HYBRID POWER MANAGEMENT WHITEPAPER
# TABLE OF CONTENTS

- The power landscape .................................................. 1
- What is hybrid power management and why is it important? 2
- The benefits of hybrid power management .................... 3
  - Optimize energy use .................................................. 4
  - Reduce operating costs ............................................. 4
  - Increase network reliability and visibility ..................... 5
  - Improve performance of existing infrastructure .......... 5
  - Meet government regulations and/or obtain funding .... 5
- Kentrox hybrid power management solution ................. 6
- Appendix A: Kentrox products ................................... 11
  - Optima management system ................................... 11
  - Remote family for monitoring and control ................. 11
THE POWER LANDSCAPE

Power - all networks require it. Whether it is a cell site, roadside cabinet, hut, vault, utility facility, or any other type of site, power is a necessity for the equipment. It can come from commercial service, solar panels, generators (diesel or propane), batteries, wind turbines, or hydrogen fuel cells, and it must be provided 24 hours per day, 7 days a week, to ensure the network availability that customers expect.

Utility companies, telephone operators, and companies managing sites along a transportation line are examples of organizations that benefit from a comprehensive power management solution by reducing the need for physical site visits and enabling structured and routine preventative maintenance. A power management solution that can monitor primary and backup power sources and their energy consumption should be available from anywhere at anytime. Important elements for a power management solution include the following:

- Commercial power monitoring to receive proactive notification of failures from rectifiers, automatic transfer switches, and circuit breakers with specific site-affecting conditions
- Battery monitoring to prioritize generator refueling visits during power failures with integrated battery life analysis and identification of weak or underpowered battery banks
- Generator management to monitor fuel levels for facilitating timely refills and knowing how much runtime remains while under load as well as the ability to monitor and manage refueling schedules, fuel delivery accuracy, and fuel contamination. Perform power cycles remotely as part of a routine maintenance schedule. Meet EPA and other mandates through accurate measurement of generator runtime
- Security monitoring of the fuel source and critical infrastructure to ensure power and equipment are available and minimize theft
- Heating, Ventilating, and Air Conditioning (HVAC) management to automatically and remotely manage and control the HVAC equipment and settings. HVAC is the largest consumer of power at a site, and it is critical in managing the amount of power consumed
- Complete network view and history reporting to gain a single, consolidated view of all primary and backup power system status and to meet EPA and other mandates with accurate reports

Figure 1 shows the overall power landscape and is a representation of the critical power infrastructure components at a site. It includes the security and environmental aspects that significantly impact how the power infrastructure is utilized.
This whitepaper will focus specifically on hybrid power management:

- What is hybrid power management?
- Why is managing hybrid power important?
- The benefits of hybrid power management
- The hybrid power management solution from Kentrox

WHAT IS HYBRID POWER MANAGEMENT AND WHY IS IT IMPORTANT?

It is becoming common throughout the world to deploy sites without commercial power or with unstable power. These sites are 100% reliant on other forms of power, which have traditionally been considered backup power sources. Today, only 3.1% of the mobile base stations deployed worldwide are “green”, using alternative energy as the primary source of power1, but power must be managed from any source, including:

- Commercial power
- Generators
- Batteries
- Wind turbines
- Solar panels
- Bio-fuel
- Hydrogen fuel cells

Hybrid power management (HPM) is the ability to support and provide the management, monitoring, and control of all power sources. For traditional commercial power, this includes systems such as rectifiers, circuit breakers, and automatic transfer switches. For generator power deployed as the primary or backup power source, monitoring the status, condition, fuel, and oil are critical. Battery strings are often the next power alternative when commercial power fails. Battery cells must be monitored to ensure they will be available when the main power source fails. Alternative energy sources such as wind turbines, solar panels, bio-fuel, and hydrogen fuel cells must also be monitored to determine how much power is being generated and used. This could help the service provider receive energy credits from a local government or provide an additional source of income if they can sell clean energy back to a power company.

When combining the new technologies with extensive build outs, the stability of the power infrastructure is not only critical to developing the network but is one of the more complex components to the solution. Automated real-time power management is imperative for a network’s availability and success. These sites must be equipped with a complete monitoring and control solution by introducing a comprehensive management system that works with intelligent site devices to deliver proven data collection and control.

An HPM application should make ‘informed’ decisions in situations where commercial power has failed, is unreliable, or does not exist (see Figure 2). Traditional hybrid power management solutions momentarily revert to discharging site batteries when a commercial power outage occurs. Subsequently, an Automatic Transfer Switch engages and

---

1 http://www.balancingact-africa.com/node/21174
the generator is started. In contrast, a comprehensive solution must continue to discharge the batteries until voltage levels reach an appropriate end-of-discharge limit. When the limit is reached, the generator will start and continue to run until the batteries have been fully recharged. By optimizing battery discharge cycles, the generator isn’t over-working, the maintenance lifecycle is extended, and fuel consumption is minimized.

In addition to using an efficient power management solution to ensure high availability infrastructure, it is important to enhance operational efficiencies. Market drivers have led providers to complete more tasks with fewer resources. One solution to combat decreasing resources is to reduce physical dispatches by remotely accessing and controlling managed site devices. With all of the new technology, providers must also focus on extending the life of capital investments which ultimately will improve maintenance schedules and enhance planning.

While the HPM application’s intelligent management logic optimizes generator runtime, it provides maintenance savings. For example, it will avoid discharging batteries during periods when a site’s temperature exceeds identified thresholds. This logic improves battery performance and prevents damage during discharge periods and premature replacement.

A hybrid power management solution for today’s complex environment must include support for all power sources. Additionally, it must provide tools that allow customers to monitor energy consumption, especially the HVAC system, since it is often the largest consumer of power within a site. The solution must also provide an intuitive, easy-to-use interface displaying critical alarm status and performance reports from a central console or technician’s laptop to ensure the information and remote control functions are accessible from anywhere at any time.

HYBRID POWER MANAGEMENT BENEFITS

A comprehensive hybrid power management solution will enable service providers to understand the current health of monitored sites and choose the best equipment for future build outs or site augmentation. It optimizes the power consumption, reducing the total power and fuel consumption required to successfully operate the site. The result of an optimized hybrid power management solution is reduced operating costs, enhanced equipment efficiency and HVAC utilization, and reduced fuel consumption. The automated maintenance work also increases the lifecycle of the equipment. As technology continues to shift in today’s networks, power remains the one constant requirement, and it must be more closely monitored, managed, and controlled in an effort to maintain highly available reliable, and profitable networks.

The benefits of a hybrid power management solution include the following:

- Optimization of energy usage
- Reduction in operating costs
- Increasing network reliability and visibility
- Improved performance of existing infrastructure
- Maintain government regulation conformities and access “green” energy funding programs

The increasing cost of fuel is forcing providers to manage the operating fuel expense both at individual sites and across the network. Fuel levels and overall consumption should be continuously monitored. When high fuel consumption thresholds are crossed, an HPM solution should generate an alarm which notifies carriers of potential fuel theft. An effective HPM solution monitors fuel levels to facilitate timely refills, verify fuel deliveries, and report how much time remains while the generator is carrying the site load.
Optimize energy use

Sites with multiple power sources must be monitored and managed to improve energy usage. Sites will become more energy efficient by monitoring and adjusting power utilization whether from commercial power, batteries, alternative power, or generators.

A comprehensive HPM solution improves energy efficiencies and reduces the carbon footprint. When primary power is not available, it is common to use a combination of battery and generator power to handle the site load. An HPM approach will automatically start a generator to recharge low batteries and then stop it once the batteries are fully charged. This reduces energy usage and extends power coverage during on-grid power outages. As an added benefit, it minimizes battery and generator replacement by extending its useful life.

HPM also reduces fuel-related expenses. With the increasing price of fuel, providers need to manage their fuel consumption across the network. Understanding and managing fuel levels in generators is critical, especially during emergency situations such as natural disasters or when sites are located in remote or difficult-to-access locations. It is important to monitor fuel levels to facilitate timely refills, verify fuel deliveries, and know how much time remains when the generator is carrying the load.

All power components are not necessarily controllable, however by providing generator and HVAC system controls, power management allows for intelligent load control resulting in power failover and consumption optimization.

Reduce operating costs

Managing a network with hundreds or thousands of sites can be extremely expensive, but a hybrid power management solution can significantly reduce the operating costs. For example, power sources must be continually monitored to ensure optimal performance. Unfortunately, in many areas of the world, dispatching technicians to a site can be a difficult and expensive trip due to poor roads, weather, safety, and the remoteness of the location. The ability to access the site remotely to check on the status of site elements such as the generator, HVAC, batteries, temperature, security systems, etc. greatly reduces the operating expenses by reducing the number of physical site visits. This ultimately saves fuel, vehicle maintenance, and will improve technician efficiencies.

Remote management and access to generators at remote sites, cell sites on wheels (COWs), switch sites on wheels (SOWs), cell sites on light truck (COLTs), or unmanned switch locations is designed to address diagnostic, repair, and preventative maintenance activities required to control operational costs and improve network quality, security, and availability. Remote access and monitoring can be used to retrieve generator information such as runtimes, oil pressure, time until maintenance, phase current, and fuel remaining. An HPM solution enables providers to schedule routine maintenance, centralize and automate routine and preventative maintenance tasks, provide immediate correction of service-affecting problems, and remotely start and stop the generator as part of regular preventative maintenance. Remote management capabilities also help reduce technician overtime.

Because all generator activity is continually recorded, accuracy is ensured. Reports are available 24 hours/day, 7 days/week and are easily accessible for regulatory or internal review. Immediate alarm notification to technicians via email and/or SMS provides an advanced warning of potential issues, and preventative maintenance can occur before a network outage.

With the increasing costs of fuel, concerns for safety where armed escorts are required, and often poor access to sites, a successful hybrid power management solution can drastically reduce operating expenses while improving efficiency and reliability with preventative maintenance.


**Increase network reliability and visibility**

According to a 2007 In-Stat report, the primary reason for subscribers to switch wireless service providers was from dissatisfaction caused by coverage, dropped calls, and network outages. Maintenance and repair issues often cause network issues, and using an HPM solution helps improve network reliability.

In addition to managing generator availability with preventative maintenance and remote monitoring capabilities, an HPM solution ensures that alternative backup power is available when the primary power source has been lost. Whether it comes from commercial service, solar panels, generators (diesel or propane), batteries, or hydrogen fuel cells, it is a critical component to providing the network availability that today’s subscribers demand. An HPM solution improves network reliability by:

- Proactively sending notifications of failures with specific site-affecting conditions
- Identifying weak or underpowered battery plants to help improve battery efficiency and effectiveness
- Monitoring fuel levels to facilitate timely refills, performing remote power cycles, and ensuring fuel levels for proper generator operation
- Providing a consolidated view of all power system status

**Improve performance of existing infrastructure**

Understanding the current situation and being made aware of potential issues related to equipment at sites such as generators, rectifiers, and batteries can significantly reduce capital expenses over time. By monitoring and managing the power infrastructure, equipment life can be extended so replacement parts and costs will be minimized and service intervals are longer. Additionally, batteries that are discharged when environmental conditions are ideal will increase their operational longevity.

Through occasional review of the site network using historical reporting, service providers can also minimize capital expenditures by using best-in-breed products and engineering based on real data from their own network. Battery and generator vendors can be ranked on performance in a particular situation to optimize equipment based on a site’s requirements.

**Meet government regulations and/or obtain funding**

A hybrid power management solution can help service providers meet government regulations, reduce carbon emissions, and with more recent opportunities, even obtain funding for “green” initiatives.

In the telecommunications industry, the number of “green” mobile base stations worldwide is only 3.1% of the total number of deployments (9,558). With the cost of crude oil reaching record levels in the last few years, service providers are hoping to reduce the reliance on diesel fuel for generators by using alternative energy options, especially for many hard-to-reach and remote locations that may require helicopter, snowmobile, boat access, all-terrain vehicle, or the use of hand carts. HPM helps reduce carbon emissions by only starting the generator after batteries have first been discharged. This reduces truck rolls that generate carbon. Figure 3 illustrates the annual CO2 emissions that can be saved by eliminating truck rolls.

In the United States, it is critical for mobile operators to be Environmental Protection Agency (EPA) and Federal Communications Commission (FCC) compliant to eliminate

<table>
<thead>
<tr>
<th></th>
<th>Eliminating 3 truck rolls/ week/truck</th>
<th>Eliminating 2 truck rolls/ week/truck</th>
<th>Eliminating 1 truck roll/ week/truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual CO₂ emissions saved for 1000 trucks</td>
<td>3.3 million pounds</td>
<td>2.2 million pounds</td>
<td>1.1 million pounds</td>
</tr>
</tbody>
</table>

Figure 3: Annual CO₂ emissions saved for 1000 trucks. Assumes 20 miles/truck roll and 18 miles/gallon.

---

2 In-stat whitepaper “The Third Wave: Why Network Availability and Quality are Key to Wireless Service Provider Success”. Whitepaper available on the Kentrox website for download.

3 http://www.balancingact-africa.com/node/21174
the possibility of fines. For example, if a generator is tested or running on an EPA’s designated “Bad Air Day”, the fine could be thousands of dollars per instance. If a generator isn’t checked per state or national standards at designated intervals, the service provider can be fined. A successful HPM solution enables service providers to show compliance and manage these activities remotely.

Governments and businesses are also becoming more interested in companies managing and more importantly, reducing their carbon footprint. For example, Nedbank Capital has designed a service that allows African telecommunications operators to claim carbon credits for their “green” implementations either via the clean development mechanism or through a voluntary process for either new network equipment rollouts or upgrading existing ones. According to a case study prepared by Nedbank Capital, assuming 75% saving on power, mobile operators can generate an additional 6% revenue annually from every base station that uses renewable energy sources as its main power supply.

**KENTROX HYBRID POWER MANAGEMENT SOLUTION**

The Kentrox Hybrid Power Management solution provides a complete monitoring and control solution (see Figure 4) by introducing a reliable, software-based application that interoperates with proven data collection devices. The Kentrox solution consists of the Optima management system and Remote suite of products.

The Optima management system provides complete visibility and control of network infrastructure sites, such as cell sites, cell sites on wheels, switch sites on wheels, cell sites on light truck, unmanned switch locations, and remote communication huts. Optima delivers these site benefits by providing remote monitoring, control, and automation over the maintenance and management of infrastructure and physical elements with an easy-to-use Graphical User Interface. (See Appendix A for more information regarding Optima.)

The Remote suite of products includes monitoring and control site devices that provide IP management to remote locations and equipment. The Remote suite provides site alarm monitoring, protocol conversion, equipment connectivity, and acts as an intelligent extension of the Operations Support Systems (OSS). It is designed to enhance the network management strategy, reduce operational costs, and improve operational efficiency with reduced truck rolls. (See Appendix A for more information regarding the Remote suite of products).

The Kentrox HPM application makes intelligent decisions in situations where commercial power has failed, is unreliable, or does not exist. Unlike traditional solutions that momentarily revert to discharging site batteries and then start a generator when a commercial power outage occurs, the Kentrox solution continues to operate the site on batteries until the DC voltage level reaches the end-of-discharge threshold. When this threshold is met, the generator is started and will operate for a pre-determined duration.

---

The HPM application avoids discharging batteries during periods when a site's temperature exceeds preconfigured thresholds. This logic improves battery performance during discharge periods and prevents premature replacement. Furthermore, by optimizing battery discharge cycles, generator operation and fuel consumption is minimized. Fuel consumption levels are carefully monitored. When high fuel consumption thresholds are crossed, the HPM application generates an alarm which notifies service providers of potential fuel theft.

The solution has been designed to interoperate with many vendors and supports numerous backup power designs including conventional and hybrid power alternatives. For example, some network providers may utilize a standby generator and DC battery as backup power sources, others may only use DC batteries, while others could use alternative sources such as hydrogen fuel cells, solar panels, and wind turbines. These can all be managed and monitored with the Kentrox solution.

The HPM application can be further enhanced to include logic that manages energy usage and allows for controllable thermostats. This architecture can be extended to include additional intelligence and decision-making logic based upon the data captured through transducers monitored by the Remote suite of products. This flexibility allows service providers to meet their needs by providing a smart, extendable, and cost-effective solution.

Through the monitoring of an analog input point (such as fuel and temperature sensors), the Kentrox HPM solution provides Key Performance Indicators (KPIs). These KPIs allow service providers to monitor site environmental conditions, such as humidity, temperature, and power status. Utilizing KPIs will provide an understanding of computed time until generator fuel levels reach empty and report on expected battery discharge duration during power outage scenarios. With this information, proactive measures can be performed to better manage sites (see Figure 5). A subset of the KPIs generated by the HPM application is:

- Generator status
- Battery voltage
- Rectifier status
- Fuel theft
- Fuel contamination
- Fuel cap open or closed
- Generator service needed
- Generator oil pressure
- Mains power failure and restoral

The solution is typically deployed at sites equipped with commercial AC grid power, a rectifier, an associated DC +24/-48 battery string, and a generator. In the simplest scenario, the solution monitors the health of mains power through a controller or related contact closures. If AC Mains 3-phase voltage drops below the configured nominal voltage boundaries, the HPM application will determine that commercial power (AC) has been lost.

![Figure 5: Optima executive report on key performance indicators](image-url)
When commercial AC power has been lost, the Kentrox HPM solution will make an intelligent decision on where the site load should be transferred based on the battery life assessment and capacity available. As part of the HPM provisioning, an abnormally high temperature is defined. If the site temperature exceeds the user-defined threshold, the HPM solution will decide that AC power is necessary and the air conditioner and/or fan system will engage to cool the site. The generator will start and operate until the site temperature is below the high temperature threshold defined in the temperature profile. If a short outage occurs and the load was transferred to DC battery power only for a short time, the Kentrox HPM solution makes intelligent decisions to avoid unnecessary cycling and maximizes the service life of the site batteries.

Additional hybrid power management provisioning includes the following:

- Identifying the expected capacity for the battery string that will be monitored by the HPM application (3, 5, or 8 hours for example). This allows the HPM solution to more efficiently utilize capacity of the batteries to minimize generator fuel consumption.
- Identifying the end of discharge voltage that must be reached before the generator is started to recharge the batteries. This protects expensive battery strings from damage and increases the life expectancy of the batteries.
- Determining the site temperature profile including high temperature, nominal operation range, and low temperature. This allows the service provider to achieve maximum possible energy savings while maintaining a suitable environment for the service-bearing equipment.

HPM data collection and fuel monitoring will take place at the remote site using one of the Remote suite of products. All of the critical site performance data will then be transmitted over the corporate LAN or preferred GPRS/HSPA transmission network to a central collection point, typically the end user’s NOC. Optima will be installed at the NOC and will collect the IP traffic from the numerous remote sites and display this information in a format (graphical or tabular - see Figures 6 and 7) of the user’s choosing. Optima uses performance dashboards and makes it easy to determine HPM performance and related fuel information.

The Kentrox hybrid power management solution can provide an alarm threshold on KPIs that collect raw data from generating set (genset) controllers. For example, it will continuously poll intelligent genset controllers that have a generator start battery voltage parameter. If the start voltage falls below a user defined threshold, the application will automatically generate an SNMP alarm with a...
“warning” severity. In addition to this alarm, a notification rule can be defined to send an email or SMS message in conjunction with the alarm message from Optima.

The Kentrox solution supports the addition of a fuel level sensor. This sensor is a pressure-based sensor using an available access port on the top of the fuel tank. This sensor will provide an accurate fuel reading and can detect minimal fluctuations of the fuel level. HPM will provide fuel theft detection if fuel is consumed when the generator is not operating or when the fuel flow exceeds normal generator consumption within a user defined window of time. The solution will also send a notification when fuel tanks are filled. Knowing both the empty and full level ensures the fuel provider is properly billing for fuel delivered.

Because Kentrox hardware contains a scripting engine built directly into each unit, support for generator controllers can be made quickly to specification on a vendor-by-vendor basis. The Kentrox HPM solution supports numerous controllers from manufacturers such as Lovato, Intellilite, and Deepsea.

In addition to the reports that are available within Optima, the hybrid power management solution introduces the following set of 24 hour and seven (7) day aggregated view reports:

Application-generated reports
- Commercial power runtime
- Generator runtime
- Battery string discharge duration
- Overall cell site power distribution
- Battery string charge % (single site view)
- Battery string charge % (multisite view)
- Generator runtime remaining (applicable during failover)
- Generator time until refuel (time estimate based on generator rate of consumption)
- Generator fuel consumption (single site view)
- Generator fuel consumption (multisite view)
- Generator fuel level
- Battery voltage
- Site temperature
- Site temperature and battery voltage (multi-measurement view)
- Site temperature and fuel consumption (multi-measurement view)
- Site humidity
- Custom site event list
- Estimated time until battery reaches end of discharge

The Remote suite of products will integrate directly to a third party automatic transfer switch or solar powered inverter for hybrid power management control and functionality. The HPM application will determine whether commercial mains power is present, is operating within normal limits, and be able to interface directly with an intelligent generator controller. If an intelligent interface does not exist, the Kentrox HPM solution can easily obtain this information (in the form of a discrete alarm) from the automatic transfer switch where available.
Intelligent controller-derived reports

- Generator frequency
- Generator L12 voltage
- Generator L1N voltage
- Generator L23 voltage
- Generator L2N voltage
- Generator L31 voltage
- Generator L3N voltage
- Mains frequency
- Mains L12 voltage
- Mains L1N voltage
- Mains L23 voltage
- Mains L2N voltage
- Mains L31 voltage
- Mains L3N voltage
- Generator start battery voltage
- Generator engine speed
- Generator oil pressure
- Generator oil temperature
- Generator time until maintenance

NOTE: The above list is an example of sample performance data that can be generated by the Kentrox hybrid power management solution. The actual list of measurements will vary based upon the interface into the generator or genset controller.

The Kentrox hybrid power management solution is used by service providers worldwide. The operational and equipment savings has been significant by reducing fuel costs, minimizing truck rolls for routine maintenance that can be conducted remotely, monitoring fuel deliveries and for fuel theft, reducing greenhouse gas emissions, and providing improved network performance and reliability.
**APPENDIX A**

**Optima management system**

The Optima management system provides complete visibility and control of network infrastructure sites, such as cell sites and remote communication huts. It gives immediate operational cost reduction to organizations that need to access, monitor, and manage large numbers of sites. Optima delivers these site benefits by providing remote monitoring, control, and automation over the maintenance and management of infrastructure and physical elements.

Virtually any type of system can be integrated with Optima to provide detailed surveillance, remote control, and periodic maintenance automation. This enhanced visibility into the network allows users to work proactively to prevent and repair site problems quickly. When outages do occur, Optima reduces the need for site visits while enabling your operations personnel to resolve most network issues in 50% less time. This is accomplished by using the data collected by Optima and intelligently dispatching appropriate resources with the proper tools and replacement equipment to get the job done during the first site visit.

The main functions of the Optima management system include:

- Performance and element management
- Generator management
- Event management
- Remote access
- Site data collection and control

**Kentrox Remote suite of products**

The Remote product family includes monitoring and control site devices that provide IP management to remote locations and equipment. Remote provides site alarm monitoring, protocol conversion and equipment connectivity and acts as an intelligent extension of your Operations Support Systems (OSS). It is designed to enhance your network management strategy, reduce operational costs, and improve operational efficiency with reduced truck rolls.

The Remote family features the RMX-3200, a highly integrated site management system that includes serial, Ethernet, and discrete digital I/O ports. It also includes modular WAN communication and expansion options, providing site management flexibility and growth. A cost-effective alternative is the Remote RMM-1400 site management solution for smaller sites or locations where a limited number of systems require integration. Adding the Remote RMB-1 provides access to analog and digital I/O ports and built-in temperature and humidity sensors. The Remote RMX-3200 supports multiple RME-1000 expansion shelves for increased port capacity.

The Remote products reside at your network’s remote locations and connect to each element via a wide variety of interface options. Remote products can connect to the Optima management system via Ethernet, T1/E1, EVDO/CDMA, or GSM/GPRS/HSPA wireless communication options. Together, Remote and Optima provide detailed monitoring, remote control, and management for virtually all remote site devices.

Both the Remote RMX-3200 and Remote RMM-1400 site controllers support many intelligent site sensors including virtually any device that provides bi-state, RS422/485, RS232, voltage, and current outputs.