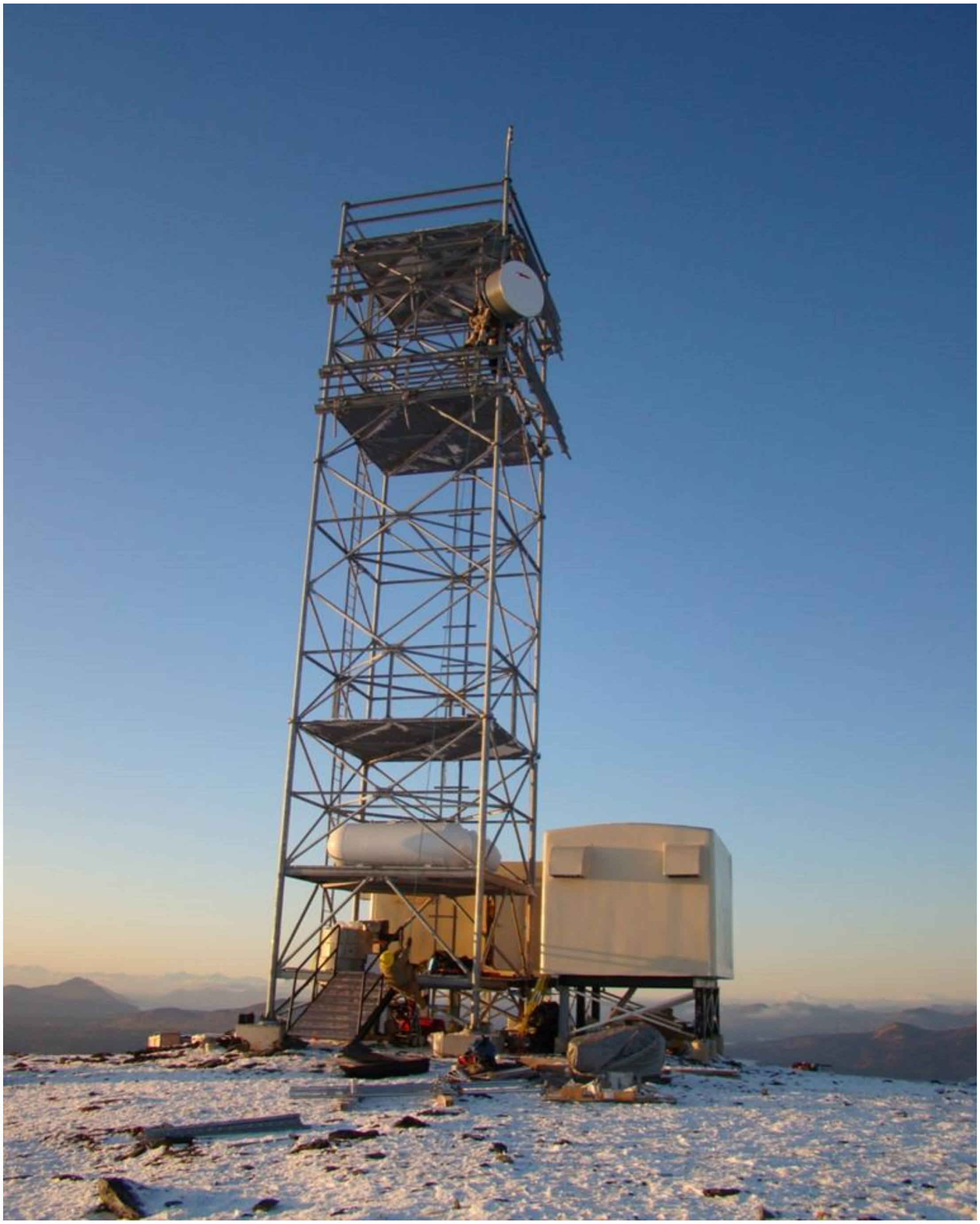
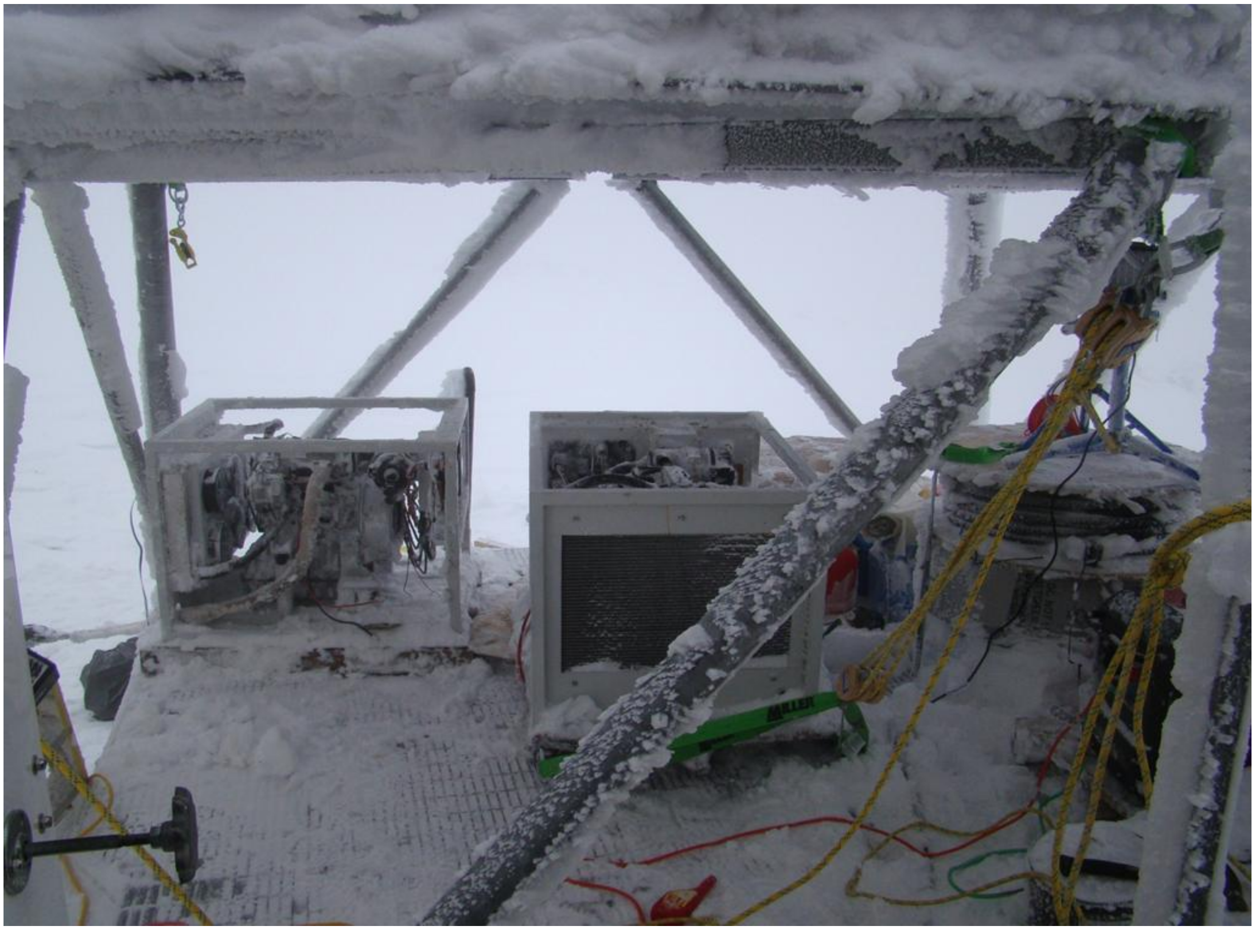
Meeting Telecommunications need for Power since 1995



You can count on our experience in weather extremes

Fuel efficiency, reliability, and low maintenance are paramount when access is limited.

Sometimes you can't complete the job before the storm comes. Polar Power products are rugged enough to survive.



Solar and Wind Generators are useless during winter. A Polar Power DC Generator keeps the site online

Providing innovative and comprehensive solutions for Telecom power and cooling since 1995.

Polar Power provides prime power and backup solutions that are:

- Continuous run
- Hybrid cycle
- Renewable energy

Polar Power meets the customers' program goals for increased reliability, reduced maintenance, and fuel efficiency though our many years of experience and our willingness to invest in new tooling and technology.

Polar DC Hybrid Power Solution

Combining Renewable Energy and Fuel

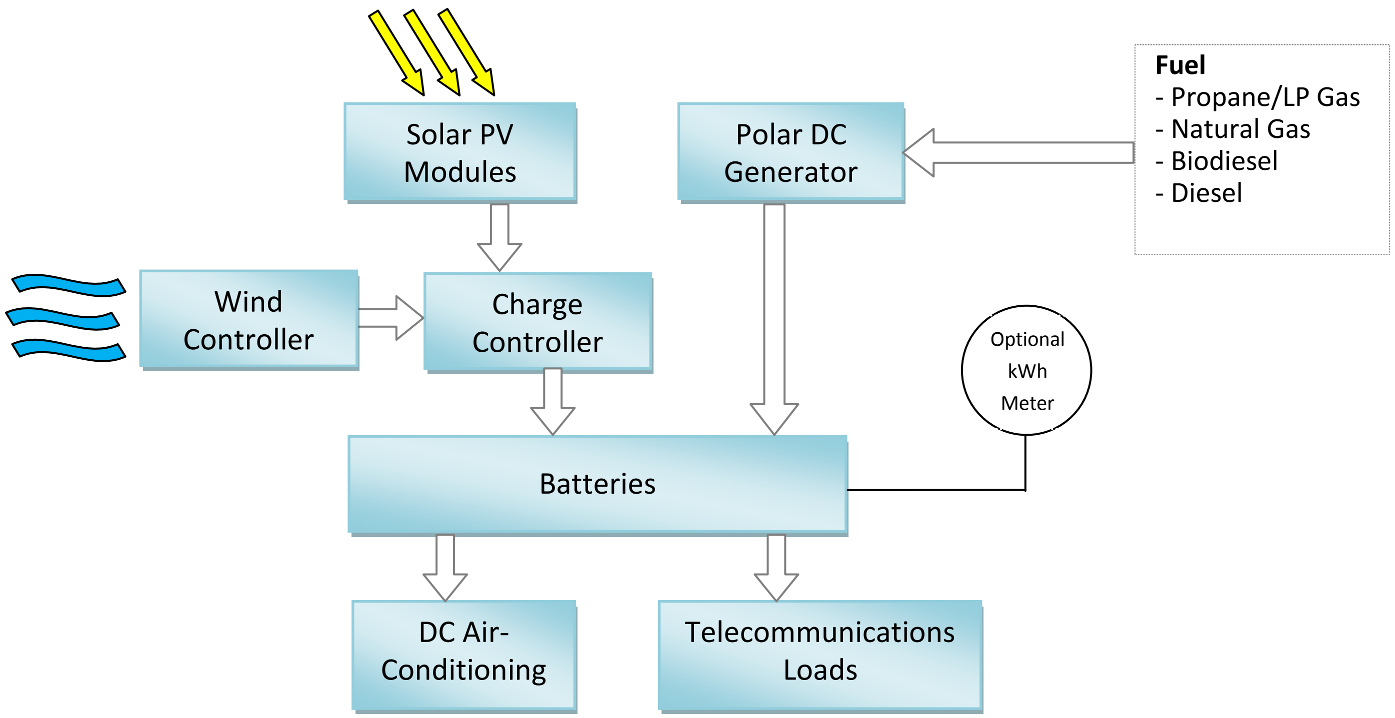
High Efficiency DC Generator Low Capital Cost	+	**Zero Emission Renewable Energy** Low Operating Cost	=	**Low Cost Sustainable Power**

Polar Power's DC 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. Polar Power's hybrid power solution allows the convenient integration of solar and wind for fuel reduction and lower generator maintenance. Our hybrid system allows the convenient integration of solar and wind for fuel reduction and lower generator maintenance. Solar and wind can be added at any time and incrementally.

The amount of fuel saving is dependent on the size of the Solar and Wind generators.

*Polar uses the term DC Hybrid when we are combining power producing sources like Solar, Wind, Hydro and Fuel

Hybrid Power System



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.

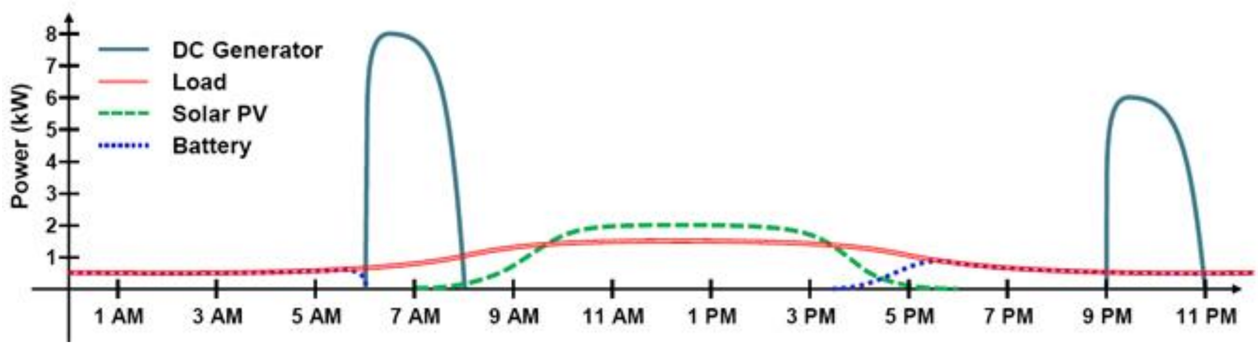
The 80/20 Rule

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, when it’s providing the bulk charge into the battery and powering the load at the same time.

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 or battery failure.

Because of variable weather conditions, the CAPEX and OPEX cost favor the use of the DC generator.

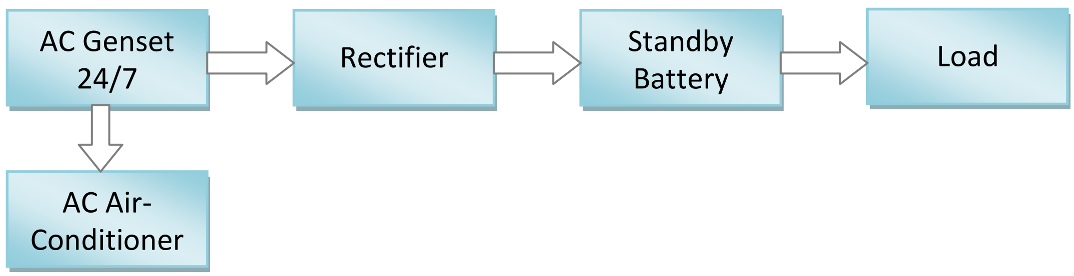


6 AM – 8 AM DC Generator
7 AM – 6 PM Solar PV
4 PM – 9 PM Battery
9 PM – 11 PM Generator
11 PM – 6 AM Battery

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 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 and 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 or similar. After 1 or 2 years a year a determination can be made to remove the wind generator, increase its size, or leave it alone.

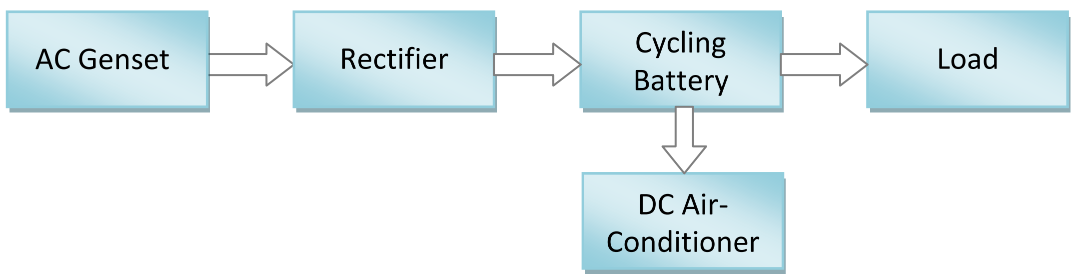
AC – Non Cycling



Bad

High Fuel Cost
Lowest Reliability
Highest Maintenance

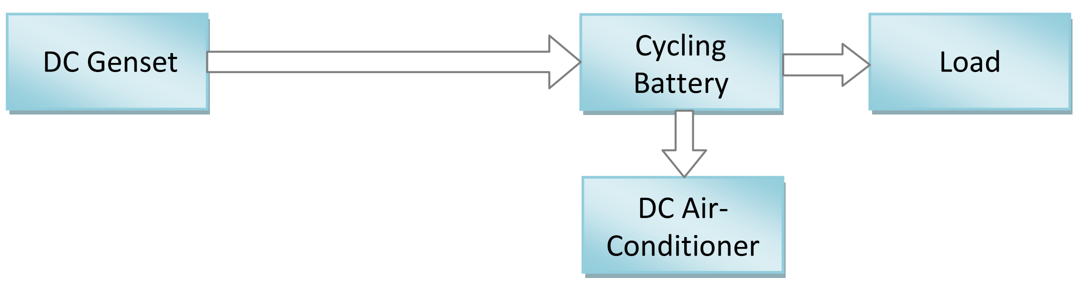
AC - Cycling



Better

Lower Fuel Cost
Lower Reliability
High Maintenance

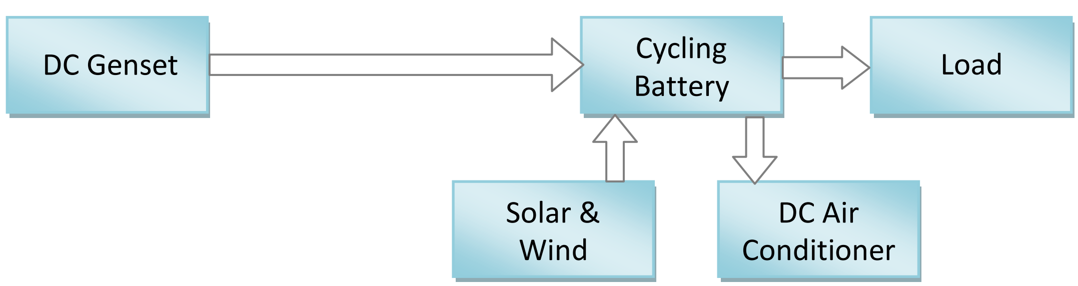
DC - Cycling



Best

Best Fuel Savings
Good Reliability
Lowest Maintenance

DC – Solar Hybrid

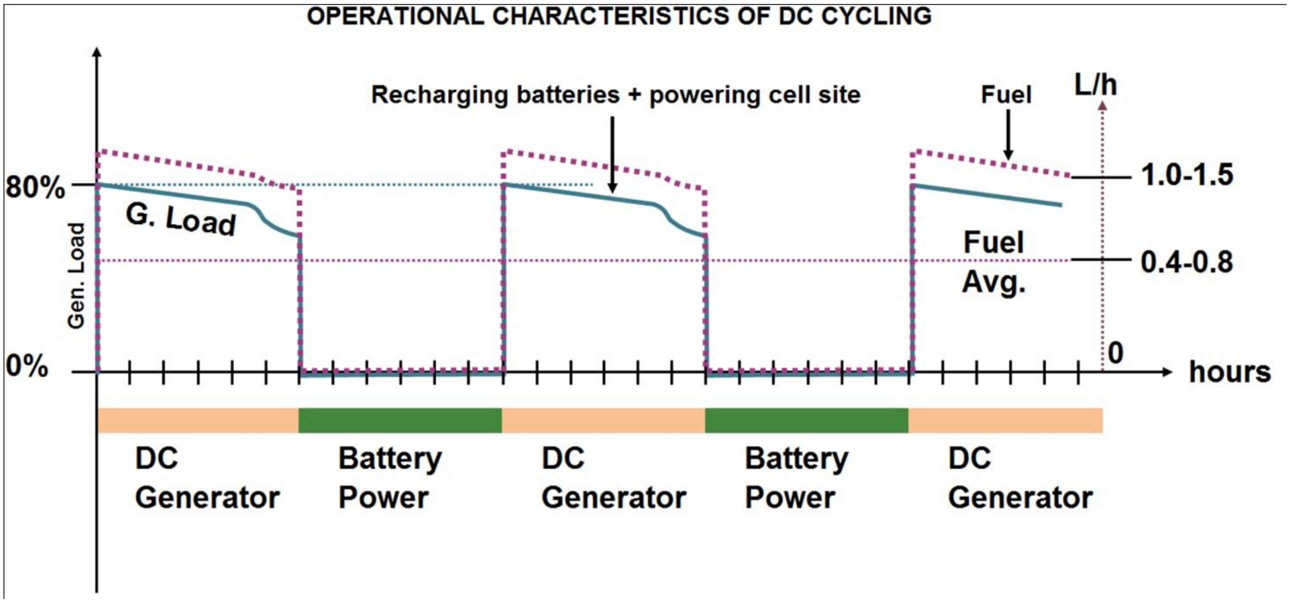


Green Option

Greatest Fuel Savings
Best Reliability
Low Maintenance

Polar DC Cycling for both Off-Grid and On-Grid Applications

Field trials have shown a 70% and greater fuel savings over the conventional AC generators. Also reliability is enhanced and maintenance is reduced using the Polar Cycling solution.



As shown by the graph, 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 is the DC generator's fuel reduction as the load decreases due to the variable speed feature of the DC generator. Allowing the engine speed to change and operate at near its most efficient power points also reduces the fuel consumption rate.

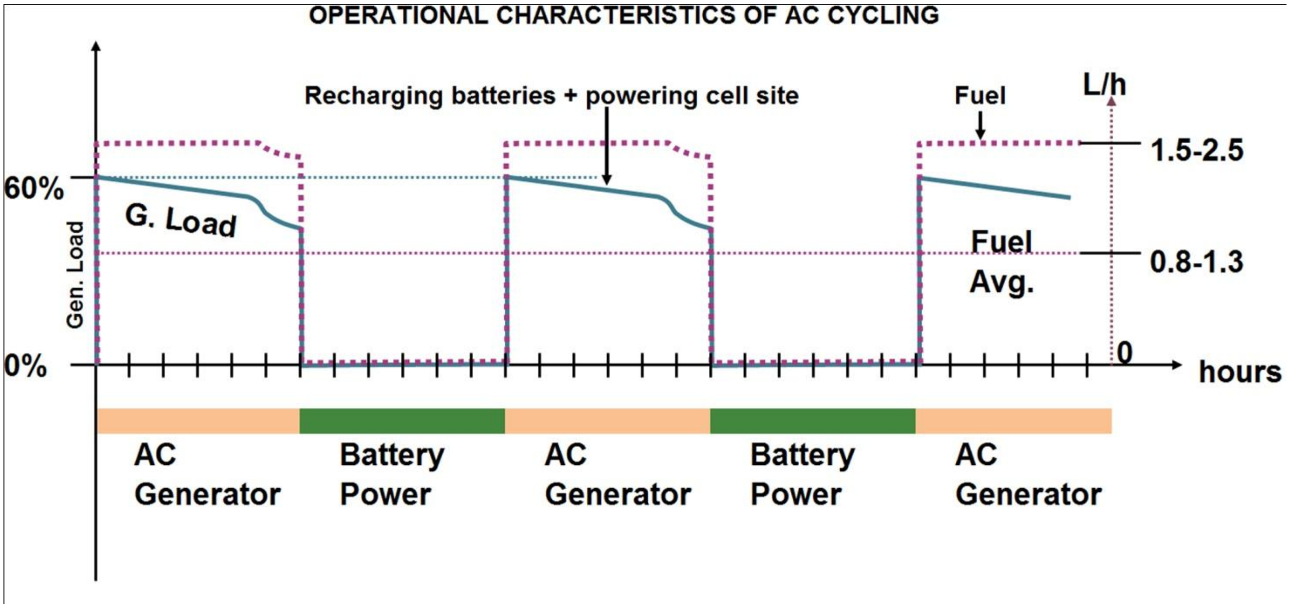
The power output of a DC generator can be regulated so we can operate closer to the ideal engine power curve. This saves fuel because we can make use of smaller engines displacements. In the chart we show the DC generator operating at 80% of its rated power.

Sizing an AC generator requires that it is larger in capacity than the sum of all the loads that may operate at the same time.

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.

AC Cycling

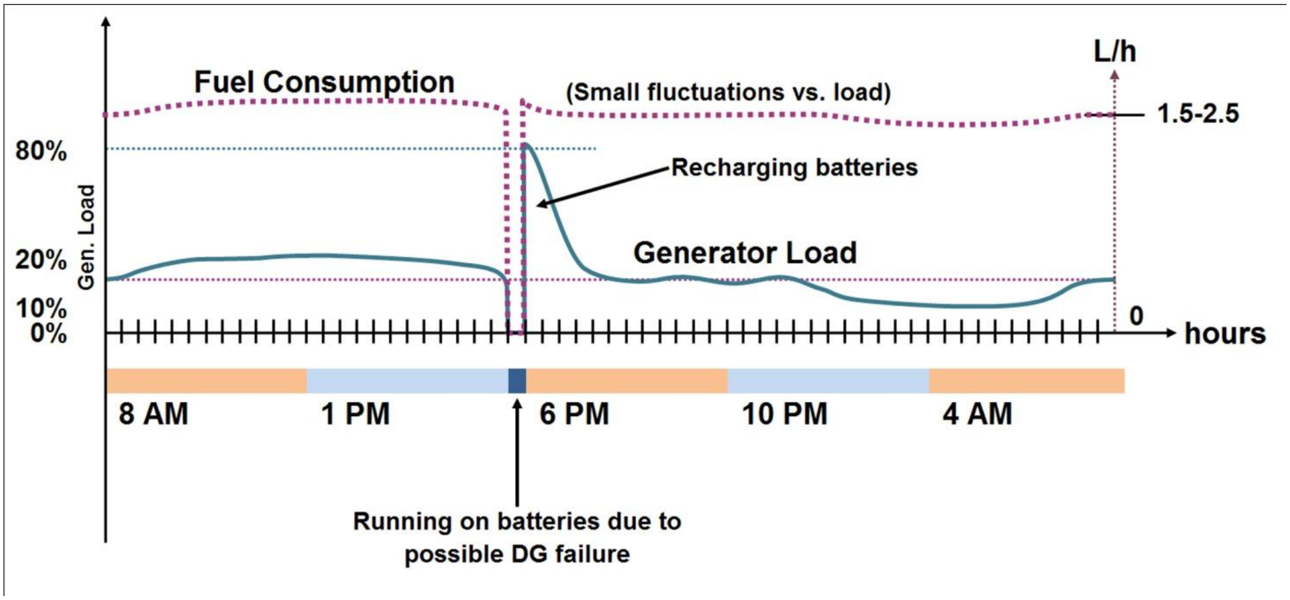
AC generators can be used with rectifiers / battery chargers and operated in a cycle charging fashion; this also offers a fuel saving advantage over operating an AC generator 24 / 7.



The disadvantages of the AC generator cycling are:

- There is a power loss of 10% to 20% through the battery charger/rectifier, the generator is required to produce more power, consuming more fuel.
- The AC generator is not efficient as the DC 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. The system requires the AC generator, transfer switch, battery charger/rectifier, and system controller.
- OPEX costs are higher with the AC cycling as the system consumes more fuel.
- The DC cycling is 25% to 40% more fuel efficient than the AC cycling solution.

AC Generator Operating 24/7



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!

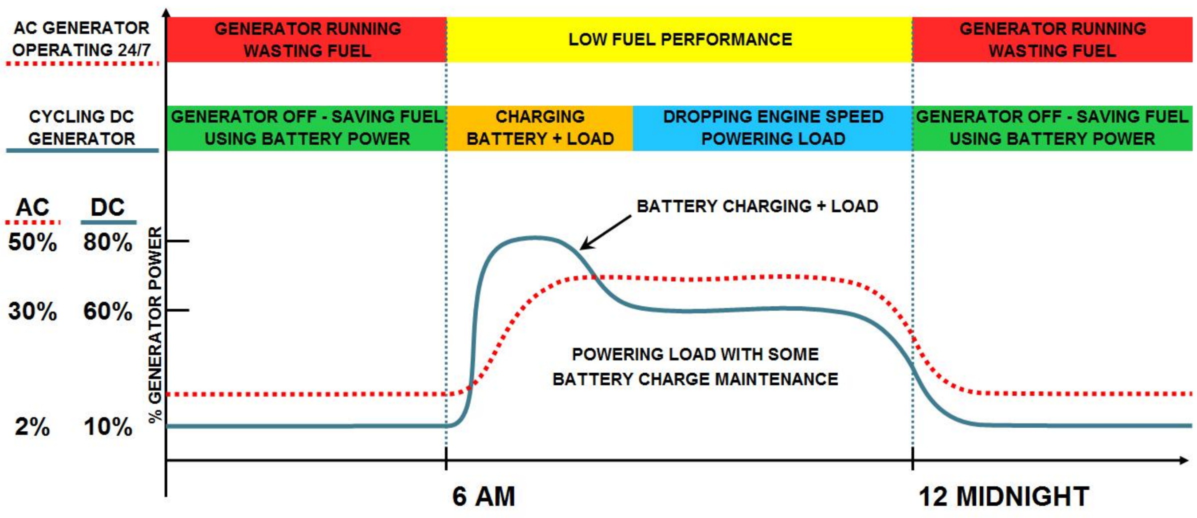
Running an AC generator 24 hours a day and seven days a week is the traditional but least efficient method of powering a cell site. The two principal problems of a constant run AC generator are the large engine displacement and operating while the loads are small.

Typically 20 to 40 kW 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:

- AC generators less than 10 kW 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 in 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

AC vs DC Generator



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

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 at higher and more fuel consuming level than the blue line for the DC generator.

The most significant waste fuel represented by the graph is the AC generator is running while the load is at a minimum power level. Using the DC cycling approach the DC generator is off and the load is powered by the battery.

Polar DC 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

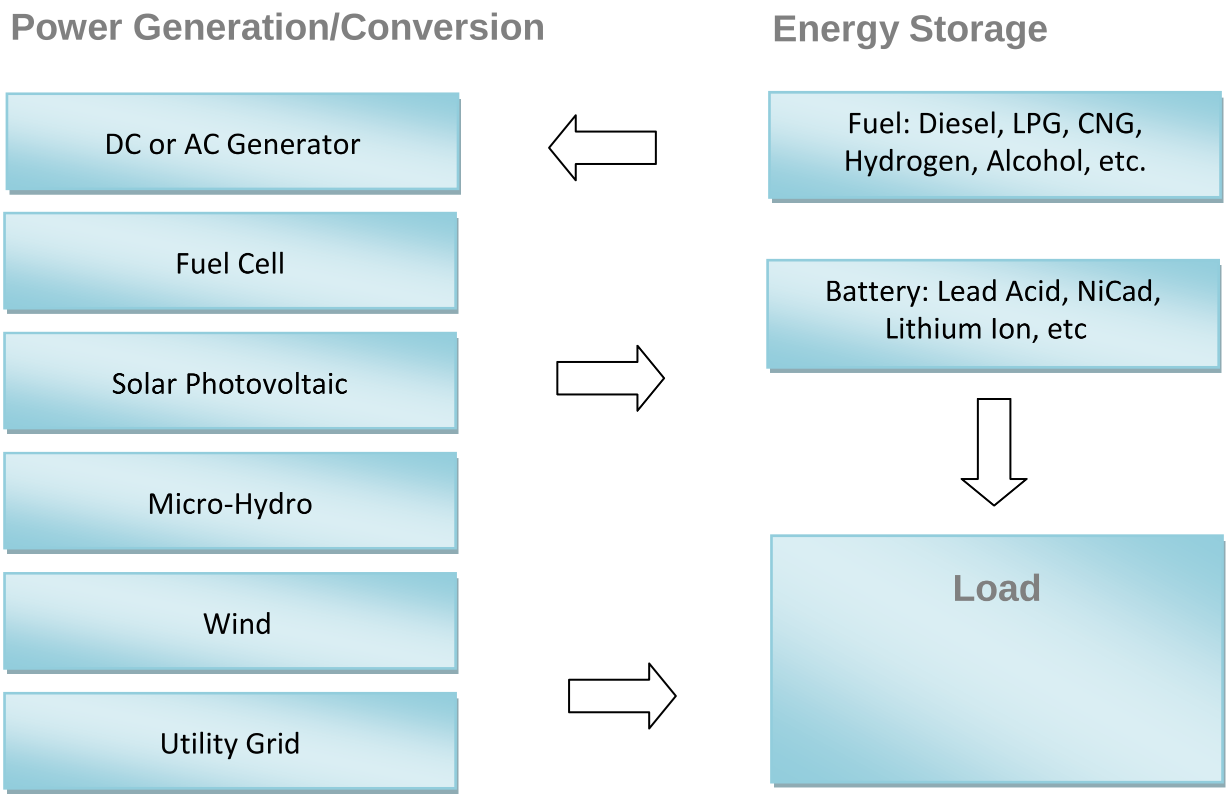
- The AC generator has conversion losses going from AC to DC through the rectifier / battery charger
- The DC generator is variable speed and operates near the engine's most fuel efficient point
- The DC generator is engineered to provided a significantly longer operational life
- The Supra controller allows system recalibrations and software updates without the cost of traveling to the site.
- Oversized fuel and oil filters reduce the periodic maintenance cost
- Polar uses novel filter assemblies to substantially reduce oil, fuel, and air filter replacement costs

Polar Power DC 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 voltage regulator)
- Polar's alternator has no bearings, slip rings, brushes, exciters, or attached diodes
- Polar offers options where: the engine's charging alternator, coolant and mechanical fuel pumps, and all V- Belts, have been removed for enhanced reliability
- No transfer switches required for the DC generator
- Polar's Supra controls have a high level electrical isolation, up to 1500 Volts.
- Supra controls are designed for positive and negative grounding
- 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

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.



For instance, in computer UPS systems, increasing the battery bank size is a solution to provide reliable power in the events of longer utility power outages. Increasing the battery bank size also compensates for problems of bad cells within the battery bank.

In traditional Telecommunications Systems, BTS site batteries are used to back up the grid and follow the same example in computer UPS systems. Battery banks are increased in capacity to provide power for power outages of longer duration, to compensate for problems within the battery bank itself, or to allow sufficient time for service personnel to arrive at site with a 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 5 days of autonomy.

It should be appreciated that increasing battery bank sizes to provide sole energy storage is very expensive and decreases reliability. Design engineers are now appreciating that, Diesel, LPG, or CNG can 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 the system is the most efficient and reliable means to improve 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 size, maintenance, and cost of the power system.

The DC Generator/Battery Bank System

With this improved system, the battery bank and DC generator are used in combination to complement each other and to greatly reduce cost. 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.

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 is 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 that 60% 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 at the storage medium. Increasing reliability means improving the availability of power; therefore, to improve site reliability means adding a second DC generator and possibly more solar.

Improving storage reliability requires the proper selection of battery chemistry and construction. Many applications have been using batteries that were optimized for standby applications and not cycling applications. And some battery manufacturers have exaggerated the performance of their batteries and cycling applications.

Having an oversized battery bank on site simply means that you buy more time for the technician to arrive on site. And in rural areas it may take a week to get the technician on site. Once the technician is on site he is faced servicing a large dead battery. Solution is to keep the battery small and to make the power generation sources redundant.

Traditional and New Ideas behind Sizing the Battery Bank Capacity

Old: Solar and Wind systems, without a fuel sourced generator, have a design preference for 5 days of autonomy.

New: With the addition of the DC generator the need for 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 demand DC generators can reduce the battery bank size and maintenance.

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 a high CAPEX and OPEX cost.

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: To improve the operational reliability of the generator by increasing the size of the battery bank to reduce the runtime and cycling of the generator. Telecom sites that are off grid and use either an AC generator or DC generator in conjunction with battery cycling to save fuel and reduce generator maintenance. These sites may also incorporate solar and wind to further 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. Selection of generators with long endurance engines is a better choice than larger battery banks.

Continuous Run versus Cycling with Battery

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 W we can supply a DC generator to deliver 1500 W operating at an 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 1 to 2 years for diesel and 3 1/2 to 4 1/2 years for LPG (the alternator and controls are reused).

Traditionally an AC generator is run 24/7 and on sizes less than 10 kW generators the generator may require replacement every 4 to 6 months. 20 kW sets are used on loads as small as 1.5 kW to increase operational life at the sacrifice of fuel efficiency.

Cycling

For the same application powering constant 1500 W 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 4.5 to 7 years or diesel and in 16 years for LPG.

Discussion

- In this example with the 1500 W 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.
- As the load decreases in size 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 daily 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.

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.

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.

With so many advantages including the large fuel savings why are there so few DC Generators installed in Telecomm sites?

- Obtaining substantiated OPEX and reliability performance data
- Retaining DC generator application experience
- CAPEX costs for DC generator are incorrectly compared against the AC generator
- Long delivery for DC generators
- Poor selection of DC generators

With non-disclosure agreements in place, Polar has limitations on disseminating field performance results from one Telco company to another. With limited field trial data and experience within the Telco, each Telco wants to validate the technology using their own sites. Most field trials last 1 to 3 years. Unfortunately by the time the field trials are completed frequently the Telco employees that managed the trials change jobs or departments and their knowledge is not transferred within the company.

A program manager will typically compare the cost of an AC generator against the cost of the DC generator system. The AC generator is typically priced without: automatic start stop controls, remote monitoring electronics and software, transfer switch, and the battery charger/rectifier. The Polar DC generator system does not require the transfer switch, battery charger/rectifier, and includes the electronics and software for remote monitoring and fully Automatic operation.

AC generators enjoy wide distribution with high inventory levels providing most programs with short delivery timeframes. DC generators are manufactured to order and do not presently benefit from distributors stocking; this will change when the Telco's start purchasing in volume.

Frequently trials ending with very favorable results for the DC generator still encounter Telcos purchasing the AC generators because of the shorter delivery schedules. The field trial itself sets the program schedule behind forcing the purchase of AC generators.

If there is enough schedule time for the Telcos 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.