Various Approaches to Powering Telecom Sites

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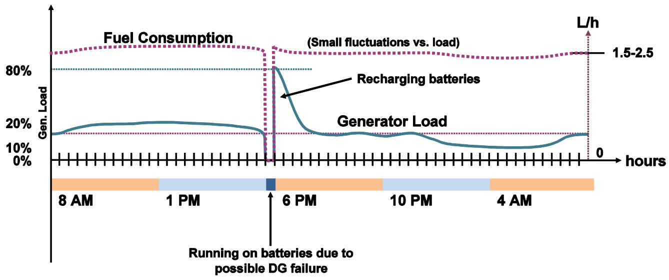
Abstract - **Optimizing DC Hybrid power systems for Telecom BTS off grid sites and sites with poor utility service. Focus in lowering both CAPEX and OPEX costs and countering rising energy costs while incorporating Green Solutions. Discussions of new approaches in systems integration with DC Generators, Solar Photovoltaic, DC Air Conditioning, Lithium Ion and Lead Acid Batteries.**

Keywords-Cycling AC Generator; BTS Site; DC Generator; Green Energy , Lithium Ion Battery, Telecommunications; Hydrogen Fuel Cell; Solar Hybrid Power Systems, DC Air Conditioning, Fuel Efficiency, Off-Grid, Photovoltaic, Radio Repeater Site

I. Introduction

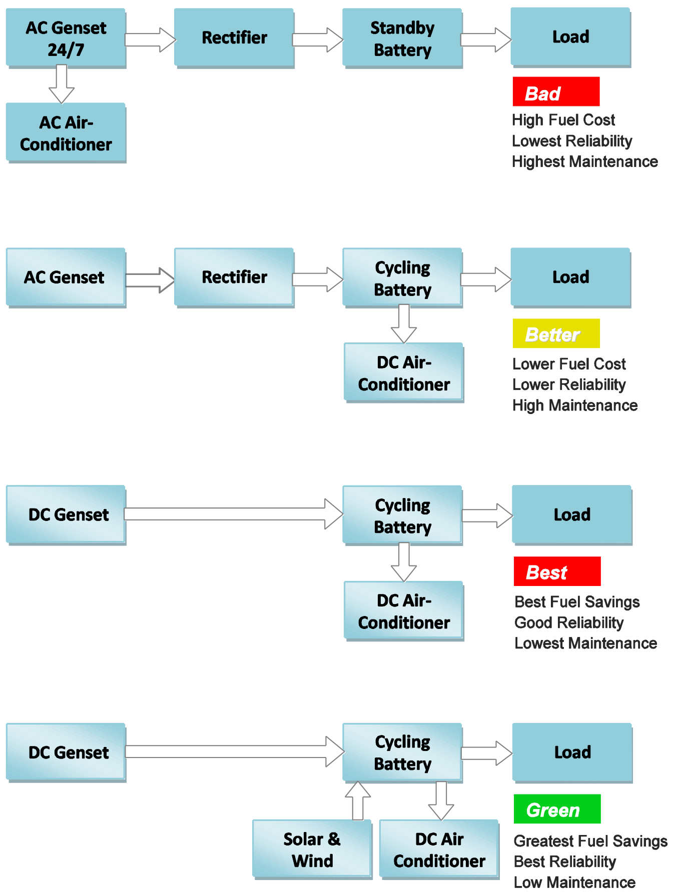
Competition between telecommunications companies and the goal of making telephone and broadband services available to lower income groups is driving the need to reduce OPEX cost. Reducing energy costs presents the largest opportunity in reducing the cost to deliver service to customers!



Running an ***AC generator*** 24 hours a day and seven days a week is the traditional but least efficient method of powering an off grid site in rural and remote areas. The two principal problems of a constant run AC generator are the larger displacement engine powering small loads and the troublesome engine maintenance.

Typically 20 to 40 kVA AC generators are used at sites where a 3 kW to 15 kW ***DC generator*** performs well. Larger AC generators are used because they have proven to last longer than smaller AC generators. Additional factors:

- AC generators less than 10 kVA are aimed at either temporary construction work or standby use. These applications require low cost and do not need long operational life. The 7 to 10 kVA AC generators typically last 1 year before requiring replacement.
- Many sites pay a heavy fuel penalty and use the 20 to 40 kVA for longer life and better reliability.
- Electronic governors are required to regulate the 50 / 60 Hz frequency to meet telecom industry standards; electronic governors are typically supplied with generators larger than 10 kVA.
- You cannot operate an AC generator close to its rated capacity and maintain frequency and voltage regulation required by the cell site equipment installed.
- Air-conditioning starting current requirements
- Providing the power capacity to recharge the batteries and power the load after a disruption in power



II. Cycling for both Off-Grid and On-Grid Applications with Poor Utility Service

Field trials have shown significant fuel savings over 40% when using a cycling AC generator as opposed to the AC generator operating 24/7. Using a DC PM (permanent magnet) generator further increases the fuels to savings to over 60%.

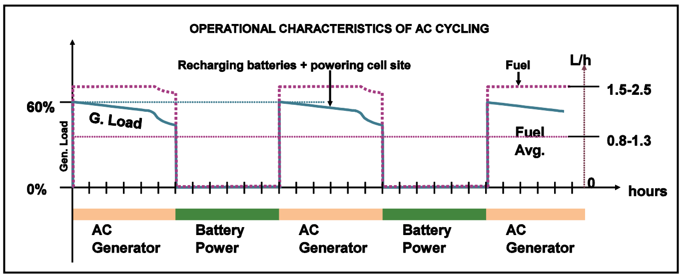
Reliability is enhanced and maintenance is reduced using the cycling solution.

A. AC Cycling

Generators can be used with rectifiers / battery chargers and operated in a cycle charging fashion; this offers a fuel saving advantage over operating an AC generator 24 / 7.

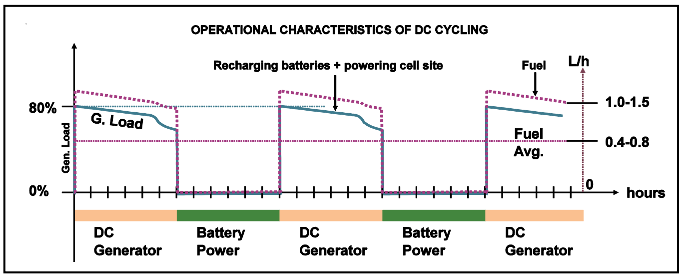
The disadvantages of the ***AC generator*** cycling are:

- There is a power loss of 8% to 15% through the battery charger/rectifier, the generator is required to produce more power, consuming more fuel.
- The AC generator is less efficient than the DC PM generator in converting engine's mechanical power into electricity. The DC generator is about 20% more fuel efficient than the AC generator.
- The AC generator has to be oversized because its power output cannot be regulated; an over current condition trips a circuit breaker and this typically requires a manual reset. Larger generators with larger engine displacements consume more fuel.
- The AC generator is fixed speed; fuel consumption diminishes only slightly with decreasing loads as shown in the graph.
- CAPEX costs are higher with the AC cycling in off grid systems. The system requires an AC generator, transfer switch, battery charger/rectifier, and system controller.
- OPEX costs are higher with the AC cycling as the system consumes more fuel and maintenance.



B. DC Cycling

DC Cycling is 25% to 40% more fuel efficient than AC cycling. As shown by the graph below, the concept behind DC cycling is to allow the generator to operate at its peak efficiency and to shut off during low load demand and let the batteries power the load. This saves fuel and engine maintenance. Also shown in the graph is the DC generator's additional fuel reduction due to the variable speed feature of the DC generator. As the load decreases so does the engine speed, allowing the engine to continuously operate at near its peak efficiency.



The power output of a Polar DC generator is regulated so we can operate closer to the ideal engine power curve. This saves fuel because we can make use of smaller engines displacements. In the chart we show the DC generator operating at 80% of its rated power.

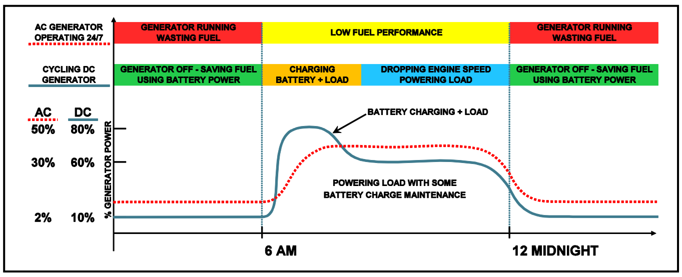
III. Sizing

Sizing an ***AC generator*** requires that its capacity is greater than the sum of all the loads that may operate at the same time. This would include the surges for air-conditioning startup. An AC generator cannot regulate its power output and requires a circuit breaker to prevent alternator and engine overloading. To keep the circuit breaker from tripping the AC generator is oversized in capacity in relation to the sum of all loads.

Typically the sizing of the ***DC generator*** into an application is based on the amount of energy required in a 24 hour period plus charging losses in the battery divided by the desired generator runtime within the same period.

IV. AC vs. DC Generator

Field trials have shown 70% and greater fuel reduction over the conventional AC generators operating 24/7.



Polar Power's ***DC generator*** makes use of smaller displacement engines operating near their most fuel-efficient points. You can efficiently operate the Polar Power DC generator at 100% of its power rating. In comparison, the AC generator in the typical installation is operating a larger engine at less than 50% of its power rating. In the graph above the dotted red line representing the AC generator is consuming more fuel than the blue line for the DC generator.

The ***AC generator*** running while the load is at a minimum power level represents a significant waste of fuel. Using the ***DC***

cycling approach, the DC generator is off and the load is powered by the battery.

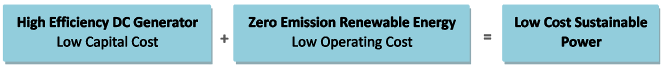
V. DC PM GENERATORS OFFER A LOWER OPEX COST THAN AC GENERATORS:

- The Permanent Magnet DC alternator (synchronous) is more efficient than the asynchronous AC alternator in the conversion of mechanical energy to electrical
- The AC generator has lower efficiency converting from AC to DC through the rectifier / battery charger
- The DC generator is variable speed and operates near the engine's most fuel efficient point
- The DC generator is engineered to provided a significantly longer operational life.
- Polar's Supra controller allows the system to be tuned remotely for higher efficiencies without the cost of traveling to the site.
- Oversized fuel and oil filters reduce the periodic maintenance cost.
- Polar uses novel filtering modules to substantially reduce oil, fuel, and air filter maintenance intervals and replacement costs.

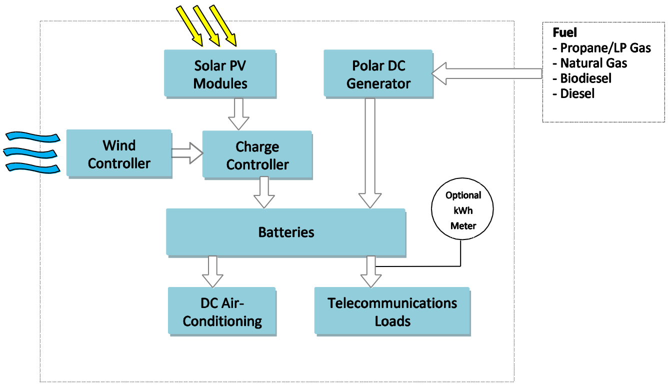
VI. DC PM GENERATOR SYSTEMS ARE MORE RELIABLE THAN THE AC SYSTEMS:

- The DC generator eliminates any compatibility problems that may arise between the AC generator and the rectifier / battery charger (ripple currents confusing the AC generator's voltage regulator).
- Polar's DC alternator has no bearings, slip rings, brushes, exciters, or attached diodes
- Polar offers DC generator models that eliminate all V-Belts from the engine by removing the: charging alternator, coolant and mechanical fuel pumps. These functions are replaced with DC to DC charging and electric hermetic pumps.
- No transfer switches are required for the DC generator.
- Polar's Supra controls have a high level electrical isolation, up to 1500 Volts.
- An over current condition in an AC generator causes the circuit breaker to trip. Power is lost and a field visit is required.
- Polar's DC generator is current regulated so in an over current condition power output is kept constant and not interrupted.

VII. DC HYBRID POWER SOLUTION - COMBINING RENEWABLE ENERGY AND FUEL



The ***Hybrid*** solution consists of a DC generator which charges the battery and powers the load at the same time. The DC generator is designed to shut down after the battery is charged and the load demand is low. The battery provides power to the load while the generator is shut down. This is an energy efficient alternative to an AC generator operating 24/7. The hybrid power solution allows the convenient integration of solar and wind for further fuel reduction and lower generator maintenance. Solar and wind can be added at any time and incrementally.



For most Telecom applications the use of 100% solar and wind power is not practical. This is due to high CAPEX cost, lower reliability, higher maintenance, and significantly more space required for installation. The larger battery bank and solar array drives CAPEX cost high. The large battery bank drives down the system reliability. The weather creates unknown periods of energy generation from the solar and wind. Without the incorporation of a DC generator there will be long periods where the batteries remain in the low state of charge and this shortens the life of the battery, diminishes system reliability, and increases the OPEX cost.

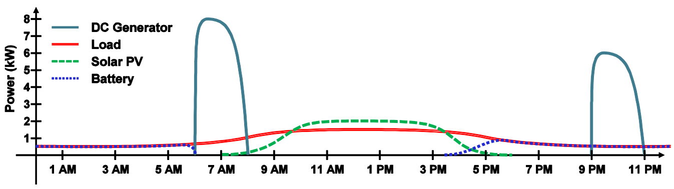
A. 80/20 Rule

Producing 80% of the sites energy requirement using fuel and 20% using renewable energy is an optimal configuration. For typical lead acid battery technology, the last 20% charge requires low power over a long period of time. Powering the load and providing the finishing charge is an ideal application for the solar array. This allows the DC generator to work at its peak efficiency providing the bulk charge into the battery and powering the load at the same time.

B. The 20/80 Rule

If there is sufficient CAPEX budget and installation area at the site, using 80% renewable energy and 20% fuel is also an optimal configuration. In most regions of the world, trying to derive 100% of the site energy from renewable energy during the winter months or monsoon season can require the solar array and the battery bank to increase in size by a factor of two or three times. Allowing the DC generator to provide most of the energy during poor weather conditions greatly reduces the CAPEX cost and provides system backup in case of solar, solar controller, or battery failure.

C. Because of variable weather conditions the CAPEX and OPEX costs favor the use of the DC generator.



6 AM-8 AM DC Generator

7AM-6PM Solar PV

4 PM-9 PM DC Battery

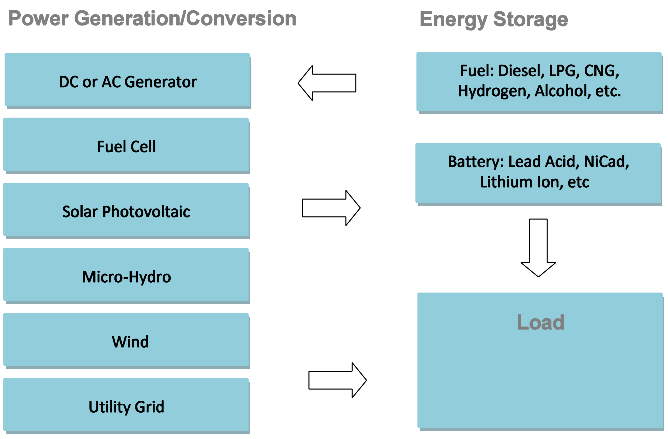
9 PM-11 PM DC Generator

11 PM-6 AM DC Battery

The ***80/20*** fuel to solar configuration is represented in this graph. The graph shows the solar powering the load and providing the battery's finishing charge during a 5 (peak) hour period, typical of summertime. To increase the input of solar energy into the system, the solar array and the battery bank would have to increase in size

The graph above shows the battery providing 2 discharge cycles per 24 hours and receiving one finishing charge and one bulk charge. A lead acid battery bank would be sized for a depth of discharge not to exceed 20%; the lower depth of discharge provides a greater number of charge cycles and this helps offset the penalty of 2 daily cycles.

A wind generator can be added to the ***solar hybrid*** system to reduce fuel consumption and battery cycling. We recommend using a small wind generator to determine the available wind energy on-site to produce usable power. The other choice is to install wind energy measuring equipment on-site, but the cost of instrumentation and a small wind generator are similar. After 1 or 2 years a determination can be made to remove the wind generator, increase its size, or leave it alone. It should be noted that many programs complain about the reliability of wind generators, careful selection is required.



VIII. If You Want to Improve Reliability Add a DC Generator Rather Than Increase the Battery Bank.

When optimizing a power system for efficiency and reliability too many engineers fail to create a balance between Power Generation and Energy Storage. Too frequently the battery, which is a storage device, gets placed in the role of a power generation device; compromising the efficiency and reliability of the system.

In UPS systems (i.e. for computers), increasing the battery bank size is a solution to provide reliable power for longer utility power outages. Increasing the battery bank size also compensates for problems of bad cells within the battery bank.

Historically in ***Telecommunications power systems***, batteries are used to back up the grid and follow the same example in UPS systems. Battery banks are increased in capacity for power outages of longer duration and to compensate for problems within the battery bank itself, or to allow sufficient time for service personnel to arrive at site with a mobile generator.

In Solar Photovoltaic Systems the battery stores the surplus energy produced by the solar and the stored energy powers the load at night and during poor weather conditions. Battery banks are increased in size to match the worst-case weather conditions, and to compensate for problems within the battery bank itself. The typical design principle on ***solar systems*** is to size the battery bank for 3 to 5 days of autonomy.

Increasing battery bank sizes to provide the sole means of energy storage is very expensive and decreases system reliability. Design engineers are now using Diesel, LPG, or CNG to reduce the need for larger battery banks. Fuel is also an energy storage medium and together with a smaller battery bank will create a more efficient, reliable, and cost-effective system.

Adding a DC Generator to either the UPS or ***BTS site*** improves system efficiency and reliability while reducing both the capital cost and operating costs of the system. The DC generator allows a system integrator the ability to reduce the area of the site, maintenance, and cost.

IX. The DC Generator/Battery Bank System

The battery bank and DC generator are used in combination to complement the performance of each other. The battery bank is used to improve the performance of the DC generator in applications where the loads vary in power demand. At low loads, where the DC generator would operate outside its peak efficiency, the battery bank saves fuel by allowing the DC generator to cycle off. The DC generator reduces the depth of battery discharge and eliminates long periods of the of low state of charge.

Polar has worked with Lithium Ion batteries over the past 3 years in various applications not pertaining to telecomm. Just recently we started incorporating Lithium Ion into our telecom installations with very good results. The Lithium Ion batteries have the following advantages over lead acid (flooded, AGM / Starved Electrolyte, Gel, etc.) in cycling applications**:**

- 3 times more discharge cycles for service longer life.
- Deeper discharge capacity (i.e 70% vs 20%) than lead acid. The deeper discharge put the cost of the Lithium Ion competitive with the Lead acid.
- Can tolerate higher and lower ambient temperatures than sealed lead batteries. Eliminates air-conditioning.
- The Lithium Ion battery can be charged at higher power levels and has a significantly higher charging efficiency; this reduces generator runtime and fuel consumption.
- The Battery Management System incorporated into a Lithium Ion pack monitors each cell and can provide remote monitoring of the battery bank's state of health.
- The Lithium Ion chemistry produces a higher voltage per cell than lead acid; only 15 cells series are required to make up a 48 Volt battery as opposed to 24 for lead acid. Fewer cells in series increase reliability.

X. Application Example

In ***solar hybrid*** systems the battery bank is used to absorb the excess energy from the photovoltaic arrays and wind generators. For example, if the load is 1.5 kW and the solar array produces 5 kW, the battery would absorb 3.5 kW averaged over the peak sun period (5 hours x 3.5 kW=17.5 kWH). The battery would start to deliver the stored 17.5 kWH late in the afternoon when the sun's energy declines and the array output drops below 1.5 kW. This would be one cycle using solar energy. The next cycle is generator powering the load and charging the battery at the same time. The sizing of a battery bank is optimized by combining the following requirements:

- Being able to absorb all of the excess energy from the solar array, wind turbines.
- Having sufficient storage capacity to power the system at low loads; thereby, supporting the off cycle of the ***DC generator***. Start your optimization with an 8 to 12 hour run time on the battery alone.
- Optimizing the battery service life by minimizing the number of charge/discharge cycles. Increasing the storage capacity reduces the number of charge/discharge cycles thereby increasing the battery service life; but at the same time more battery increases the cost of the battery bank. For off grid applications start with 20% discharge for lead acid batteries with 1 or 2 cycles per day. For lithium-ion batteries start with 70% discharge with 2 or 3 cycles per day.

Increasing the size of the battery bank does not help to increase reliability as the battery is only a storage device not a power producing device. The solution for increased reliability is at the power producing / energy conversion sources and not the storage medium. Increasing reliability means improving the availability of power; therefore, to improve site reliability means adding a second ***DC generator*** and adding more ***solar*** (if space is available).

Improving storage reliability requires the proper selection of battery chemistry and construction. Many applications have been using batteries optimized for standby applications and not ***cycling*** applications. Most battery manufacturers have exaggerated the performance of their batteries performance making proper battery selection difficult.

Having an oversized battery bank on site simply means that you buy more time for the technician to arrive on site. But having more batteries on site decreases reliability and increases maintenance. In rural areas it may take a week to get the technician on site. Increasing the battery bank size may only create the situation that once the technician arrives on site he/she may be simply faced with servicing a larger dead battery! This places the technician in the challenging role of having to transport a portable generator with him/her to the site or making sure there are sufficient resources to repair the power source (Generator or Solar). Solution is to invest the money and space into redundant power generation sources (DC generator and Solar) as opposed to increasing the battery bank size.

XI. Traditional and New Ideas behind Sizing the Battery Bank Capacity

Old: Solar and Wind systems, without a DC generator have a design preference for 3 to 5 days of no sun autonomy.

New: With the addition of the ***DC generator*** the need for 3 to 5 day autonomy is eliminated. Battery sizing with a DC generator is focused on optimizing cycle life and OPEX costs, not autonomy.

Old: Telecom sites that are powered by a reliable utility grid use a battery backup sized to power the load during average power outages. The more critical sites will incorporate larger battery banks for worst-case power outages. Here the battery banks are relatively small and there is limited need for backup generator due to grid reliability.

New: As the cell sites grow in power requirement, battery banks become larger in capacity and cost. These battery banks are being replaced routinely ever 2 year intervals at great cost. Polar DC generators can last 20 to 35 years and reduce the battery bank size to between 15 minutes to 3 hours.

Old: Telecom sites that are powered by a less reliable utility grid that experiences longer and more frequent outages will incorporate a backup generator with the battery bank. The purpose of the battery bank is to power the load while the generator is starting or to continue powering the load should the generator fail to start. Battery banks are frequently sized with sufficient storage capacity to allow a service technician time to arrive on site to service the generator. 2 to 4 days of autonomy is commonly chosen and this presents high CAPEX and OPEX costs.

New: The solution is to increase the reliability of the backup generator not the size of the battery bank. Using a Polar DC generator with a super capacitor for starting the generator is the best solution.

Old: Telecom sites that are off grid and use an AC generator operating 24/7 use a battery bank that is sized with sufficient capacity to keep the site on line in the event one or more of the AC generators fail allowing time for the technician to affect repair.

New: The solution is to increase the reliability of the backup generator and not the size of the battery bank. Increasing the reliability requires that generator incorporate superior means of: starting, remote control and monitoring, fuel system, cooling, and durable engines. This is more cost-effective and reliable than increasing the battery banks size.

Old: Design persons using DC generators on cycling applications with will attempt reduce generator run time to a few hours each week by installing a very large kW generator with a very large battery banks. The goal is to improve the operational reliability of the generator by reducing its run time. These configurations may also incorporate solar and wind to reduce fuel consumption.

New: Increasing the size of the battery bank increases cost and lowers reliability. It's more cost-effective to install multiple generators of higher reliability as opposed to one single larger generator. Also selection of generators with long endurance engines is a better choice than larger battery banks to decrease generator run time.

XII. Continuous Run with DC Generator versus Cycling with Battery

A. Continuous

If the load operates 24/7 at the same power level with only minimal fluctuations, a Polar DC generator can be tuned to meet this specific power requirement. For example if the load is 1500 watts we can supply a DC generator optimized to deliver 1500 watts by winding the alternator stator to match the ideal engine RPM range. This type of configuration would limit the requirement for the battery bank and the system would not see the charging and discharging losses. Running 24 hours a day the DC generator will require a new or rebuilt engine every 2 years for diesel and 3 1/2 to 4 1/2 years for LPG (note that the alternator and controls are reused).

B. Cycling

For the same application powering constant 1500 watt load we would select an 8 kW DC generator and operate it approximately 5 hours a day. In this scenario a new or rebuilt engine for the generator would be required every 7 years for diesel and in 16 years for LPG. But there is a sacrifice of fuel efficiency and the cost of the battery bank is increased.

C. Discussion

- In this example with the 1500 watt load the decision between continuous and cycling comes down to the logistics and OPEX of engine maintenance versus CAPEX and OPEX of the battery bank.
- The battery's performance (CAPEX, OPEX, and reliability) is constantly changing with new technologies continually entering the market.
- For load of small wattage, cycling with the battery becomes the preferred choice.
- For most applications the load is not constant and varies throughout the day; varying loads favor the cycling technology.
- On loads less than 2,000 watt hours a day it may be reasonable to size the battery bank to allow the generator to come on 3 or 4 times each week. But on larger energy demands to oversize the battery bank to reduce generator run time if not efficient or cost-effective. It's more cost-effective to put multiple generators on-site to reduce individual generator run time as opposed to placing larger battery banks.

D. Difficulties in Implementation of Improved Power Systems

There is confusion over the role of batteries within power system that operate off grid or are serviced with intermittent utility power. Battery stores energy that is supplied by other sources including: utility power, solar, wind, and generators. Batteries provide transitional or a load leveling source of power. Batteries are limited in the amount of energy in which they can cost-effectively store. Increasing the battery banks size does not increase the reliability of backing up the utility grid or generator. To back up the generator use a second generator. To backup the utility you add a generator. To increase the site's autonomy you increase the amount of fuel or solar on site.

If a larger battery bank is used to allow time for the technician to effect repair the site may still go down if the technician is unable to repair on the first visit. The solution is to have the technician travel with the spare generator or it is more cost-effective to reduce the battery bank size and use those funds to install a second generator on site. Now the site's reliability is not dependent on the arrival time of the technician or any additional cost incurred to expedite the technician's arrival on site.

Most engineers cite the problem of generators failing to start or come on line as the reason to trust in large battery banks. It is more cost effective with increased reliability to fix the failure points for starting and coming on line than increasing battery bank size. Consider that using fuel as energy storage is lower in cost and more reliable than using a battery bank. Polar has been successful in increasing generator reliability by:

- Eliminating the starting battery and using a Super Capacitor. A Super Capacitor can provide up to 500,000 starting cycles
- Eliminating the starting battery and using a Super Capacitor. A Super Capacitor can provide up to 500,000 starting cycles
- Remote monitoring facilities maintenance. Good maintenance is the most important issue with starting and operational reliability.

The space available at most sites is very limited, many program managers feel there is no room for more than one ***AC generator*** and the battery bank presents itself as a more compact "solution". This is not true for the Polar ***DC generator***; our DC generators are significantly smaller in size than the AC generator or the additional batteries.

Telecom companies competitively bid the generator requirement and seek the lowest bidder and then spend a far greater amount of capital on the battery bank. If they spent more capital on a reliable generator they would be able to save significantly on the CAPEX and OPEX costs by purchasing smaller battery banks.

If there is enough schedule time for the Telecoms to purchase a DC generator sets frequently they go out for bid and purchase lower-cost DC generators that fail meet their requirements. Not all DC generators are created equal.

XIII. Not all DC generators and controls are created equal.

There are two classes of DC generators on the market, backup power and prime power.

A. Backup power Generators

Backup power generators use light duty engines with common AC alternators rewound for lower voltages. The alternators typically do not use permanent magnets and instead use a wound rotating rotor with brushes and slip rings or an exciter. On the output of these generators is a large transformer / choke with huge electrolytic capacitors required to filter the power output to meet the low ripple requirements of Telco power. These sets are built as cheaply as possible to compete with the lower cost AC generators. Engines are from the “lawn and garden” applications which are typically air cooled and have very small lubricating oil reservoirs. These light duty air cooled engines have a design life of between 500 to 1,000 hours of run time. Most all small air cooled gas and diesel engines require between 8 to 30 hour oil maintenance intervals; this is attributed to the high oil temperatures of 160° C plus and under 1.6 liter oil capacity. There is water / fluid cooled “lawn and garden” type engines for the larger generator sizes and these engines improve upon the oil maintenance period, but durability is compromised due to the low cost light duty bearings supporting the crankshaft and pistons. The fluid cooled engines have a design life of 2,000 to 4,000 hours. What compromises the life of the small fluid cooled diesels is that the engines are run fast at speeds of around 3,600 RPM to save alternator and engine costs.

Solar Hybrid systems engineers refer to the generator in their system as backup, they assume that either all generators are similar in performance or the generator will run less than a few hundred hours each year. We see project managers complaining about having to replace a light duty DC or AC generator 1 to 3 times a year. The high maintenance requirements of the light duty generators cannot be met reliability so the system fails often.

B. Prime power Generators

Prime power DC generators will incorporate permanent magnet alternators for increased efficiency and simplicity. DC alternators will incorporate 12 to 32 pole configurations with 3 to 6 phases. This eliminates the requirement for chokes and huge filter capacitors and provides for better efficiencies. Prime power generators use heavy duty, fluid cooled engines, with oil capacities of 2 to 17 liters with very heavy duty bearings. These generators operated at slower engine speeds of 1,500 to 2,600 RPM. Engine operation life will range from 16,000 to 35,000 run time hours.

Electronics for backup generators tend to have limited communications and remote control features. Standard alarms are typically limited to: generator run, warning, and fail. To save production costs electronics are typically open to the environment, terminal strips are used in place of sealed connectors, and lower quality wire for connections.

Polar builds its controls to automotive and military standards. We avoid terminal strips whenever possible, use gold plated sealed connectors, sealed electronics assemblies, plated copper wire with higher temperature and more chemical resistant insulation. Circuit isolation and lightning surge resistance are incorporated to our control design. To reduce the costs of site visits our DC generators can be monitored, controlled, and calibrated remotely.

Give the loss of revenues due to a site being offline and the cost to get a qualified service technician on site, cutting cost on a generator does not make sense.

XIV. Hydrogen Fuel Cells

Hydrogen Fuel cells are a promising future technology in an application to backup the utility grid at sites where disruption of power is very rare. The concept is not to install a backup battery and generator on site and instead use a fuel cell to convert the compressed hydrogen gas into electricity. The fuel cell combines oxygen from the ambient air with the hydrogen fuel and produce electricity and water; a very clean process. For all but the smallest power loads (i.e. 100 watt) the cost of the fuel cell is too expensive to be competitive with batteries and DC generator. If the goal is clean energy the DC generator can be tuned to run on hydrogen as a fuel at a lower cost than using a fuel cell.

For sites that are off grid or serviced with utility power with frequent interruptions, hydrogen fuel is too expensive of a fuel. A convenient distribution of Hydrogen as a competitive fuel source is decades away into the future. Compressed natural gas and LPG are significantly lower in cost and more readily available now. Natural gas and LPG have advantages over diesel:

- Diesel is easy to pilfer. Natural gas and LPG are more difficult to steal.
- In many regions the cost of natural gas is lower than diesel.
- LPG and natural gas are clean burning and increase engine life by up to 3 times that of diesel.
- Unlike diesel, it's very difficult to dilute or ruin natural gas or LPG. Engine maintenance is lower because the fuel has less destructive impurities.
- Natural gas and LPG do not spoil. As fuels they can last for hundreds of years. Diesel can spoil in a few years and does require fuel maintenance.

XV. Comment

According to latest figures issued by the GSM Association, around 640,000 off-grid base stations (BTS) will be rolled out across emerging markets by 2012. The target is for 118,000 of these BTSs to be powered by renewable energy. It is clear that rising fuel prices and environmental considerations such as emission control, noise, carbon footprint and environmental impact are all issues that will be influencing specification decisions. With rapidly rising fuel costs, de-regulation and elimination of subsidies for fuel in many developing economies around the world, ***DC Hybrid*** solutions will provide the ideal solution by:

- Reducing fuel consumption by 30 to 70 % for most telecom sites.
- Reducing overall carbon foot-print by half.
- Reducing maintenance costs of the site.
- Eliminating redundant components like Power Monitoring Units or transfer switches.
- Offsetting high utility costs in peak period in grid powered sites.
- Increase the R.O.I. for Telecom customers.