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Original Research Article

The Role of Energy Storage in addressing Energy Challenges in Nigeria

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Nigeria is among underdeveloped countries in the world due to persistence energy crises which has weakened the industrialization process and effort to achieve sustainable growth. The role of energy storage is still high in various aspects and there are needs to sustain energy storage to address the energy challenges in the country, most of the various utility companies do not have enough energy to meet the needs of everybody at the same time. The energy sources that can be stored are hydro power, solar power, biomass, wind and fossil fuels. The potential benefit of energy storage earmarked to increase by 40 % over the next 10 years, ranging from 584 MW in 2014 to 2080 MW in 2024. The government and non governmental agencies should promote the storage of available energy in various sectors such as manufacturing, industries, residential buildings and transportation.

Keywords Energy Storage, Energy Efficiency, Renewable Energy, Sustainable Electricity

INTRODUCTION

Energy storage has been earmarked as a possible backup that will play a key role in enabling countries develop a low-carbon electricity system (EU, 2012 and IEC, 2011). Energy storage can supply more flexibility and balancing to the grid, providing a back-up to intermittent renewable energy. Locally, it can improve the management of distribution networks, reducing costs and improving efficiency. In this way, it eases the way for renewable energy introduction into the market, accelerate the decarbonisation of the electricity grid, improve the security and efficiency of electricity transmission and distribution (reduce unplanned loop flows, grid congestion, voltage and frequency variations), stabilize market prices for electricity, while also ensuring a higher security of energy supply(Oyedepo, 2012).

According to the survey of ECN (2008), energy is said to be used in all aspects of human endeavours such as agricultural productivity, job creation, environmental sustainability and access to clean water. Okafor (2010) described energy as essential for social development; that about 90 % of the world energy supplies are by fossil fuels with associated emission leading to regional and global problems. Currently there is minimal energy storage across the country which translates less than 5 % of the total installed capacity (Oyedepo, 2012). Other forms of storage such as batteries, electric cars and chemical storage are at their minimal or very early developmental stage. According to Oyedepo (2012), energy is said to play a key role in the economic growth, progress, and development, as well as poverty eradication and security of any nation. Today uninterrupted energy supply is a vital issue across the world. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible, and environmentally friendly(Adenikinju, 2008). The energy crisis, which has engulfed Nigeria for almost two decades, has been enormous and has largely contributed to the poverty rate by paralyzing both the industrial and commercial activities which led to an estimated loss of 126 billion naira (US$ 984.38 million) annually(Sambo, 2012). To determine the potential role of storage in the grid of the future, it is important to examine the technical and economic impacts of variable renewable energy sources to enable greater use of Energy storage technologies. This review considers the role of energy storage in addressing economic challenges in Nigeria.

ENERGY EFFICIENCY

Energy efficiency is a set of measures whose objective is to reduce energy consumption, such that consumer satisfaction is maintained (Adenikinju, 2008). Energy efficiency is not only applied to management of demand, but can also be attributed to production, transportation and energy distribution.

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Table1. Status of Government owned Power Plant and their availability.

	Stations	Initial capacity (MW)	Available capacity (MW)	Operational capacity (MW)
1	Geregu	414	414	140
2	Omotosho	335	300	75
3	Olorunsogo	335	300	75
4	Alaoji	515	0	0
	Total	1599	1014	290

Source: Okafor (2010).

Energy efficiency has become a key driver of sustainable development in many world economies; this has helped in reduction of construction of more power stations where the money for building power station would be spent on other sector of the economy (Adenikinju, 2008). In Nigeria various utility companies do not have enough energy to meet the needs of everybody at the same time, energy supply is alternated. The energy generated in Nigeria mostly comes from burning of fossil fuel (oil and gas), for every kilowatt of electricity we consume there is an equivalent emission of greenhouse gas (Sambo, 2012). Energy efficiency can help reduce emissions of greenhouse gas, thereby reducing reliance on petroleum to drive our economy.

According to Sambo, 2008 the current record of generating electricity is lost through poor maintenance and poor network; this signifies a great potential for substantial energy saving if the transmission system is made more efficient. The total installed capacity of power generating stations in Nigeria is 7876 MW but the total available installed capacity is less than 4000 MW, some of the generating stations are over 20 years old and the daily average generating power is 2700 MW, which is far below peak load of 8900 MW for existing infrastructure (Ogunji et al., 2013). As a result of this the country experiences load shedding. Table 1 is showing the power plant in Nigeria.

Energy efficiency increase will help break up economic growth from electricity consumption growth and slow down annual power plant capacity addition (Ministry of power, 2015). Such a break up will lead to the development of large renewable energy projects to be transmitted via the grid.

A recent survey conducted by ECN (2008), revealed that about 500 million incandescent lamps are used for lighting alone in residential areas and the survey further revealed that as much as 25 % of industrial energy can be saved through simple housekeeping. The energy ratings for incandescent bulbs that can be found in Nigeria market ranges from 40W to 200W (CRDC, 2009). According to Ndinichi et al., (2012) comparison has been done between incandescent lamp and compact fluorescent lamps showing the compact fluorescent obvious advantage to incandescent bulbs, the compact fluorescent are not problem free but it has a better advantage in energy saving.

STORAGE TECHNOLOGIES

Research and development is very essential in sustaining socioeconmic advancement of any nation (Denholm et al., 2010). Research is very vital to different sectors of the economy, such as renewable energy and energy efficiency subsector. According to the survey conducted by Ministry of power (2015) research and technological development is needed to enable wider applications of many known technologies and to develop new ones. Storage can be on small, medium, or large scale depending on the location such as GW, MW, and KW. Some of the key technologies not all of these are at the stage of commercial application.

1. Thermal storage, pumped hydro;
2. Compressed Air Energy Storage (CAES)
3. Chemical storage (e.g. hydrogen - large scale >100MW, up to weeks and months)

Grid storage systems (MW) able to provide

1. Power: super-capacitors, Superconducting Magnetic Energy Storage (SMES), flywheels,
2. Energy: batteries such as Lead Acid, Li-ion, NaS & Flow batteries
3. Energy & Power: Lead Acid & Li-Ion batteries
4. Hydrogen Energy Storage / Compressed Air Energy Storage (CAES) / Pumped Hydro Energy Storage (PHES) (small scale, 10MW< P > 100MW, hours to days)

End-user storage systems (kW)

1. Power: super-capacitors, flywheels
2. Energy: batteries such as Lead acid and Li-ion
3. Energy & Power: Li-ion batteries

TYPES OF ENERGY STORAGE

High-Energy Batteries

For many batteries, there is considerable overlap between energy management and the Shorter-term applications. Furthermore, batteries can generally provide rapid response, which means that batteries “designed” for energy management can potentially provide services over all the applications and timescales. Several battery technologies have been used or deployed for energy management applications. In addition to the chemistries discussed previously, the commercially available batteries targeted to energy management include two general types: high temperature batteries and liquid electrolyte flow batteries. The most mature high-temperature battery as of 2009 is the sodium-sulfur battery, which has worldwide installations that exceed 270 MW (Rastler 2008). Alternative high temperature chemistries have been proposed and are in various stages of development and commercialization. One example is the sodium-nickel chloride (ZEBRA) battery.

The second class of high-energy batteries is the liquid electrolyte “flow” battery. This battery uses a liquid electrolyte that flows across a membrane. The advantage of this technology is that the power component and energy component can be sized independently. As of 2009, there has been limited deployment of two types of flow batteries – vanadium redox and zinc-bromine. Other combinations such as polysulfide bromine have been pursed, and new chemistries are under development. The European battery industry has been encouraged to continue its work to optimize the technological and economic competitiveness of battery energy storage system for grid support (EUROBAT, 2013). Battery storage system ranges from 2 KW up to 50 MW are set apart by their fast response, mobility, and flexibility to be filled with either high power or high energy application. Batteries posses the unique potential to provide storage services at all levels to the grid- generation, transmission, distribution or customers while also providing ancillary services to the end users.

Pumped Hydro Storage (PHS)

Pumped hydro is the only energy storage technology deployed on a Gigawatt scale in the United States and worldwide. In the United States, about 20 GW is deployed at 39 sites, and installations range in capacity from less than 50 MW to 2,100 MW. Many of these technology store 10 hours or more and thereby making the technology useful for load levelling. PHS is also used for ancillary services. PHS uses conventional pumps and turbines and requires a significant amount of land and water for the upper and lower reservoirs. PHS plants can achieve round-trip efficiencies that exceed 75% and may have capacities that exceed 20 hours of discharge capacity (Okafor, 2010). Environmental regulations may limit large-scale aboveground PHS development. However, given the high round-trip efficiencies, proven technology, and low cost compared to most alternatives, conventional PHS is still being pursued in a number of locations.

Compressed Air Energy Storage (CAES)

CAES technology is based on conventional gas turbine technology and uses the elastic potential energy of compressed air. Energy is stored by compressing air in an airtight underground storage cavern. To extract the stored energy, compressed air is drawn from the storage vessel, heated, and then expanded through a high-pressure turbine that captures some of the energy in the compressed air. The air is then mixed with fuel and combusted, with the exhaust expanded through a low-pressure gas turbine. The turbines are connected to an electrical generator. Alternative lower-impact configurations have been studied, including using a natural or mined underground formation for the lower reservoir, but this configuration has yet to be commercialized. CAES is considered a hybrid generation or storage system because it requires combustion in the gas turbine. The performance of a CAES plant is based on its energy ratio (energy in/energy out) and its fuel use (typically expressed as heat rate in BTU/kWh). CAES performance is estimated at an energy ratio of 0.6 - 0.8 and a heat rate of 4,000 - 4,300 BTU/kWh (Ogunji et al., 2013). Because CAES uses both electricity and natural gas, a single-point definition of the round-trip efficiency of a CAES device does not represent an economic figure of merit.

Thermal Energy Storage

Thermal energy storage is sometimes ignored as an electricity storage technology because it typically is not used to store and then discharge electricity directly. However, in some applications, thermal storage can be functionally equivalent to electricity storage. One example is storing thermal energy from the sun that is later converted into electricity in a conventional thermal generator. Another example is converting electricity into a form of thermal energy that later substitutes for electricity use such as electric cooling or heating. One of the major issues with electricity storage is efficiency losses. Electricity is a high quality source of energy, and transforming electricity into a stored medium and back incurs considerable losses. Thermal energy is a much lower quality of energy, but can be stored with much higher efficiency.

TYPES OF ENERGY WE CAN STORE

Energy storage plays a vital role in the use of renewable energies particularly solar and wind. Nanotechnology has been identified to play a major role in the energy distribution generation through the development of cost effective energy storage in batteries, capacitors and fuel cells (Ogunji et al., 2007).

Solar Energy: The first impression of the design of solar energy system is the availability of solar energy in the present and also in the future, the availability of solar energy also depend on time scale and geographical location. The solar power reaching the earth is typically 1000 W/m2 and the total amount of energy that the earth receives is 1353 W/m2. Solar energy characterizes a clean pollution free and inexhaustible energy source. In addition to these factors the declining cost and prices of solar modules an increasing efficiency of solar cell manufacturing technology improvement and economics of scale.

Rotational Energy: according to Dotsch (2007), flywheel energy storage stores rotational energy in an accelerated rotor of a huge cylinder. The main components of flywheels are the rotating body in a compartment, and the bearing and transmission device (motor). The energy in the flywheel is maintained by keeping the rotating body constant speed, an increase in the speed results in the higher amount of energy stored

BENEFIT OF ENERGY STORAGE

The temporary flexibility offered by storing energy can help the power sector accommodate period of demand and supply mismatch thereby improving reliability of the grid, the quality of its electricity and the profitability of infrastructural development (IEC, 2011). Storage from social perspective can address the emerging energy demand of rural areas, empower consumers to manage their energy consumption and also strengthen the value proposition of renewable energy installations. Energy storage can reduce the need for major new transmission grid construction upgrade as well as augment the performance of existing transmission and distribution assets (GES, 2013). The potential benefits of storage have caught the attention of many stakeholders in the power sector leading to significant growth. Installation associated with grid and ancillary service is projected to grow by 40 % over the next 10 years (538.4 MW in 2014 to 2080MW in 2024). According to Ogunji et al., 2013 energy storage among end user is expected to see even greater growth by 70 % (172 MW in 2014 to 12147 MW in 2024) due to large part in small grid technology. Energy storage technologies are therefore just as important as environmentally friendly and cost efficient alternatives to the conventional options.

APPLICATIONS OF ENRGY STORAGE

There are several services that energy storage could provide in the current grid, these are listed below;

Transmission and Distribution: In addition to the generation, storage can act as an alternative or supplement to new transmission and distribution (T&D). Distribution systems must be sized for peak demand; as demand grows, new systems (both lines and substations) must be installed, often only to meet the peak demand for a few hours per year. New distribution lines may be difficult or expensive to build, and can be avoided or deferred by deploying distributed storage located near the load (Ridge Energy, 2015). (Energy can be stored during off-peak periods when the distribution system is lightly loaded, and discharged during peak periods when the system may otherwise be overloaded.) Energy storage can also reduce the high line-loss rates that occur during peak demand (Ridge Energy, 2015).

Black-Start: Black-start provides capacity and energy after a system failure. A black-start unit provides energy to help other units restart and provide a reference frequency for synchronization. Pumped hydro units have been used for this application.

Power Quality and Stability: Power Quality and Stability Energy storage can be used to assist in a general class of services referred to as power quality and stability. Power quality refers to voltage spikes, sags, momentary outages, and harmonics. Storage devices are often used at customer load sites to buffer sensitive equipment against power quality issues. Electric power systems can also experience oscillations of frequency and voltage. Unless damped, these disturbances can limit the ability of utilities to transmit power and affect the stability and reliability of the entire system. System stability requires response times of less than a second, and can be met by a variety of devices including fast-responding energy storage.

End use and Remote Application: End-Use/Remote Applications Other applications for energy storage are at the end use. Storage can provide firm power for off-grid homes, but also can provide value when grid-tied through management of time-of-use rates, or demand charges in large commercial and industrial buildings. Energy storage also provides emergency and backup power for increased reliability. In many cases, end-user applications have analogous applications in the grid as a whole (and potentially compete with these applications). For example, using energy storage to time-shift end use is functionally equivalent to energy arbitrage, and a flatter load on the demand side reduces the potential need for load levelling in central storage applications (and vice-versa). To be economic, end-use applications require time-varying prices and are extremely site-specific.

CONCLUSION

Nigeria is blessed with abundant renewable energy resources and one of the major challenges is the utilization of various energy systems. In order to ensure the sustainability of the energy supply, there is a need for the government to increase its effort on renewable energy and efficiency programs. There is also need to ensure that the present generated energy in the country is by the use of energy efficiency products and practice which is essential for sustainable development. Developing technology to store electrical energy so it can be available to meet demand whenever needed and would represent a major breakthrough in electricity distribution in Nigeria. These devices can also help make renewable energy whose power output cannot be controlled by the grid operators, smooth and dispatch able, but can balance micro grids to achieve a good match between generation and load. Thus, energy storage holds sustainable promise for addressing the energy challenges in Nigeria.

RECOMMENDATIONS

- Create awareness on energy storage and efficiency.
- Promote energy efficiency product and practice at the side of the end user and energy generation.
- Develop policies on energy storage efficiencies and integrate them into the country’s current energy policy.
- Create awareness on the need to change the attitude of Nigerians on the need to save energy by using the right technology.
- Develop policy option that will include phase out of incandescent bulbs and place ban on importation and also encourages the production of energy efficient light bulb which will enhance the efficient use of energy.

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