

Battery Energy Storage

Batteries based renewable energy systems bring stable and reliable power that supports critical applications.

Cost, life cycle, safety, energy and power are major barriers in energy storage systems. The economic viability of renewable energy source largely depends on the efficiency of the battery and the cost effectiveness of the storage system.

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Fig 1. Small wind turbines of 3.2 kW under testing at Wind Turbine Research Station

Chronic power shortage coupled with an increased need for energy in a backdrop of rapidly growing population and emerging economies is posing challenges to the energy market. Renewable energy is an alternative that can meet the global energy supply deficit with the help of good energy storage systems. Batteries are extensively used with renewable energy utilities to store energy for later use, to supply energy on demand. Wind and solar power is susceptible to weather and its output is intermittent. Battery energy storage station makes renewable energy relevant to the grid and stabilises output from wind power plants and solar farms, strengthening the on-grid proportion of this power and enhances grid security. Taking advantage of storage battery discharge, a combined system of wind and solar power and energy storage can smoothen power output, stabilise electricity transfer and improve quality of grid connection for renewable energy power plants. In fuel cells, the energy reservoir in the form of a battery may be required to offset the relatively slow response during transient load demands. With the recent advancements in battery technology, efficient storage of energy in battery has become feasible and the conversion efficiency has also increased (Fig. 1 & 2).

Battery parameters

There are several parameters that are specified for a given battery. They vary from one battery type to another and also depend on operating conditions. Some of these parameters that serve as useful indicators of battery's performance are:

Capacity: It is the maximum charge storage capacity of a battery, represented in terms of Ampere-hour.

Voltage: These are the open circuit voltage (theoretical voltage), working voltage (available voltage during



Fig 2. Solar battery system

operating conditions) and cutoff voltages (voltages after which the battery needs to be recharged).

Depth of discharge: This is a measure of how much energy has been withdrawn from a battery and is expressed as a percentage of its full capacity.

Life cycle: It is the number of complete charge-discharge cycles that a battery can perform before its normal capacity falls below 80 per cent of its initial rated capacity.

Self discharge: It is the electrical capacity that is lost when a battery is not being used.

Factors affecting battery performance

The theoretically available energy of a battery cannot be completely converted into electrical energy. Only a fraction of the theoretical capacity of the battery can be used. The performance of the battery is affected by various factors, some of which are:

Voltage levels: When a battery is discharged its terminal voltage is always lower than the theoretical voltage. This is due to ohmic and polarisation losses.

Discharge current: The magnitude of discharge current affects the battery's terminal voltage and its service life. Higher discharge current results in shorter service life.

Temperature during discharge: The temperature has a significant effect of battery capacity and its terminal voltage. As the battery temperature reduces both the voltage and capacity of battery decreases.

Battery parameters vary from one battery type to another and also depend on operating conditions which serve as useful indicators of a battery's performance.

Table 1. Table showing relative performance of various types of batteries

	Lead acid	Nickel metal hydride	Nickel-cadmium	Lithium ion	Ferrous
Voltage	**	*	*	*****	****
Cycle life	**	***	***	***	*****
Energy density (by weight)	*	***	**	*****	****
Energy density (by volume)	*	***	**	*****	***
Safety	****	***	*****	*	*****
High current discharge	***	***	*****	*****	*****
High temperature performance	*	*	****	***	****
Low temperature performance	*****	*	***	***	***

Types of batteries and their comparison

Batteries are typically classified as primary and secondary batteries. The primary batteries are non-rechargeable batteries. They need to be discarded once they discharge. They normally have a long shelf life and are used for portable electronic devices. They include alkaline and lithium batteries. Secondary batteries are rechargeable batteries. They are used as storage devices for electrical energy as their charge retention period is poor resulting in poor shelf life. They include the lead-acid batteries, Ni-Cd batteries and lithium ion batteries. Traction secondary batteries are used for storing energy in solar photovoltaic systems. They involve number of charge and discharge cycles. A comparison of the performance of popularly used lead acid, nickel metal hydride, nickel-cadmium, lithium ion and ferrous batteries is shown in Table 1. Li-ion and Fe batteries provide superior battery life, performance, safety and density compared to lead acid batteries.

Lead acid batteries are cheap, bulky, need high maintenance and exhibit low power density. Nickel – metal hydride batteries are costly, rugged, need low maintenance and have a low power density. Lithium ion batteries have a high power/energy density and low weight/volume. They have very high efficiency but are expensive.

Choice of a battery

The choice of a battery depends on the given applications and is determined by following factors:

- Working voltage and battery capacity
- Cyclic requirements (in solar PV systems, batteries are required to provide energy whenever sunlight is not available. It is required to undergo a number of charge/discharge cycles and are subjected to deep discharge due to load demands)
- Range of operating temperatures
- Self discharge rate of batteries

Nanotechnology for energy storage

The overall performance and reliability of an advanced battery system depends largely on the cell chemistry. Lithium ion batteries can be used for a wide range of applications. Nanophosphate is an engineered nanoscale material with specific structural and chemical properties designed to

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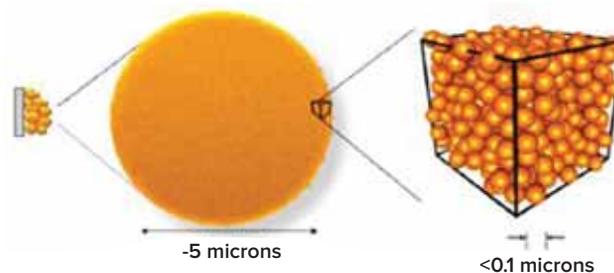


Fig 3. Electrochemical structure of nanophosphate

maximise the performance of lithium-ion batteries.

Fig 3 is an illustration of a cathode electrode, with the aluminium current collector foil covered with nanophosphate particles. The middle image is the nanophosphate secondary particle and the image on the right illustrates the primary particles. The primary nanophosphate particles are on the order of one-tenth of a micron in diameter and are agglomerated into much larger secondary particles, which have diameters of a few microns. Micron-sized secondary particles allow the nanophosphate powder to be handled and processed more easily. This unique electrochemical structure of nanophosphate enables a number of performance advantages, including higher power, excellent safety, long life and greater usable energy.

A very recent study at Stanford University has demonstrated that it is possible to build a solar battery entirely with carbon. Carbon has the potential to deliver high performance at a low cost. Scientists at University of Texas are developing safe nano-engineered alloy anodes to replace the unsafe graphite anodes now used in lithium-ion technology to store electricity produced by renewable sources.

Conclusion

Batteries are useful in ensuring the optimum use of renewable energy. In fact the economic viability of renewable energy source largely depends on the efficiency of the battery and cost effectiveness of the storage system. The ultimate miracle battery is however, nowhere in sight and the battery remains the 'weak link' for the foreseeable future. As long as the battery is based on an electro-chemical process, limitations of power density and short life expectancy must be taken into account. It is necessary to adapt to this constraint and design the equipment around it. People want an inexhaustible pool of energy in a small package that is cheap, safe and clean. A radical turn will be needed to satisfy the unquenchable thirst for portable and mobile power. It is doubtful whether a superior electro-chemical battery, an improved fuel cell, a futuristic atomic fusion battery or some other ground breaking energy storage device will fulfil this dream. ❁

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