Renewable Energy Storage Technologies - A Review

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***Abstract*— The imbalances between supply and demand requirements and thus efficiency of electrical systems can be improved by Energy storage systems (ESS).Energy storage systems are needed to ensure stability, reliability and quality of electrical systems. The contribution of renewable energy systems in meeting Global electrical needs in view of the depleting fossil fuels and environmental issues. These renewable energy systems are intermittent in nature and so the dependency on an appropriate ESS is more important. Many ESS have been developed in the recent past like mechanical, electrical, magnetic , thermal systems etc., Every technology has its own areas of application, life cycle, cost and environmental impact.**

This paper reviews the types of ESS, specifically Compressed air energy storage, Thermal energy storage, Flywheel energy storage, Electro-chemical energy storage and Pumped hydro energy storage systems briefly. The research work on these technologies of energy storage are covered in this paper with an intention to get a basic understanding of these ESS.

Keywords-Energy storage systems (ESS), Renewable energy, Types of energy storage

I. INTRODUCTION

A next-generation smart grid without energy storage is like a computer without a hard drive, severely limited. Accordingly, the energy storage market is set to "explode" globally in the next decade as indicated by market researchers. Energy storage deployments in emerging markets worldwide are expected to grow over 40 percent annually in the coming decade, adding approximately 80 GW of new storage capacity to the estimated 2 GW existing today[1].A recent market assessment by India Energy Storage Alliance suggests a potential of Rs 16500 crores by 2022 in India. Immediate applications range from telecom tower backups to grid ancillary services and renewable integration. The ESS has importance in stand alone, micro grid as well as large scale grid integrations. Energy storage technology not only can be used for peak load regulation of power grid, smooth load, improving the utility ratio of electrical equipment, and reducing the power cost, but also can be used to promote the use of renewable energy, improve the system running stability, adjust the frequency, and as a means to adjust the impact of overload in the power grid. However, the selection criteria and the diversity of technologies make choice difficult. It is particularly important to select the energy storage technology scientifically.

Energy storage systems (ESS) provide a means for improving the efficiency of electrical systems when there are imbalances between supply and demand. Additionally, they are a key element for improving the stability and quality of electrical networks. They add flexibility into the electrical system by mitigating the supply intermittency, recently made worse by an increased penetration of renewable generation. Energy storage helps to save already generated energy and use it at a needed time. The generated energy can be stored as potential, kinetic, chemical, or thermal energy and then can be released in various forms, most commonly as electricity. This ability to store is a useful and versatile resource for electric companies and their customers [2].

This paper aims to cover the developments in the recent past on the various technologies to store energy briefly, indicating the technology, their merits and limitations.

II. ENERGY STORAGE TECHNOLOGIES

Storage is a major issue with the increase of renewable but decentralized energy sources that penetrate power networks as per the findings of Multon B[3].The available energy storage systems has been reviewed by H. Ibrahim. and others. The storage storage will be crucial when the energy source is intermittent and located in isolated areas which can not be connected to distributed network [4]. An examination of how hybrid ESS would work out in different residential grid-tied micro-grid scenarios was done by Abdrahamane Traore and others [5]. Various storage technologies like pumped hyrdo,Batteries,thermal, CAES (compressed air energy storage) and Flywheel has been briefly discussed in the report by Edison Electric Institute. In US almost 93% of energy storage is by pumped storage followed by thermal storage as reported [6].

A. Compressed air energy storage(CAES)

In a CAES plant, air is compressed and stored under high pressure in an underground cavern, storage for compressed air. When electricity is required, the pressurized air is heated and expanded in an expansion turbine driving a generator for power production. Historical background, classification and comparison of various CAES and upcoming challenges were dicussed in their work by MarcusBudt and others[7].A discussion on state-of-the-art technologies of CAES, explaining the fundamental principles, classifications and operation modes of CAES was presented by Laijun Chen et al [8]. A review of different types of CAES, working principles, applications, challenges, and economics of CAES has been presented by Xing Luo et al. in their work [9]. An analysis of A-CAES (Adiabatic-CAES)was presented by Edward Barbour and others . This work included thermodynamics and cost estimations as well [10].

B. Thermal energy storage systems

Large scale thermal energy storage like underground thermal energy storage (UTES) and a system based on phase change materials named as latent heat storage (LHS) were reviewed by B. Akhmetov and others[11].The common thermal storage systems like Borehole Thermal Energy Storage (BTES), Aquifer Thermal Energy Storage (ATES), Tank Thermal Energy Storage (TTES) and Pit Thermal Energy Storage (PTES) were discussed in [12].

C. Flywheel energy storage systems(FESS)

One energy storage technology now arousing great interest is the flywheel energy storage systems (FESS), since this technology can offer many advantages as an energy storage solution over the alternatives. Flywheels have attributes of a high cycle life, long operational life, high round-trip efficiency, high power density, low environmental impact, and can store megajoule (MJ) levels of energy. A comprehensive review of FESS for hybrid vehicle, railway, wind power system, hybrid power generation system, power network, marine, space and other applications were presented in the paper by S.M. Mousavi and others [13].The study by Mustafa E. Amiryar has presented a critical review of FESS with reference to its main components and applications[14].Multiphase machines in FESS has been discussed in the paper by Keyin W et al [15]. Two types of FESS low-speed and high-speed FESSs were discussed by A.A. Khodadoost Arania and others. Also drawbacks such as low energy density and high initial cost limit its usage for some high technological applications such as space projects, military services were also analysed[16].

D. Electro chemical storage systems

Electrochemical energy storage is a general term all types of secondary batteries. Batteries convert the chemical energy contained in its active materials into electric energy by an electrochemical oxidation-reduction reverse reaction. The batteries available now are of many sizes for wide spectrum of applications. Supplied powers move from W to the hundreds of kW (an example can be battery for power supply of pace makers to the battery for heavy motor vehicle or for power station). A wide overview of electrochemical energy storage projects in Italin High voltage network has been presented in this paper by Roberto Benato and others[17].The recent advances in the lithium-ion battery concept towards the development of sustainable energy storage systems were discussed by Daniele Di Lecce et al. including the new lithium-ion cells for improving the performance and sustainability of electrochemical energy storage [18]. A study on graphene based materials for improving electrochemical performance in EESDs(Electrochemical energy storage devices) in terms of life cycle and energy/power density, resulted in new opportunities for developing high performance electrodes [19]. The basics of Electro chemical Energy storage systems specifically, supercapacitor and also supercapattery which is a generic term for various hybrid devices combining the merits of rechargeable battery and supercapacitor has been explained by George Z.Chen[20].The effect of chemicals used in modern electrochemical batteries were discussed, and the protective means of safe utilization with minimum environmental impact were discussed in the analysis by P.I. Kokkotis et al.[21].

E. Pumped Hydro Energy Storage systems (PHES)

Pumped hydroelectric storage facilities store energy in the form of water in an upper reservoir, pumped from another reservoir at a lower elevation and released for power generation at times of need. Pumped hydroelectric storage is a mature and established concept of energy storage as it has been in operation since the 1890s. It is the largest available grid storage system in the world constituting 97 per cent of the world's total energy storage (about 143GW over 40 countries) [22,23]. An extensive review of pumped hydroelectric energy storage (PHES) systems was conducted, detailing existing technologies,

practices, operation and maintenance, advantages & limitations, environmental aspects, and economics of using PHES systems to store energy produced by wind and solar photovoltaic power plants[23].Reasons for choosing PHES, selection criteria and methodologies, types like Solar photovoltaic pumped hydroelectric energy storage(PV-PHES) plants, wind-solar-photo voltic pumped hydroelectric storage systems, seawater pumped hydroelectric storage systems has also been discussed in the review[23].A traditional and mature storage technology, pumped hydro storage (PHS), was studied by Tao Ma and others to support the standalone microgrid hybrid solar-wind system: mathematical model and simulation studies were also done with a conclusion that the system was feasible for the location selected for study[24].

III. CONCLUSIONS

This paper is focused on a brief review of the most commonly used energy storage technologies covering the recent developments with related references. The field of ESS is fast growing with a great global market for the future. So an understanding of the technologies is required to select one for an application depending on the renewable energy systems, control systems, economics and environmental factors. This paper will definitely be of use as a reference for this.

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