Energy Savings using Flow Batteries
Telecom Base Station Application
Introduction

The mobile telecommunications networks in emerging markets such as Africa and Asia have grown beyond the reach of other supporting infrastructure including power and roads. The limited reach of power infrastructure and poor accessibility to widely dispersed networks of telecom sites has impacted the operations and costs of running the network.

Operation and maintenance of remote networks remains a challenge impacting the overall operating cost, network availability and reliability of service. Reliable, cost effective energy availability has become a key factor in maintaining a competitive network operation.

In areas where grid power is unavailable (off-grid) or only intermittently available (weak-grid) telecom operators have relied on diesel generators to power their Base Transceiver Stations (BTS). Though installation is inexpensive, the rising cost of diesel fuel and its delivery to remote locations, has driven the development of alternative solutions with a lower total cost of ownership.

In response to this situation, telecom operators have begun to deploy hybrid diesel/battery energy storage systems that deliver a reduction in fuel usage, improved overall fuel efficiency of diesel generators, reduced run hours, and a back-up power supply. By coupling the generator with batteries, the generator can be run more efficiently while the batteries charge, and then turned off while the batteries discharge to support the BTS. In some cases, fuel savings can reach up to 60%, not including the ancillary benefits of fewer fuel deliveries, and reduced generator run-time, lower maintenance and fewer replacements.
However, using lead acid battery technology for energy storage has severe performance and asset life limitations, and critically introduces a high security risk of theft at remote locations.

Imergy’s Energy Storage Platform (ESP) has replaced lead acid batteries in more than 70 off-grid or weak-grid telecom applications in remote areas of Africa and India. The Imergy ESP system is a game-changing smart battery that seamlessly integrates into a telecom site and intelligently plans energy management. The ESP provides a high quality, reliable solution to rising fuel costs, increasing greenhouse emission pressures and unreliable electric grids, while mitigating the security risk of theft which exists with other energy storage solutions.

This paper presents the Imergy ESP battery technology, performance in hybrid telecom applications, and demonstrates the value that the Imergy ESP brings to off-grid and weak grid telecommunications customers.

**IMERGY ESP™ SERIES SYSTEM SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Power</td>
<td>5 kW</td>
</tr>
<tr>
<td>Energy Capacity</td>
<td>15/20/25/30 kWh</td>
</tr>
<tr>
<td>Cycle Life</td>
<td>Unlimited or 10 years</td>
</tr>
<tr>
<td>Discharge : Charge Ratio</td>
<td>Up to 3 : 1</td>
</tr>
<tr>
<td>Ambient Operating Conditions</td>
<td>-20°C to 55°C / -4°F to 131°F</td>
</tr>
<tr>
<td>Charge Voltage Range</td>
<td>Up to 58 VDC</td>
</tr>
<tr>
<td>Output Voltage Range</td>
<td>Nominal 48 VDC</td>
</tr>
<tr>
<td>Duty Cycle</td>
<td>Continuous</td>
</tr>
<tr>
<td>DC Efficiency</td>
<td>70-75%</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Five-band: UMTS/HSPA 850/800, 900, 1900, 2100 MHz</td>
</tr>
<tr>
<td></td>
<td>Quad-band: GSM/GPRS/EDGE 850/900/1800/1900 MHz</td>
</tr>
<tr>
<td></td>
<td>SMS messaging</td>
</tr>
<tr>
<td></td>
<td>Ethernet/RS485/RS232</td>
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</table>

**Physical Dimensions**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Footprint</td>
<td>2.9 m² / 31.2 sq ft</td>
</tr>
<tr>
<td>Dimensions (W x D x H)</td>
<td>2.15 x 1.33 x 2.08 m / 7.1 x 4.4 x 6.8 ft</td>
</tr>
<tr>
<td>Shipping Weight (dry)</td>
<td>~890 kg / 1962 lbs</td>
</tr>
<tr>
<td>Weight</td>
<td>~3100 kg / 6834 lbs</td>
</tr>
<tr>
<td>Certification</td>
<td>IP54</td>
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Telecom Application

The past two decades have seen massive proliferation of mobile communication devices. The cellular technology that has made this possible has required a commensurate increase in base stations and microwave transmission equipment. The telecoms towers on these base stations have now become part of the landscape in virtually every corner of the globe.

Power for telecom sites is either drawn from the grid, or generated on-site using diesel generators sometimes in combination with solar panels and wind turbines. In many remote areas, diesel engines are the only source of power. The cost of supplying diesel to these sites is often very high due to their remote nature and unpredictable due to global price fluctuations and foreign exchange uncertainty of purchasing diesel in a local currency.

The operating cost of a diesel engine is a function of its run hours, load and temperature. Generally the lower the load, the lower the efficiency; in addition, lower loads create carbon deposits (or coking) inside a diesel engine resulting in shorter asset life and increased maintenance. Additionally considerable theft of fuel and other materials occur which is often un-quantified.

When a diesel generator is coupled to a remote or islanded grid, the load can vary considerably. The diesel engine has to be sized to cater for maximum demand which can be 80% greater than the average load. Fuel usage will drop by up to 35% per kWh produced when a diesel engine is operated from 25% to 75% of full load – the conclusion is that a diesel engine is far more fuel efficient when operating near its maximum rated load.

<table>
<thead>
<tr>
<th>Generator Size (kVA)</th>
<th>25% Load (L/hr)</th>
<th>50% Load (L/hr)</th>
<th>75% Load (L/hr)</th>
<th>100% Load (L/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1.9</td>
<td>2.6</td>
<td>3.4</td>
<td>4.1</td>
</tr>
<tr>
<td>25</td>
<td>2.5</td>
<td>3.7</td>
<td>5.0</td>
<td>6.2</td>
</tr>
<tr>
<td>30</td>
<td>2.8</td>
<td>4.3</td>
<td>5.8</td>
<td>7.3</td>
</tr>
<tr>
<td>40</td>
<td>3.4</td>
<td>5.4</td>
<td>7.4</td>
<td>9.4</td>
</tr>
<tr>
<td>50</td>
<td>4.0</td>
<td>6.5</td>
<td>9.0</td>
<td>11.5</td>
</tr>
</tbody>
</table>
To increase engine efficiency and reduce coking, a “dummy load” in the form of a resistor bank is often 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 and re-use this excess electrical energy by turning 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 several fundamental issues with this solution.

**Issues using Lead Acid batteries for Cyclic Energy Storage**

Lead acid batteries were never designed to hold up to an aggressive charge and discharge cycling without constant replacement. The cost to constantly replace damaged lead acid batteries erodes the operating expense saving realized through more efficient fuel utilization. Lead acid batteries are limited to the number of deep discharge cycles before degradation or permanent damage occurs. Guidance from battery manufacturers is to limit the depth of discharge (DoD) to a maximum of 50% of the batteries fully charged state. Replacement is recommended after around 1500 cycles at 50% DoD. (Certain lower grade, cheap lead acid batteries are unable to meet even 1,500 partial discharge cycles despite marketing claims to the contrary.)

Additionally, the batteries must be kept at close to 25°C/77°F to ensure even these limited number of cycles and the rate (c rate) of charge and discharge must be managed as well.

To maximize battery life, current charging technology relies on microprocessors (controlled battery charges) to recharge using 3 stage regulated charging. The three stages or steps in lead acid battery charging are bulk, absorption, and float modes. Qualification, or equalization, is sometimes considered another stage. It is imperative to use battery manufacturer recommendations on charging procedures and voltages to maintain battery capacity and service life. This eliminates the possibility of fast charging or partial charging which is essential for maximizing fuel efficiency.
Lead acid batteries have a manufacturer’s recommended temperature restriction of 25°C/77°F to maintain battery capacity and service life, which in many countries requires cooling and therefore parasitic energy consumption through non-essential air conditioning.

This is a very onerous load and applies not only to lead acid batteries but also lithium batteries when greater than 40°C/104°F ambient temperatures occur.

At greater than 40°C/104°F ambient temperatures, the life of the batteries are reduced and the charge rate is limited. Although lead acid energy storage systems are usually located outdoors, the system’s battery bank, BTS, controller and rectifier bank need to be in a temperature-controlled environment and are typically placed indoors inside a shelter or in a controlled container. Those that do use a shelter still use air-conditioning, which significantly increases the operating costs.

**Vanadium Redox Energy Storage**

For the telecommunications market, an innovative energy storage technology is required that is unaffected by routine 100% discharge or partial discharge cycling, has the ability to be charged much faster than it is discharged, and can operate at extreme temperatures without the added cost of air conditioning systems.

By using advanced flow battery technology as the primary energy source in a continuous charge-discharge-cycling operating mode, fuel costs and emissions can be significantly reduced and overall system efficiency dramatically improved.
Imergy’s Vanadium Redox Energy Storage Platform (ESP) allows users to scale power and storage capacity independently of one another, which enables close matching of load and storage that is beyond the capability of conventional batteries.

The Imergy ESP is designed to manage an unlimited level of discharge cycling allowing on-site generators at remote telecoms sites to be turned off for significant periods of time on a daily basis. This energy storage technology dramatically cuts the costs of on-site diesel power generation for remote telecommunication transmission sites.

The Imergy ESP also provides the ancillary benefit of remote monitoring of the battery, which allows the customer to verify the fuel savings, detect and manage faults, and schedule preventative maintenance.

### Telecom Site Configurations: Off grid, Weak Grid and Microgrid, Diesel Energy Cost Reductions

**Imergy Tower & Antennae**

**Power & Communications Electronics**

**Poor / No Grid Electricity**

<table>
<thead>
<tr>
<th>Competitor Lead-Acid Battery</th>
<th>Imergy’s Superior ESP Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>Slow charging, limited cycles, 2 year outdoor life</td>
</tr>
<tr>
<td>Power</td>
<td>Runs most hours on generator</td>
</tr>
<tr>
<td>Cost</td>
<td>Expensive: Fuel &amp; batteries</td>
</tr>
<tr>
<td>Environment</td>
<td>CO₂, lead, landfill</td>
</tr>
</tbody>
</table>
The Imergy ESP delivers unparalleled performance with no active temperature control required, even at 50°C/122°F. Telecom operators save money and space by removing unnecessary HVAC and cooling systems, making it an ideal solution for extreme temperature environments. And with its high charge acceptance, integrated smart battery architecture allowing optimum programmable battery usage, and unlimited cycling performance, the Imergy ESP system can be the primary energy source for telecom installations that have historically relied on diesel generators as the primary power source with lead acid batteries as the hybrid backup.

Telecom Value Proposition

ESP’s ability to fast charge on weak grid and off grid sites allows the generator run to be substantially reduced. The generator runtime can be reduced to zero with daily grid availability of 4 and 7 hours in sites with loads of 1 kW and 2 kW, respectively. In addition long life, unlimited cycles and high temperatures tolerance makes it the least cost energy storage solution for Telecom tower based on Total Cost of Ownership (TCO) which includes ESP & Generator capex, Generator O&M cost, diesel and grid energy cost.

Note: 5 Year TCO, Diesel price = 1 $/Liter, Generator O&M = 0.2 $/hr, Grid = 0.1 $/kWh
Integration with Renewable Power Sources

Imergy’s ESP can be seamlessly integrated with renewable power sources such as solar photovoltaic (PV) panels to further improve on the telecom energy savings value proposition. Solar PV can power the telecom tower with no diesel consumption for a few hours during daytime, as illustrated in the plot below, so the number of hours of grid availability required to eliminate generator run also decreases. Savings on fuel and O&M pays back the investment on PV typically in 2-3 years. Therefore addition of PV to ESP will further reduce the TCO. On weak grid sites where ESP alone is sufficient to reduce generator run time to zero hours, the addition of PV will reduce the grid energy consumption. In such case it will be economical solution only if the grid energy cost is high.
The PV output is intermittent, thereby needing another fast-reacting, long duration power source to support the telecom load when PV output drops. Batteries can be this alternative power source, but this application can require a large increase in number of charge-discharge cycles vs the case without PV, greatly reducing the life of conventional batteries. The ESP technology benefits such as long life and unlimited cycles make it an ideal PV + Battery hybrid system. The following plot of customer site data from a PV + ESP installation illustrates the intermittency of PV output and the large number of charge discharge cycles. The sizing of PV depends upon the available space, load and grid availability. In this site a 2.25 kW PV panel is integrated with ESP at a 1.1 kW site load. This results in several charge discharge cycles on daily basis. The number of charge discharge cycles can be seen when ESP transitions from positive to negative power, where negative power indicates ESP is charging.
The following figure shows a simple block diagram of PV and ESP integration at a typical telecom site. A maximum power point tracking (MPPT) based charge controller connects the PV output to the telecom DC voltage bus. The configuration would ensure the priority of energy usage from PV followed by grid power, ESP and finally generator if required. If PV output is in excess of load requirement, it would charge the ESP with the excess power and in case the PV output is less it would draw the balance power from ESP. In the presence of grid power the power sharing is between PV and grid with ESP in charging mode. This ensures the optimum utilization of available energy.
Proven Performance: Deep Cycles at High Temperature - Field data collected over 3 years
Stable output over 11,000 cycles, even up to 50°C/122°F ambient. No active cooling requirements so reduced cost, enhanced efficiency and improved reliability.

Regular energy expenses include grid power if available and diesel fuel expenses. The Imergy ESP can also be used profitably at sites that suffer from weak grids, where grid energy is available less than 14 hours/day. The ability to manage unlimited partial states of charge is a fundamental requirement for weak grid storage installations where the time of grid availability is largely unknown. The ESP is the first line of back-up power for weak grids and in many cases reduces the generator run time to zero.

The Imergy ESP is non-flammable and non-combustible and contains no diesel fuel or other components commonly targeted for theft.

Following is the field data from three Imergy ESP installations in India and Africa at rural BTS sites in both off-grid and weak-grid situations. All three sites originally had lead acid (VRLA) battery banks that were cycled every day to reduce generator run time and operating expense.
Case Study: India 1 – Three Weak-Grid Sites

These three sites were originally installed with valve-regulated lead acid (VRLA) batteries that were controlled with an external diesel hybrid controller set to manage the generator in a timer and voltage cut-off mode of operation. The baseline fuel consumption measurements shown below are for newly installed VRLA batteries. The average ambient temperature at these remote sites was 35°C/95°F, with a peak of 50°C/122°F. The Imergy ESP system was configured to act as the primary back up power source in the event of a grid outage, after which the generator is used to power both the BTS and charge the battery at a higher efficiency than if powering the BTS alone.

<table>
<thead>
<tr>
<th>Site</th>
<th>BTS Load (kW)</th>
<th>Grid Availability (hr/day)</th>
<th>Monthly Fuel Consumption Using VRLA (Liters)</th>
<th>Monthly Fuel Consumption Using ESP (Liters)</th>
<th>Monthly Fuel Savings (Liters)</th>
<th>Monthly Fuel Saving (%)</th>
<th>Annual Fuel Savings ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.4</td>
<td>0.0</td>
<td>1130</td>
<td>711</td>
<td>419</td>
<td>37%</td>
<td>$6,536</td>
</tr>
<tr>
<td>2</td>
<td>1.2</td>
<td>4.2</td>
<td>661</td>
<td>232</td>
<td>429</td>
<td>65%</td>
<td>$6,692</td>
</tr>
<tr>
<td>3</td>
<td>1.1</td>
<td>5.9</td>
<td>498</td>
<td>75</td>
<td>423</td>
<td>85%</td>
<td>$6,599</td>
</tr>
</tbody>
</table>

After installation of the Imergy ESPs, fuel usage decreased dramatically. The Imergy ESP delivered monthly fuel savings of up to 100%. And with an average delivered fuel cost of $1.30 per Liter, the Imergy system delivered payback in 2-3 years in all three cases on fuel savings alone. Additionally, integration of the Imergy ESP increased the life of the diesel generators and reduced the overall operations and maintenance costs, which provided further cost savings.
Case Study: India 2 – Grid with PV

Combining locally available power sources such as photovoltaics (PV) and/or wind turbines with the Imergy EPS can further reduce fuel costs and in some cases completely eliminate the need for a diesel generator altogether. This telecommunications site in India was equipped with a 3kW solar panel array (74W x 40 panels) with an integrated maximum power point tracking (MPPT) controller connected to the 48V DC bus. The Imergy ESP system replaced lead acid (VRLA) batteries that were run with a timer and voltage cut-off mode of operation. The remote location has an average grid insolation of 12.5 hours per day. The average ambient temperature at this site is 36°C/97°F, with a peak of 52°C/125°F.

<table>
<thead>
<tr>
<th>Site</th>
<th>ESP Capacity (kW)</th>
<th>BTS Load (kWh)</th>
<th>Grid Availability (hr/day)</th>
<th>Monthly Fuel Consumption Using VRLA (Liters)</th>
<th>Monthly Fuel Consumption Using ESP (Liters)</th>
<th>Monthly Fuel Savings (Liters)</th>
<th>Monthly Fuel Savings (%)</th>
<th>Annual Fuel Savings ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>2.5</td>
<td>11.5</td>
<td>653</td>
<td>83</td>
<td>570</td>
<td>87%</td>
<td>$8,892</td>
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</tbody>
</table>

The Imergy ESP/PV solution delivered monthly fuel savings of up to 87%. With delivered fuel at an average cost of $1.30 per Liter, the Imergy system yields a total payback within 2 years.
Case Study: Africa (Off-Grid Site)

At this telecommunications site in Africa, the Imergy ESP was installed in an effort to compare its performance against a lead acid hybrid system that had been deployed at the remote location. Here again, the Imergy ESP is used to share the load with the diesel generator. Once the system is charged, the generator is turned off and the ESP sustains the BTS load. Average ambient temperature at this site is 35°C/95°F, with a peak of 48°C/118°F. Though actual fuel was not measured in this case, the number of battery support hours was recorded to assess the Imergy ESP value proposition.

![Image](image_url)

<table>
<thead>
<tr>
<th>Imergy ESP</th>
<th>Generator Usage</th>
<th>37.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Usage</td>
<td>63.00%</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Lead Acid</th>
<th>Generator Usage</th>
<th>55.60%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Usage</td>
<td>44.40%</td>
<td></td>
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</tbody>
</table>

Customer Requirement for Battery Usage

0.00% 10.00% 20.00% 30.00% 40.00% 50.00% 60.00% 70.00% 80.00% 90.00% 100.00%

Source: African telecom operator

The customer’s TCO model called for a diesel runtime reduction of more than 60%. Using optimized protocols, the Imergy ESP delivered a 63% reduction in diesel run-time, a dramatic improvement over the lead acid (VRLA’s) 44%.
In summary, the Imergy ESP reduces operating expenses for off grid and weak grid telecom installations by:

- Reducing overall fuel consumption
- Reducing generator run time and therefore maintenance scheduling cost
- Eliminating parasitic cooling requirement for battery
- Providing long battery life (>10 years)
- Eliminating the need to replace and dispose of lead acid batteries every 2 years
- Extending the asset life for diesel generator replacement

The case studies above demonstrate that Imergy ESP’s Vanadium Flow Battery architecture, fast charge capability, full and partial charge capacity, unlimited cycle life, and compatibility with extreme operating temperatures make it ideally suited for hybrid applications such as primary back up power in areas where the electrical grid is unreliable or unavailable. In off-grid or weak-grid telecom applications, cell sites that rely on diesel generators and batteries can operate more fuel-efficiently by utilizing Imergy’s ESP systems compared to lead acid or lithium batteries for energy storage, reducing both fuel costs and associated emissions. With the added benefits of its built-in remote monitoring system to verify fuel savings, detect faults, and schedule preventive maintenance, the Imergy ESP delivers a dramatically lower total cost of ownership.

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