2018 3rd International Electrical Engineering Conference (IEEC 2018)
Feb, 2018 at IEP Centre, Karachi, Pakistan

# Future of Renewable Energy Technologies In Pakistan: A Policy Recommendation For Energy Storage Systems

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**Abstract:** Energy demand and supply will become a difficult and complex process when electricity is generated through modern renewable energy resource such as solar photo voltaic plant, wind turbine power plant and tidal resources which heavily rely on environmental conditions. For a reliable and sustainable energy to the power grid, Electricity storage technologies have a significant function while considering the weather changes effects on renewable energy technologies. In this paper, we have presented and briefly discussed the electricity storage technologies by providing the operational mechanism of each type of energy storage technologies and policy recommendations for the energy storage technologies utilization have been suggested in order to attain, sustainable, reliable and secure energy provision.

**Keywords:** Electricity Storage System, Pump Hydro Storage System, Electro-Chemical Energy Storage systems, Energy Policy.

## I. INTRODUCTION

For security, reliability and sustainability of energy production, Electricity storage will have animperativefunction in renewable energy technologies implementation in the future.Through energy storage technology services and smooth operationsthe power qualitywill certainly improve, along with reliability, voltage support, electric supply capacity and power time shift to support the integration of renewable technologies[1]. Fig. 1 provides a list of accessible Electricity storage technologies which can be utilized and installed for different application from power generation site to residential areas depending upon the benefits and draw backs of each electricity storage technologies. In this regards, [2-9]provided an overview and detailedexplanation of each energy storage technologies system by comparing the battery storage system in-terms of technical and economical features. Work in [10] compares the lithium ion battery to lead acid batterywith regard to capacity fading and partial charging of batteries and describe the procedure of battery testing in off grid renewable energy applications. Similarly, work in [11] developed the 12 models of lithium ion batteries. The datasets of each modelshave been collected under three different temperatures of two lithium ion cell by utilizing swarm optimization algorithm technique. Work in [12] briefly explain the battery storage system and through simulation of photo voltaic system and HOMER analysis developed the actual cost of solar panel, lead acid battery, NiCd battery, NiMH battery and lithium-ion batteries. Currently, AES, Energy Storage Company which is the pioneer in providing the solution of energy storage with renewable energy technologies did merger with Siemens by adopting a new name *Fluence*. AES is recognized as the global leader interms of energy storage technologies deployment. About a decade ago AES, successfully deployed its first ever 1 MW of grid scale battery energy storage technology. The other major project deployed by AES with a capacity of 32 MW of energy storage array has been installed at Laural Mountain, West Virginia, USA. Another project by AES, of 100 MW/ 400 MWh energy storage plan has been successfully completed at Alamitos Energy centre long beach California which also entails a 640 MW of combined cycle power plant. A major project by AES Company is under commissioning stage at Kauai Hawaii USA, with an energy storage capacity of 20 MW/ 100 MWh. Tokelau, a dependent territory ofNewZealand has been utilizing the lead acid battery storage system for affordable and secure production of energy.

## II. ELECTRICITY STORAGE TECHNOLOGIES

Electricity storage system (ESS) is widely considered and deployed in developed countries like china, Australia,Japan, USA, Spain etc for provision of reliable, sustainable and affordable energy supply to the respective grids. Electricity storage technologies are basically split in to 6 categories depending upon its construction and usage as mentioned in fig. 1. Each category of electricity storage technologies is further classified based on their respective application. Till now, the top 10 countries in storage technology fully utilized the available option of battery energy technologies, pumped hydro energy storage technologies and thermal storage energy technologies in their power sector to provide safe, sustainable, affordable and secure energy to consumers. The global capacity share of each storage technologies utilized by different countries are as follows:

- Chilled water thermal storage capacity: 4%
- Heat Thermal Storage : 4%
- Ice Thermal Storage : 2%
- Molten Salt Thermal Storage: 7%
- Other Thermal Storage: 15%
- Electro-chemical Capacitor: 4%
- Flow Battery: 2%

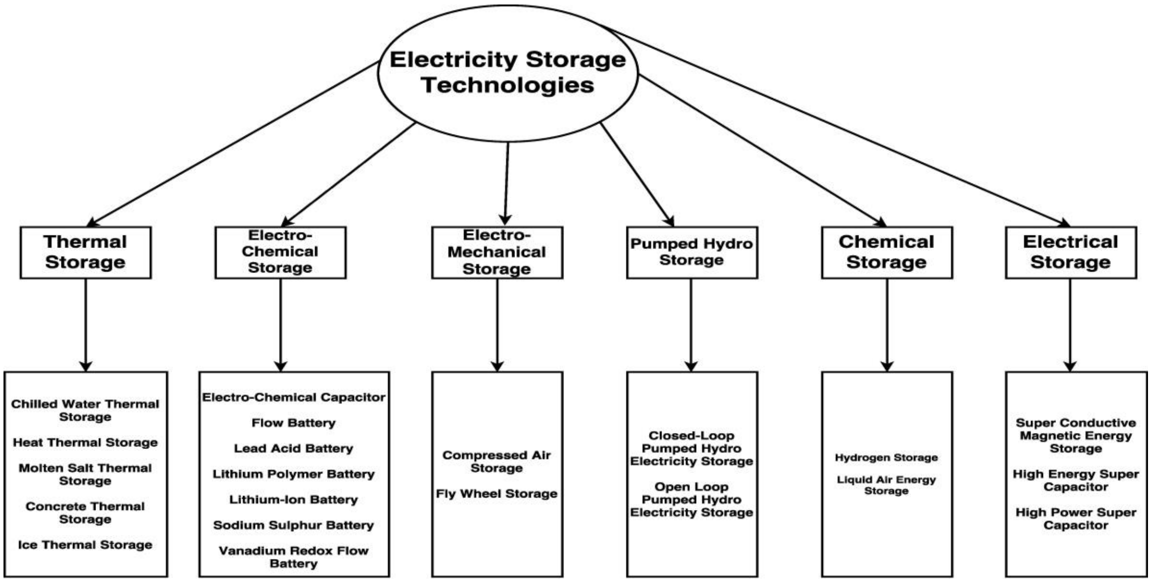


Fig. 1 Electricity Storage Technologies

- Lead-acid Battery: 3%
- Lithium Polymer Battery: 0%
- Lithium-ion Battery: 59%
- Nickel based Battery: 2%
- Other electro-chemical: 19%
- Sodium-based Battery: 8%
- Sodium Sulphur Battery: 3%
- Vanadium Redox Flow Battery: 0%
- Compressed Air Storage: 41%
- Flywheel: 59%

## III. ELECTRICITY STORAGE TECHNOLGIES WORKING PRINCIPLE

In this section, each electricity storage technologies have been briefly explained by highlighting its working principle.

### A. Pumped Hydro Storage

Pumped hydro energy storage technology utilizes the gravitational prospective power linking the two lakes which can be located at two different locations. The pump is utilized to flow the water between two reservoirs and stores power in the shape of gravitational force. If the requirement is low, the stream is pumped in the penstock from lower reservoir to upward reservoir through external power supply and in this way electrical storage system charges itself. When the need of energy is soaring, stream released from the higher reservoir through the penstock to the lesser lake where turbine is connected to generator for power production which is ultimately supplied to the transmission grid.

### B. Compressed Air Storage Energy (CASE)

Compressed air energy is stocked upin the shape of compacted air in the reservoir. Usually, salt deposits or depleted gas fields are used as suitable caverns to store the air compressed energy. Compressed air storage system works on the same phenomenon as the gas turbine.CASE is charged through a surplus or excessenergy which is routed through a pump driving the compressors sequence in order to accumulate the energy in the cavern. The reservoir or cavern which basically contain salt, possesses the capacity to store the compacted air energy at a stress of 4.0 MPa - 8.0 MPa[13]. When energy demand is high, the CASE system discharges, by releasing the compressed air from the reservoir toprocess a gas flamed turbine generator.

### C. Fly Wheel Energy Storage (FWES)

FWES accumulates the power in the shape of rotating kinetic force by speeding up and putting on the brakes in a turning accumulation. FWES technology composed of a revolving mass about a flywheel rotor in which a reversible electrical machine is connected and perform work as a motor during charging phase and draws the current from power grid to rotate the flywheel to its rated pace. During the discharge phase of flywheel, the electrical machine act as a generator and already moving flywheels transports torque to the producer in order to supply the energy to the exterior power grid.

### D. Lithium- Ion Batteries

In lithium-ion batteries, lithium ion (Li+) moves from the anode to the cathode which are made of lithium cobalt oxide ($LiCoO_2$) and act as a substance with positive charge in Sony's original lithium battery [14, 15]while cathode which is composed of lithium ion batteries contains lithium metal oxide ($LiMEO_2$) and anode contains graphite [16, 17].Battery with lithium ion electricity storage system has a built-in thermal management system and monitoring process.

### E. Lead Acid Battery Systems (LABS)

$H_2SO4$ is used as an electrolyte in LABS. It consists of loaded cells deep inside aqueous solution of $H_2SO4$ which act as an electrolyte.

Each cell has a $PbO_2$made up of positive electrode i.e lead dioxide and metallic lead (Pb) made up of negative electrode in a sponge lead. To insulate the electrodes from each other, a separator is used. During electrochemical reaction, in the discharge phase, the electrode transform into lead sulphate and the concentration of sulphuric acid is minimized, only the water will remain there as primarily in the electrolyte solution.

### F. Flow Battery Systems(FBS)

In flow batteries, energy is not stored in electrolyte rather than dissolved in electrolyte solution which makes flow batteries different from rechargeable batteries. FBS uses two separate tanks to store electrolytes in which single container holds anode side, also called anolyte tank and other is catholyte tank. Both tanks are separated from each other through regenerative cell stacks.

### G. High Temperature Battery Systems (HTBS)

The HTBS keep the active material in liquid state. It also keeps a firm ceramic electrolyte finished with beta aluminum as well known as sodium ion performing membrane. It is named as the HTBS for the reason that it needs an elevated temperature to retain the dynamic supplies in a state of liquidity. The electrolyte which is beta aluminum also performs as a barrier among electrodes of batteries.

### H. Hydrogen storage

Through Electrolysis of water, hydrogen is generated by utilizing the electrical energy from the alternative power technologies. The hydrogen which is produced through this process has 30-300 psia which can be increased by compressing and storing at an elevated force of 3000 psia in container. The hydrogen storage has a revolving trip competence of 40-60 %.

## IV. ENERGY STORAGE POLICY RECOMMENDATIONS

In this section, energy storage policy is briefly explained in order to deploy energy storage technologies with renewable energy resources.

### A. Instruments, enabling direct financing from Independent investors in alternative power technology and other zero emission technologies

The German alternative power technologies act (EEG) is one of the finest as well as successful policy frame work in which they introduce the fixed feed-in-tariff for the employment of alternative power technologies. The policy reduces the cost for initial cost intensive wind and solar PV technologies. The EEG law gives a privileged grant for the renewable energy generation.

### B. Eliminating all concessions to conventional fuel power production

In order to implement alternative power resources, it is necessary that all state subsidies should be minimized and tax to import fossil fuel should be maximized. This would save foreign exchange and also public investment which can be utilized in the development of research and educational infrastructure.

### C. Tax exemption for investment in renewable energy technology and energy storage technologies

Energy generation and storage through renewable energy technologies should be exempted from tax on property and trade. As this is the new emerging market, it is essential that to encourage the market growth of alternative power resources and power storage methods, no tax be imposed on the relevant material.

### D. Introducing carbon Tax

With the introduction of the carbon tax, the electricity generation from fossil fuel consumption will become more costly as compared to the generation of electricity through alternative power technologies and power storage methods. With rise in the tax constantly, it will be impossible to produce electricity through fossil fuels in the near future.

### E. Research & development work for upgrading the renewable energy technologies to make them more efficient and zero emission technologies

Training, research and education should be provided at all levels from vocational school to colleges and universities to create awareness regarding climate change, zero emission gas and implementation of alternative power resources implementation. It is also essential to promote the collaborative work in-terms of scientific research amongst the engineering varsities which should be promoted in order to exchange the scientific views and for making the use of technology more efficient, affordable and secure.

## V. CONCLUSION

After reviewing the existing literature and the statistics from IRENA, Pakistan does not lie in the list of top ten countries who have successfully adopted energy storage policies. Moreover, these countries are also leading cases for the implementation of alternative power technologies in their power policies. With the changing global environment and growing concern for these climatic changes amongst the international community, there are greater chances of Carbon Tax imposition on the countries emitting CO2 in the environment. Keeping in view, all these concerns and energy security perspectives, Pakistan need to devise aenergy storage policy alongside adoption of renewable energy technologies policies on the priority basis.

## REFERENCES


[1] "IRENA (2017), Electricity Storage and Renewables: Costs and Markets to 2030, International Renewable Energy Agency, Abu Dhabi.."

[2] A. Poullikkas, "A comparative overview of large-scale battery systems for electricity storage," *Renewable and Sustainable Energy Reviews,* vol. 27, pp. 778-788, 2013.

[3] S. Koohi-Kamali, V. Tyagi, N. Rahim, N. Panwar, and H. Mokhlis, "Emergence of energy storage technologies as the solution for reliable operation of smart power systems: A review," *Renewable and Sustainable Energy Reviews,* vol. 25, pp. 135-165, 2013.

[4] T. Kousksou, P. Bruel, A. Jamil, T. El Rhafiki, and Y. Zeraouli, "Energy storage: Applications and challenges," *Solar Energy Materials and Solar Cells,* vol. 120, pp. 59-80, 2014.

[5] M. Beaudin, H. Zareipour, A. Schellenberglabe, and W. Rosehart, "Energy storage for mitigating the variability of renewable electricity sources: An updated review," *Energy for Sustainable Development,* vol. 14, pp. 302-314, 2010.

[6] H. Ibrahim, A. Ilinca, and J. Perron, "Energy storage systems—characteristics and comparisons," *Renewable and sustainable energy reviews,* vol. 12, pp. 1221-1250, 2008.

[7] P. J. Hall and E. J. Bain, "Energy-storage technologies and electricity generation," *Energy policy,* vol. 36, pp. 4352-4355, 2008.

[8] S. G. Chalk and J. F. Miller, "Key challenges and recent progress in batteries, fuel cells, and hydrogen storage for clean energy systems," *Journal of Power Sources,* vol. 159, pp. 73-80, 2006.

[9] I. Hadjipaschalis, A. Poullikkas, and V. Efthimiou, "Overview of current and future energy storage technologies for electric power applications," *Renewable and sustainable energy reviews,* vol. 13, pp. 1513-1522, 2009.

[10] E. M. Krieger, J. Cannarella, and C. B. Arnold, "A comparison of lead-acid and lithium-based battery behavior and capacity fade in off-grid renewable charging applications," *Energy,* vol. 60, pp. 492-500, 2013.

[11] X. Hu, S. Li, and H. Peng, "A comparative study of equivalent circuit models for Li-ion batteries," *Journal of Power Sources,* vol. 198, pp. 359-367, 2012.

[12] N.-K. C. Nair and N. Garimella, "Battery energy storage systems: Assessment for small-scale renewable energy integration," *Energy and Buildings,* vol. 42, pp. 2124-2130, 2010.

[13] "Chen, H., Cong, T. N., Yang, W., Tan, C., Li, Y. and Ding, Y. (2009) ‘Progress in electrical energy storage system: A critical review’, Progress inNatural Science, vol. 19, no. 3, pp. 291–312 [Online]. DOI: 10.1016/j.pnsc.2008.07.014."

[14] "Ozawa, K. (1994) ‘Lithium-ion rechargeable batteries with LiCoO2 and carbon electrodes: the LiCoO2/C system’, Solid State Ionics, vol. 69, no.3–4, pp. 212–221 [Online]. DOI: 10.1016/0167-2738(94)90411-1."

[15] "Mizushima, K., Jones, P. C., Wiseman, P. J. and Goodenough, J. B. (1980) ‘LixCoO2 (0<x<-1): A new cathode material for batteries of high energydensity’, Materials Research Bulletin, vol. 15, no. 6, pp. 783–789 [Online]. DOI: 10.1016/0025-5408(80)90012-4."

[16] "Díaz-González, F., Sumper, A., Gomis-Bellmunt, O. and Villafáfila-Robles, R. (2012) ‘A review of energy storage technologies for wind powerapplications’, Renewable and Sustainable Energy Reviews, vol. 16, no. 4, pp. 2154–2171 [Online]. DOI: 10.1016/j.rser.2012.01.029."

[17] "Linden, D. and Reddy, T. B. (2002) Handbook of Batteries. 3rd, McGraw-Hill.."