ELECTRICITY STORAGE

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ABSTRACT

Renewable energy sources are making a more and more important contribution to the total energy consumed in the world. It is independent of limited fuels and has a very low impact on the environment. Today the contribution from photovoltaic (PV) energy compared to the other energy sources is very low, but due to decreasing system prices the market for PV systems is one of the most stable and fastest growing in the world. If this trend continues, PV will be one of the most important energy sources in the future. To maintain the further spread of PV systems, it is important to decrease the cost and make valuable improvements on the battery back-up PV-systems and at the same time improve the efficiency and reliability of these systems.

Keywords: Renewable Energy, Photovoltaic, Battery Back-up etc.

I.INTRODUCTION

Electricity storage is a key technology for electricity systems with a high share of renewables as it allows electricity to be generated when renewable sources (i.e. wind, sunlight) are available and to be consumed on demand. It is expected that with the increasing price of fossil fuels and peak-load electricity, coupled with the growing share of renewables will result in electricity storage to grow rapidly and become more cost effective. Storage technologies with different characteristics (i.e. storage process and capacity, conversion back to electricity and response to power demand, energy losses and costs) are currently in demonstration or pre-commercial stages.

Fig.1. A 5 MW Lithium-Ion Energy Storage System

PUMPED HYDRO PLANTS are large-scale storage systems with a typical efficiency between 70 percent and 80 percent, which means that a quarter of the energy is lost in the process. The only commercial storage option is pumped hydro power where surplus electricity (e.g. electricity produced overnight by base-load coal or nuclear power)is used to pump water from a lower to an upper reservoir. Pumped hydro systems consist typically of two reservoirs located at different elevations, a pump and a hydro turbine or a reversible pump-turbine. The global installed capacity is currently about 104 GW (2008) in some 200 plants, of which 38 GW are in the EU, 25 GW in Japan and 22 GW in the United States.

COMPRESSED AIR ENERGY STORAGE (CAES) systems store energy by compressing air. They require large, low cost natural buffers (e.g. caverns) to store compressed air, which is then used in gas-fired turbines to generate electricity on demand. CAES systems use off-peak electricity to compress and store air into underground mines or caverns. Compressed air is then used in natural gas turbines to generate peak-load electricity. Usually simple-cycle gas turbines use almost two- thirds of the input fuel to compress air prior to combustion (i.e. efficiency of 37–38 percent). Using compressed air from CAES, the turbine can save up to 40 percent of the input fuel used to generate electricity, and the typical efficiency (i.e. ratio of energy output to energy needed for compression) of a CAES with a simple-cycle gas turbine is about 50 percent. This efficiency can be increased using combined cycle gas turbines.

FLYWHEELS store electricity as mechanical energy, which M is then converted back to electricity. During charging, the flywheel rotation speed increases up to 30,000-50,000 rpm driven by a motor-generator. During discharging, the flywheel rotation drives the generator to produce electricity. To minimize the energy loss, friction must be minimized by operating the flywheel in a vacuum and using magnetic bearing instead of mechanical bearing. This considerably increases the cost of the device but enables storage efficiency of more than 85 percent.

ELECTRICAL BATTERIES AND VANADIUM REDOX FLOW CELLS store electricity as chemical energy. Vanadium redox flow cells or batteries (VRB) are electro-chemical energy storage systems based on the vanadium ability to exist at four different oxidation levels. During energy charging, vanadium ions in a diluted solution of sulphuric acid vary their oxidation, thus storing electricity in the form of electro-chemical energy. The process reverses during discharging. The main disadvantages are the complexity of the system (unsuited for mobile applications) and the relatively low energy density by volume, i.e. 20–40Wh/l compared with 40–80Wh/l for lead-acid batteries, 140–170Wh/l for NaS batteries and 140–210 Wh/l (up to 630) for Li-ion batteries.

Fig.2.Battery Bank Installed to Store Solar Power

■**THERMAL ENERGY STORAGE** is under demonstration in concentrating solar power (CSP) plants where excess daily solar heat is stored and used to generate electricity at sunset. Super capacitors store electricity as electrostatic energy and are often combined with batteries. Super capacitors (electrochemical double-layer capacitors or ultra-capacitors) are high-capacitance electrochemical condensers. They are based on a thin, layered solid-liquid interface created by special, high-surface (1000 m2/g) carbon electrodes and electrolytes. Super-capacitors enable energy storage with higher power density (up to 6-8 kW/kg) and lower specific energy (e.g 30Wh/kg) in comparison with Li-ion batteries (100-250Wh/kg). They can discharge their energy content in a short time, depending inversely on the output power (e.g. 10 kW for seconds or 1kW for one minute), and offer long lifetimes (e.g. 100,000 cycles).

■**SUPER CONDUCTING MAGNETIC STORAGE** use superconducting technology to store electricity efficiently but need more research to be developed. An SMES system consists of a superconducting coil, a DC/AC converter, a quench protection system and a magnet cooling system. The AC/ DC converter rectifies the grid alternate current (AC) to generate the magnetic field where energy is stored. After charging, the current does not decay and the energy can be stored indefinitely with negligible or no losses. The stored energy can be released back to the grid by discharging the coil through the AC/DC converter.

II. NEED FOR ELECTRICITY STORAGE

Electricity can only be stored after conversion into other forms of energy (i.e. potential, mechanical, thermal, chemical, electrostatic or magnetic energy). In general, electricity storage (i.e. storing electricity when production exceeds demand and using it during peak-demand periods) is a challenging and costly process. In today’s power grids, electricity storage capacity is modest about 110GW on a global basis and power generation varies continuously to meet demand fluctuations. More electricity storage could help balance the grid, reduce the need for costly peak load capacity and operate base-load power plants efficiently at full power. More importantly, electricity storage can facilitate the grid integration of renewable power technologies, such as wind and solar, the production of which varies depending on meteorological conditions with variations lasting for seconds to minutes to hours.

III. TECHNOLOGY STATUS AND PERFORMANCE

Depending on the specific technology, the performance of a storage system can be defined by the following parameters:

- Energy storage capacity is the amount of energy that can be stored in the system.
- Charge and discharge rates define how fast energy can be charged/ discharged. For most technologies, the discharge rate can vary during operation and is often higher than the charge rate.
- Response time (in seconds, minutes) is the time needed for the storage system to start providing energy on demand.
- Lifetime of a storage system is given as the number of cycles, years or stored/ provided energy, depending on the specific technology.
- Efficiency (or roundtrip efficiency, percent) is the ratio of energy discharged by the system to the energy needed to charge it at each cycle and accounts for energy lost in the storage cycle.
- Energy density (kWh/kg, kWh/m3,Wh/l) and power density (kW/kg and kW/m3) matter in applications where space is at a premium.

IV. COSTS AND ITS PROJECTION

In general, energy storage is economically competitive if the electricity marginal price is higher than the cost of storing and retrieving electricity, including the cost of energy lost in the process. Investment or capital costs of a storage technology can be given per unit of power capacity (USD /kW) or per unit of energy storage capacity (USD /kWh). Operating costs are given per unit of power capacity per year (USD /kW-yr). The overall cost and the levelized cost of energy storage are given per unit of energy (USD / kWh) as the ratio of all costs incurred for storing the energy (capital, operation and energy costs, if any) to the total amount of energy stored in all storage cycles over the plant's lifetime. Pumped hydro is the cheapest option for large-scale electricity storage. The current capital cost of new pumped hydro facilities is estimated to range between 2000–4000 USD/kW, with dam and civil infrastructure accounting for 60 percent, pump turbine devices for 15 per cent and other components and systems for the remaining 25 percent. The estimated capital cost for new Compressed Air Energy Storage (CAES) facilities using natural underground caverns is on the order of 800–1000 USD/kW for capacities of 100-300 MW (assuming a cheap availability of natural underground storage sites) and 1500–1800 USD/kW for small capacity (10–20 MW). The capital cost of CAES systems is also sensitive to the site. Flywheels' capital cost is also sensitive to size and applications. It ranges from less than 1000 USD/kW for small, simple UPS systems to 4000 USD/ kW for MW-size systems. Super capacitor cost is estimated to range between 1500 USD and 2500 USD per kW with a learning rate of 14-15 percent based on the current production (the current value of super capacitors' global market in sectors other than energy storage is estimated to amount to a few hundred million dollars per year). Vanadium flow cells are also projected to reduce their capital cost from the current level of 3000 to 4000 USD per kW to about 2000 USD/kW with a prospective overall storage cost of 250–300 USD/MW, depending of actual lifetime. Li-ion batteries for power applications are still expensive (up to 2500 USD/kW) because of the need for new materials and technology, as well as overcharging protection and packaging to improve reliability and safety.

V. POTENTIAL AND BARRIERS

Energy storage technologies and markets are quickly evolving as the share of renewable electricity grows and there is an increasing need for grid stabilization, load leveling and integration of variable renewables.The increasing cost of peak electricity will also make energy storage more attractive. The Pike Market Research firm estimates that the global energy storage market could rise from 1.5 billion USD in 2010 to about 35 billion USD in 2020. Among storage technologies, pumped hydro still has considerable expansion potential, the only barriers being the lack of suitable sites for installation and the local environmental impact. A large potential is associated with seawater pumped hydro, which offers comparatively easier coastal location. A 30 MW demonstration plant with 136 m head and 546,000 m3 water storage is in operation in Okinawa (Japan). CAES expansion is also limited by the lack of suitable natural storage sites (e.g. caverns). However, significant R&D efforts focus on improving CAES efficiency. A large market expansion potential is anticipated for Li-ion batteries. The market intelligence firm IHS I Supply estimates the grid-tied Li-ion battery market to reach USD 6 billion by 2020. Policy measures are needed to support the energy storage market. An important storage technology for low-cost (night) electricity is the conversion into hydrogen via electrolysis. At present, some utilities are reconsidering the process due to the increased efficiency (more than 75 percent) of electrolyzers and the possible conversion of hydrogen into methane (methanation) with CO_2 absorption. This process is under consideration as a storage option for wind power. Electric utilities are also considering potential electricity storage in the batteries of electric vehicles: charging the batteries of electric vehicles overnight would offer a unique opportunity for distributed electricity storage with virtually no cost and could also contribute to emission reductions in the transport sector.

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