V-Fuel Pty Ltd

COMPARISONS WITH LEAD ACID BATTERY COSTS

This report covers the investigations of the relative cost effectiveness of lead acid batteries versus V-fuel's VRB.

Since a typical application for lead acid battery storage is as a backup to photovoltaic cells for small scale, remote area generation systems (i.e. small scale RAPS), the comparison was carried out for a 5 KW solar photovoltaic system with no diesel generator backup. The cost comparisons are for the batteries only and do not include any costs of installation, electrical connection to the photovoltaic arrays or buildings.

The estimates for the cost of the lead acid battery system was estimated as discussed below.

Lead acid battery system costs.

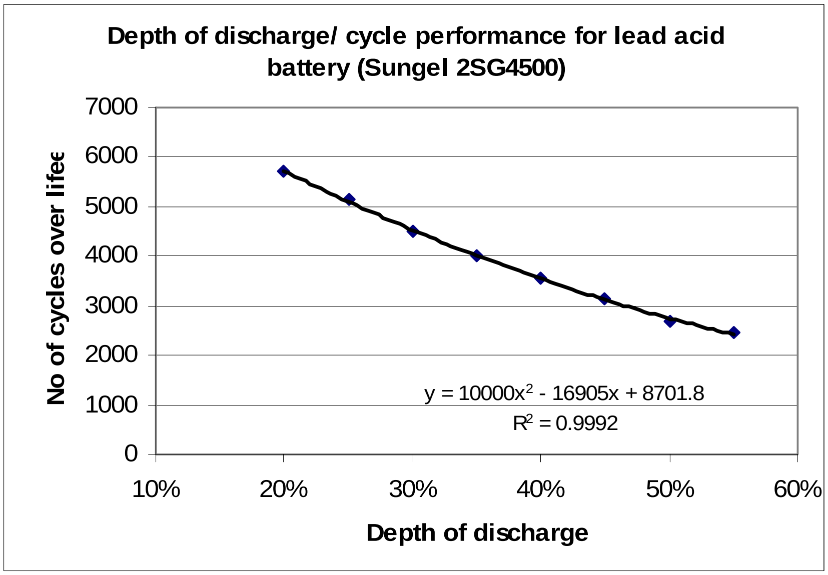
A review of the lead acid batteries on sale in the Australian market was conducted to find a suitable battery. This review revealed a particular range of lead acid batteries, the "Sungel" range, that had been designed specifically for solar applications with emphasis on maximising the deep discharge / cycle performance of the battery.(The CSIRO had been involved in the development of this battery range.) Consequently the Sungel range of batteries can be considered as the commercial state of the art in terms of lead acid batteries for use in solar applications.

The detailed performance specifications of these Sungel batteries are available form the suppliers of these batteries and are reproduced in Attachment B2 (see also www.batteryenergy.com.au/02_sungel_battery.htm.)

The largest battery in the Sungel range, the 2SG4500 battery was selected as base battery for building the battery bank with the required performance.

There are a number of performance characteristics that need to be taken into account in attempting to use lead acid batteries for specific applications. These are:

The relationship between depth of discharge and the lifetime of the battery as measured in no of charge discharge cycles.

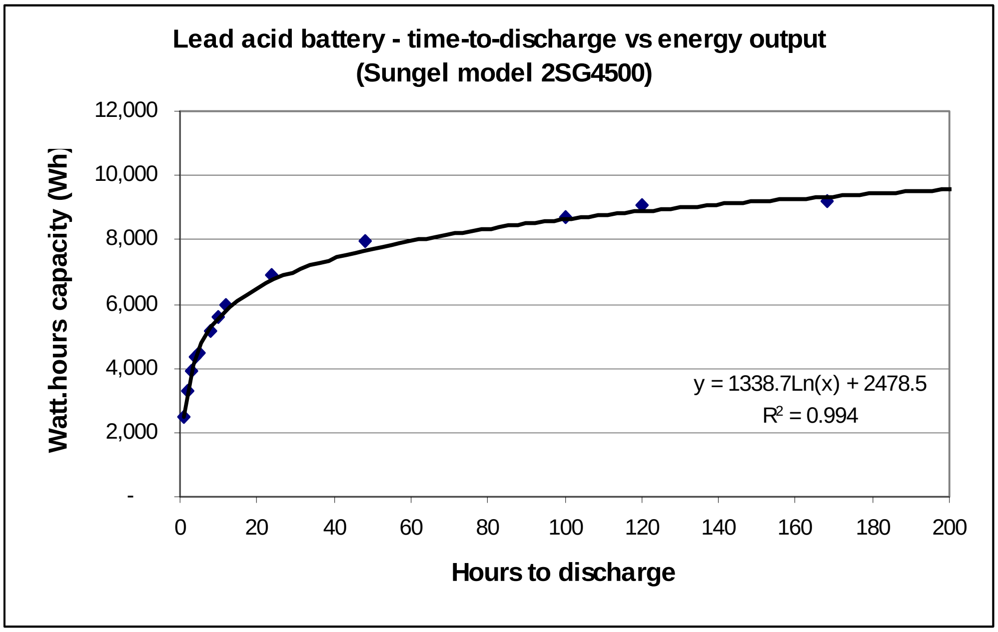


The lifetime of lead acid batteries deteriorates with the depth of discharge of the battery. The graph below illustrates this point. (The data for this graph were obtained form the detailed performance specifications of the Sungel battery). In order to maintain a reasonable lifetime for the batteries, it is clear that the depth of discharge in any cycle needs to be restricted to above (say) 50% depth of discharge.

Given that in a solar application, there is one cycle per day or 365 cycles per year, the number of cycles that the battery can sustain is equivalent to a certain number of years of operation in a solar application. For this application, it was decided to use a maximum depth of discharge of 40% per cycle. From the graph this corresponds to 3,540 cycles or 9.7 years of operations.

The relationship between the rate of energy discharge and the energy recovered form the battery.

If lead acid batteries are discharged quickly (i.e. at high power), the amount of energy that can be extracted from the battery is much less than if the battery is discharged very slowly. In other words there is an inverse relationship between the power of the battery and the storage capacity. (Note that this relationship does not exist fro the VRB because the power and energy and independent.) Consequently an individual lead acid battery



The calculations to take account of the above two performance characteristics and to produce a battery pack with a 5KW power output and various hours of energy storage are provided in Attachment B3. (A softcopy of this excel spreadsheet is also supplied with this document.)

For example, for a 5kW system the following figures apply.

No. of batteries	Hours of storage	Capital cost	Annualised cost	Energy produced per year	Cost of energy produced
	(hours)	*(AU$)*	*(AU$/year)*	*(MWh)*	*(AU$/MWh)*
10	4.6	16,000	2,434	8.4	290
12	5.8	19,200	2,921	10.6	275
14	7.1	22,400	3,407	12.9	263
16	8.4	25,600	3,894	15.3	254
18	9.7	28,800	4,381	17.7	247

To give some idea of the space required to house the batteries, the floor space required for 18 batteries is only approximately 3.2 square metres but the weight is about 4 tonnes.

Under the operating conditions proposed for these batteries, they would have a lifespan of 9.7 years. The annualised costs in the table above assume this lifetime and a discount rate of 8% p.a. (real).

Note that the costs calculated above are the costs for the entity setting up the battery system and are based on real prices for which batteries can be purchased today. The VRB costs are estimates of expected costs for V-fuel in manufacturing the batteries.

V-fuels estimates of a 5KW VRB

V-Fuel estimates of the capital costs of the 5KW VRB for various hours of storage are presented below.

The assumptions used for the cost of the 5 kW stack and the electrolyte system respectively were:

Stack cost	$5,410
Electrolyte cost	$118 / KWh of storage

For example, for 8 hours or 40kWhs of energy storage, the electrolyte cost is $4,470 giving a total capital cost of $10,150.

Note that these cost estimates are based on the long term assumptions for costs including low cost stacks due to volume productions and low resistance cell membranes. Furthermore, the electrolyte costs assume a vanadium pentoxide price of US$5 / lb.

The volume of electrolyte is 1,720 Litres and the battery should occupy no more than 3 square metres of floor space and have a weight of around 2 tonnes.

Assuming the above capital costs, the annualised costs and hence the Cost per MWh of energy produced were calculated and these results are presented below.

As mentioned before, the V-Fuel cost estimates are estimates of the direct manufacturing costs for the 5 KW battery rather than the selling price.

To accommodate these extra required costs associated with overhead and profits, multiples have been applied to the base VRB costs. Consequently if the price that the VRB could sell for was (say) 2.0 times the direct manufacturing cost, then the results for the 2.0 times multiple should be compared with the results for the lead acid battery.

Comparison of results

The comparison between a 5KW lead acid battery and a 5 KW VRB is summarized in the following graph. Note that the comparisons are made on the basis of dollars per MWh produced by the battery. This basis takes account of the different lives of the two batteries and in addition facilitates comparisons with costs of power from other sources.

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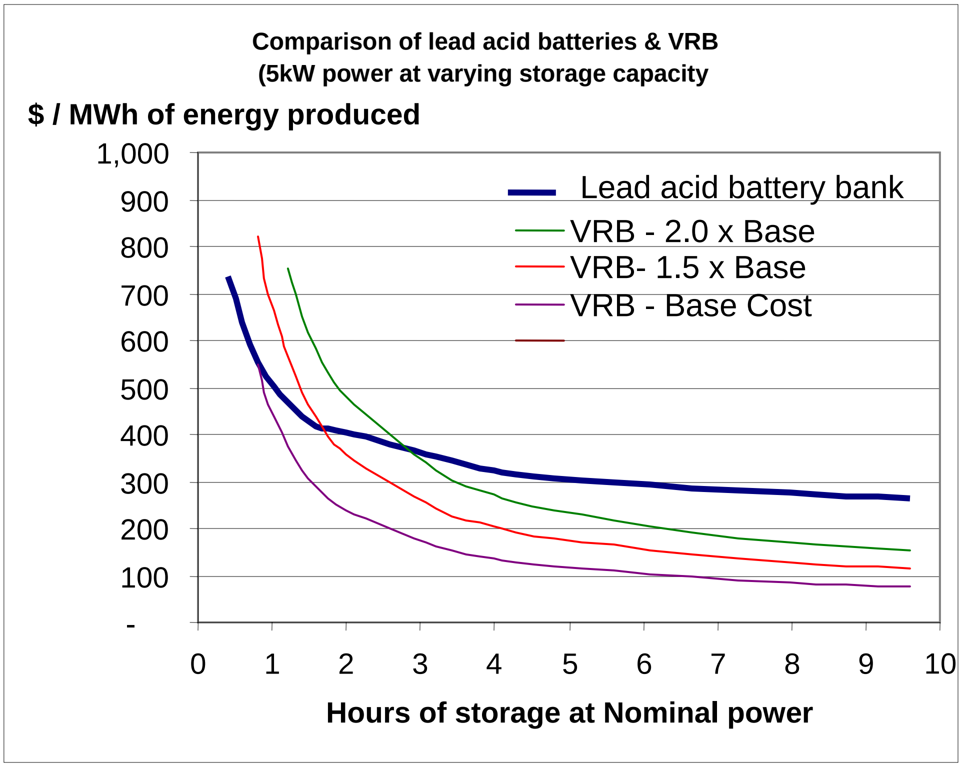

Conclusion

For energy storage systems, requiring more than approximately 3-4 hours storage therefore, the VRB should offer a significant cost advantage if the assumed VRB production costs are achieved.