1481/

the consumer electronic industry and others such as military, space and medical applications will create a booming effect and open new opportunities to cut down the cost of rechargeable lithium batteries and make them ideal candidates for common storage in off-grid renewable energy. In fact, for this type of stationary storage application, Li-ion batteries can potentially feature two main fundamental characteristics: longer cycle life and lower life cycle cost. The cost per cycle can be less for Li-ion batteries compared to lead-acid batteries when their lifespans considered. So, even with the current status of development, for a long-term vision it may be more advisable to invest in Li-ion rather than lead-acid even if the upfront cost is higher. But the unique energy storage in renewable energies is not sufficiently appealing to Li-ion industrials for mass production.

Most developed countries to support renewable energies production and distribution promote grid-tie systems with “net metering” type concepts that do not require a battery, the energy transformed is directly injected in the grid via a controller [14]. Such policies had created the conditions for the boost in the PV panel industry and the consecutive mass production dragged the prices down. In developing countries where batteries are more needed because generally PV systems are off-grid, they are less affordable due to populations' revenues [15,16]. This is an important limitation for what should have been a large market for Li-ion storage and is a limiting factor in the mass introduction of Li-ion batteries as primary storage systems in renewable energy. It appears that the renewable energy sector will only benefit of the development of the Li-ion batteries but will not be the driving objective of industries. It is then important to understand and follow the evolution of the sectors that will drive the cost, technical achievements and solutions for safety issues obtained from research and development in the Li-ion batteries. Upfront price will remain an important parameter in the choice of the battery in a standalone system. At the moment the market of electric vehicles seems to be the strongest driving force for the development of Li-ion batteries capable of bringing change in renewable energies. Therefore the future of renewable energy may be looked at as tightly correlated with the future of the electric and hybrid vehicles. To achieve the popularization of li-ion batteries, it is necessary to make them safer and pricewise more competitive. The market expansion of the electric car will accompany the mass production of Li-ion batteries. Furthermore, to replace the internal combustion engine, the development of the electric car itself, is conditioned by the achievement of longer autonomy range, faster charge, good acceleration and longer lifespan, so better energy and power densities but that increases as well the safety challenges to overcome [17]. Academic institutions and industries are currently developing innovative materials and design to the reach that goal [4,6].

2. The driving sectors of Li-ion batteries

The automobile industry is persistently looking for an alternative to the internal combustion engine. It is now admitted that greenhouse gases do not just pollute [5] but more, they hold important responsibility in global warming with terrible consequences. According to a report from Wards Auto, the global number of cars exceeded 1.015 billion in 2010, jumping from 980 million the year before. The OECD's International Transport Forum forecast that the number of cars worldwide would reach 2.5 billion by 2050.

Electric vehicles are drawing more and more attention due to their potential in the reduction of greenhouse gases in one hand and the current dependence and limitation of oil resources in the other that brings national vulnerabilities. The current limitation for the development of the electric automobile is the storage battery. The development of Li-ion batteries will certainly be decisive for larger scale commercialization of electric vehicles [18]. Li-ion battery technology for electric vehicles (EVs), hybrid electrics vehicles (HEVs) and plug in hybrid vehicles (PHEV) is still in its infancy, it started in 2009 [5,8,19].

Compared with other technologies, Li-ion batteries are the most suitable for electric vehicles [7,20] because of their capacity for higher energy and power output per unit of battery mass (Fig. 1). It makes them lighter and smaller than other rechargeable batteries for the same energy storage capacity [21,22]. It is foreseen that by 2020, more than half of new vehicle sales will likely consist of HEVs, PHEVs and EVs. At the moment majority of all hybrids on the market uses nickel metal hydride (NiMH) batteries. According to studies, this may change within a decade, 70% of hybrids, and 100% of plug-in hybrid and all-electric vehicles are expected to run on Li-ion batteries [23].

Currently, the HEV uses mostly the battery to save fuel in acceleration phases and charges it while braking [8]. For example a Toyota Prius can travel only 2–3 miles in all-electric mode. Both, the Chevy Volt and Nissan Leaf are electrically powered by Li-ion batteries [8]. The Chevy Volt a PHEV has autonomy of about 35 miles in all-electric mode before switching to gasoline, while the Nissan Leaf, an EV, can run approximately 70 miles between charges [8].

The higher energy and power densities are the same reasons why Li-ion batteries are already widely dominating the consumer electronics market such as cell phones, laptop computers, digital cameras and many other portable electronic devices [7,24]. Strong demand for Li-ion batteries in the consumer electronics sector will help electric vehicle batteries move down cost/experience curve [25]. Other advantages of Li-ion batteries compared to lead acid and nickel metal hydride batteries (NiMH), summarized in Table 1 below, relate to their high-energy efficiency, no memory effects, and a relatively long cycle life. Furthermore, the flat discharge curve of the Li-ion cell offers effective utilization of the stored power while the voltage remains almost constant.

To have a better market penetration, the relatively high cost of Li-ion batteries for vehicles is one of the main parameter to adjust to make the technology more competitive despite its incomparable technical advantages. According to recent estimates for vehicles' batteries, the cost of Li-ion is four to eight times the price of lead-acid and one to four times the price of NiMH [26]. However, the cost of lithium batteries is expected to drop significantly because the batteries will be increasingly used for many applications, along with the electric car, such as in medical equipment, uninterruptible

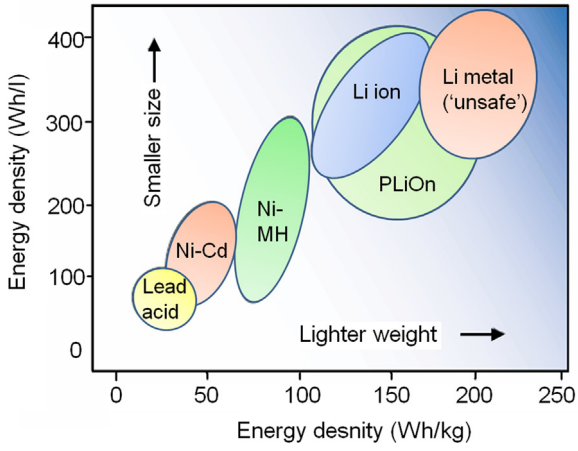

Fig. 1. Comparison between different battery technologies in term of volumetric and gravimetric energy densities.