ELECTRICAL ENERGY STORAGE METHODS IN DISTRIBUTED GENERATION INTEGRATION TO SMART GRID

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ABSTRACT

Smart grid provides power utilities with smart metering techniques and intelligent control system when integrated to renewable energy sources such as wind and solar it enhances electricity management and ensures increased reliability, efficiency and security of system. Due to intensity of isolation and wind strength the generated electricity by renewable energy sources is fluctuated, therefore its performance has been decreased. The main issue relating to performance of renewable energy system can be improved by energy storage system. In this paper we studied different energy storage methods used in distributed generation.

Keywords: Renewable energy sources, Distributed generation, Energy storage

I. INTRODUCTION

Although in most power-generating systems, the main source of energy (the fuel) can be manipulated, this is not true for solar and wind energies. The main problems with these energy sources are cost and availability: wind and solar power are not always available where and when needed. Unlike conventional sources of electric power, these renewable sources are not "dispatch able"—the power output cannot be controlled. Daily and seasonal effects and limited predictability result in intermittent generation. Smart grids promise to facilitate the integration of renewable energy and will provide other benefits as well. Both wind and solar have tremendous potential for fulfilling the world's energy needs another abundant, sustainable source of energy is the sun. One of the greatest scientific and technological opportunities we face is developing efficient ways to collect, convert, store, and utilize solar energy at an affordable cost. The solar power reaching the earth's surface is about 86,000 TW. Covering 0.22% of our planet with solar collectors with an efficiency of 8% would be enough to satisfy the current global power consumption.[1] Estimates are that an energy project utilizing concentrating solar power (CSP) technology deployed over an area of approximately 160 x 160 km in the Southwest U.S. could produce enough power for the entire U.S. consumption.

Energy storage system can be classified as:

Electrical energy Storage: Directly electricity storage in devices such as capacitors or super-conducting magnetic devices. Those storage methods have the advantage of quickly discharging the energy stored.

Mechanical energy Storage: Storage of electrical energy in the form of kinetic energy such as flywheel or potential energy such as pumped hydroelectric storage (PHS) or compressed air energy storage(CAES).

Chemical energy Storage: Storage in chemical energy form as in batteries, fuel cells and flow batteries. Chemical energy storage usually has small losses during storage.

II. ELECTRICAL ENERGY STORAGE METHODS

3.1 Pumped Hydroelectric Storage (PHS)

Pumped hydroelectric storage (PHS) has the largest storage capacity that is commercially available. PHS is the only widely adopted utility-scale electricity storage technology. As of 2009, there are hundreds of PHS stations operating with total capacity of 127 GW worldwide [1]. Japan currently has the largest PHS capacity in the world. Table 1 shows the installed PHS capacities in major countries.

Table: Installed PHS Capacity(MW)

country	**Installed PHS Capacity(MW)**
Japan	**25,183**
USA	21,886
China	15,643
Italy	7,544
Spain	5,347

The basic idea is simple: use the excess electrical energy generated at off peak hours to pump water from a lower reservoir to a higher reservoir. The electrical energy is converted into gravitational potential energy. Since the electrical energy will be supplies from the grid, it can be generated from not only photovoltaic, but also from other kinds of renewable energy sources. When the peak hour comes, the water then will be discharged from the higher reservoir to the lower reservoir. The potential energy of water converts into electrical energy as normal hydroelectric power plants do. Typically, a turbine will be used to generate electricity. The typical power rating, i.e. the maximum power output, for a PHS system is typically about 1000 MW.8 There are some small-scale PHS systems as well. These often have a capacity range from 1 MV to 30 MV.9 8 The storage capacity of the PHS will depend on the size of the reservoirs and the elevation difference between them. **Fig. 1** shows a diagram of a pumped hydroelectric storage system. This technology is currently the most used for high-power applications (a few tens of GWh or 100 of MW).

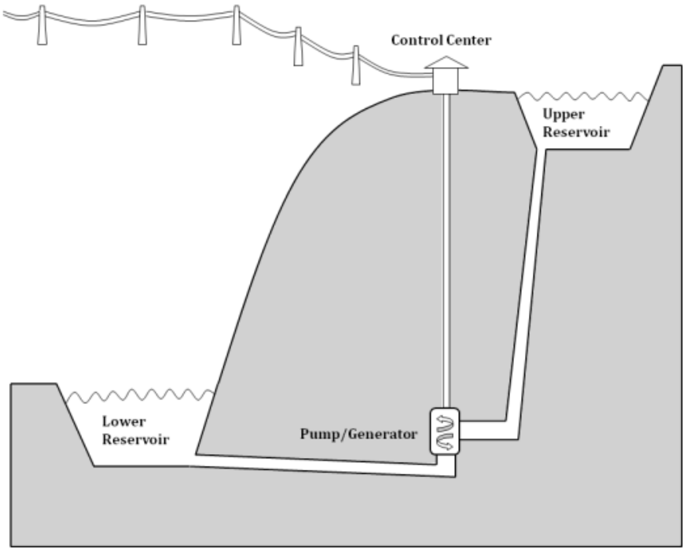

Fig.1: Pumped hydroelectric storage system

The energy related cost for pumped hydroelectric storage system is about 10 $/kWh and the discharge efficiency is about 87 percent. It should be noted that the 10 $/kWh is the incremental cost, which means the cost to generate one additional unit (kWh) of electricity. The total cost of the system will range from 1,100 $/kWh to as high as 2,000 $/kWh. Energy can be stored in the PHS system for a long period of time. However, the system can be charged and discharged multiple times a day and the discharge time is just a few minutes. The drawback of PHS is that suitable sites are limited and many have already been used. The infrastructures for PHS system are expected to last for about 60 years. Using life cycle assessment, the average life cycle energy of nine different PHS facilities in United State for each MWh storage capacity is 373 GJ [5].This includes all the energy required from construction to operation and maintenance, and then decommissions over the lifetime of the PHS system. PHS is a mature technology; there is little space for conceptual improvement. However, there are many possibilities for improvement in construction and operation to reduce cost and improve efficiency.

3.2 Flywheels

A flywheel energy storage system stores energy in the form of angular momentum. During peak time, energy is used to spin a mass via a motor. At discharge, the motor becomes a generator that produces electricity. The system is usually kept in a vacuum containment at pressures around 10-6-10-8 atm.2 The energy storage capacity depends on the speed, the mass of the spinning object and the size of the flywheel, Some flywheels can store 25 kWh of energy with power rating of 100 kW.

$$E=1/2\ mV^2 \tag{1}$$

where E is the energy stored, and m and V are the mass and velocity of the spinning object, respectively. Flywheel energy storage system can be categorized into high-speed flywheels and low-speed flywheels. The high-speed flywheel is mostly made of high strength composite material and the low-speed flywheel is mostly made of metals. The high-speed flywheel has higher tensile strength and is more durable than the low-speed flywheel, but it is also more expensive to fabricate. A high-speed flywheel can cost $25,000 for each kWh energy stored while a low speed flywheel only costs about $300 for each kWh.16 This system can also be categorized as mechanical bearings and magnetic bearing. For magnetic bearing system, spinning speed from 20,000 to 50,000 rpm can be achieved. The efficiency for the system can be at 90 to 95 percent in short amounts of time.17 The system can go through 5,000,000 recharge/discharge cycles. The major limitation is the storage duration. The system is generally only good for short-time bridging storage as defined in the classification chapter.

3.3 Compressed Air Energy Storage (CAES)

The basic idea of a CAES system is to use the off peak excess electricity to compress air. At a later time, the compressed air can be used along with gas turbine to generate electricity. As shown in Fig.2, electricity from the grid can be used to compress air into an air storage facility. Ideal air storage facilities are typically underground caverns, usually salt, mined hard rock or limestone caverns. Beside the PHS system, the CAES system is the only other large capacity system that is commercially available. During off peak hours, excess electricity can be used to run an air compressor to compress air into underground caverns. During discharge, the compressed air is released and a conventional gas turbine is used to generate electricity.

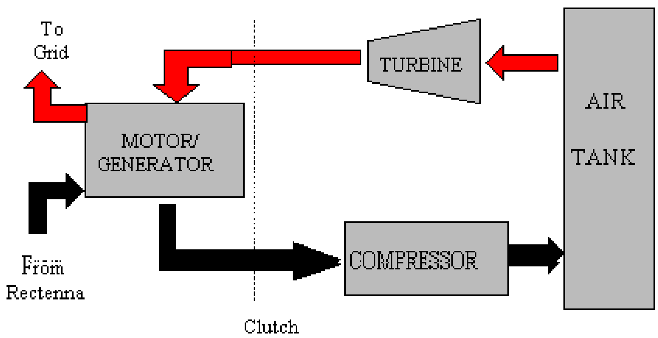

Fig.2 CAES System

The storage capacity of CAES system depends on the size of the underground cavern. A cavern size of 700,000 m3 corresponds to a capacity of 1500 MWh.18 The power rating of a CAES system ranges from 50 to 300 MW and the system is expected to charge and discharge on a daily basis. The storage efficiency of a CAES system is typically about 70 percent and the incremental

cost is 3 $/kWh.9 The typical life time of a CAES system is about 40 years.18 19 Life cycle energy for each MWh storage capacity is about 270 GJ[4]. The drawback of a CAES system is similar to the PHS system; a unique geographic location is required for the system. In addition, fossil fuel is often used for the gas turbine in a combined cycle power plant in a heat recovery steam generator (HRSG) because it combines the Brayton cycle of the gas turbine with the Rankine cycle of the HRSG. Thus, during operation, green house gas is emitted. A hybrid energy storage system based on CAES and a supercapacitor has been studied to improve the efficiency of the system.19 Performance analysis and optimal operation strategies have also being investigated.

3.4 Batteries, flow batteries and fuel cells

A battery is an electrochemical cell that converts stored chemical energy into electrical energy. Rechargeable batteries can have their chemical reaction reversed by supplying electrical energy to the cell; therefore, they can be used to store electricity generated by solar panels. Battery performance is evaluated by the following characteristics: energy and power capacity, efficiency, life span, operating temperature, depth of discharge, self-discharge (loss during storage) and energy density. Operation life cycle depends heavily on the depth of discharge and operating temperature. Discharging completely and operating at higher than ambient temperature will reduce battery life. Voltage and current level were not evaluated because desired voltage and current levels can be achieved by connecting cells in series and parallel.

III. CONCLUSION

Solar energy storage methods are most urgently needed due to unsteady nature of solar power and the increased demand. The application of proper energy storage remains necessary to achieve energy security and to reduce environmental impact. It is difficult to compare different types of storage methods using only one factor. In fact, no single type of storage method can be universally used to store energy. For specific situations, geological locations and existing facilities, different storage methods are possible and need to be considered. At present, batteries are the most common method in use to store solar energy.

For more mature technologies such as PHS and CAES, current developments are mostly focused on performance optimization and integration with the power grid. For many other storage methods, such as batteries, capacitors, sorption, and solar fuels, the advancements for those methods depend on discovery of new materials and characterization of materials and properties. Less expensive, high capacity and environmentally friendly materials are some of the criteria in choosing the right materials. While using renewable energy sources such as solar power, storage methods based on nonrenewable resources may undermine the initial effort to resolve the energy problem. In addition, hybrid systems of two or more storage systems working together have been suggested to take advantage of various technologies.

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REFERENCES

[1] Huanran Wang *, Liqin Wang, Xinbing Wang and Erren Yao, "A Novel Pumped Hydro Combined with Compressed Air Energy Storage System", *Energies* 2013, *6*, 1554-1567; doi:10.3390/en6031554, ISSN 1996-1073.

[2] H. Ibrahim, A. Ilinca, J. Perron , "*Energy* storage systems Characteristics and Comparisons", Renewable and Sustainable Energy Reviews 12 (2008) 1221–1250.

[3] Paul Denholm, Erik Ela, Brendan Kirby,and Michael Milligan, "The Role of Energy Storage with Renewable Electricity Generation", *Technical Report* NREL/TP-6A2-47187 January 2010.

[4] Maurizio Delfanti, Davide Falabretti,MarcoMerlo, and Gabriele Monfredini, "Distributed Generation Integration in the Electric Grid: Energy Storage System for Frequency Control", Hindawi Publishing Corporation,Journal of Applied Mathematics,Volume 2014, Article ID 198427, 13 pages.

[5] Energy Research and Development Division FINAL PROJECT REPORT, " Report on Solar Energy Storage Methods and Life Cycle Assessment", MAY2012.