Research Article Impact Factor: 4.226 ISSN: 2319-507X
K. U. Deshmukh, IJPRET, 2016; Volume 4 (8): 599-607 IJPRET

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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SPECIAL ISSUE FOR
NATIONAL LEVEL CONFERENCE
"RENEWABLE ENERGY RESOURCES & IT'S APPLICATION"

LARGE SCALE STATIONARY ELECTRICAL STORAGE BATTERIES AND RESEARCH AREA

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Accepted Date: 12/03/2016; Published Date: 02/04/2016

Abstract: The need of generation of power from renewable sources of energy is the hot issue over the world. Over the last few decade's developments in the renewable energy sources has increased dramatically and is now considered a mainstream form of generation as it would lead to a reduction in global consumption of the limited supplies of fossil fuels and in the associate production of greenhouse gas emission. Since wind and solar come and go energy storage fills the critical gap in terms of availability and reliability. This paper presents the review of developments in battery for large scale stationary electrical energy storage over the last decades and the field of research required in this area.

Keywords: Larglе Scale, Electrical Storage.

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How to Cite This Article:

K. U. Deshmukh, IJPRET, 2016; Volume 4 (8): 599-607

PAPER-QR CODE

INTRODUCTION

Rapid rate of growth in the recent has increased the gap between demand and supply. Captive power generation is the only solution for industries, commercial complexes, residential buildings and agriculture to meet the demand. Diesel generators are the single largest source of captive power & also largest source of green house gases.

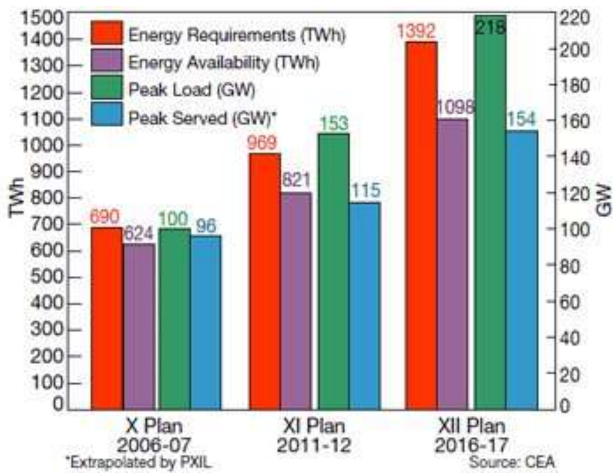

Fig1: Demand and supply

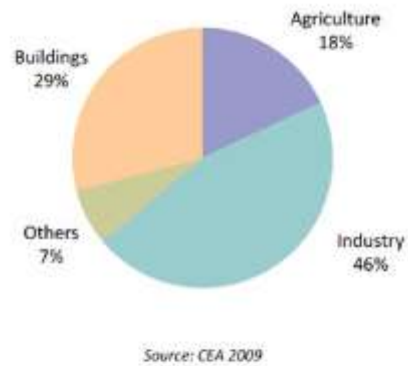

Fig 2: Electricity users

To reduce the gap between the demand and supply of energy for growth prospects & welfare of renewable energy not only compliments electricity by generators but also environmental friendly. Non-traditional sources of energy are required to meet the gap between demand & supply. Batteries are the heart of non conventional energy storage. They can directly supply power to electric cars and buses and, indirectly, homes and big buildings by storing solar and wind power for times when the sun doesn't shine and the wind doesn't blow. They balance out renewable that produce energy intermittently so consumers can use power 24hours 7days. It is the dawn of energy storage age and it could be the holy grail for renewable energy. There was no battery market three years ago, but it is changing quickly.

Many battery technologies have been proposed and developed for electrical energy storage applications, but a few are practically liable. Technologies that are used in the field systems are Valve Regulated Lead Acid (VRLA), Sodium Sulfur, Lithium Ion, and vanadium redox flow batteries. Industrial-scale batteries, known as flow batteries, could one day be the master of batteries in the use of renewable energy but only if the devices can store large amounts of energy cheaply and feed it to the grid when the sun isn't shining and the winds is not blowing. Now, researchers report that they've created a novel type of flow battery that uses lithium ion technology to store about 10 times as much energy as the most common flow batteries on the market. With a few improvements, the new batteries could make a major impact on the way we store and deliver energy.

Lithium Ion Technology

The most common material used for anode in lithium ion battery is graphite. Graphite is a solid carbon whose stacked layers take a form of 2D honey comb lattice, hence positive charged lithium ion slips between graphite layers while carbon layers gain electrons to balance the charge in intercalation compound. They are cheap, having long cycle life but have average density.

Silicon anode is an alternative to graphite anode for lithium ion batteries since the maximum energy density of silicon anode is much higher approximately ten times than that of graphite anode. But it has been observed due to high ratio of lithium to silicon in case of fully charged battery lead to increase the volume approximately three times which result in cracking and degradation of anode performance after a few numbers of cycles. New anode design embeds silicon nano particles in a matrix of sulphur doped grapheme and polycrylonitrile (PAN). Strong chemical bonds are created when graphene is doped with sulphur. Research work is going on for graphene as it has unique chemical, electronic and mechanical properties. But methods for large scale production of graphene have not been developed yet.

Recently Electrovaya / Litarion produced lithium ion battery with cycle life greater than 9000 at 100% depth of discharge. This cell offer superior safety characteristics and low manufacturing cost than conventional automotive lithium ion batteries. The new feature in this battery is the ceramic coated separator. It is a thin porous membrane which allows ion to move from one electrode to other but prevents contact between the electrodes. This result in battery safety and better cycle life Electrovaya/ Litarion claims that this new separator will reduce cost of battery by 50%. A cycle life of 9000 means an automotive battery back can be used for the life time of car which will avoid replacing the battery midway through the life of an electric vehicle. But this battery does not represent an improvement in energy density.

Lithium Sulphur Technology

Theoretical maximum density of Lithium Sulphur batteries is higher than lithium ion batteries approximately three to five times but so far practical implementation of this battery chemistry is only a fraction of the theoretically maximum energy density and have relatively short life cycle as the undesirable side reaction of the lithium sulphite formed in the sulphur cathode and hence physical degradation of the cathode due to swelling and shrinking of the sulphur cathode during the charge/ discharge cycle. Research is being done to overcome to overcome these problems but commercialisation is still not possible. Even the cost of these batteries is fairly higher than lithium ion batteries.

Valve Regulated Lead Acid Battery (VRLAB)

First lead acid cells were manufactured over 150 years ago and this technology has seen much improvement since then. Battery consortium was formed in 1992 and has been a major sponsor of the advancement of new generation The advance led acid of led acid battery design over the past 20 years. This research has included the investigation of performance limitations of led acid batteries. After high carbon contained was found to provide benefits the focus moved on to carbon enhanced design. Integrating carbon into negative electrode of the cell has allowed VRLA Cells to enter a new application space, cycling for extended periods at a partial stage state of charge. This ability is essential for a energy storage system that is ready to either except a release energy. A VRLA Cells enter new application areas such as partial charge operation, different failure mechanism can dominate. Valve regulated technology is improvement in lead acid cell. Even if VRLA technology could not improve the power handling performance but it reduced the maintenance to a large extent. The use of carbon as an enhancement to the negative electrodes of VRLA batteries allowed a significant improvement in the ability of VRLA cells to operate in Free State of health for extended period. After this focus moved to carbon enhanced design. This allowed VRLA cells to cycle for extended periods at a partial state of charge which is essential for an energy storage system. One drawback of VRLA cells that they were more prone to dry out failures. Temperature control management minimized this problem. The use of carbon as an enhancement to the positive negative electrodes of VRLA batteries has allowed a significant improvement in the ability of VRLA cells to operate in free state of health for extended period.

Sodium Sulfur Technology

The dominant organization i.e. presently developing and commercializing the Sodium Sulfur Technology is Japanese Tokio Eletrical Power Company in collaboration with NGK Insulator. As discussed above stationery application representations a very promising use for Sodium Sulfur Technology primarily because of its small high energy density and excellent electrical efficiency if routinely used, lack of required maintenance and cycling flexibility.

Operation and Properties

Sodium sulphur batteries are typically operated at high temperatures between 300–350° C. Below this temperature range, the battery is inactive. This type of battery has the following attributes:

Properties of the Sodium Sulfur Battery

Capacity:	**300MWh (renewable integration support)**
Power:	50MW (renewable integration support)
Energy Density:	150-240 J/kg
Power Density:	15-230 W/kg
Charge/Discharge Duration:	6 hours (renewable integration support)
Response Time:	Quick (a few milliseconds)
Lifetime (years/cycles):	15 yrs/4500 cycles
Roundtrip Efficiency:	80%

Applications

Due to requiring high temperatures to operate, uses for sodium sulphur batteries are limited to large, immobile technologies, such as distribution grid support. Other uses include, but are not limited to, wind power integration, and high-value applications on islands. The largest installation of sodium sulphur batteries powers a wind-stabilization project in Rokkasho, Japan. Usage of this battery type in space missions has been proposed in 1986 and1991 due to its high energy density and high charge/discharge rates. However, no official source can be found stating operational use of this battery outside of testing.

Advantages/Disadvantages

One advantage of a sodium sulfur battery is that it is a mature system with established experience and presence on the market. Since their container is entirely sealed while in operation, they are environmentally friendly. Their cost per capacity is in the middle compared to other options. Although they are not the most cost effective in terms of cost per capacity or output and duration, this type of battery does not require a supportive geographical location (such as an abundance or water and space or an underground cave) to remain in operation like pumped hydro systems and CAES systems. The battery also has no self-discharged, unlike lead-acid options, Nickel cadmium options, and Lithium ion Their extremely quick response time make them an excellent candidate for responding to changes in demand in a grid system.

The battery type's main disadvantage is that it requires a heat source for operational conditions. This makes the battery more or less immobile and impractical for residential use, especially when compared to the Li-ion rechargeable batteries currently employed on most mobile computing devices. The most unfortunate of all, is it also drains part of the battery's efficiency since the heat source needed for continuing operation is maintained using part of the battery's own stored energy.

Vanadium Redox Flow Battery

Flow batteries aren't much different from the rechargeable we're all used to, aside from their massive size. In conventional rechargeable, electrical charges are stored in an electrode called an anode. When discharged, electrons are pulled off the anode, fed through an external circuit where they do work, and returned to a second electrode called a cathode. Liquid electrolytes between the electrodes ferry ions through the battery to balance the charges. The batteries can be recharged by plugging them in, which forces the charges and the ions to flow in reverse. Its storage capacity is high; temperature is moderate and has long cycle life. Iron exchange membrane which separates positive and negative electrodes, prevents cross mixing of two electrolytes and provides the proton conduction. Properties of ideal Membrane

1. Low permeation rates of vanadium ions and water to minimise self-discharge of battery.
2. High ionic conductivity for the transport of charge carrying ions.
3. Excellent chemical stability.
4. Low cost for commercialisation.

But in flow batteries, the charges are stored in liquid electrolytes that sit in external tanks. The charge-carrying electrolytes are then pumped through an electrode assembly, known as a stack, containing two electrodes separated by an ion-conducting membrane. This setup allows large volumes of the electrolytes to be stored in the tanks. Because those tanks have no size limit, the storage capacity of a flow battery can be scaled up as needed. That makes them ideal for storing large amounts of power for the grid.

Today, the most advanced flow batteries are known as vanadium redox batteries (VRBs), which store charges in electrolytes that contain vanadium ions dissolved in a water-based solution. Vanadium's advantage is that its ions are stable and can be cycled through the battery over and over without undergoing unwanted side reactions. But vanadium is costly, and VRBs have a relatively low energy density. This means that the external tanks must be quite large to hold enough power to be useful.

The Vanadium Redox Flow Batteries invented by the M Skyllas Kazacos Group at University of New South Wales in 1980s, more than 20 large scales demonstrations have been dealt in different countries, including Australia, Thailand, Japan, U.S.A. and China. One recent example is a 260 kW system installed by Dalian Institute of Chemical Physics and Ronke Power in 2010 in China. Despite those practical applications, commercialized Vanadium Redox Flow Battery is still not available.

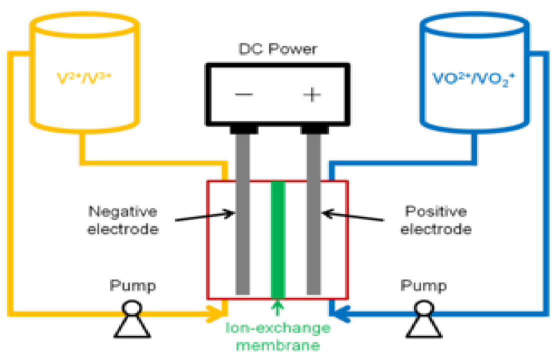

Fig 3: Vanadium Redox Flow Battery

Operating Principles of Redox Flow Battery

A flow battery is a form of rechargeable battery in which electrolyte containing one or more dissolve electro active species flows through an electro chemical cell that converts chemical energy directly to electricity. Additional electrolyte is stored externally, generally in tanks, and is usually pumped through the cell (or cells) of the reactor, although gravity feed system are also known. Flow batteries can be rapidly "Recharged" by replacing the electrolyte liquid while simultaneously recovering the spent material that would be "Recharged" in a separate step.

The Cellcube is a milestone in the history of renewable energy management. Whether in combination with photovoltaic systems wind power plants, biogas generators or for parallel operation to the public grid the Vanadium Redox Flow large battery ensures and uninterrupted power supply. It is independent of weather related fluctuations, temperatures, length of days or unstable grids.

Benefits of the Vanadium Redox Flow Battery

1. Almost unlimited life span of the energy sources (the system is designed for a life up to 20 years)
2. Electrolytes can be reused even after 20 years.
3. Out-put and energy are scalable independently of each other.
4. Deep discharge does not result in damage.
5. Unlimited cyclisation (loading/unloading) at the energy source without effect of lifespan.
6. Low maintenance.

One disadvantage of vanadium redox-flow batteries is the low volumetric energy storage capacity, limited by the solubility's of the active species in the electrolyte. The cost of vanadium may be acceptable, because it is a relatively abundant material. However, the system requires the using of expensive ion-exchange membrane, which can contribute more than 40% of the overall battery cost. Aiming to eventually promote the vanadium redox-flow batteries to commercial application, studies are carried out on the following aspects: Robust ion-exchange membranes with high proton conductivity, good selectivity, and especially low cost; three-dimensional electrodes with large surface area, good chemical stability in strong acid, and high catalytic activity; and additives or other approaches to stabilize the active vanadium species in electrolytes with high concentrations.

CONCLUSION

1. Cycle life is the current problem of lithium battery, as unwanted side reaction of lithium sulfide formed in the sulfur cathode reduces the cycle life of battery. Research is required to overcome the cycle life of lithium ion battery.
2. Even though results show that all the requirements of membrane in RFB are full filled for commercialization, economic viable systems is still a challenge and hence require development for large scale grid system.
3. The separators of Li-ion battery are very expensive. If cost is reduced and improved energy density, we can effectively use it for large scale storage.

Frequent developments in large storage battery systems are going on to meet all requirements for commercialization, still research required to achieve the required cost structure for large grid connected applications.

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