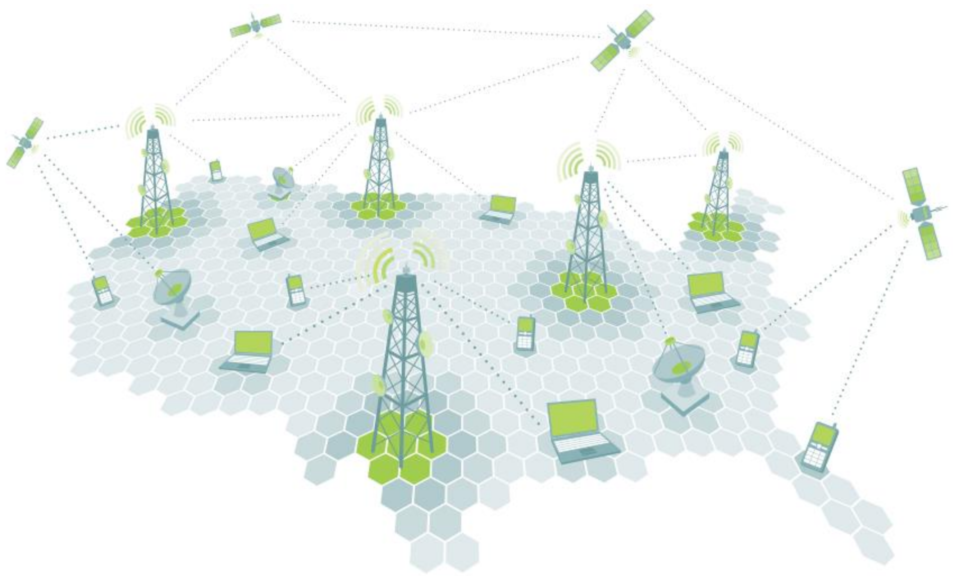
Telecommunications Storage

This document deals with telecommunications storage and compares various types of batteries within the telecommunication environment.



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Introduction

In the world of Telecommunications, “up-time” and “coverage” is the name of the game. “Up-time” simply means what it says, when a tower loses power clients can’t communicate and the network loses revenue, in some cases even customers. “Coverage” is the ability to connect people in remote locations. Coverage plays a role when customers in remote locations decide which network operator to choose.

The price for up-time is the cost of back-up power. Back-up power is not as simple as adding batteries to solve the problem. Many hidden pitfalls cost network providers a lot of money when dealing with batteries.

The price for coverage includes operating without a national grid to connect to. In most cases remote sites need to supply their own electricity, which is accomplished through the use of generators and/or solar panels. The cost of these generators is not only related to fuel, but should include the cost to service these locations. It is important to keep in mind that the site most likely needs a generator due to the remoteness of location itself, and is therefore potentially difficult to access.

Batteries are crucial to the functioning of the network in both cases, but for different reasons. Theft is a major concern in some countries, but theft is not the only problem relating to batteries. We will deal with the most significant issues in this document.

We will focus on “grid-connected” and “diesel or hybrid” sites without solar. Solar powered sites will be dealt with in a separate document, as they relate more closely to those parameters.

Challenges

In order to understand what benefits Supercap storage offers, one should first understand the problems the network operators are facing.

Base stations house sophisticated electronic transmission equipment in unsophisticated housing with no supervision. These base stations stand in the sun most of the time, doors and windows locked due to risk of theft, tampering, and other reasons. Telecommunications companies have standardized transmission equipment operating on 48V DC.

In order to provide back-up in case of power cuts the network operators install battery back-up power. Every thinkable electricity storage medium has been tested in this environment. The reality is that this environment has such a vast set of challenges that none of the current offerings out there can fulfil all the needs. Users currently face the question of what they are willing to sacrifice.

Power cuts can be as brief as a few seconds or up to several weeks. Power outages can occur at high- or low-priority sites. High priority sites are typically business hubs or high network traffic sites. These base stations are installed across the planet in some of the harshest environments the world has to offer. Batteries in general don’t appreciate harsh environments, and any deviation from what we know as perfect conditions will negatively impact the batteries in some way. Diesel or hybrid sites are in a constant state of charge or discharge, and by combining harsh environments with a constantly working batteries, you create a battery’s worst nightmare.

The first part of this document will focus on the various factors influencing chemical batteries to place into perspective and explain why the network operators face the challenges they do.

Temperature Effect

Temperature is one of the major factors to consider when dealing with chemical batteries. Some manufacturers void warranties if the battery temperature exceeds 25°C. Other than warranty issues, chemical batteries have roughly a 50% reduction in cycles life for every 8°C over 25°C. The same applies to the standby life of most chemical batteries.

For this reason, battery temperature should be controlled very closely. To add to this problem, chemical batteries are not 100% efficient, as losses are converted to heat during the chemical process of charging and discharging. Thus the more inefficient the operating of a battery the more heat will be generated and the shorter the life. This is one of the contributing factors as to why lead batteries need at least 2.5-3.0 days autonomy. At faster charge rates like C5 or C1 up to 50% of the energy stored converts to heat loss.

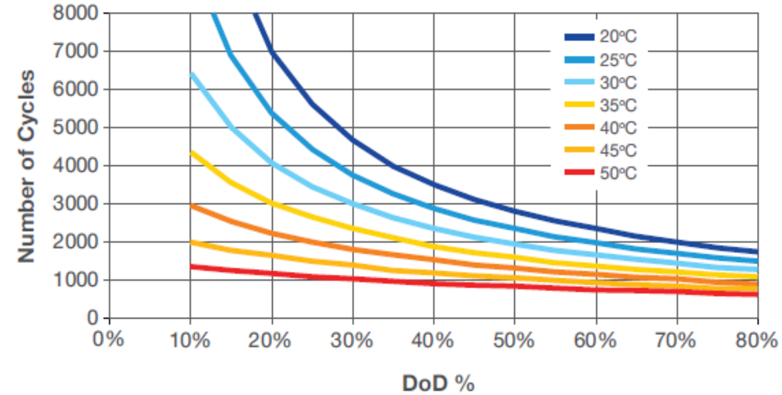


Figure 1.1 – DoD vs cycle life of OPzS lead acid at various temperatures

High temperature sodium batteries have a problem of a different nature. These batteries operate at temperatures in excess of 270°C. When these batteries run out of energy, they cool down and solidify. To rectify this problem, the battery needs too be heated with elements installed internally. This is by no means a maintenance free solution, and has proven to have drawbacks for network operators.

Unlike other technologies, Supercaps can efficiently operate at temperatures between -25°C up to 85°C with **NO DEGRADATION**. As such, no air conditioning is required and "free cooling" (exchange of air from inside the battery room with ambient air outside the room) is sufficient for Supercap storage. In most geographic areas, free cooling remaining electronics is acceptable. Supercaps are 99.1% efficient and do not heat internally--even at very high charge/discharge rates.

C- Rates

Keeping in mind that telecommunication operators have various types of sites--grid fed, generator, solar, and combinations of these--which for now will be referred to as hybrid. Charge rates consist of three factors working against each other, energy absorption or round trip efficiency, speed of charge and temperature of batteries. The main objective is efficiency, an umbrella term for “capital in” / “energy out”. Diesel generators operate more efficiently at higher output rates. The fuel-to-energy ratio is best around 75%-85% of rated capacity. Service hours obviously follow the rule of thumb “less is better”. It is ideal for a generator to charge the batteries quickly, but chemical batteries prefer a slow charge.

Pure grid-powered sites have a different reason for the need to recharge quickly. If power is lost, and the site uses battery power for an extended period of time, the quicker you can recharge the system, the longer you will be able to operate if the next power outage occurs before the battery is fully charged again.

For chemical batteries, a slower charging process is more efficient for the battery, and the more energy it will store. Faster charge and discharge means less efficiency, and therefore decreased cycle and standby life. The only way to get around this fact is to install a larger storage bank, thereby dispersing the load over more batteries. This method, however, increases the capex requirement. Thus, when comparing various chemical technologies the same problem simply looks a bit different for each. Lithium maintains higher efficiency at faster charge and discharge rates, but are three to four times the cost of lead acid technologies. As such, the same result could be achieved by installing three to four times more lead.

In contrast to this, Supercap used for telecommunications applications has the ability to charge in less than one hour without generating heat, at 99.1% efficiency and no degradation to life expectancy. This ability makes Supercap ideal for fuel saving and fast recovery, which is a priority for tele-communication operators. While Supercap is capable of operating at 112.5C (32 Second charge/discharge), this feature is not required in the telecommunications space.

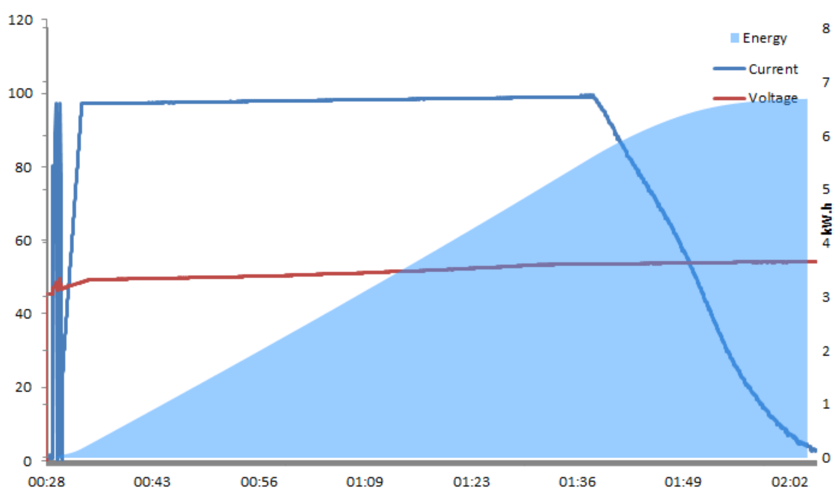


Figure 1.2 – C2 charge of a 7.1kW.h Sirius Supercap

Average DOD and Cycle Life

Chemical batteries cannot be fully discharged without immediate and permanent degradation. Depending on the construction of the battery, acceptable DoD varies between 40% and 80% for most batteries, and DoD plays an important role in cycle life. The type of battery used in a specific application will determine the expected service life of a battery bank and is used to calculate the R/kW.h cycle cost of a battery in an application.

Standby lead acid batteries (high rate discharge) should preferably not be discharged deeper than 40%. This results in a larger bank of storage relative to the usable power. At 40% DoD the battery should deliver around 1000 cycles.

Tubular Lead acid batteries like OPzV or OPzS do not have the energy density that standby batteries have, but can work much longer in application. These can typically be discharged down to 50% or 60%, but due to the power density these banks need to be adequately sized in order to maintain the load.

Lithium DoD should not exceed 70%-80% if the battery is to live longer than 10 years. Expected lifespan for Lithium batteries is approximately 3000-4000 cycles at 70%-80% DoD.

Supercap, on the other hand, can be discharged 100% multiple times per day with no degradation. It is therefore possible to size this battery to the exact power requirement of the application. At 1 Million cycles the capacitors will likely outlive the rest of the equipment.

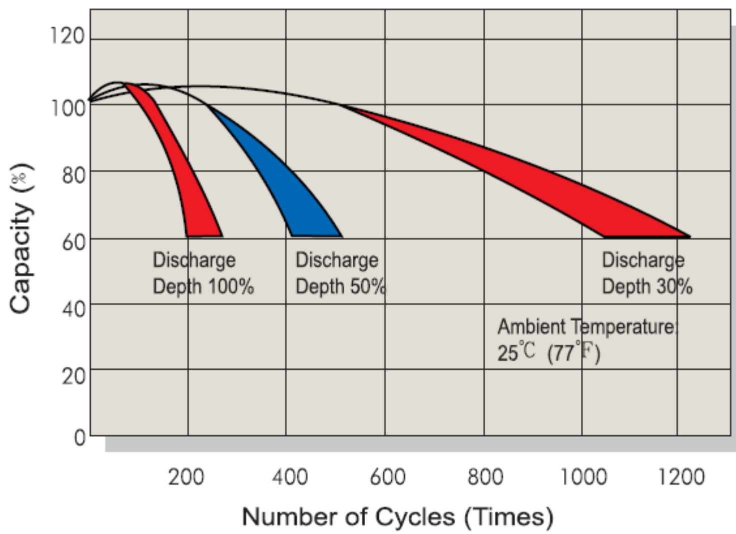


Figure 1.3 – 12V Lead Acid DoD vs Cycles at 25°C

Round Trip Efficiency

Chemical batteries experience inherent losses converting electrical energy to chemical and back. The conversion process efficiency is affected by speed as well as construction and chemical composition. As mentioned earlier, heat is a by-product of the chemical process of converting electricity to chemical storage and determines/impacts inefficiencies. The slower the charge process the less heat is generated, resulting in higher efficiencies. Another factor to consider, where applicable, is the absorption period. Lead batteries need to be maintained at “absorption voltage” for a fixed period, often 1-2hours during which the battery in this state does not absorb much energy at all, but rather stabilizes the cell voltages. If a generator is used for absorption, this is a very inefficient period as the generator runs at practically no load, but needs to run to maintain the voltage required for absorption. Not taking a lead acid battery through absorption will result in the battery operating at charge states lower than 85%, which will drastically impact expected life. Lead batteries should ideally be absorbed daily and equalized every 14-28days.

Standby lead acid batteries have a round trip efficiency of around 75% on pure energy in and out, not taking generator or other inefficiencies into account, if they operate at C-rates higher than 10 hours. Lithium has a round trip of around 90% if operating at C rates higher than 4 hours.

Supercap has a round trip efficiency of 99.1%, even at very low C-rates like 1 hour (with very little heat generation and almost no losses). Supercap does not need to go through absorption or equalization like other batteries. Not charging a Supercap battery to 100% will have no adverse effect on expected life.

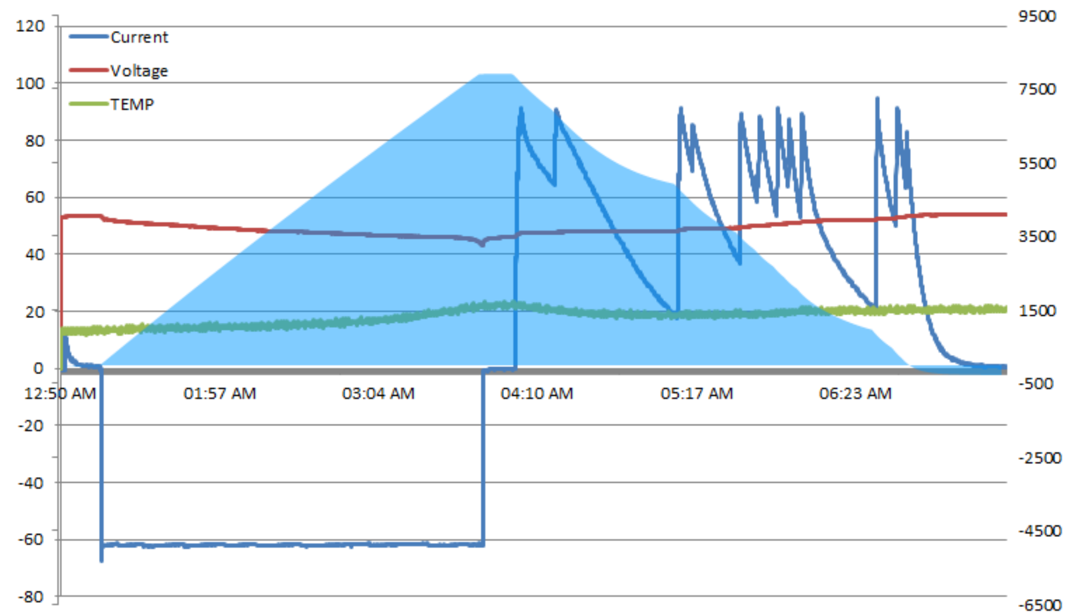


Figure 1.4 – Round trip efficiency of a Sirius Supercap

Application - Grid Backup

The majority of base towers have access to grid power. In this case, batteries rarely cycle, as they are installed purely in case of grid failure. There are, however, a different set of problems that come with batteries maintained for standby power.

The first issue to consider with standby application batteries is the usable power, or DoD. For standby lead acid we will use a 40% DoD. For Cyclic Lead we will use 60% of the battery in standby applications. Lithium we can use 75% as it is not cycling daily. Supercap can use 100%. The resulting quantities for each technology therefore differs by type.

The second consideration is ambient temperature. For lead acid and lithium the temperature needs to be controlled in order to get a reasonable operational life. This is done through installation of air conditioning. For the simulation we will not include the cost of installing air condition, as most of the retrofit base towers already have units installed, however the electricity usage will be included at 9kW.h/day.

The third consideration is expected life. The simulation calculates how long the batteries will last and amortizes this cost monthly. This is considered the most significant portion of OPEX.

The fourth consideration is theft. For this simulation a reasonable insurance premium is used, taking into consideration the fact that some countries having very few problems with theft while others serious problems with it. As such, insurance is included at 1% of the value of the battery bank. Supercap and lithium has little to no value as scrap and therefore will not include insurance premiums.

The fifth consideration is standing losses. Lead acid needs to be equalized every 14 to 28 days. Lithium has a BMS that takes some energy, and Supercap has losses as well. These losses are included in the simulation. Standing losses are very small, but play a role non-the-less.

Application – Grid Backup

Technology Name	Cost/kW.h	Temp derating % per 10°C	Cycles in Life @ 100% DOD	Safe C-rating	Round trip Efficiency @ Suggested C-Rating	Average Max DOD	Temp Requirements	Ave Temp Energy / Day kW.h	Standby Life	Grid Cost	Standing Loss/week	Insurance (Monthly)
Stanby Lead Acid	$ 150.00	40%	350	10	75%	40%	AC Required	9	10	R 1.86	5%	1.0%
Cyclic Lead (OPzV)	$ 250.00	40%	900	10	75%	60%	AC Required	9	15	R 1.86	5%	1.0%
Lithium	$ 450.00	35%	2800	3	90%	75%	AC Required	9	20	R 1.86	1%	0.0%
Supercap	$ 700.00	0%	1000000	1	99%	100%	Free Cooling	0	45	R 1.86	5%	0.0%

Table 1.1 – Battery Design Parameters for Grid Backup

- Costs are a rounded average of a few supplies and may vary from the values used in this document.
- Lead and Lithium requires cooling as life would be severely impacted by temperature (9kW.h/day is an average for an AC in high temperature areas and could be achieved with inverter based AC technology).
- Standing Loss includes equalization charge for lead. Lithium has a BMS that requires energy.
- Lead acid is the most prone to theft due the valuable elements and multiple applications and use.
- Supercap has theft protection and no scrap value, and so would have little to no use for thieves.
- 1 USD at 14 ZAR

Application	Standby	
Load	3.8	kW
Time Required	6	Hrs
Energy Required	22.8	kW.h
Power Cut / Week	1	/week
Duration of Power Outage	4	hrs
Energy Per Outage	15.2	kW.h/week

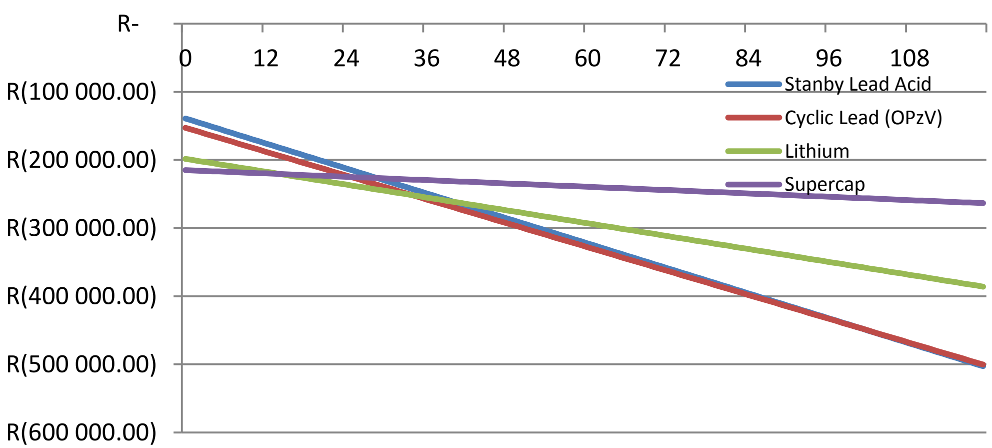
Table 1.1 – Application Parameters

Application – Grid Backup

On-Grid										
CAPEX						OPEX Monthly				
Technology	Required Storage KW.h	KW.h Cost	AC Cost			AC Cooling cost (monthly)	Replacement Cost (monthly)	Charge Losses	Standing Loss	Theft Insurance
Standby Lead Acid	57.0	R 123 975.00	R 15 000.00			R 735.48	R 1 033.13	R 28.27	R 21.20	R 1 239.75
Cyclic Lead (OPzV)	38.0	R 137 750.00	R 15 000.00			R 735.48	R 765.28	R 28.27	R 14.14	R 1 377.50
Lithium	30.4	R 198 360.00	R -			R 735.48	R 826.50	R 11.31	R 2.26	R -
Supercap	22.8	R 231 420.00	R -				R 428.56	R 1.02	R 8.48	R -

Table 1.3 – CAPEX and OPEX breakdown

- Costs are broken down into CAPEX and OPEX. This is projected over a 10 year period to see what the total cost of ownership would be for the various technologies. A cost that is not included is the physical installation when batteries need to be replaced due to theft or end of life. Insurance of 1% is included for lead acid, as it is prone to theft. 1% equates to one replacement every 8.3 years due to theft without taking inflation into account.
- Air conditioning maintenance and services are not taken into account



Graph 1.1 – Total cost of ownership comparison

Results

- Lead acid has a much lower Capex, but due to theft, replacement, and AC Cooling overall cost is higher.
- Lithium requires cooling, resulting in second highest operating cost.
- Supercap is the highest on the CAPEX, but has a very low OPEX due to long expected life (no additional costs involved).
- After 10 years, Supercap cost of ownership is 50% of Lead Acid and about 30% less than Lithium.

Application – Generator Hybrid Site

Hybrid sites are the worst possible environment for any battery, as the battery is constantly in a state of charge or discharge. Charging temperature as well as environment will play a role in chemical battery life. The sites usually have a diesel generator of approximately 30kW to 40kW installed to handle the load while charging the battery bank. During the discharge period, the battery will have to supply the power for its own air conditioning.

To keep generator service cost to a minimum, the generator should be loaded at rated capacity to minimize the running time. By sizing the battery bank correctly this could be achieved. Properly sized battery banks should result in similar service costs, as the generator should be operating at rated capacity. The smaller Supercap banks should operate more frequently but have shorter cycles in comparison to the larger lead acid banks. Service cost should be similar for all the batteries if they can keep the generators at rated capacity.

Lithium and Supercap banks are sized according to C-Rate as a portion of generator size. Supercap can charge at C1, so sized to 35.8kW.h. Lithium is sized to C3, so equates to a 107.4kW.h bank. Lead is sized for an average of one full DoD per day, so for standby that equites to a 304.0kW.h battery bank and cyclic lead it equates to 228.4kW.h/day. By reducing the size of the lead acid banks, the capex will reduce, however the generator will not be operating at maximum capacity and will be lower on the efficiency curve, resulting in higher fuel and maintenance cost. Further to this, by doing more than an average of one full DoD cycle per day will result in a higher replacement cost/month curve as the C-rate will change as well as the operating temperature.

Standby lead acid will only be used at a DoD of 30% per cycle, and at C10 will recharge in 3 hours plus 1 hour absorption. Cyclic Lead will be used at a DoD of 40% and will therefore need 4 hours plus 1 hour for absorption to recharge.

Fuel cost is similar, with the only variables the round trip efficiency and air conditioning for chemical batteries. Again, it is important to be able to load the generator to rated capacity with all the technologies, otherwise the fuel bill will increase, as it will operate on a lower efficiency.

Application – Generator Hybrid Site

- Costs are rounded averages and may vary from the values used in this document in practice.
- Lead and Lithium require cooling as life would be severely impacted by temperature (9kW.h/day is conservative and could only be achieved with inverter based AC technology).
- Lead acid is the most prone to theft due the valuable elements and multiple applications and use.
- Supercap has theft protection and no scrap value, so it would have little to no value for thieves.
- Sizing of storage. There are two factors to consider. Firstly the generator efficiency and secondly daily cycles or daily DoD.
- Standby lead
  - First Consideration - Size for Average Max DoD per day (91.2kW.h / 30% = 304.0kW.h)
  - Second Consideration – Size for generator optimal load (3hrs to replace 30% Usage (C10), plus 1 hr Absorption = 22.8kW.h)
- Cyclic Lead
  - First Consideration - Size for Average Max DoD per day (91.2kW.h / 40% = 228.0kW.h)
  - Second Consideration – Size for generator optimal load (3hrs to replace 30% Usage (C10), plus 1 hr Absorption = 22.8kW.h)
- Lithium
  - First Consideration – Size for generator optimal load. Battery max charge is C3. (Gen optimal Load * 3) = 107.4kW.h Storage
  - Second Consideration – Usage is 75%. Leaving 80.55k.Wh usable / Cycle
- Supercap
  - First Consideration – Size for generator optimal load. Battery max charge is C1. (Gen optimal Load * 1) = 35.8kW.h Storage

Application	Load Requirements		Generator Usage			
Load	3.8	kW	No Load Fuel use		0.8	L/Hr
Time Required	24	Hrs	Fuel Cost	R	13.50	R/Litre
Load Energy Required	91.2	kW.h	Best Fuel Conversiont		3.5	kW.h/litre
Generator Load capabilty	35.8	KW	Fuel R/KW.h	R	3.86	R/kW.h
Service Cost	1500	R/Month				

Table 2.1 – Application Parameters

Application – Generator Hybrid Site

Generator Service Costs										
Technology	Storage	Usage / Cycle	Discharge Time (HRS)	Charge Time (HRS)	Cycle Time	Cycles per month	Gen Running Hrs/Month	Maintenance Cycle @ 500Hrs	Cost/ Month @ R1500/Service	Gen Load
Standby Lead Acid	304.0	91.2	24.0	4	28.0	26.1	104.3	4.8	R 312.86	22.8
Cyclic Lead (OPzV)	228.0	91.2	24.0	5	29.0	25.2	125.9	4.0	R 377.59	18.24
Lithium	107.4	80.55	21.2	3	24.2	30.2	90.5	5.5	R 271.52	26.85
Supercap	35.8	35.8	9.4	1	10.4	70.1	70.1	7.1	R 210.15	35.8

Table 2.2 – Calculating monthly generator service fees

Fuel Costs					
Technology	Operating Efficiency	Energy / Cycle	AC Energy	Energy / Month	Fuel Cost / Month
Standby Lead Acid	75%	136.8	9	3840.3	R 14 896.10
Cyclic Lead (OPzV)	75%	140.6	9	3813.0	R 14 807.94
Lithium	90%	100.9	9	3317.8	R 12 869.47
Supercap	99%	39.9	0	2796.8	R 10 843.60

Table 2.3 – Calculating monthly fuel costs

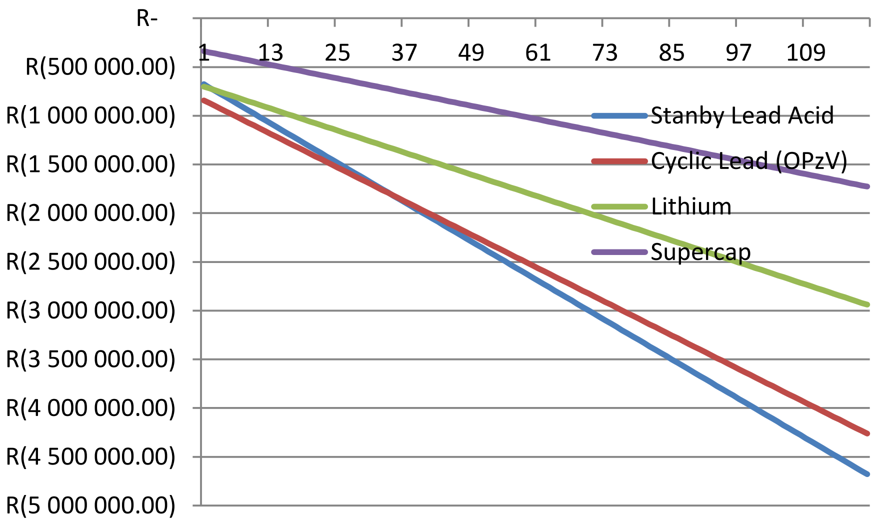
Replacement Costs & Service life						
Technology	% Cycle / Day	Cycles in life	Days to 1 Cycle	Total Days	Years	Monthly Replacement Cost
Standby Lead Acid	25.7%	350	3.89	1361.11	3.73	R 15 117.79
Cyclic Lead (OPzV)	33.1%	900	3.02	2718.75	7.45	R 9 417.03
Lithium	74.4%	2800	1.34	3764.04	10.31	R 5 663.82
Supercap	230.3%	1000000	0.43	434210.53	1189.62	R 23.64

Table 2.4 – Calculating service life and replacement costs monthly

Application – Hybrid Sites

On-Grid							
CAPEX				OPEX Monthly			
Technology	Required Storage KW.h	KW.h Cost	AC Cost	Generator Service Cost	Fuel Cost	Replacement Cost	Theft Insurance
Stanby Lead Acid	304.0	R 661 200.00	R 15 000.00	R 312.86	R 14 896.10	R 15 117.79	R 3 306.00
Cyclic Lead (OPzV)	228.0	R 826 500.00	R 15 000.00	R 377.59	R 14 807.94	R 9 417.03	R 4 132.50
Lithium	107.4	R 700 785.00	R -	R 271.52	R 12 869.47	R 5 663.82	R -
Supercap	35.8	R 363 370.00	R -	R 210.15	R 10 843.60	R 672.97	R -

Table 2.5 – CAPEX and OPEX breakdown



Graph 2.1 – Total cost of ownership comparison

Results

- On capex Supercap ranges between 30% and 50% of the cost of the other technologies, purely because it can handle multiple cycles per day.
- Genset running hours are similar (Supercap 70% of lead and 80% of lithium) due to the sizing of the other banks. Storage is sized for maximum generator efficiency, resulting in similar monthly maintenance costs.
- Fuel cost differs mainly due to difference in efficiency and air-conditioning.
- Monthly replacement cost is very high for chemical batteries due to cycle cost, and this application is cycle biased.
- Total cost of ownership over 10 years for Supercap is R1.7Mil, compared to Standby lead at R4.7Mil, Cyclic Lead at R4.3Mil and Lithium at R2.9Mil.

Summary

In order to satisfy the requirements of the telecommunications industry, in practical terms “ideal storage” is required. The Sirius Supercap battery comes as close to ideal storage as with any technology. Chemical batteries have many shortcomings and although Capex is slightly less than Supercap, OPEX soon catches up. With chemical batteries a choice must be made as to which shortcomings the user is prepared to deal with and how to work around them.

The main advantages of Supecap are:

- The Sirius Supercapacitor Storage developed for the telecommunications market achieves 1.35C, resulting in a charge and discharge time of 45 minutes.
- The round trip efficiency is 99.1% if one were to discard the cable losses connecting the battery.
- Operating temperature range is -25°C up to 85°C with no damage to the unit.
- Expected lifespan 1 Million cycles.
- No degradation expected during lifespan.
- Expected operational life of 45 years.
- 10-year warranty.
- No change in capacity at different charge rates.
- Safeties that protect the battery from overvoltage, under-voltage and short circuit.
- Built in theft protection renders the Supercap useless when removed from site.
- Built in monitoring that connects via the internet.

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