International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Energy Storage and Electric Power Stabilisation

N. Achara

Mechanical Engineering Department, Nigerian Defence Academy, Kaduna, Nigeria

Abstract: ***The availability of solar and wind energy is unpredictable and intermittent. As these energy resources gain popularity, the need for storage to cushion out the period when these resources are unavailable becomes desirable. For acceptability therefore, there is need to factor in energy storage in the planning and design of projects based on solar and wind energy resources. The various types of energy storage include pumped hydro, compressed air, battery and thermal systems. Electric energy storage can be used not only to stabilise the grid but also to reduce cost by storing during off-peak periods and injecting this back in the grid during peak demand time. With energy storage, the generating company will not only reduce cost but meet its contractual obligation manifested by steady and reduced outages. The consumer who installs electric energy storage facility will experience less disruption in supply and may sell back the excess storage where feed-in tariffs are practiced.***

Keywords: microgrid, graphene, peak-demand, nickel-ion, anolyte, catholite, methanation

1. Introduction

The unpredictability of the wind for the wind turbine and when the sky is not overcast, the availability of the sun only in the day time is a weakness in the quest to advance the case for the renewables. However, this drawback can be reduced considerably with energy storage measures.. With adequate planning and management, conventional generation facilities can also benefit from energy storage in the form of grid stabilisation. A user who is tied to the grid but has installed a storage system will find that his/her dependency on the utility companies is reduced and will have the assurance that power will continue to be available without interruption should the public power grid temporarily fail. It has to be noted however that it is necessary in grid connected systems that the storage facility automatically disconnects from the grid during power failure/outages in order to protect workers.

The shift to renewable energy is challenging the power supply industry worldwide due to the intermittency of renewable sources. A solution is needed to store and recover electric energy so as to reduce disruptions in supply. The critical issue however is the cost of energy storage.

Any solution to energy storage that would take care of the intermittency of renewable energy resources in particular, solar, wind turbine and ocean wave, would be popular with practitioners and therefore find a niche place in the market. The arrival of the microgrids is bound to add more emphasis on the development of energy storage facilities especially after the havoc caused by hurricane Sandy in the US and similar extreme weather conditions elsewhere in the world. These severe weather conditions are followed by outages that render the grid non-functional for a significant period. As a result a number of communities are known to be searching for backup systems in emergency planning for such extreme weather conditions. Following the hurricane havoc, Thurston has reported of a $30m investment in Connecticut, USA on microgrid for emergencies [1]. The completion of the first commercial-scale migrogrid in Chicago has been reported [2]. Energy storage is also beneficial to the public grid when the extra energy generated during the off-peak period is stored for use during peak demand.

The purpose of this study is to look at the various means of storing energy and possibly indicate where each is best suited in application.

2. Storage Types

Electric energy storage systems can broadly be classified into the following methods: Mechanical (flywheels, pumped hydro and compressed air), electrochemical (Lead, Lithium, Nickel and Sodium–based batteries), chemical (hydrogen and synthetic natural gas), electrical (capacitors and superconducting magnetic energy storage (SMES)) and thermal storage (hot water/phasechange material (PCM) and molten salt).

2.1 Mechanical Storage

2.1.1 Compressed Air Energy Storage

Compressed air energy storage (CAES) has been around for decades, mostly using abandoned mines or salt caverns for the storage and retrieval of compressed air to generate electricity. The CAES has the advantage of large capacity but also with disadvantages of low round-trip efficiency and geographical limitation of locations. With limited availability of abandoned mines and salt caverns, companies looking to exploit the technology have focused on smaller and more convenient methods of storing and retrieving the energy stored in compressed air. The company, SustainX has used a combination of a proprietary and proven technology to develop what it calls ICAES (isothermal CAES) system. The company is able to conserve the heat of compression at a fairly low temperature and this is released during expansion. The energy can be stored in pipelines or storage vessels. It is claimed that unlike traditional compressed air system, this can operate fuel free. Furthermore, with a lifespan of twenty years as reported, the ICAES system is more cost effective than batteries and electro-chemical storage systems with only about five years and deep discharge cycle life. A pilot plant has been designed and built and a demonstration plant is planned for 2014 [3].

The compressed air may be mixed with fuel gas, burned and expanded in a modified gas turbine that drives a generator. The air must be reheated before expansion in the turbine if the heat released during compression is dissipated by cooling and not stored. The process is referred to as diabatic and it leads to low round-trip efficiencies less than 50 %. Diabatic plants have a high reliability and are capable of starting without extraneous power.

2.1.2 Pumped Hydro (PH)

Pumped hydro is the traditional and for decades, accepted as the gold standard for electric energy storage. This method of storage uses off-peak power to pump water uphill to be recycled through the pump/generators during peak periods. One such system is the Ludington Pumped Storage on the Michigan shores of Lake Michigan, USA which is said to have been in operation since the 70s [1]. The pumped hydro storage is claimed IEC [4] to have over 120 GW capacity world-wide and to represent nearly 99% of global installed electrical storage capacity and represents, about 3 % of global generation capacity. The drawback is its dependence on topographical conditions and large land use.

2.1.3 Flywheel Storage

In flywheel storage, energy is stored in a cylinder/rim attached to a rotating shaft. To accelerate the flywheel electricity is supplied by a transmission device. If the rotational speed of the flywheel is reduced electricity may be extracted from the system by the same transmission device. The main features of flywheels are the excellent cycle stability and long life, little maintenance, high power density and the use of environmentally inert material [5]. However, flywheels have a high level of self-discharge due to air resistance and bearing losses and suffer as well from low current efficiency.

2.2 Electrochemical storage

2.2.1 Batteries

In battery storage systems the fast-charge and the fast-discharge types are required. At peak demand, it is the fast discharge batteries that would be called to play and conversely when demand is low, it is necessary that the fast charge soaks up the excess electric energy generated.

Batteries, are the main technology used in off-grid, and sometimes in grid backup. However, ARE has indicated that other energy storage modes that may be used for the provision of decentralised power services include small water reservoirs and biomass and has also listed a number of indicators that are used to measure the performance and the ideal role of the battery. These indicators include energy storage capacity, energy density efficiency or round trip efficiency, operating temperature, charge and discharge rates, percentage depth of discharge, (DOD), life of the battery and total cost of ownership (TCO) among others. Each battery has its recommended threshold level of DOD . Generally, no battery can operate below 20% DOD without seriously shortening its life [6].

Six types of secondary batteries most of which are mature technologically for practical application, are briefly described in this section. The batteries include lead acid, nickel cadmium and nickel metal hydride (NiCd/NiMH), lithium ion (Li-ion), metal air, sodium sulphur and sodium nickel chloride. There are also the flow batteries. It is important to stress that lead-acid automotive batteries cannot be used for electrification purposes, because they are primarily designed for providing high current for a short duration whereas batteries for rural electrification systems are specifically designed for deep-cycling operations.

2.2.1 Lead-based Batteries

These batteries are still the most commercially viable technology in the off-grid renewable energy market, and are generally used for home and residential systems as well as mini-grids These batteries are very robust and those required for shallow depth of discharge for example those used in solar electricity generation, do not require sophisticated management. For optimal battery life, those systems requiring deep depth of discharge, a more complex control system would be needed. The lead based batteries come in two different forms, the flooded version requiring periodic water top up maintenance and the sealed version which is maintenance free. Costs of stationary batteries are currently far higher than for starter batteries

2.2.2 The lithium-ion Batteries

Since around the year 2000, the lithium ion batteries have become the first choice in mobile and portable electricity storage applications (e.g. laptop, mobil/cell phone, solar lantern, electric bicycle, electric car etc.) The lithium ion batteries cell voltage is 3.7 nominal volts compared with the NiCd or NiMH with a cell voltage of only 1.2 volts. In effect therefore, the high cell voltage level means that the number of cells in series required to obtain a target voltage with the associated connections and electronics can be reduced. The Li-ion batteries also have high gravimetric energy density and currently have a share of over 50% in the small portable devices market. The main issue with the product is the high cost, about USD 600/kWh in 2011. The Li-ion batteries are very efficient clocking between 95 to 98% efficiency and are very flexible as any discharge time from seconds to weeks is available. Standard cells with 5 000 full cycles and higher cycle rates are available on the market. There is however room for large price reduction through mass production.

2.2.3 Nickel Based Batteries

Nickel-based batteries are of two types – the nickel-cadmium system (NiCd) and the nickel-metal hydride system (NiMH). The electrolyte in both cases is a strong alkaline. Although on average more expensive, NiCd batteries have a long calendar life (typically over 20 years and are capable of withstanding mechanical and electrical abuse [6]. They can operate in a wide range of temperature -40°C to +60°C. The nickel based batteries, as in lead based case, have a version that requires water topping up (from 10Ah to 1500Ah) and the other version that is maintenance-free (usually below 10Ah). Nickel-Metal Hydride batteries are used in remote small PV applications such as in navigation aids and solar street lighting, where their high energy density levels are beneficial. They are resistant to overcharging and deep discharge. Technically, the NiCd batteries are a very successful product and in particular, IEC has noted that they are capable of performing well even at low temperatures in the range of -20 °C to -40 °C [4].

However, because of the toxicity of cadmium, these batteries are presently used only for stationary applications in Europe. Since 2006 they have been prohibited for consumer use. On the other hand, many of the hybrid vehicles available on today's market operate with sealed NiMH batteries, as these are robust and far safer than lithium ion batteries. In 2011, for which a cost comparison is available, there is virtually no difference in cost between the NiMH and lithium ion batteries.

2.2.4 Sodium Based Batteries

The sodium-based batteries are suitable for large scale grid stabilisation, for maintenance of power quality and for peak shaving. They are maintenance-free, tolerate high temperatures and less sensitive to application environmental conditions thereby making them good candidates for rural electrification in tropical, arid and semiarid rural areas.

For the battery types considered, Table 1 is a summary of the indicators that are used to measure the performance of each type.

Table 1: Performance Indicators for Various Type of Batteries, source ARE[6]

Battery Type	Energy Density	Energy Efficiency (%)	Cycle Life (No)	Discharge Depth (%)	Calendar Life	Operating Temperature (^oC)	Recycling Efficiency (%)
Lead Based	25-40 Wh/kg	>85	2000	80	20+	-30 to 50	>95
Lithium-ion	150-200 Wh/m^3	~100	5000	80	20+	-40 to 75	50
Nickel Cadmium	20 – 80 Wh/kg	>90	3000	n/a	25	-40-60	75
Sodium Batteries	120-140 Wh/kg	95	4500	80	10+	-30-60	n/a

2.2.4 Metal Air Battery (Me-air)

The cathode of the metal air electrochemical cell is made from pure metal and the cathode is connected to an inexhaustible supply of air. It is only the oxygen in the air that is used in the electrochemical reaction. The most attractive metal air battery is the lithium-air combination as it has a theoretical specific energy excluding oxygen (oxygen is not stored in the battery) of 11.14 kWh/kg, corresponding to about 100 times more than those of other battery types and even greater than petrol (10.15 kWh/kg), [4]. However, lithium is very reactive in air and in humidity and this poses a fire risk. As a result, only a zinc-air battery with a theoretical specific energy excluding oxygen of 1.35 kWh/kg is technically feasible. Some properties of the zinc-air battery are similar to those of the fuel cell and conventional batteries. By varying the air flow, the reaction rate can be controlled. With zinc as the fuel, oxidized zinc/electrolyte paste can be replaced with fresh paste.

The development of thin electrodes based on fuel-cell research in the 1970s made small button prismatic primary cells possible for hearing aids, pagers and medical devices, especially cardiac telemetry. Rechargeable zinc air cells are difficult to design since zinc precipitation from the water-based electrolyte must be closely controlled. A satisfactory, electrically rechargeable metal air system potentially offers low materials cost and high specific energy, but none has reached commercial application yet.

2.2.5 Sodium Sulphur Batteries (NaS)

Molten (liquid) (sulphur constitutes the positive electrode and molten (liquid) sodium the negative electrode of the sodium sulphur battery. A solid beta alumina ceramic electrolyte separates the active materials. In order that the electrodes will remain in the molten form, the battery temperature is kept between 300°C and 350°C. These batteries reach typical life cycles of around 4500 with a discharge time of 6.0 hours to 7.2 hours. They are efficient (AC-based round-trip efficiency is about 75 %) and have fast response.

2.2.6 Sodium Nickel Chloride Battery (NaNiCl)

The sodium nickel chloride (NaNiCl) battery which has been commercially available since about 1995, is a high temperature battery (just like the NaS battery). It is better known as the ZEBRA (Zero Emission Battery Research) battery and its operating temperature hovers around 270°C. Nickel chloride instead of sulphur acts as the positive electrode with sodium as the negative electrode. The NaNiCl batteries can withstand limited overcharge and discharge and have potentially better safety characteristics and a higher cell voltage than NaS batteries. They tend to develop low resistance when faults occur and this is why cell faults in serial connections only result in the loss of the voltage from one cell, instead of premature failure of the complete system.

Springer reports of companies pursuing battery storage developments and these include Aquion Energy which in collaboration with Carnegie Mellon University has developed a **sodium-water battery** claimed to require no maintenance over time [3].

A team led by Sadoway at MIT has developed a battery that works with **molten metal separated by molten salt [7]**. Scaling up is a possibility. In the liquid battery development, magnesium and antimony form the negative and positive electrodes with the molten salt in between. Following the report by Ambri, the technology appears to have been commercialised [8].

2.2.7 Redox Flow Battery (RFB)

In the redox flow batteries, two liquid electrolyte containing dissolved metal ions as active masses are pumped to the opposite sides of the electrochemical cell. The electrolytes at the negative and positive electrodes are called anolyte and catholyte respectively. During charging and discharging the metal ions stay dissolved in the fluid electrolyte as liquid; no phase change of these active masses takes place. Anolyte and catholyte flow through porous electrodes, separated by a membrane which allows protons to pass through it for the electron transfer process. During the exchange of charge a current flows over the electrodes, which can be used by a battery-powered device. During discharge the electrodes are continually supplied with the dissolved active masses from the tanks; once they are converted the resulting product is removed to the tank.

Considerable interest has been shown by mobile applications such as electric vehicle since in theory the RFB can be "recharged" within a few minutes by pumping out the discharged electrolyte and replacing it with recharged electrolyte. However, the energy density of the electrolytes has been found to be too low for electric vehicles as a result other redox couples are being investigated.

The flow battery was originally developed by NASA in the early 70s as electric energy storage for long-term space flights
Thurston has written of a grid storage company called Urban Electric Power that has commercialised an Ni-Zn flow-assisted 100-kW battery system that can discharge 85% of its power in 30 minutes and with a life of ten years [1]. This battery belongs to the fast discharge range. The same company has also developed a Zn-MnO2 energy battery that can be used in industrial applications where the peak in use is flatter than commercial spikes. The battery according to the company retails at $70/kWh, a price it claims is cheaper than a car battery

2.3 Chemical Energy Storage

Electricity can be used to produce hydrogen through the electrolysis of water. Once the hydrogen is produced various means are available to use it as energy carrier in its pure form or as synthetic natural gas (SNG) as secondary energy carriers. This could have significant impact on the storage of electrical energy in large quantities. Although the overall efficiency of hydrogen and SNG is low compared to storage technologies such as PHS and Li-ion, chemical energy storage is the only concept which allows storage of large amounts of energy, up to the TWh range, and for greater periods of time – even as seasonal storage. hydrogen and SNG are universal energy carriers and can be used in different sectors, such as transport, mobility, heating and the chemical industry.

2.3.1 Hydrogen (H_2)

A typical hydrogen storage system consists of an electrolyzer, a hydrogen storage tank and a fuel cell. An electrolyzer is an electrochemical converter which splits water with the help of electricity into hydrogen and oxygen. It is an endothermic process, i.e. heat is required during the reaction. Hydrogen is stored under pressure in gas bottles or tanks, and this can be done practically for an unlimited time. To generate electricity, both gases flow into the fuel cell where an electrochemical reaction which is the reverse of water splitting takes place: hydrogen and oxygen react to produce water, heat is released and electricity is generated. For economic and practical reasons oxygen is not stored but vented to the atmosphere on electrolysis, and oxygen from the air is taken for the power generation.

2.3.2 Synthetic Natural Gas (SNG)

Synthesis of methane (also called synthetic natural gas, SNG) is the second option to store electricity as chemical energy. Here a second step is required beyond the water splitting process in an electrolyzer, a step in which hydrogen and carbon dioxide react to form methane in a methanation reactor. As is the case for hydrogen, the SNG produced can be stored in pressure tanks, underground, or fed directly into the gas grid. Several CO2 sources are conceivable for the methanation process, such as fossil-fuelled power stations, industrial installations or biogas plants. A pilot-scale plant is reported to be under construction in Germany [4].

2.4 Electrical Storage Systems

2.4.1 Double-layer Capacitors (DLC)

Electrochemical double-layer capacitors (DLC), also known as supercapacitors, are a technology which has been known for 60 years. They fill the gap between classical capacitors used in electronics and general batteries. They have nearly unlimited cycle stability as well as extremely high power capability and many orders of magnitude higher energy storage capability compared with the traditional capacitors.

They have extremely high capacitance values, of the order of many thousand farads, and the possibility of very fast charges and discharges due to extraordinarily low inner resistance which are features not available with conventional batteries. Other advantages include durability, high reliability, low maintenance, long lifetime and operation over a wide temperature range and in diverse environments (hot, cold and moist).

Springer has also reported of a company EnerG2 that has developed and patented a synthetic carbon storage device [3]. This product could also be used as ultracapacitor. The synthetic carbon can store 50% more energy than natural carbon. Natural carbon, for example that from coconut husks, contain iron which is said to act as a catalyst that promotes early failure.

2.4.2 Superconducting Magnetic Energy Storage

Superconducting magnetic energy storage (SMES) systems work according to electrodynamic principle. The energy is stored in the magnetic field created by the flow of direct current in a superconducting coil, which is kept below its superconducting critical temperature. Hundred years ago at the discovery of superconductivity a temperature of about 4 °K was needed. Much research and some luck have now produced superconducting materials with higher critical temperatures. Today materials are available which can function at around 100 °K. The main component of this storage system is a coil made of superconducting material. Additional components include power conditioning equipment and a cryogenically cooled refrigeration system. The main advantage of SMES is the very quick response time: the requested power is available almost instantaneously.

2.5 Thermal Storage Systems

Thermal (energy) storage systems store available heat by different means in an insulated repository for later use in different industrial and residential applications, such as space heating or cooling, hot water production or electricity generation. Thermal storage systems are deployed to overcome the mismatch between demand and supply of thermal energy and thus they are important for the integration of renewable energy sources.

The contribution of the company, Isentropic to the problem of energy storage consists of transforming the electrical energy into heat and using this to maintain a temperature difference between two volumes of crushed mineral materials. The energy is recovered as electricity when needed [9]. The company refers to this as Pumped Heat Electricity Storage (PHES) and claims that it is the cheapest and most convenient way to store and recover electricity.

The development by SHEC Energy uses either a hydrocarbon or salt based solution to transport the heat from the solar collector to the boiler or storage system [10]. Current available technology, it claims, is limited by operating temperature levels which range from 390°C to 560°C. These temperature levels lower the heat transport capacity and overall plant efficiency especially if thermal storage is incorporated

Table 2 below summarises the features of the various energy storage types and their area of application.

Table 2: Technical overview of electrical energy storage technology types (source [4])

Battery Technology	Nominal Voltage [V]	Response Time	Energy Density [Wh/kg]	Power Density W/l	TypicalDischarge Time	Energy Efficiency	Life time	Typ Cycle	Typ Application
PHS		min	0.2-2	0.1-0.2	Hrs	70-80	>50	>15000	Time shifting, power quality, emergency supply
CAES		min		0.2-0.6	Hrs	41-75	>25	>10000	Timeshifting,
Flywgeel		<sec	5-30	5000	Secs	80-90	15-20	2*10p4-10p7	Power quality
Lead Acid	2.0	<sec	30-45	90-700	hrs	75-90	3-15	250-1500	Off-grid,power shifting, emergency supply, power quality
NiCd vented sealed	1.2	<sec	15-40 30-45	75-700 vented	Hrs	60-80 60-70	5-20 5-10	1500-3000 500-800	Off-Grid, Emergency supply, Time shifting, Power quality
NiMH sealed	1.2	<sec	40-80	500-3000	Hrs	65-75	5-10	600-1200	Electric vehicles
Li-ion	3.7	<sec	60-200	1300-10000	hrs	85-98	5-15	500-10p4	Power quality, network efficiency,off-grid, time shifting, electric vehicle
Zinc-air	1.0	<sec	130-200	50-100	Hrs	50-70	>1	>1000	Off-grid, electric vehicles
NaS	2.1	<sec	100-250	120-160	hrs	75-85	10-15	2500-4500	Time shifting network efficiency, off-grid
NaNiCl	2.6	<sec	100-200	250-270	Hrs	80-90	10-15	~1000	Time shifting electric vehicles
VRFB	1.6	Sec	15-50	0.5-2	Hrs	60-75	5-20	>10000	Time shifting, network efficiency, off-grid
HFB	1.8	Sec	75-85	1-25	Hrs	65-75	5-10	1000-3650	Time shifting, network efficiency, off-grid
H2 Central Decentral		Sec-min	33-330	0.2-2 2.0-20	Hrs-wks	34-44	10-30	10p3-4	Time shifting
SNG		Min	10000	0.2-2	Hrs-wks	30-38	10-20	10p3-4	Time shifting
DLC	2.5	<sec	1-15	40000-120000	Secs	85-98	4-12	10p3-6	Power quality effective connection
SMES		<sec		2600	Secs	75-80	*)	*)	Time shifting, Power quality

3. Discussion

Appropriate amount of electricity must be generated but accurate forecast and planning of demand is a difficult task because of the peculiar nature of electricity generation, distribution. and use. Electricity is consumed at the same time as it is generated but enough electricity must be generated to meet varying demand. Any imbalance between supply and demand is manifested by deterioration in stability and quality of supply. The consumer is only interested in steady uninterrupted supply. It is left for the generating company to grapple with maintaining the quality of supply without the waste caused by over-generation. Generation cost is higher at peak period compared with the off-peak period. During the peak period, the supplier must augment the base load with extra generation capacity. Usually this is achieved by bringing online less cost-effective but flexible types of generation fuel such as oil and gas instead of coal which, even after the cost of scrubbing the stack gases, turns out cheaper. The beneficial effect of electric energy storage can be enjoyed by suppliers if the excess generated using cheaper fuels during the off-peak period is stored and used for the extra power requirement during the peak demand period.

During the off-peak period, costly types of generation are taken out of action. Owners of Electric Energy Storage (EES) systems stand to benefit financially because of the associated lower tariff. From the utilities' viewpoint there is a huge potential to reduce total generation costs by eliminating the costlier methods through storage of electricity generated by low-cost power plants during the night and reinserting this into the power grid during peak periods. With high solar and wind power penetration in some regions, cost-free surplus energy is sometimes available. This surplus can be stored in EES and used to reduce generation costs. Conversely, from the consumers' point of view, EES can lower electricity costs since it can store electricity purchased at low off-peak prices and used during peak demand periods when tariff is high. In an area where Feed-in-tariffs (FITs) is practiced, consumers who charge batteries during off-peak hours may also sell the electricity to the utilities or to other consumers during peak hours. However in future, there will be increase in distributed generation where generation and consumption are typically close together. With proper planning and management, the benefits of energy storage can be enjoyed by both parties because the supplier would not only reduce cost but also meet its contractual obligation manifested by reduced outages and all users would benefit from reduced bill as well as reduced power disruption. Thurston has reported of a company, Greensmith Energy Management Systems that can, using a computerised system, provide such planning and management services [1]. For the grid also large scale electric power storage would help to stabilise the grid against supply and demand shock if used to even out the peaks and troughs of supply. In many developing countries the tariff is not time-of-use dependent but users can still benefit from electric energy storage by storing during the off-peak period, usually late in the night and using the stored energy during the peak period to cushion out the erratic, unreliable supply.

Electric energy storage price reduction is a key and quite important and in recognition of this, Thurston has reported of a company, Ionex Advanced Energy Storage Systems that is working on a battery development based on silicon and graphene at a target price tag of $150/kWh [1]**.** This is derived from the original technology developed at Argonne National Laboratory. In recognition of the need for energy storage cost reduction, the DOE and Stanford University USA are reported, by Ross to have developed a low cost and long lasting flow battery [11].

In the quest to alleviate energy poverty in rural communities, Wiemann has noted that decentralised electric power provision often proves to be a more feasible option than grid extension [12]. Decentralised deployment is not only cost-effective over the system's lifetime but also easy to install, maintain and with design tailored to demand needs. For decentralised grid to be acceptable to the rural folks, a solution has to be found that overcomes the intermittency in the availability of the solar and wind energy resources. The issue of energy storage facility should, therefore be an integral part of the design of rural community based power projects whether it is off- grid or decentralised grid. Battery is one form of storage facility and is available in different chemical families each with its specific features and with a wide range of roles to fit local conditions.

The production cost of Ni-ion batteries is still high. This may be attributed to the need for special packaging and internal overcharge protection circuits required to prevent thermal runaway. Thermal runaway is a serious safety issue in Ni-ion technology. Most of the metal oxide electrodes are thermally unstable as they can decompose at elevated temperatures to release oxygen, the source of the thermal runaway. This can account for the provision of monitoring unit in the Ni-ion batteries to avoid over-charging and over-discharging.

4. Conclusion

1) Various types of electric energy storage facilities have been investigated and where each is best suited for use indicated.
2) The acceptability of renewable energy with its intermittency nature will be enhanced with energy storage facilities.
3) The pumped hydro and compressed air may be limited in application by geographical features.
4) Energy storage is recognised as being beneficial but there is still need to bring down the cost of storage

References

[1] Thurston C, Energy Storage Technology at Renewable Markets Edge, Renewable Energy World, 13, August, 2013
[2] V Font, Solar PV + Storage = The Next Big Thing, Renewable Energy World, Oct. 25 2013
[3] Springer R, Energy Storage Wars: Which Technology Will Win the Battle?, Renewable Energy World, 14 January 2013
[4] IEC, Electrical Energy Storage, International Electrotechnical Commission. CH-1211 Geneva 20 Switzerland, 2011.
[5] FEMP, Flywheel Energy Storage, Federal Energy Management Program,, DOE/EE-0286 Sept 2003
[6] ARE, Using Batteries to Ensure Clean Reliable and Affordable Universal Electricity Access, Alliance for Rural Electrification (ARE), Position Paper – Energy Storage Campaign, June 2013.
[7] Sadoway D, The Missing Link to Renewable Energy, TED Ideas Worth Spreading, http://www.ted.com/talks/donald_sadoway_the_missing_link_to_renewable_energy.html, Retrieved 03 August 2013
[8] Ambri, Liquid Metal Battery Technology, www.ambri.com, retrieved on 16 July 2013
[9] Isentropic, www.isentropic.co.uk, Retrieved 10 August 2013
[10] SHEC Energy, The SHEC Heat Transfer Technology, www.shecenergy.com/, Retrieved on 06, September 2013.
[11] Ross M, New Battery Design Could Help Solar and Wind Energy Power the Grid, Renewable Energy World, 02 May 2013.
[12] Wiemann M, Energy Storage: Rural Electrification Backup, Renewable Energy World, 07 August, 2013