Batteries for autonomous renewable energy systems*

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Abstract

Now that the Coconut Island plant has been running successfully for three years, it is appropriate to review the design decisions that were made with regard to the battery and to consider how these might be changed for future systems The following aspects are discussed type, package, energy storage, voltage, parallel operation, installation, charging, watering, life and quality assurance

Introduction

The Coconut Island solar hybrid power plant [1] commenced operation on 1 November, 1987 Modularity was a feature of the design and was aimed at achieving high system reliability and easy replacement of modules in case of breakdown. As a result of a conservative and cautious approach, components were required to be proven commercial products that would function together in a previously tested circuit In other words, the plant was not seen as a test bed for experimental development At installation, the battery consisted of 220 cells but was enlarged after eighteen months to cope better with the load growth and the addition of extra inverters The battery has functioned faultlessly to date During the design stage, several decisions were made with rather inadequate information It is time to review these decisions with the hope of providing future designers with better information

Specifications of Coconut Island battery

To simplify the electrical installation, a battery voltage of 110 V was chosen The capacity was determined from the system design and was required to store energy for 1 to 2 days. The details of the cells are·

Manufacturer	JRA (NZ) Ltd
Design	BP Solar, type 2P1101
Dimensions (mm)	233×210×675

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Weight (kg)	60 5 (wet), 35 5 (dry)
Case	clear
Electrolyte (sp. gr.)	1250 (fully charged)
Capacity (A h, C/100 rate)	1101
Self discharge (% per month at 20 °C)	2–3
Electrolyte buffer capacity (l)	5
Operating temperature range (°C)	17–55

The battery particulars are

Voltage (V)	110 (nominal), 105–145 (actual)
Cells	330, arranged in 6 strings of 55 cells per string
Capacity (A h, C/100 rate)	6606 (nominal 726 kW h)

The battery is claimed to have a high charge efficiency The buffer capacity is claimed to be sufficient for a 12-month operation It was decided that a 60% depth-of-discharge (DOD) would be utilized to give an anticipated life of 2000 cycles If the diesel only started every three days, the cycling rate would be around 120 cycles per year and the life would be 17 years

Design parameters of Coconut Island battery

Battery type

Only the flooded design of the lead/acid battery was seriously considered for the Coconut Island facility The reliability of sealed lead/acid batteries (i e , gelled-electrolyte or absorptive-glass-mat types) was unknown Nickel/cadmium cells were considered too expensive for an already capital-intensive system

Package

The specification called for battery units to be no heavier than 70 kg to facilitate handling. The result was single cells weighing 60 5 kg wet Delivery of the cells was made in crates, each holding nine cells At the island, the crates had to be removed from the barge and transported about 1 km to the site. The barge carried a fork lift and the island front-end loader managed transport on the island Perhaps the crate was inadequate because one was damaged and resulted in the loss of several cells From a practical viewpoint, delivery of wet cells is simplest since separate shipments of acid and water would create handling problems After unpacking the crates, the cells were manhandled into position in the battery room

The cells have a clear case which enables the position of the electrolyte level to be determined easily The view of the state of the plates is not optimal, however, since a majority of the cells are turned sideways in the string Packaging of a number of cells, e g , six, in a permanent container could be an option, the container would provide safer transport On the other hand, the extra unit weight would require mechanical handling in the battery room With such an arrangement, the loss of case transparency would not be a serious disadvantage

Energy storage

Calculations to determine the energy storage requirement should be based on a DOD of around 60%, average (rather than worst case) solar radiation, and charge/discharge cycles of sufficient duration to give an expected battery life of 7–10 years The Coconut Island battery at 60% DOD should have a life of 2000 cycles and require a cycle duration of around 1 5 days (Fig. 1).

Voltage

The voltage chosen for Coconut Island was 110 V, mainly on the grounds of safety Nevertheless, the currents are relatively high For larger systems, 440 V would be better Obviously, greater care will be necessary to ensure safe operation With an earthed centre tap the voltage is reduced to ± 220 V from earth

A slightly lower nominal voltage may match the 378 V peak of the 240 V a c wave and reduce inverter losses Of course, the inverter must still cope with the battery voltage variation of −5 to +30%, thus the actual nominal voltage is only of marginal importance

Parallel operation

Parallelling of cells is required to increase the storage capacity of a battery when voltage is fixed and cell size is limited There can be a problem in achieving equal current sharing between the parallel strings during both charge and discharge

Cross-connection of cells at the same voltage is recommended, but is impracticable for an arrangement of cells separated by aisles Cross-connection can be achieved, however, if cells are packaged in containers and connected in parallel within the container

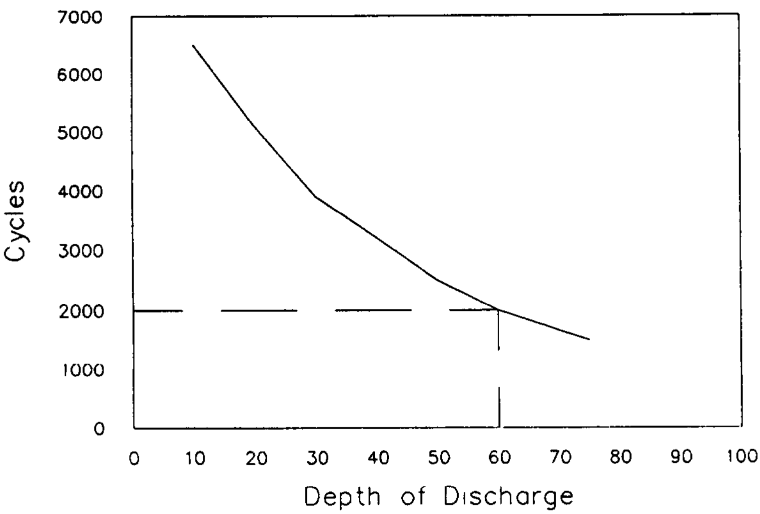

Fig 1 Number of duty cycles as a function of depth of discharge for the BP solar battery

Installation

The battery room at Coconut Island was designed according to Australian Standard AS 2676 Each cell is readily accessible since all the cells are at floor-level and are arranged in double rows separated by aisles. The resulting storage energy per unit area, or per unit volume, is low Ventilation to dispose of the heat losses and gas production is not a problem

Future installations might pack more cells in a given space by using double tiers and containerized cells Mechanical handling would be needed Automatic watering, recombinators or sealed cases, may be desirable to reduce the need for access to individual cells Ventilation may limit the packing density of cells in the space

Charging

In order to design the charger and the charge control, the battery voltage and current under the specified charging characteristic should be provided on a Type Test Certificate (Fig 2).

The production of gas during charging wastes energy so it should be reduced to a minimum. Gassing is required with the 2P1101 cells to reduce stratification of the electrolyte Air-lift pumps may be a better alternative.

Continued charging at the top-of-charge voltage (called 'boost charging') is recommended both to bring the battery to full charge and to equalize charge between cells This procedure produces excessive gas, however, and should be minimized. Cell monitoring may permit a better evaluation of the amount of boost required to equalize the cells A sensor for measuring the average specific gravity of the electrolyte may provide a superior means of controlling charging

Watering

Replacement of lost water from the electrolyte has been a problem on Coconut Island. Demineralised water has been transported from Cairns in 20 litre containers at relatively high cost Investigations have been made

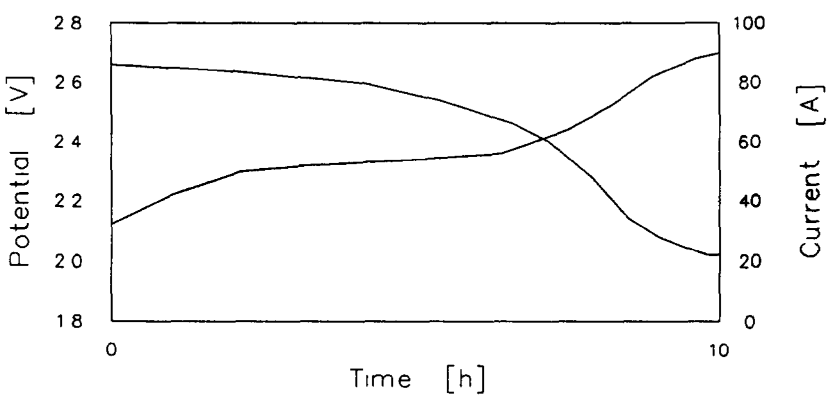

Fig 2 Charging of battery

into purchasing a suitable demineralizer for use on the island Tank water would be used as feed. A disposable cartridge unit may be suitable

Life

A life of 10 years for the battery would be acceptable and should be achievable Improved cycling life would increase the DOD allowable and reduce the required battery size

The effect on battery life of transients generated by the inverter and/or the rectifier should be studied More accurate determination of the state-of-charge, e g., with a specific gravity sensor, may reduce the over-discharge of the battery and any tendency to over-charge. As a result, battery life may be extended

Quality assurance

When a large number of cells is involved, a quality assurance programme should be instituted as part of the supply contract While the battery will be approved on the results of type tests, a sample of production cells shall be subjected to the following tests:

Capacity	As agreed
Leakage of post seals and covers	AS 1981
Action of safety vents	AS 1981
Stability of containers	AS D23
Cycling performance	*
Charge/discharge profile	$C/10$ test
Self-discharge loss over 3 months	As agreed

Conclusions

Much has been learned about the operation of batteries for renewable energy systems from the Coconut Island facility Some suggestions have been made for future battery designers but no attempt has been made to define an ideal battery

Reference

1 N R Sheridan, *J Power Sources*, *25* (1989) 243–256

*The battery will be operated for 200 cycles to 100 per cent depth-of-discharge at the $C/5$ rate and 40 °C After these cycles, the capacity shall not be less than 100 per cent of the guaranteed capacity
(N B Number of cells to be tested will be subject to agreement but will be statistically significant)