Experiences with lead/acid battery management in remote-area power-supply (RAPS) systems*

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Abstract

Battery management and general storage performance and cost remain major problems in remote-area power-supply (RAPS) systems utilizing renewable energy sources A brief review of field experiences with lead/acid batteries is presented, together with results from battery tests carried out in the laboratory It is recommended that further collaboration between battery manufacturers and system designers is established to develop improved storage systems for RAPS applications

Introduction

The role of the storage component and its associated control elements is of particular importance in renewable energy systems where daily demand and supply patterns are often poorly related to each other. This paper discusses some of these issues with reference to field experiences and various hardware developments undertaken to improve overall renewable energy systems' outcomes.

Work in renewable electricity systems (i.e , photovoltaic (PV) and wind power) in Western Australia began in the 1970s with the evaluation of PV modules and batteries at the Solar Energy Research Institute of Western Australia (SERIWA) By 1982 work had progressed such that a battery workshop [1] was organized in 1983 whereby industry, end-users, and researchers were able to share knowledge and attempt to identify problem areas that required further improvements. In particular, a set of technical and cost objectives was proposed for batteries. It should be noted, however, that these were not agreed to by all in attendance. In summary, the objectives were·

- long life – typically 10 years at 50% daily depth-of-discharge (DOD)
- improved energy efficiency – 80% round trip
- state-of-charge (SOC) determination facility
- ruggedness and durability for transport
- costs not exceeding \$150 (kW h)$^{-1}$ (C/10 rate)
- transparent containers

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These objectives were more or less restated at the National Energy Research Development and Demonstration Council Workshop in 1989 [2]. Today, however, it is reasonably clear that the above targets are still some way from being achieved

Battery control

The operation of electronic controllers for managing the charge and discharge of open-vented lead/acid batteries has generally been based on the use of battery voltage, with temperature compensation sometimes included as the primary control input While this has long been recognised as inadequate, the absence of a reliable SOC indication has given the control engineer little else with which to work Despite the limitations of a simple voltage-based controller, a popular scheme based on this technique is shown in Fig 1

The procedure allows for regular charging within specific limits. If the battery falls to some defined 'low level', the next recharge is at a 'high level' or a quasi-equalizing charge. Such control has, it is argued, very little benefit in the recharge process. Even simpler systems, which are presently used in the great majority of both small and large systems, operate only over the inner limits, with additional circuitry to manage the loads, and an alarm facility Overall, it appears that the application of these controllers is restricted to small systems where the battery cost is very low, i.e , around several hundred dollars. The most severe problem with these simple systems is that the set point is either too low for equalizing or too high for average recharging,

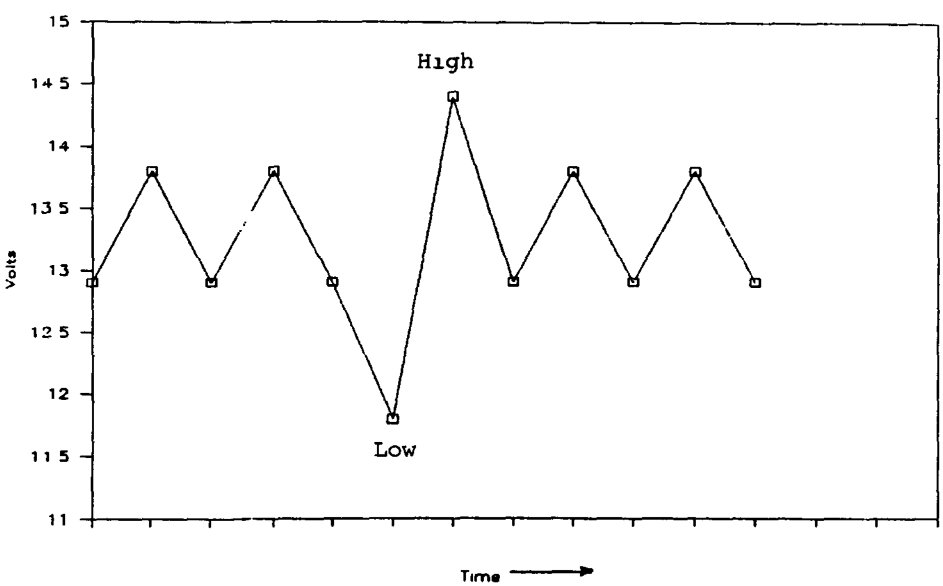

Fig 1 Voltage profile of a simple charge controller

so that excessive loss of electrolyte and/or enhanced plate corrosion are encountered.

A further problem is the disparity in battery performance, on a cell-by-cell basis, in systems where many cells are connected in series. Recent laboratory tests carried out on a battery bank clearly illustrated this difficulty. Figure 2 shows the variability measured during discharge with the control system operating at its nominal terminal voltage The individual batteries are designated as E9 to D3; i e , fifteen 12 V cells in total Charge data for the same battery bank are given in Fig 3. The corresponding charging times and rates are also included

For the past two years, trials have been conducted on the efficacy of cell equalizers. The latter have been used as 2-V and 12-V cell units with some apparent success This approach could provide benefits with sealed battery systems where overvoltages on the cells are a particular problem

Improved controllers for PV arrays are under investigation Attention is being directed towards a more closely controlled recharge process which could assist in achieving cell-by-cell uniformity A disadvantage is that the concept could mean foregoing energy from the renewable source or extended hours of diesel operation, even though maximum-power-point tracking is included The actual benefits of such systems are also relatively unknown at this stage.

Larger systems developed in Western Australia have attempted to resolve some of the above issues by developing control- and power-processing-systems that: (i) minimize battery storage requirements, (ii) utilize fully sealed batteries. Such systems impose a more dynamic and higher instantaneous charge/discharge profile on the battery This effect is illustrated in Fig 4 for a parallel, bi-directional inverter/diesel system. The corresponding battery

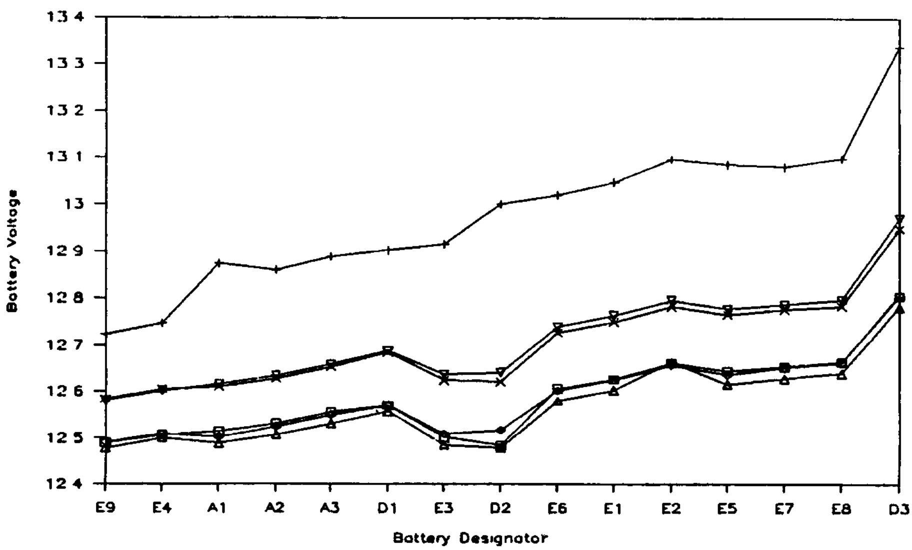

Fig 2 Discharge profiles for 15 batteries

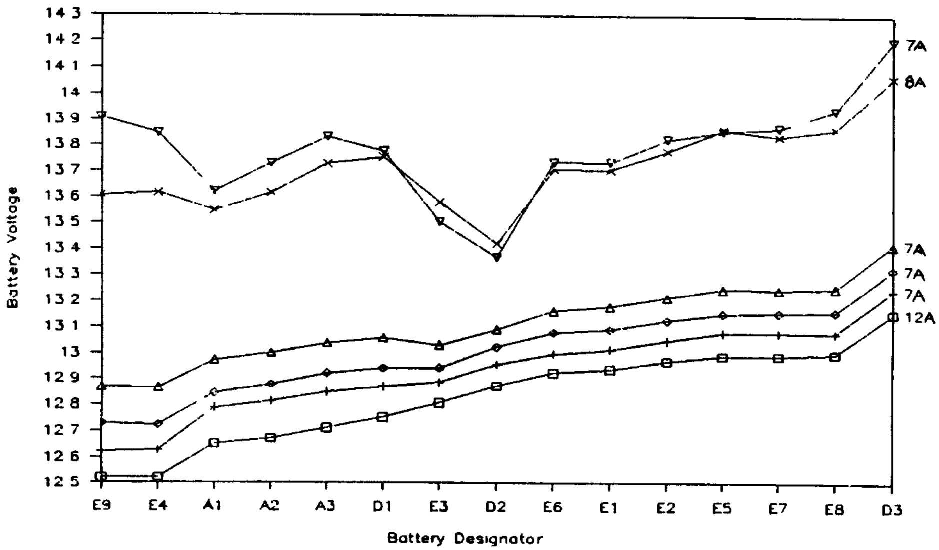

Fig 3 Charge profiles for 15 batteries ○, 0 h, +, 1 h, ◇, 2 h, △, 3 h, ×, 6 h, ▽, 7 h

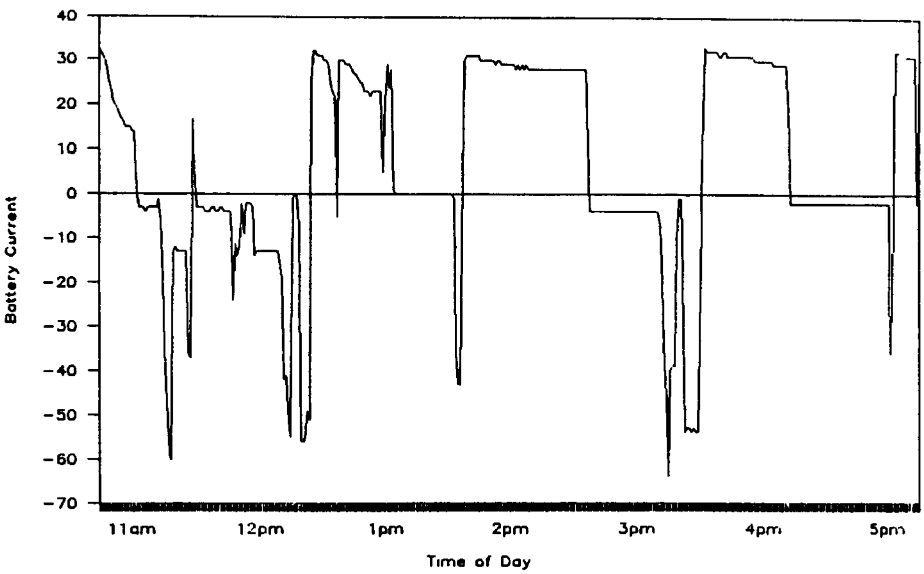

Fig 4 High cycling rate current profile

voltage profile is shown in Fig. 5. In this example, the battery is working regularly at the $C/4$ rate. This is somewhat higher than rates normally recommended by most manufacturers High charging rates are essential, however, for good system performance in the context of a diesel/battery/inverter system.

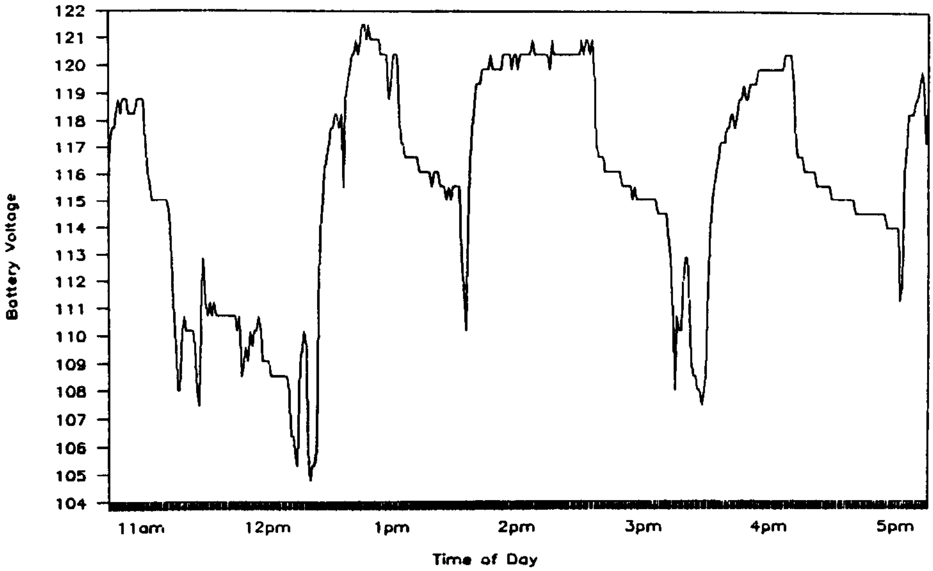

Fig 5 Voltage profile in static power pack

Conclusions

The use of battery storage in RAPS systems remains relatively underdeveloped and somewhat poorly understood Major advances in other components of the systems, i e , PV devices, inverters, are not being matched in the lead/acid battery area.

Despite the work done to date, considerable uncertainty remains when designers attempt to predict battery performance. Previous suggestions with regard to the required battery performance objectives may need to be replaced for the time being by some estimation of the current status of the technology From this understanding, future performance objectives might be established with industry collaboration. Areas of concern include

- predicting battery performance
- control input for valid system control
- handling of cell-by-cell variability (especially with sealed batteries where voltage is critical)
- high charge/discharge rates introduced by diesel/battery/inverter systems

Some technical developments in terms of battery management offer some assistance, but these often add to the cost and can introduce additional complexity

References

1 W L James, *Battery Workshop Proc , Solar Energy Res Inst Western Australia, Perth, 1983*

2 S J Phillips, *National Energy Res Dev Demonstration Council Battery Conf , Sydney, 1989*