Battery Testing at ResLab

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Abstract

ResLab, a test facility within the Research Institute for Sustainable Energy, RISE, is based at Murdoch University. The laboratory provides testing services for the renewable energy industry. Its key interests are in standards, component reliability and system performance.

As a partner in the EU Benchmarking Project - Benchmarking RE Components & Systems, ResLab has developed the capability to perform temperature controlled-long-term battery testing.

ResLab's new battery test facility includes a 4-channel 18V/50A BaSyTec High Power Battery Test System and a 0.2m^3 insulated, temperature controlled bath to house the batteries. The BaSyTec system enables charging and discharging of 12Volt 500Ah batteries at I_{10} currents, and the constant temperature bath allows temperature control in the range of 10°C-50°C

This paper presents details of ResLab's Battery Test Facility together with examples of actual battery test results.

1. INTRODUCTION

ResLab, the Renewable Energy Systems Test Centre, was originally conceived as a laboratory for testing renewable energy systems and their components. Two independent test beds are used for the purpose; a small system test area aimed at single phase systems up to 5 kVA and a large test area focused on single or three phase systems up to 50 kVA. In addition to these test beds ResLab has recently installed and commissioned an automated battery test facility. The initial use of the new battery test facility has been to fulfill a commitment to the European Union (EU) Benchmarking RE Components & Systems Project (Wenzl *et al.*, 2004, EU Benchmarking Project, 2004a). This facility enables ResLab to perform a complete range of tests furthering the types of services that can be provided to the RE industry. Participation in the EU project has provided valuable contacts, guidance and battery testing experience.

In determining the performance of batteries many different procedures are available in standards and also as results of other international activities. Some of these are discussed.

1.1. Current Standards and other test procedures

Batteries in RE systems undergo a variety of charge and discharge patterns, and also experience a wide range of operating conditions. This variation is due to the differences in load or application, the energy generation source, the available resource and the climate of the installation. In turn, this results in different performance characteristics and failure mechanisms for a battery or battery bank. At present there are many standards, both from international sources and Australia (see list below) that can be applied to the testing of the types of batteries used in RE systems. Some of these are more specific to stand-alone systems.

- AS 4029.1-1994 Stationary batteries – Lead acid – Part 1: Vented type – (based on IEC 60896-11 with amendments).
- AS 4029.2-2000 Stationary batteries – Lead acid – Part 2: Valve-regulated type – (based on IEC 60896-2 – with amendments).
- AS 4029.3-1993 Stationary batteries – Lead acid – Part 3 Pure lead positive pasted plate type
- AS 4086.1-1993 Secondary batteries for use with stand-alone power systems Part 1: General requirements.
- AS 4086.1-1997 Secondary batteries for use with stand-alone power systems Part 2: Installation and maintenance.
- IEC 60896-11 Ed. 1.0 (Bilingual 2002) : Stationary lead-acid batteries - Part 11: Vented types - General requirements and methods of tests
- IEC 60896-21 Ed. 1.0 (Bilingual 2004) : Stationary lead-acid batteries - Part 21: Valve regulated types - Methods of test
- IEC 60896-22 Ed. 1.0 (Bilingual 2004) : Stationary lead-acid batteries - Part 22: Valve regulated types – Requirements
- IEC 61427 Ed. 1.0 (Bilingual 1999) : Secondary cells and batteries for solar photovoltaic energy systems - General requirements and methods of test
- DIN 41 773: Static power converters; semiconductor rectifier equipment with IU-characteristics for charging of lead-acid batteries, guidelines. Publication date:1979-02
- DIN 41 774: Static power converters; semiconductor rectifier equipment with W-characteristic for charging of lead-acid batteries; requirements. Publication date:1987-11
- DIN 41 776: Static power converters; semiconductor rectifier equipment with I characteristic for charging of batteries; requirements. Publication date:1983-01.

In addition to these standards many different test methodologies have been developed for batteries used in RE systems. These methodologies, mostly cycling test procedures, try to establish the cycle life and provide users with valuable information on the suitability of the battery for their application. An analysis of the more commonly used procedures for PV systems is available in the report "Task 3 of the International Energy Agency, IEA, Photovoltaic Power Systems, PVPS programme –Testing of Storage Batteries used in Stand Alone Photovoltaic Power Systems", (IEA, 2002).

The Benchmarking project uses the analysis of actual system operation data to define categories of battery operation in RE systems (Svoboda, 2003), and then using either existing procedures or through the development of new procedures, define tests that will evaluate a particular battery's performance in a given category (Ruddell, 2004).

2. BATTERY TEST SYSTEM SPECIFICATIONS

ResLab's battery testing capabilities include a fully programmable automated battery test system and a temperature controlled bath (Figure 1). The system allows up to four separate tests on four different batteries to be performed simultaneously. The voltages for each battery cell can be monitored and electrolyte density measurements can also be made.

While the tests performed to date have taken 20 - 50 days to run, some test procedures can last for many months, or even years (IEA, 2002). Typically battery test cycles are repeated until an end of test state is achieved; this is usually defined by a stated loss in the measured capacity. For example AS 4086.1-1993 ((Standards Australia, 1993) presents a cycle life test method in which the given procedure is repeated until the measured capacity has dropped to 80% of its rated value. The new ResLab battery test facility is capable of performing these much longer procedures. The following sections present details of the system components.

2.1. BaSyTec High Power Battery Test System

The BaSyTec High Power Battery Test system is software driven and has its own data acquisition capability. It can be programmed to perform a wide range of charge and discharge patterns including constant current charging or discharging and constant voltage charging. This allows the user to design any number of charge-discharge cycles using time, current, voltage or several other parameters to end any particular step.

ResLab has installed two of these units, each unit has two test channels (Figure 2). The test channels have a voltage rating of 3V-18V each, although it may be possible to achieve lower voltages, and a current rating of 50A. Each channel records the voltage and current of the battery under test. ResLab's system has the capacity to measure two separate temperature values, using platinum RTD devices, and it can also measure two extra voltages, allowing individual cell voltages to be measured. However, ResLab also has a separate system monitoring individual cell voltages.

Figure 1 ResLab Battery Test Facility

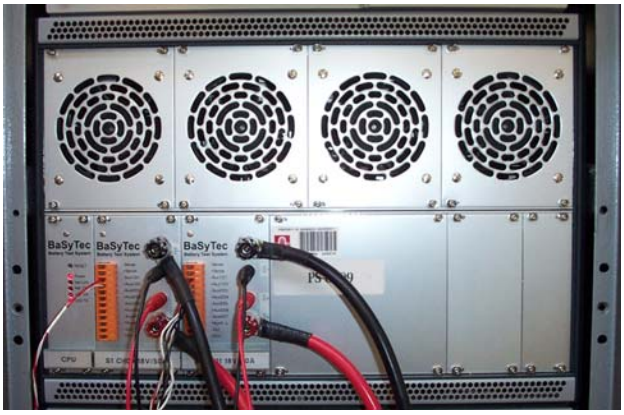

Figure 2 BaSyTec High Power Battery Test System

2.2. Individual Cell Voltages

An Agilent 34970A data acquisition/switch unit is used to measure individual cell voltages. The ResLab system has been configured to measure up to 24 cell voltages, based on six cells and four batteries, but it is only limited by the number of channels available on the data acquisition unit.

Measuring the individual cell voltages provides the test engineer with extra information regarding the state of the battery under test. Bad cells can be quickly and easily detected, which helps in understanding some failure mechanisms. The information gathered helps provide a more complete data set when the test is complete.

2.3. Temperature Control

The most common temperatures required for battery testing are 20°C, 25°C and 40°C with a stability requirement of around +/- 2°C (Standards Australia, 1993).

The constant temperature bath is an insulated stainless steel tank measuring 870mm x 550mm x 460mm (deep). It can comfortably accommodate the four 12V 54Ah batteries (272mm (L) x 205mm (W) x 385mm (H)), which are currently under test, or any batteries that are smaller or similarly sized (Figure 3).

The bath uses a Haake DC10 circulating immersion heater and a Haake EK20 immersion cooler to achieve and maintain these temperatures at the required accuracy and stability.

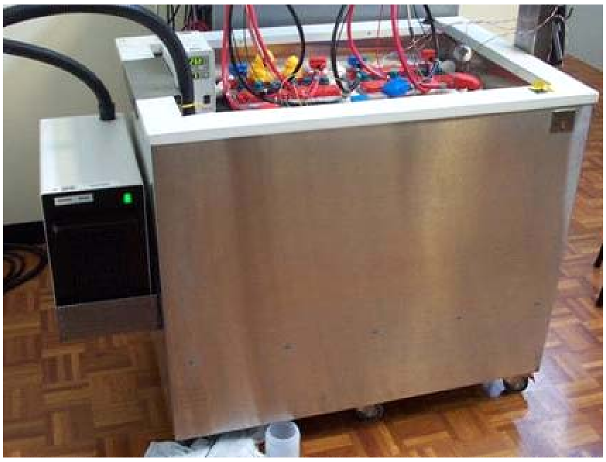

Figure 3 Constant Temperature Bath

Figure 4 Electrolyte Density Measurements

2.4. Electrolyte Density Measurement

Voltage is one indicator of the state of charge of a battery; another, more accurate one, is to measure the specific gravity or density of the electrolyte in the battery. Manufacturers' specification sheets for batteries generally give density values, at a particular temperature, which indicate a fully charged battery. In the case of the batteries currently being used for testing at ResLab, this value is 1.24 g/cm^3 at 20°C. Information is usually provided on a temperature correction factor to allow for different temperatures.

At ResLab an Anton Paar DMA 35N Portable Density, Specific Gravity & Concentration Meter is used to measure electrolyte density (Figure 4). This is a digital meter with the ability to store measurements. As it also measures temperature it can perform corrections to compensate for temperature that vary from the stated reference temperature. The meter requires a very small sample of electrolyte to perform the measurement; a measured sample is pumped manually into the sample tube using the plunger, and the reading taken from instrument display. This is a very safe and accurate way to perform this measurement.

3. SAMPLE TESTS RESULTS

ResLab's involvement in the EU Benchmarking project is in Task 3.3 - *Practicability of tests of energy storage systems*. This task is part of Work Plan 3 - *Definition of performance requirements and test procedures for benchmarking products*. ResLab's role is to test, evaluate and report on the proposed new battery test procedures defined in Task 3.2 (EU Benchmarking Project, 2004b).

Some of the procedures performed include combinations of commissioning charge routines on new batteries, capacity measurements, and more complex repeating charge-discharge patterns that attempt to either simulate battery operation in a particular RE system, or accelerate a particular aging mechanism. The following charts give examples of some routines performed on the system. All these tests were performed on 12Volt (6 cell) batteries with C_{10} ratings of 54Ah; the tests were done at a constant temperature of 25°C.

Figure 5 shows the battery voltage and current over time of a typical commissioning charge. It is a two stage process with a constant voltage of 2.45V/ cell (14.7V for this six cell battery) which is terminated when the current drops to 1A, and then switched to float voltage of 2.3V/cell (13.8V), the charge is complete when the battery current drops to a few mA and remains stable.

A capacity test is shown in Figure 6. This particular routine is measuring the nominal C_{10} and C_{100}

capacities of the battery. The routine starts with two discharge-charge cycles before the actual C_{10} measurement. The capacity measurement is made by discharging the battery at the nominal I_{10} current to a voltage of 1.8V/ cell (10.8V) and recording the delivered Ah delivered. In measuring the C_{100} capacity a discharge current of $0.1I_{10}$ is used, with the discharge being terminated at 1.85V/cell (11.1V).

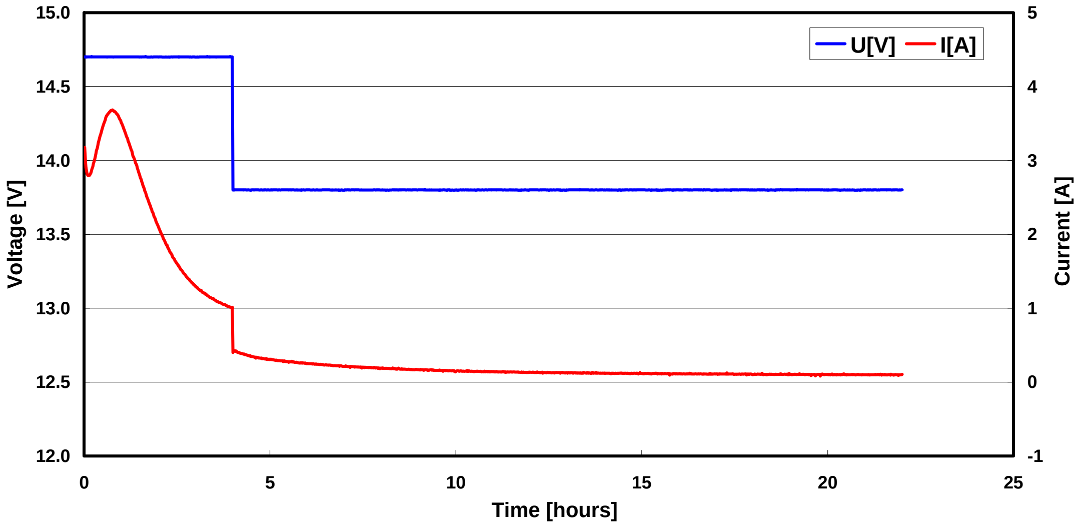

Figure 5 Commissioning charge on 12V 54Ah Battery, - 2 step constant voltage charge.

While this particular battery has a nominal C_{10} capacity of 54Ah, the actual measured output, at an I_{10} discharge current of 5.4A, was 83Ah. The manufacturers' specification sheet does not give a C_{100} capacity value for this battery. However, the Ah delivered at a discharge current of $0.1I_{10}$ was 110Ah.

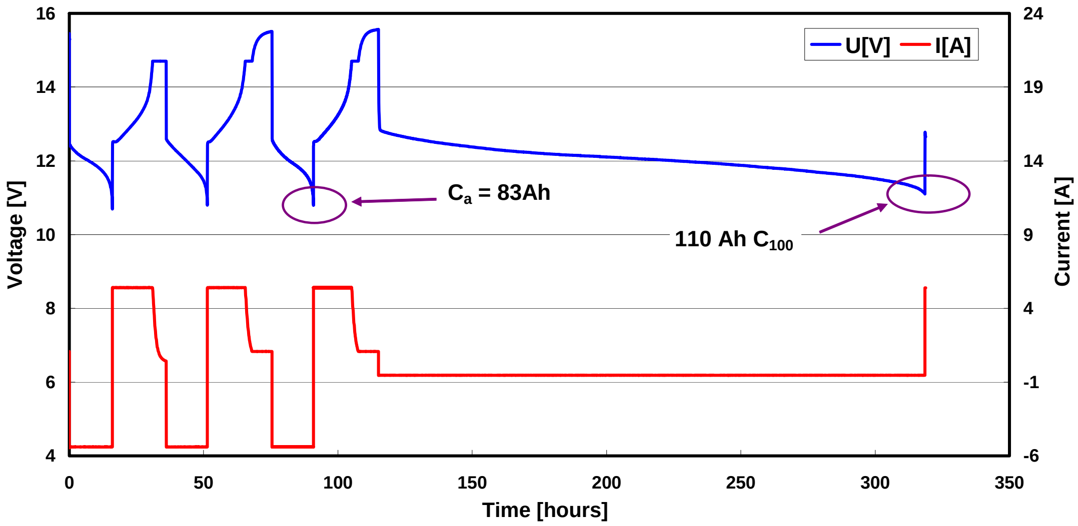

Figure 6 Capacity Test on 12V 54Ah Battery

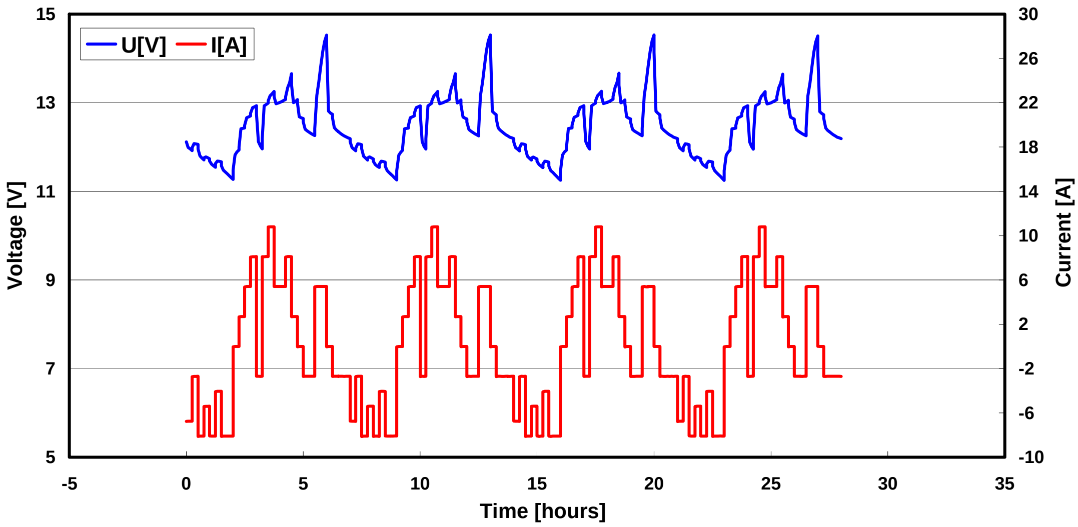

Figure 7 Complex repeating charge-discharge cycles

A more complicated procedure is presented in Figure 7. This chart shows just four cycles, of a much longer, constant current charge-discharge pattern, where each step is set to run for 15 minutes and the total pattern lasts for 7 hours. This particular routine is designed to simulate the operation of a stand-alone energy system, the load or discharge is greatest at the start and at the end and the most charging occurs in the middle. This would be typical of a photovoltaic system.

4. CONCLUSION

The specifications and capabilities of the new battery test facility at ResLab have been described, and sections of some typical test routines have been shown. ResLab staff are currently performing battery testing with the EU Benchmarking project.

ResLab is intending to provide commercial battery testing within 12 months as part of the range of services it offers for the renewable energy industry. Reslab is capable of performing a wide variety of battery tests, including long or short-term tests, and either standard or customised charging-discharging routines depending on customer requirements.

5. ACKNOWLEDGEMENTS

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