PERMANENT LOAD SHIFTING AND UPS FUNCTIONALITY AT A TELECOMMUNICATIONS SITE USING THE VANADIUM FLOW BATTERY. A CASE STUDY

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ABSTRACT

Telecommunication facilities of all types from small cellular radio sites to microwave repeaters and larger Point-of-Presence (POP) and switching hubs, all require uninterruptible power supply (UPS) to ride through short duration interruptions. This function is supplemented by back up diesel generators for support in the event of long term outages. Conventionally, the UPS functionality has been provided through the use of lead acid batteries. In many off grid or weak grid installations, diesel generation is often the only source of power, sometimes supplemented by photovoltaic power or even wind turbines.

A novel concept which is being implemented at a POP facility in California at one of the USA's largest cellular radio network providers is to use the battery storage to provide both the basic UPS ride through function as well as to peak shave demand on a permanent basis. The system will be rated 20kW with 9 hours of storage, 6 for permanent load reduction and 3 hours for UPS functionality. This is only possible with storage systems that can be deep cycled thousands of times without significant degradation and also where it is possible to independently tailor the storage duration to match the electricity tariff structure. The project will be discussed showing the use of a VRB flow battery and the potential economic savings for different tariffs that may result for a range of battery efficiencies.

THE PROJECT OUTLINE

Telecommunications cell sites and larger POP (Point of Presence) sites are configured to operate uninterrupted in the event of voltage dips and power outages. The load curves of many such sites exhibit flat profiles with occasional demand spikes due to airconditioner inrush currents. The sites are designed with batteries which are sized to supply critical loads around 3 hours. Thereafter diesel engine generators supply the load. Diesel engines are sized to support the critical loads as well as all ancillary loads and airconditioners. This is the standard configuration.

Based on the Time-of-Use (TOU) tariffs in place in many states and across the world, it was proposed to examine the idea of shifting the load from the grid to the batteries during the peak periods. However at the same time the primary purpose of these batteries, namely to provide a UPS function, could not be compromised. Conventional and advanced batteries cannot have the power and storage duration sized separately from one another. Flow batteries however allow for the independent specification of power and energy. It has been proposed to install a flow battery supplied by VRB Power Systems at a POP site in Sacramento to demonstrate this concept. The VRB system will be sized to have a reserve of 3 hours and to add the additional electrolyte for a further 6 hours of energy storage which will be cycled each day in order to provide demand reduction during peak periods. The VRB system has several unique features which allow this form of operation. The required battery specification is as follows.

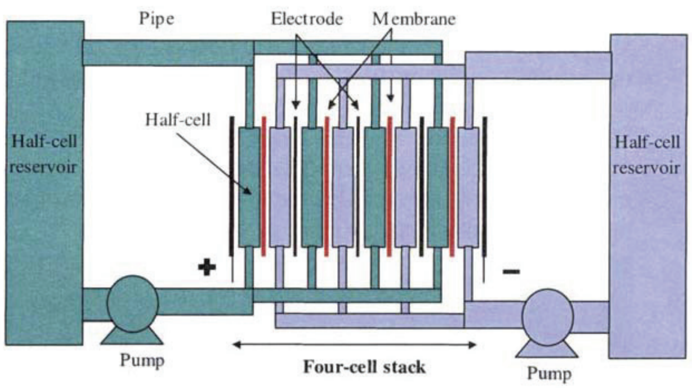
- 9 hours ride through, adjustable based on TOU periods, with known State of Charge at all times, sufficient to guarantee 3 hours UPS functionality after daily cycling.
- 20kW rating
- High efficiency – low idling losses or self discharge
- Maturity of product
- No disposal costs
- >5 year life under all operating conditions of deep (100%) daily discharging
- Rapid recharging within 10 hours
- Always on capability – no auxiliary bridging power requirements

Table 1. Battery requirements

VANADIUM REDOX BATTERY ENERGY STORAGE SYSTEM DESCRIPTION AND PERFORMANCE CHARACTERISTICS

The VRB is an electrical energy storage system based on the patented vanadium-based redox regenerative fuel cell that converts chemical energy into electrical energy. Energy is stored chemically in different ionic forms of vanadium in a dilute sulphuric acid electrolyte. The electrolyte is pumped from separate plastic storage tanks into flow cells across a proton exchange membrane (PEM) where one form of electrolyte is electrochemically oxidized and the other is electrochemically reduced. This creates a current that is collected by electrodes and made available to an external circuit. The reaction is reversible allowing the battery to be charged, discharged and recharged. The Vanadium Redox Flow battery falls into the general class of reduction/oxidation (**Redox) flow batteries**. This class of battery employs an electrolyte where energy is stored and a cell stack where energy conversion occurs.

The principle of the Vanadium Redox Flow Battery is shown in more detail in Figure 1. It consists of two electrolyte tanks, containing active vanadium species in different oxidation states. These energy-bearing liquids are circulated through the cell stack by pumps. The stack consists of many cells, each of which contains two half-cells that are separated by a membrane. In the half-cells the electrochemical reactions take place on inert carbon felt polymer composite electrodes from which current may be used to charge or discharge the battery.



Figures 1A and 1B. Concept of the Redox Flow Battery System and 5kW packaged UPS system

The VRB employs vanadium ions in both half-cell electrolytes. Therefore, cross-contamination of ions through the membrane separator has no detrimental influence on the battery capacity, as is the case in redox flow batteries employing different metal species in the positive and negative half-cells. The vanadium half-cell solutions can even be remixed bringing the system back to its original state.

Vanadium Redox flow batteries are an energy storage technology. They are charged like batteries, but the energy, rather than being stored at the electrodes, is stored by chemical changes to a working fluid, similar to regenerative fuel cells. In redox flow batteries the fluids contain dissolved species that can be electrochemically oxidized or reduced to store the energy. The vanadium-based system is rugged because it is less affected by membrane crossover problems. The cell membrane must effectively block the crossover of the electroactive species from one side of the cell to the other. At the same time, in order to minimize power losses due to the cell internal resistance, the membrane must easily allow charge to flow, usually in the form of hydrogen or sodium ions. These requirements are especially difficult to tailor if the system will be exposed to varying temperatures, because the optimal balance of cell membrane properties in terms of maximum crossover resistance and minimum resistive drop is very sensitive to temperature. Thus, the vanadium system is more suitable for remote or unattended operation, in particular with varying temperatures

The battery is made up of two plastic reservoirs, to house the two different electrolyte solutions, and a "stack" of cells.

Each cell has two half-cells, separated by a membrane, and two current-collecting electrodes. One of the two different ionic forms of the electrolyte is in each half-cell. The positive and negative half-cells respectively contain the electrolyte as Vanadium (II/III) and Vanadium (IV/V) redox couples. A pump supplies electrolyte to each half-cell, in a closed loop with the half-cell reservoir.

The operational characteristics of the VRB allows for complete discharge cycling of over 10,000 times with no measurable degradation of performance. A second important characteristic of the VRB is the charge/discharge ratio of close to 1:1 - allowing off-peak charging for on-peak dispatch, a fraction of the time required by other battery systems and ideal for prime power applications. It is possible to have the cell stack flooded at all times so the VRB is “always on” and so acts as an UPS without any immediate need for pumping of the electrolyte. The self discharge is very low and its DC stack round trip efficiency very high (80%) during full charge /discharge cycles.

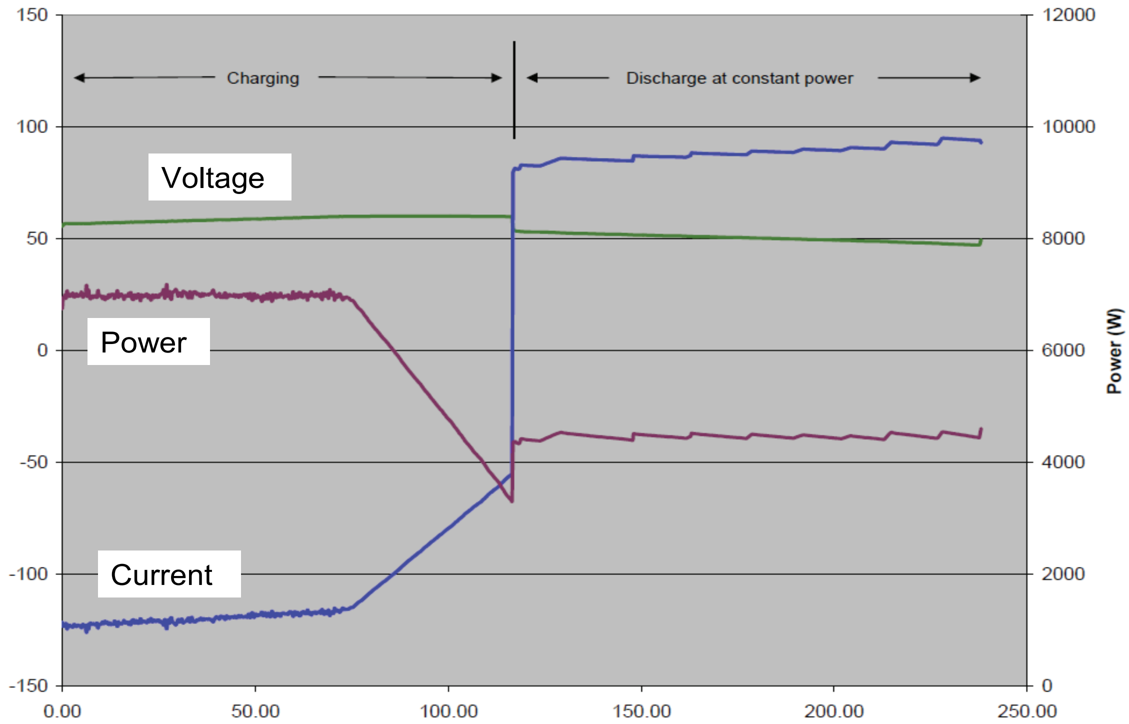


Figure 2. Graph showing cycle performance of a 5kW 2 hour storage VRB after cycling 100’s of times. Speed of recharge is evident, which allows a VRB system with 9 hours of storage to be cycled fully each day.

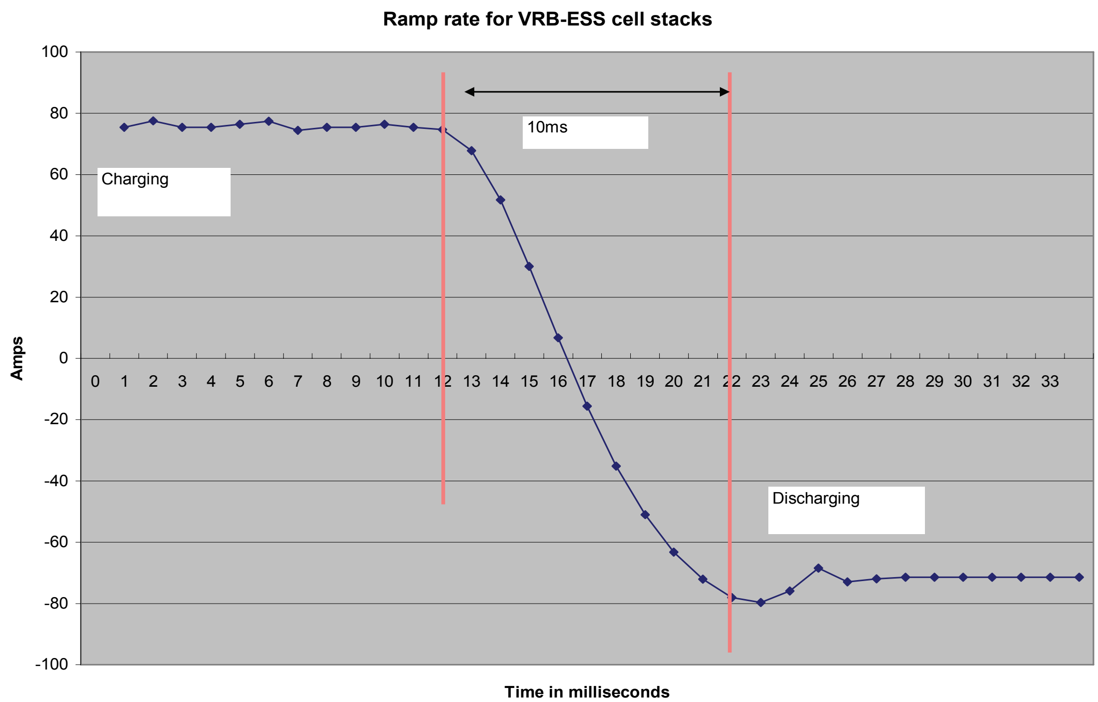


Figure 3. Graph showing the ramp rate capability for a VRB-ESS moving from full charge mode to full discharge mode inside 10milliseconds. This would be an extreme case where a power outage occurs when the VRB-ESS is charging at full rate and is called upon to provide UPS functionality.

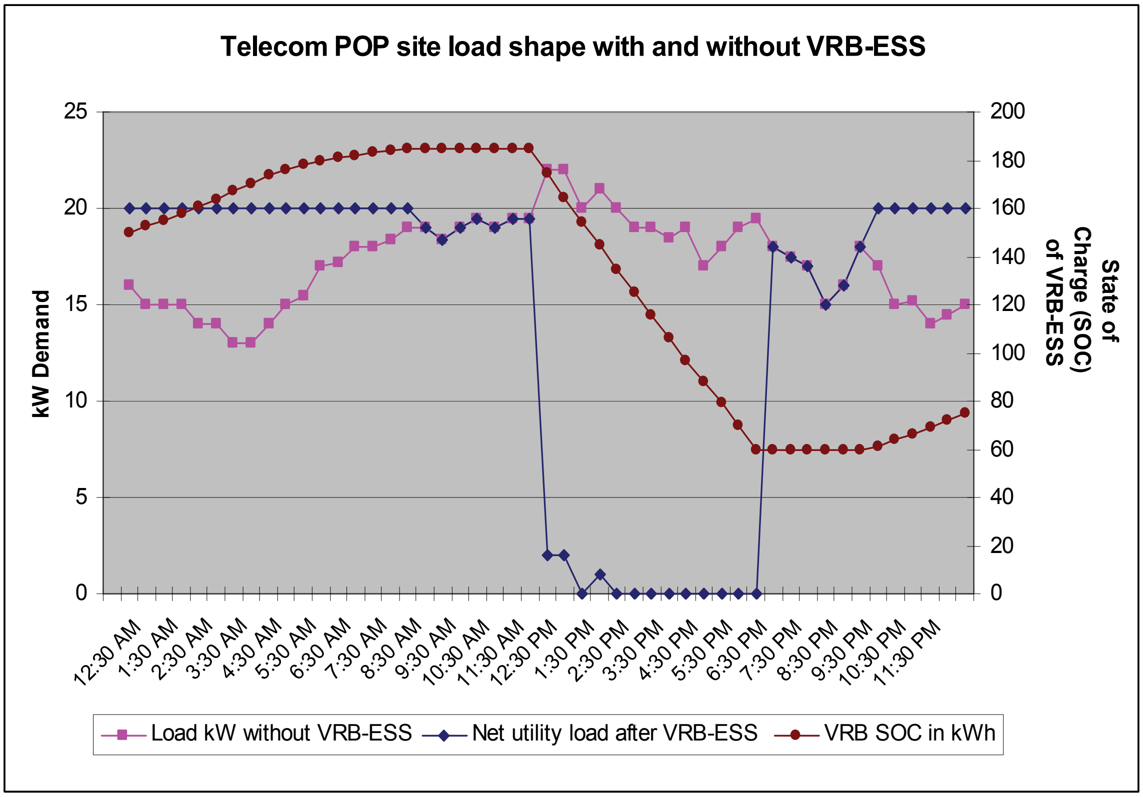


Figure 5. Graph shows the normal daily load at a POP site peaking at about 22kW during the peak daily tariff period. A VRB-ESS is used to virtually completely remove the daytime load over 6 hours, recharging at night and remaining below maximum demand levels set prior to its use. The VRB-ESS SOC is maintained at above 60kWh (30%) in order to provide 3 hour UPS functionality at all times. Depending upon tariffs the storage durations and power ratings of the VRB-ESS can be independently adjusted to optimize the economic savings.

PROJECT – ECONOMICS

The initial theoretical analysis shows that even inefficient batteries can still yield savings and that for batteries where the incremental cost of additional hours of storage is low and efficiency high (such as the VRB Flow Battery), then simple paybacks inside of 5 years are possible. This is unique in concept because for the first time a battery used primarily as a UPS, may now be able to generate savings without compromising security of supply and life cycle.

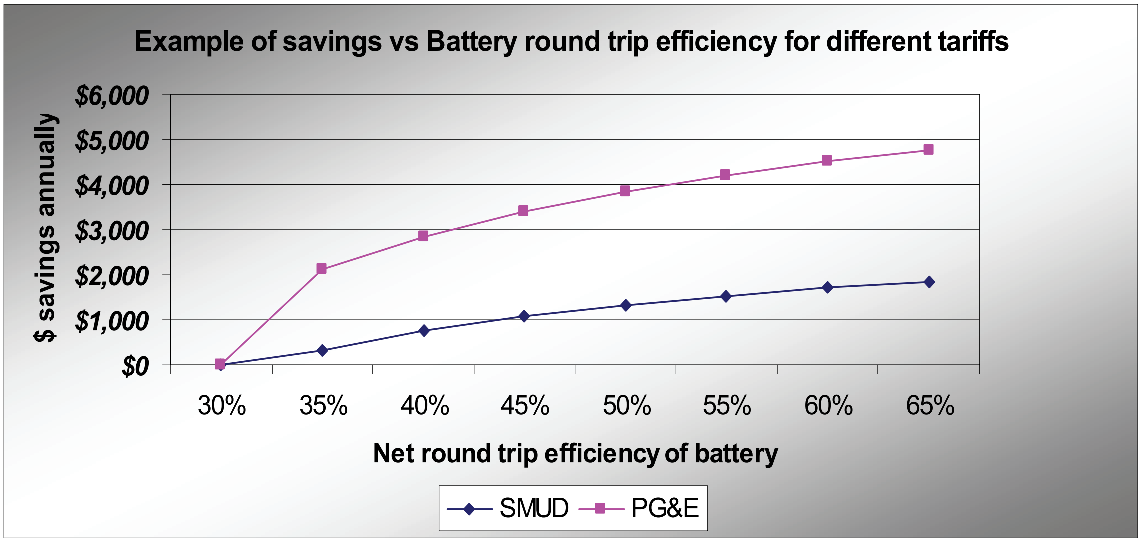


Figure 6. Example of savings sensitivity against battery roundtrip efficiency for two tariffs in use in California for a 20kW 9hour battery, cycled optimally.

CONCLUSION

VRB Power has proposed a CEC/SMUD/Customer funded project to install a 20kW 9 hour storage system. The project will evaluate the system installed at a telecommunication POP site in the Sacramento Municipal Utility District's (SMUD) distribution area. A theoretical evaluation of expected performance savings for different levels of roundtrip efficiency will be prepared in order to determine savings sensitivity for different tariffs. This will allow the same concept to be evaluated for other parts of California and the USA. The VRB system will be installed at the site by March 2008 for on site evaluation over a year. Initial estimates show that the system is capable of providing payback of under 5 years and contribute to permanent load shifting in California.

By applying the concept described in this paper, to only the POP facilities within the state of California, it is estimated that over 30MW of load can be permanently shifted and an average energy saving during peak periods of 165MWh/year can be achieved.

Logical extensions to the concept would be coupling the system to small wind turbines and or solar panels. In sites which are off grid (several hundred in the USA and Canada and tens of thousands worldwide), the concept is further enhanced because diesel engines act as prime power sources. Results from evaluations in sites in East Africa show savings in diesel use and maintenance sufficient to yield three year discounted paybacks as well as significant emission reductions.

LIST OF ABBREVIATIONS

AC	- alternating current
DC	- direct current
PG&E	- Pacific Gas and Electric -utility
POP	- point of presence
SMUD	- Sacramento Municipal Undertaking District
SOC	- state of charge
TOU	- time of use
UPS	- uninterruptible power supply
VRB-ESS	- Vanadium Redox Battery Energy Storage System