ADVANTAGES OF USING VANADIUM REDOX BATTERIES IN TELECOMMUNICATIONS PRIME POWER SITES

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ABSTRACT

Telephone service providers are constantly studying ways to curb the costs of operating remote telecommunications transmission sites. The more remote the site, the higher the costs of energy used to power the site regardless if the energy is utility power or other sources such as on-site diesel powered generators. Remote transmission sites are also expensive to service and support. Many sites are accessible only by helicopter or during summer months. There are tens of thousands of transmissions sites in North America alone, many of which rely on localized generation of electrical power from on-site diesel generators. Attempts have been made to augment the diesel generators with some form of energy storage such as large banks of lead/acid batteries. Battery banks have traditionally been used as a backup power system operating only when the main source of power is not available. There have been attempts to use traditional batteries for cycling down generators during extended periods of time. In theory, using batteries could save fuel costs or will help eliminate generator noise and pollution at sites located close to populated areas. Traditional battery technologies such as lead/acid batteries cannot hold up to this aggressive charge and discharge cycling. The cost to constantly replace damaged batteries becomes more expensive than the realized operational costs of using the batteries in this capacity.

There is a battery technology that works well in this application. Vanadium Redox Flow Batteries (VRB) have the properties needed to stand up to the high level of discharge cycling allowing on-site generators at *Prime Power* telecommunications sites to be turned off for significant periods of time on a daily basis. This paper will explain the operational characteristics of the Vanadium Redox Flow Battery and will describe how this energy storage technology will dramatically cut the costs of on-site diesel power generation for remote telecommunication transmission sites.

PRIME POWER GENERATION AT MICROWAVE TRANSMISSION SITES

Worldwide, Telecommunications service providers have relied on diesel generators as a primary source of electrical power at remote telecom sites where utility power is unavailable. Diesel generators provide primary power to microwave transmission stations located on top of mountains or on remote islands. The value of the transmitted information easily justifies the high costs of localized diesel power generation. These sites are typically referred to as ***Prime Power*** sites.

Microwave transmission is used as the backbone of many telecommunication networks. Microwave systems have proven to be a reliable and inexpensive medium to transmit voice and data communications over long distances or rough terrain such as mountain ranges, between islands, or locations where cable access is not feasible.

For prime powered microwave sites, the cost of fuel tops the list of operating expenses. Other expenses such as engine service and maintenance are directly related to engine run hours, load, and temperature. Generally, the lower the load - as a percentage of engine rating , the lower the efficiency of the diesel engine, thus the higher the maintenance costs due to premature engine wear, carbon buildup, and increased oil change schedules.
Microwave transmission equipment is usually a light load for a diesel generator. To increase engine efficiency, a “dummy load” in the form of a resistor bank is added. The energy absorbed by the resistor bank is completely wasted in the form of heat.

Operational cost savings could be realized if it were possible to store the excess electrical energy and turn off the generators for a significant period of time each day. Traditional lead/acid batteries have been used in an attempt to capture the excess energy from the generator, turn the generator off and run completely from the batteries thus turning the site into a “cycling power” site. Unfortunately, there are issues with this solution.

Traditional lead/acid batteries are limited to the number of deep discharge cycles before permanent damage occurs. An innovative energy storage technology is needed that is not affected by daily deep discharge cycling and has the ability to be quickly charged. What is the answer? This paper describes a battery technology that can change the tide on electrical energy storage. This technology is the Vanadium Redox Battery Energy Storage System (VRB-ESS™.)

VANADIUM REDOX BATTERY ENERGY STORAGE SYSTEM (VRB-ESS™) 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.

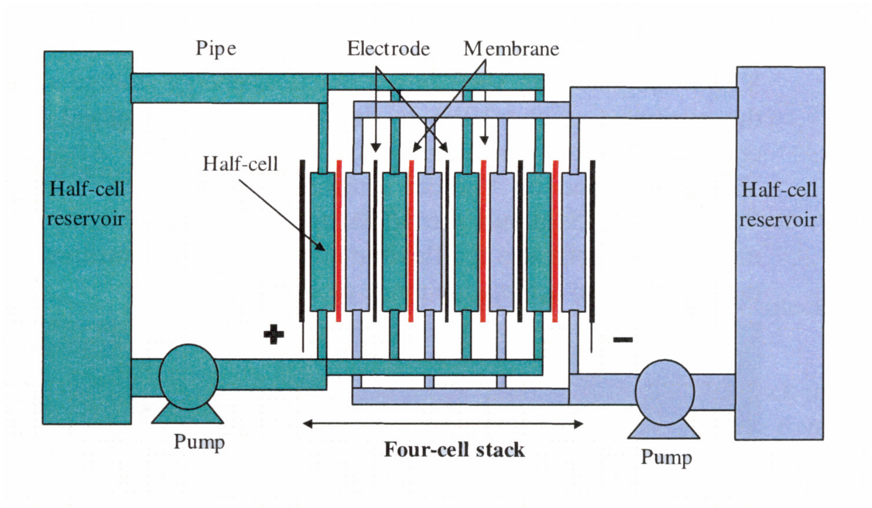


Figure 1. Concept of the Redox Flow Battery System

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 electrolyte is a solution of vanadium mixed with sulphuric acid with about 30% less acidity as in a conventional lead-acid battery. 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.

When charged electrolyte solution is allowed to flow through the stack, electron transfer between the different forms of vanadium ions across a separating membrane can be forced to flow into an external circuit and so complete the electrochemical path for discharge. Forcing current into the stack from an external source reverses the process and recharges electrolyte in the stack, which is then pumped back into the reservoirs.

The operational characteristics of the VRB allows for complete discharge cycling in the order of 12,000 times with no measurable degradation of performance. A second important characteristic of the VRB is the charge/discharge window of 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. Also, the VRB has the ability to be scaled both in power delivery, based on the size of the cell stack design, and the number of hours runtime based on the amount of vanadium and electrolyte at hand. 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 round trip efficiency very high (80%) during full charge /discharge cycles.

USING THE VRB’S HIGH DISCHARGE CYCLING CAPACITY TO CUT FUEL USE AT PRIME POWER SITES

The VRB-ESS™ now adds a significant alternative approach to powering prime power telecom sites. These sites can now be operated as cycling power sites. Let’s look at a specific example.

This analysis uses data from actual telecom sites. A major North American telephone company must transmit voice and internet data from remote communities to the main switch hub at the corporate headquarters hundreds of miles away. The remote sites require voice and data to be transmitted over a mountain range using numerous microwave towers located on the top of the mountain range. A number of these sites require diesel generators operating as the main source of power.

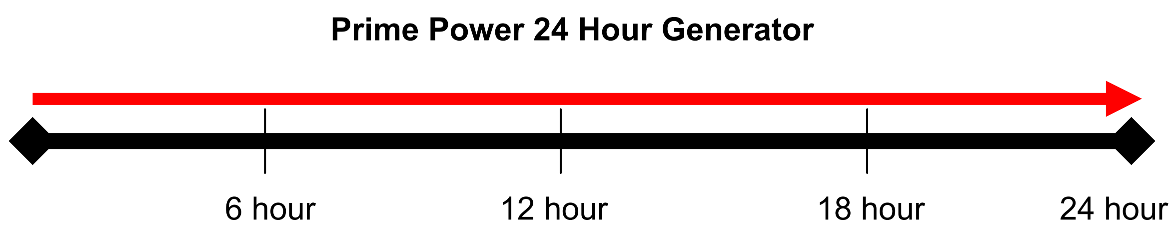
At one specific microware site, the microwave transmission equipment draws about 1 KW of power. Environmental controls at the site can drive the total power up to 3KW depending on the weather conditions. During the winter months, the site requires additional baseboard heat and during the summer months a window air conditioning system is activated. The site has a 2 - 13KW diesel generators. One generator operates at a time and runs for hundreds of hours until it requires service. At that time, the alternate generator is activated and operates until the next service date. Approximately 1kw is used for microwave transmission, with the remaining power dumped into a resistor bank.

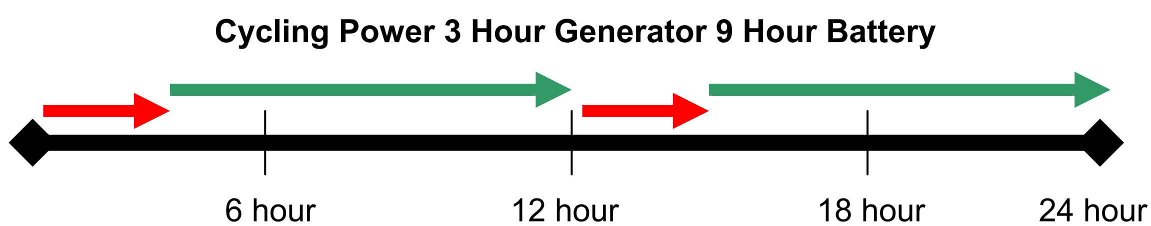
Converting a Prime Power Site into a Power Cycling Site using the VRB

The VRB has a number of unique properties that work in favor of supporting power cycling. First, the VRB can be completely discharged with no long term effect on the battery. Second, the VRB can be scaled for runtime by specifying the quantity of electrolyte the system will have on hand. Third, the VRB can be quickly recharged.

Let's assume the VRB has a 3.5KW power delivery capacity and enough electrolyte to support 9 hours of runtime at 1KW. With these parameters, the system would require 3 hours to charge between 9 hour run cycles.

The following graphs illustrates the reduction of generator runtime by storing the excess generated energy in a VRB-ESS™. In this scenario, the VRB-ESS™ would be charged and discharged twice each day. At 12,000 estimated discharge cycles, the system would have a life expectancy of over 16 years. At this time, only the components that show wear need to be serviced as the electrolyte does not wear out.





Red indicates Generator Runtime
Green indicates VRB-ESS™ Runtime

There is a concern that too much on and off cycling of the generators will lead to reliability problems. In order to reduce this to some agreed number of stop-starts, the VRB-ESS™ can be sized to have longer run hours by adjusting the electrolyte volumes. Additional storage costs less than a third of the system first cost so longer run hours are relatively inexpensive

Operational Cost Savings for Cycling Power Sites using the VRB-ESS™

By using the VRB-ESS™, the cost to operate this site is significantly reduced. The VRB-ESS™ has the ability to be scaled to store 9kwHr of energy. This would mean that at 1kw (the actual load of the microwave radio system), the VRB-ESS™ could supply up to 9 hours of uninterruptible power. Each 24 hour period would include 6 hours of generator runtime and 18 hours of battery runtime. During generator runtime, the generator would power the microwave transmission site and charge the VRB-ESS. During the VRB cycle, the generator would be switched off and the VRB-ESS™ would power the transmission equipment. By using this pattern, fuel cost of the site is slashed by over 3***5%***.

Other operational costs include scheduled service based on engine runtime. Typically, an oil change is required each 500 hours of runtime. With 2 generators on site and 500 hours of runtime for each generator, a service call would be required every 40 days. The cost to dispatch personnel to very remote locations sometimes requires helicopter service or other extreme transportation methods. Many North American microwave sites are not easily accessible during the winter months. Reducing the daily run hours on the generators extends the time between service calls. Each 500 hours of runtime per generator would stretch to over 150 days saving service expense, travel expense and labor costs.

CONCLUSIONS

Traditionally, batteries have been used as an insurance policy to keep transmission equipment from being interrupted during short term power outages or to bridge the time until an alternate source of power such as an on-site generator is activated. Deep cycling traditional batteries always comes at a high price thus eliminating their use in cycle powered applications.

Vanadium Redox Flow Batteries have unparalleled performance characteristics that other battery technologies cannot achieve. The ability to fully discharge the system allows the battery to power a load for many hours at a time, as in the example, up to nine hours discharge every day. The life of the VRB-ESS™ is measured in the number of discharge cycles and is on the order of 10s of thousands of cycles. Daily discharge means a lifespan of at least 16 years before service is required. The ability to scale the platform for both power delivery and runtime allows for a large range of applications from stationary telecommunications applications, storing energy from wind and solar generation, as well as full scale utility peak shaving. The ability to recharge the VRB at a similar rate of the discharge cycle allows for quick turnaround to a full charge.

The closing statement is clear: Using the VRB to store the excess energy generated by diesel power at remote telecommunication microwave sites significantly reduces the amount of diesel fuel burned and reduces the cost of service and support of the diesel engines.

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