EatonTowers



Opex savings initiatives

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Introduction

- Telecommunications operators in Africa face severe challenges in powering mobile base station (BTS) sites in remote areas.

- In many cases, the sites are simply too far from the AC grid for AC mains powering to be economic.

- Other sites have AC mains power, but it is extremely unreliable.

- These sites are often powered by small diesel generator sets, running continuously.

- On-going costs are high, and include:
  - Direct fuel cost
  - Refuelling is usually needed every one or two weeks, at a high cost for a very remote site.
  - Generator maintenance.
  - Generator replacement. In continuous duty a small generator may only last two years.
  - Fuel theft and leakage.

Introduction

- In the interim (first 6 to 12 months after taking on a new portfolio) Eaton would focus on:
  - ✓ Evaluating the current operating conditions and implementing processes to:
    - Reduce loss of fuel during transit to site
    - Enhance site security by increasing security presence or/and hardening of the current conditions
    - Optimise the preventative maintenance program by introducing more stringent controls
    - Correctly dimension headcount and location of field support teams
  - ✓ Stabilising the current situation, i.e. repair or replacement of faulty and end of life equipment.
- In the longer term depending on the site conditions and requirements to reduce the initial CAPEX and continuous OPEX, Eaton would implement the following:
  - ✓ Ensuring, where possible, that off-grid sites are connected to AC grid power
  - ✓ Deploying new technologies such as:
    - Power Management Systems
    - Deep Cycle Batteries
    - Power Interface Units
    - Full Hybrid Systems
  - ✓ Upgrade to intelligent generator control panels
  - ✓ Installation of site monitoring systems
  - ✓ Installation of oil management systems on generators

Power Management Systems (PMU)

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- PMU can intelligently control the available power sources and switch between them to ensure the most efficient operation depending on the current site conditions.
- PMU will produce a spike free and stable AC output voltage.
- PMU is suitable to work under harsh AC mains environment with maximum reliability.
- PMU would eliminate the complex interconnection wiring found in conventional power solutions thus making it easy to deploy and maintain.
- PMU offers a space saving all in one solution which combines Static Voltage Regulator, Isolation Transformer, Best Phase Selector, Auto Mains Failure, AC Distribution Panel, Lightning and Surge protection and Alarm systems in one modular unit.
- PMU utilises more extensive reporting abilities to offer additional operational (OPEX) savings with more accurate billing of fuel and electricity as well as precise scheduling of delivery events and maintenance.

Implementing PMU

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- Sites with unreliable, fluctuating AC grid power and frequent outages:
  - ✓ Replace the existing station battery with a deep cycle bank
  - ✓ Upgrade capacity where necessary to provide back-up of at least 8 hours
  - ✓ Implement a Power Management System (PMU)
  - ✓ During AC mains failure the build up of heat in the equipment room will be limited by utilising free cooling
  - ✓ PMU will compensate for fluctuations of single phase grid voltage ranging between 100 & 270 Volt
  - ✓ PMU will ensure three phase output when only two of the phases are available and within a voltage range of 190 and 495 Volt
  - ✓ During AC grid power failures which PMU cannot rectify, only start the generator when a battery recharge is needed or when the room temperature reaches a critical high

Implementing PMU

- Off-grid sites:
  - ✓ Replace the existing station battery with a deep cycle bank with enough capacity to provide back-up of between 8 and 12 hours
  - ✓ Implement a Power Management System (PMU)
  - ✓ The build up of heat in the equipment room will be controlled by utilising free cooling and DC air conditioners
  - ✓ The generator will only run to charge the battery bank, thereafter it will stop and the battery bank will take the load.
  - ✓ The bank will discharge until a set level is reached and then the generator will start and quickly recharge the battery bank.
  - ✓ The cycles will repeat automatically.

Deep Cycle Batteries

- AC mains outages can last for a few seconds, or for many hours. During these outages, the batteries may never be fully discharged, or fully recharged. This results in repeated shallow discharges, often with the battery in a partially charged condition, also known as PSOC (Partial State-of-Charge) cycling. Under these harsh conditions, a standard battery can quickly lose capacity and reach the end of its useful life.

- Battery capacity (how many amp-hours it can hold) is reduced as temperature goes down, and increased as temperature goes up. Even though battery capacity at high temperatures is higher, battery life is shortened.

- A battery "cycle" is one complete discharge and recharge cycle. It is usually considered to be discharging from 100% to 20%, and then back to 100%.

- A deep-cycle battery is designed to discharge between 50% and 80% depending on the manufacturer and construction of the battery. Although these batteries can be cycled down to 20% charge, the best lifespan vs. cost method is to keep the average cycle at about 50% discharge, as there is a direct correlation between depth of discharge on the battery and the number of charge and discharge cycles it can perform.

Deep Cycle Batteries

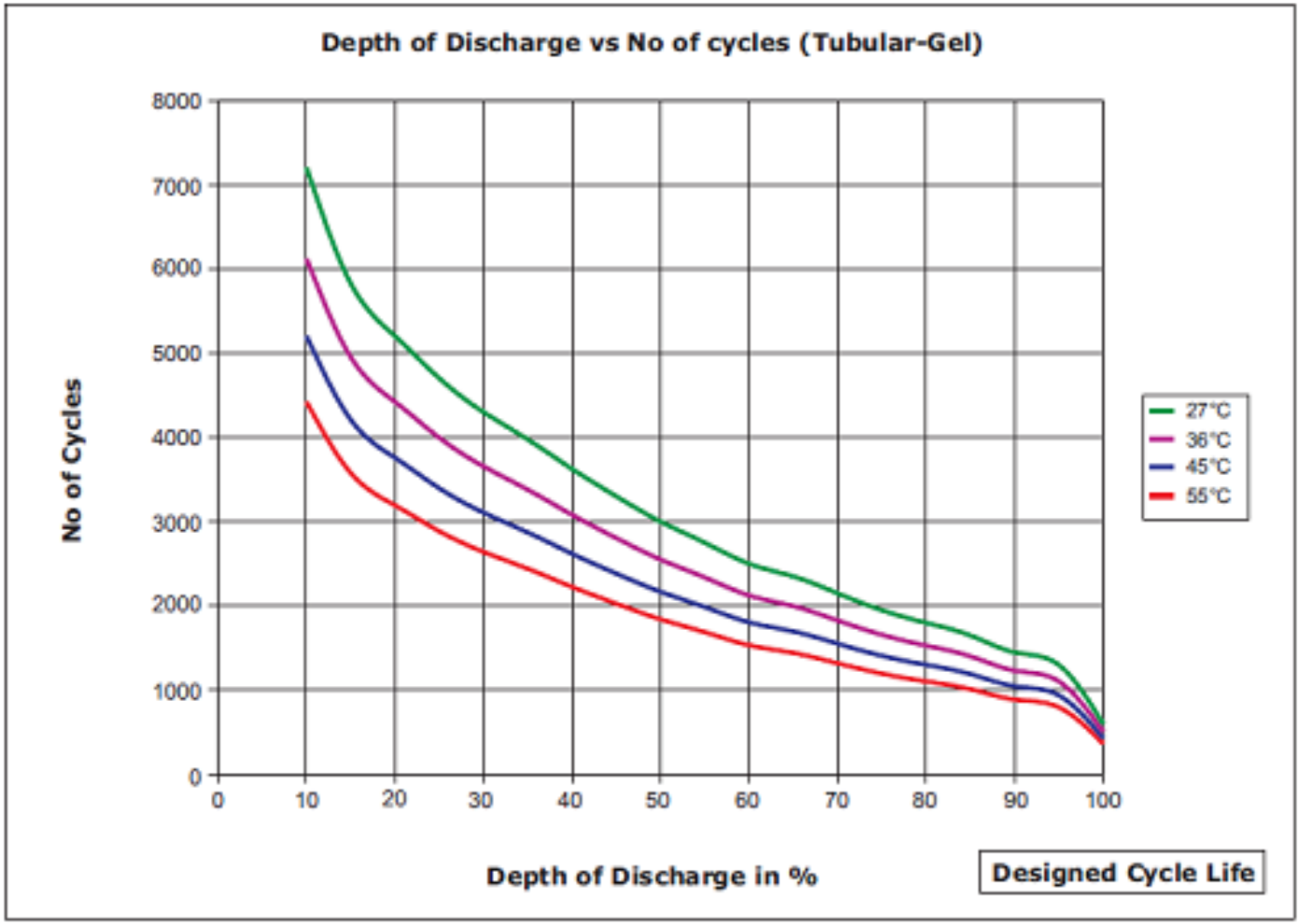
- Deep Cycle Batteries will typically be deployed on sites where the existing batteries need to be replaced or where Power Management Systems (PMU) have been integrated. Deep cycle batteries will also be utilized as part of a Hybrid system.

- Deep Cycle Batteries ensure optimal uptime in the event of a mains failure and the generator failing to start, without causing damage to the batteries.

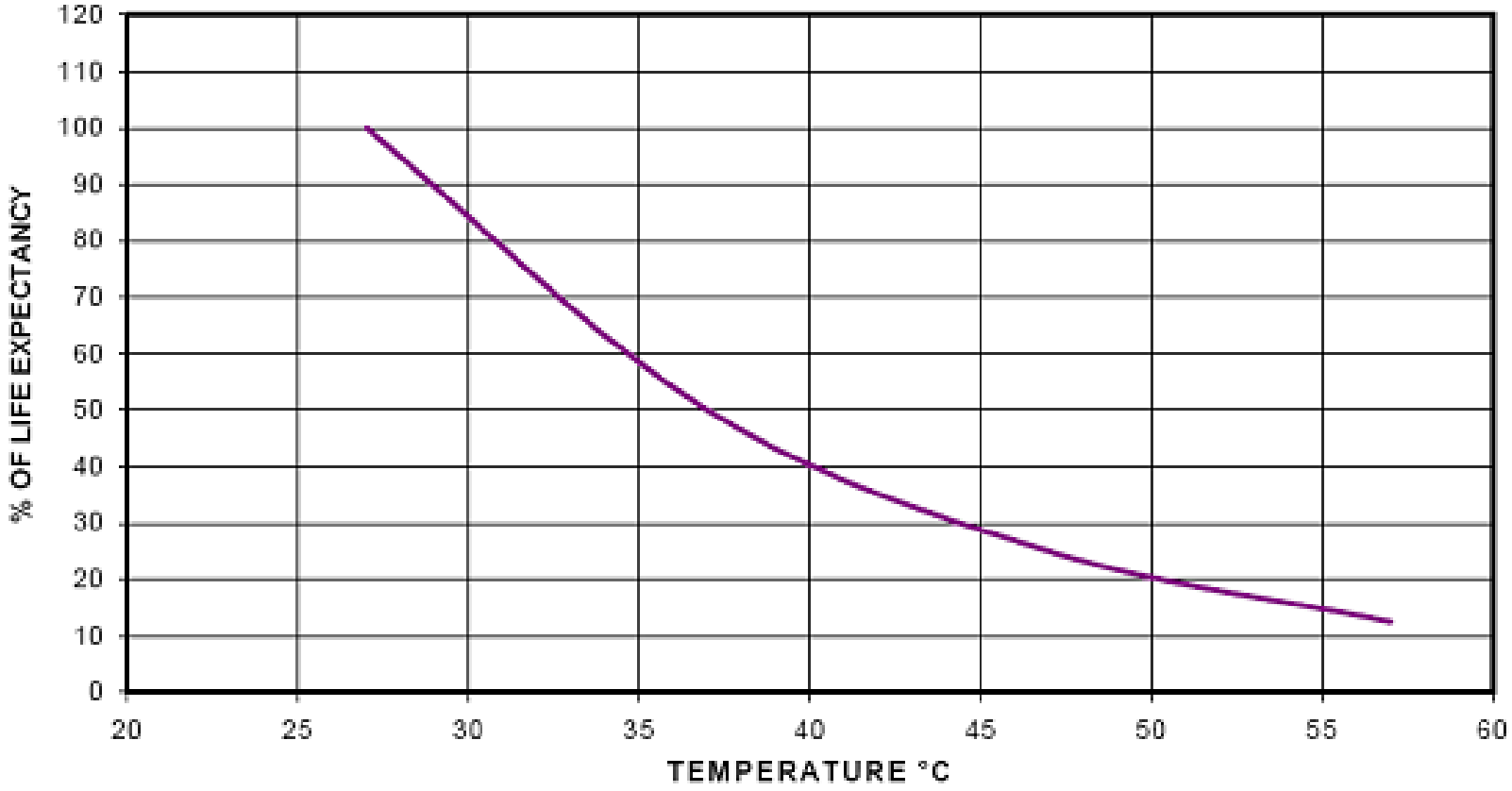
- Deep Cycle Batteries can be installed in conjunction with DC powered air conditioning to ensure optimal uptime during the discharge period, without BTS or Transmission Equipment shutting down due to high temperatures.

- Advantages of Deep Cycle when compared to conventional batteries:
  - ✓ Longer life-cycle
  - ✓ Lower Maintenance
  - ✓ Exceptional recharge efficiency
  - ✓ Exceptional charge acceptance
  - ✓ Less dependent on complete recharge following an outage
  - ✓ Better performance in adverse temperature conditions

Deep Cycle Batteries



Deep Cycle Batteries



Power Interface Units (PIU)

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- Power Interface Unit, which is commonly known as PIU, is the most modern electrical interface and control unit used for GSM / Telecom installations.
- The system is intended to replace Servo Stabilizer, AMF Panel, Isolation Transformer, AC Distribution Panel, Lightning and Surge Arresters, Alarm Panel, Generator Battery Charger, etc. installations at telecommunication sites.
- The advance feature of the unit provides input voltage correction in µs to enable the user to utilize the AC mains even under extreme low voltage conditions which servo technology was not able to offer due to slow response.
- The input voltage is isolated completely.
- PIU has very fast true RMS measurement with High and Low voltages disconnect facility.
- PIU will be installed on all newly Eaton built sites and where the existing electrical cabinets and equipment are out-dated and in need of replacement.

Power Interface Units (PIU)

- The PIU is a single outdoor unit consisting of the following components:
  - Input Interface & Auto Phase Selector Panel
  - AC Distribution Panel
  - AMF & Interlock Panel
  - Static Line Conditioner
  - Alarm Interface
  - Central Supervisory Unit

- The main advantages of the PIU includes the following:
  - ✓ Higher degree of automation
  - ✓ Longer mean time between failures (MTBF)
  - ✓ Better lightning and surge protection
  - ✓ Better generator control management
  - ✓ Inbuilt network management system, better alarms and security
  - ✓ Better input voltage correction
  - ✓ Automation with remote control of sites with either SMS or GPRS gateways
  - ✓ Isolation Transformer, AC Distribution Board, Line Conditioning & AMF Panel
  - ✓ Utilising AC mains under extreme low voltage condition

Full Hybrid Systems

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- In order to optimise the economics of a Hybrid solution, the goal is to maximise the battery time and minimise the charging time.

- The application relies on tight cyclic control to ensure that the battery achieves maximum effectiveness via either a pre-determined, or calculated based discharge and recharge regime.

- Other forms of hybrid may also include solar and wind assistance, which further complement the solution enabling reduced generator operation and extending battery life. However, the use of such components requires much further analysis on site specifics and the meteorological environment

- Typically, an AC generator system for an off-grid telecoms site runs 24 hours per day and is sized to match the site potential peak power demand - equipment start-up demand, air conditioning start-up and the large current required to charge a depleted set of UPS batteries.

Full Hybrid Systems

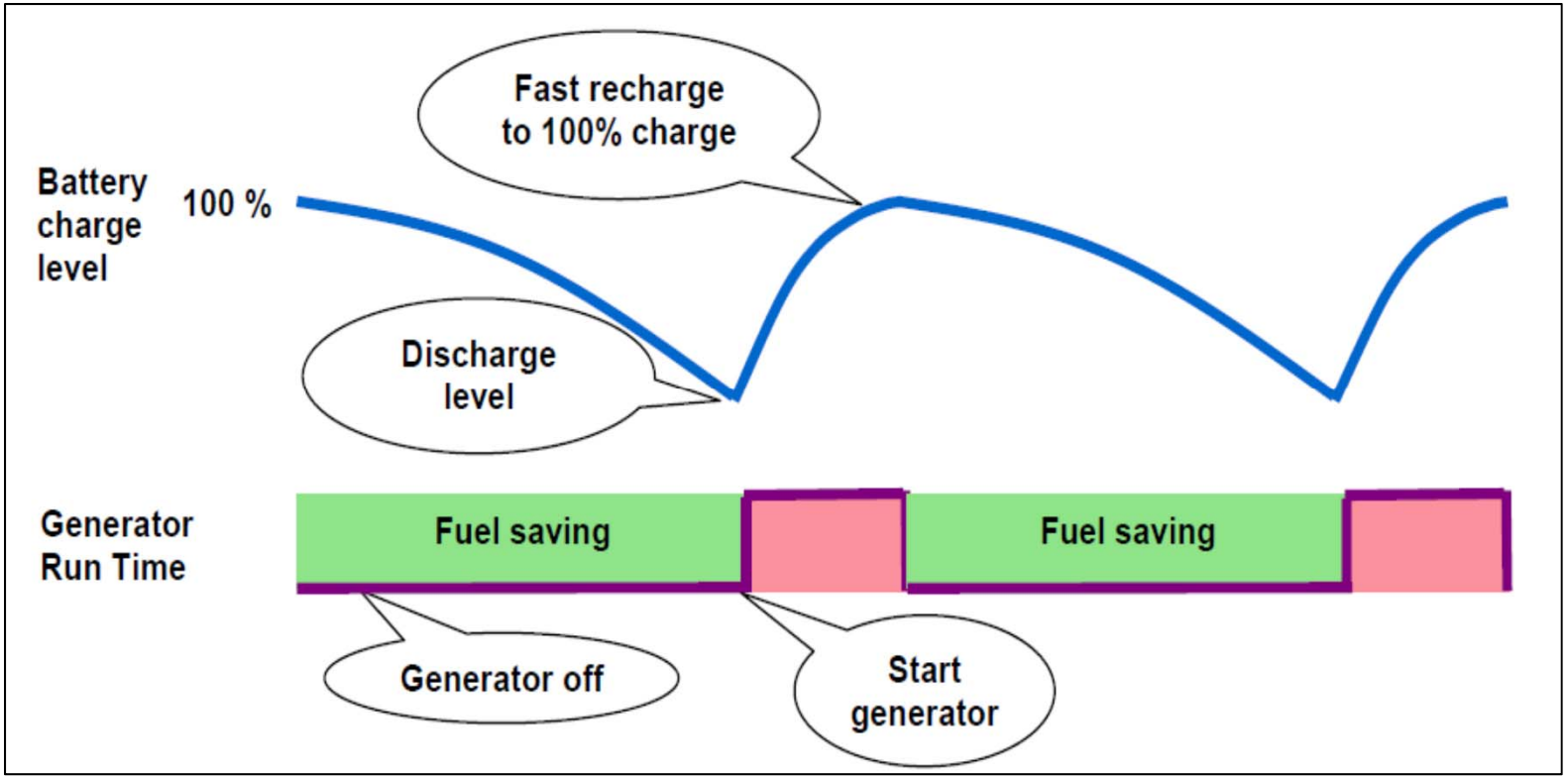
- Unfortunately the peak demand is many times greater than the average site load and very rarely occurs. On a typical site, the peak demand might be 15kW while the average site load might be only 1.5kW. This results in a generator solution which is dramatically oversized and runs 24 hours per day against a fraction of its rated load for most of the time.

- The hybrid system increases the average site load on the generator to approximately 75% of its maximum capacity ensuring better fuel efficiency.

- DC Air Conditioners will be installed for cooling the equipment shelter during the hybrid cycles. DC Air Conditioners eliminate the requirement to install an oversized generator for the high initial in rush current required by conventional air conditioners.

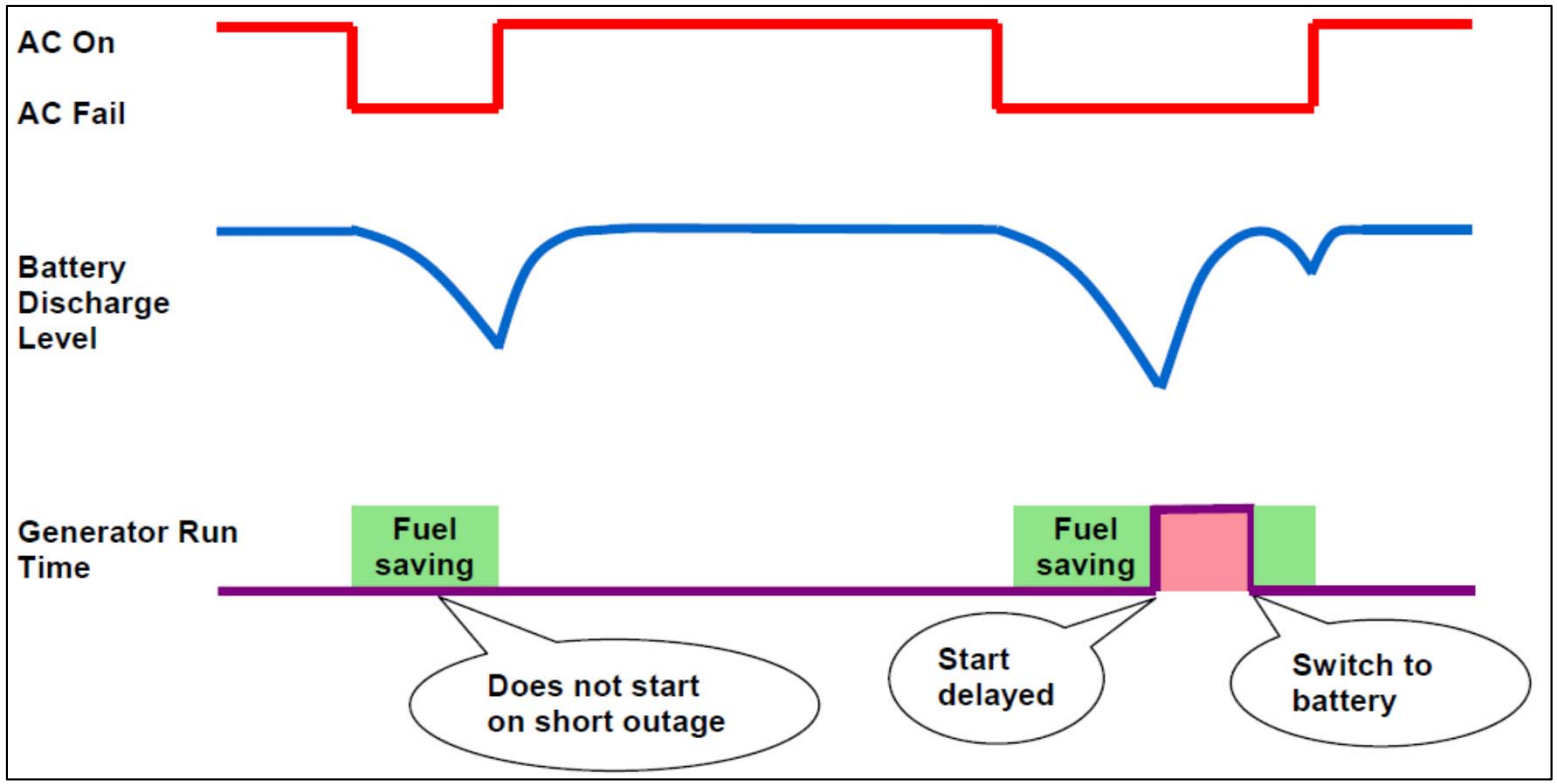
Full Hybrid Systems

- The operation of a hybrid is as follows:
  - Generator runs, powering load and charging batteries
  - Batteries reach a configured high state of charge
  - Generator stops and batteries supply power to load
  - Generator restarts when the state of charge of batteries reaches a configured low



Full Hybrid Systems

- Full Hybrid Systems can also be deployed at sites with frequent power outages.
  - The battery bank will provide power to the site until the power is restored.
  - The generator will only start if the power has not been restored before the battery bank has reached the set discharge level.
  - In some cases the standby generator can be recovered.



Full Hybrid Systems

- The generator in a hybrid system only runs between 25% and 75% of the day depending on the site load.

- Since the battery bank can supply peak power demands, the generator is sized to cope with the average site and battery charge loads ensuring optimum efficiency.

- This combination of reduced run hours and proper engine sizing delivers the following benefits:
  - daily fuel consumption reduction of up to 80%
  - extended maintenance intervals and maintenance cost reduction of up to 75%
  - extended engine lifetime of up to 300%
  - CO2 emission reduction of up to 80%

Intelligent Generator Controllers

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- An intelligent Generator Controller is an integral part of the successful integration to the Site Monitoring Equipment

- As part of standardising throughout the Eaton operation it has been decided to adopt the Deep Sea (DSE7320) controller when upgrading.

- The enhanced features DSE7320 offers include
  - ✓ A real time clock for enhanced event and performance monitoring
  - ✓ Ethernet communications for low cost monitoring
  - ✓ Preventative maintenance features to detect engine part faults prior to a major problem occurring.
  - ✓ When the module detects an alarm state, it can dial out to a PC notifying the user of the condition (Modem required).
  - ✓ The module can be controlled remotely using either a GSM Modem or via RS485.
  - ✓ The module has been designed to be integrated into Site Monitoring Equipment using RS485.
  - ✓ The module includes a comprehensive event log that shows the most recent 250 alarm conditions and the date and time that they occurred. This function assists the user when fault finding and maintaining a generating set.

Site Monitoring equipment

- The system to be installed by Eaton will provide remote management through GSM SMS messaging or GPRS connectivity.
- To provide even higher flexibility, only dual SIM card systems will be installed allowing network selection or alternative network fall back (redundancy).
- Highly reliable and compact hardware is installed on-site and continuously communicates with centralised servers.
- Web-based user interfaces provides a user friendly solution to access site information.
- Powerful graphing and report generating capabilities provide highly flexible access to site information.

Site Monitoring equipment

- Site Monitoring equipment will have the following advantages:
  - ✓ Protected revenues through improved site availability
  - ✓ Reduction of operating costs through higher efficiency
    - ➢ Improved Fault Management
      - Information on fault conditions allows the dispatch of correctly skilled engineers
      - Pre-warning of faults before site downtime occurs
    - ➢ Improved Service Management
      - Monitoring of equipment running hours and battery cycles
      - Prediction of service dates to improve scheduling
      - Monitoring of site access to test access against service bills
    - ➢ Improved Fuel Management
      - Fuel consumption, including alerts for abnormal usage
      - Refuel prediction reports for scheduling refuelling visits
      - Low fuel alerts to prevent running out of fuel
      - Monitoring of refilling times and volumes to cross-reference with billing
      - Fuel theft alerts

Site Monitoring equipment

- ✓ Improved energy efficiency
  - ➢ Power consumption monitoring
  - ➢ Power source optimisation
  - ➢ Battery cycling
- ✓ Reduced site visits by using Remote Control features
- ✓ Site Security and Environmental
  - ➢ Detect site access/intrusions
  - ➢ Fire and smoke detection
  - ➢ Temperature and humidity measurement
- ✓ Data analysis and reporting
- ✓ Numerous alarms will be available including but not limited to:
  - ➢ Smoke, Fire and Temperature alarms
  - ➢ Air conditioning status/alarm
  - ➢ Mains failure alarm
  - ➢ Generator and Diesel tank status/alarms
  - ➢ Intruder (gates and doors) alarm
  - ➢ Battery alarms
  - ➢ etc.

Oil management system

- Advanced oil management systems that significantly extend oil change intervals and filter life will be deployed in order to decrease downtime and lengthen an engine's life span.

- It is an automatic oil exchange system
  - ➢ While the engine is running the oil management system removes a small amount of used engine oil and blends it with diesel fuel to be burned during combustion.
  - ➢ The used oil is then replaced with an equal amount of fresh oil from a make-up tank.

- Benefits of using oil management systems
  - ✓ Extended periods between oil changes of up to 4,000 hours
  - ✓ Extended periods between filter changes of up to 1,000 hours
  - ✓ Enhanced engine protection
  - ✓ Converts used oil into productive energy
  - ✓ Minimizes waste handling and disposal costs

Further OPEX reductions

- BTS equipment specifically designed to support either 2G (900 and 1800) or 3G is been deployed resulting in huge power demands. Newer technologies such as software defined radios (SDR) are capable of providing all the services an operator requires within a single system.

  - ✓ Reduced power requirement of up to 60%
  - ✓ Reduced heat generation as transmitters are fitted outdoors on the tower
  - ✓ Utilising a single antenna to support all frequencies broadcasted frees up space on the tower for future expansion
  - ✓ Reduction in physical dimensions

- Typically a tenant would need two 12000 BTU AC powered air conditioner units for cooling of a 2.4m³ shelter. These shelters require a land area of 3.0m x 3.0m. Outdoor cabinets with a smaller footprint and capable of housing multiple tenants' indoor equipment are available and could be used.

  - ✓ Reduced cooling requirement leads to reduced power consumption
  - ✓ Cooling equipment has a lower start-up current demand which reduces the capacity of the back-up generator required
  - ✓ Reduces operations and maintenance costs as only one common cooling system needs to be maintained
  - ✓ Reduced footprint provides more space on site for future expansion

Future Considerations

- Renewable and alternative energy production

  - ✓ Solar
  - ✓ Wind
  - ✓ Fuel cells utilising Anhydrous Ammonia
  - ✓ Vanadium Redox Batteries (VRB)

Uganda specific – OPEX efficiency

- Electricity
  - Ensuring that all poor electrical installation works is corrected should bring about a **2%** savings
  - Reduced cooling requirements from shelters by ensuring that they are properly sealed has brought about a **1.2%** savings in our Ghana operation and we expect to realise the same in Uganda.
  - Further investment to energy savings components, i.e. LED navigation lights, replacing halogen and filament bulbs with florescent, free cooling, etc…
    - ✓ Savings from bulb replacement
      - Average NAV light bulbs per site ((615 * 5) + (65 * 2))/680 = 4.71
      - Average consumption of NAV lights per site per day (40W * 4.71 * 10h) = 1.885 kWh
      - Average site consumption per day (2.87kW * 14h) = 40.14 kWh
      - Percentage of average consumption assigned to NAV lights (1.885/40.14) = 4.69%
      - Average consumption of LED type NAV lights per site per day (7W * 4.71 * 10h) = 0.3297 kWh
      - Percentage of average consumption assigned to LED type NAV lights (0.3297/40.14) = 0.82%
      - Average savings per site when replacing existing NAV lights with LED type (4.69 – 0.82) = **3.87%**
  - Total savings (2 + 1.2 + 3.87) = **7.07%**

Uganda specific – OPEX efficiency

- Diesel
  - A **3%** savings could be realised by:
    - ✓ Improving on diesel procurement and distribution processes
    - ✓ Correcting of damaged fuel lines
    - ✓ Proper servicing of generators
  - December 2013
    - ✓ Hardening of diesel storage and fuel lines
    - ✓ Improved efficiency by replacement of end of life generators
      - o 124 generators been replaced will consume 10% less diesel
      - o 1 – ((124 * 2.78 * 0.9) + ((649 - 124) * 2.78)) / (649 * 2.78) = **1.91%**
    - ✓ Ensuring, where possible that off-grid sites are connected to the AC-grid
      - o 20% of the 174 off-grid sites = 35
      - o Cost per day of generator running for 35 off grid sites (4.38 * 24h * 35) = US$ 3,678.50
      - o Cost per day of generator running for 35 sites connected to grid (3,678.50 * (10/24)) = US$ 1,532.71
      - o Savings per day for 35 sites connected to grid (3,678.50 – 1,532.71) = US$ 2,145.79
      - o Total cost for all sites per day before (649 * 4.38 * 10) = US$ 28,426.20
      - o Savings across portfolio 1 - ((28,426.2 – 2,145.79)/28,426.20) = **7.55%**
    - ✓ Ensuring optimal usage of AC-grid power
      - o Reduction in generator run time from 10 to 4.5 hours per day on 206 sites
      - o ((10 – 4.5) * 4.38 * 206)) / (10 * 4.38 * 649)= **17.46%**
    - ✓ Total savings (3 + 1.91 + 7.55 + 17.46) = **29.92%**
  - December 2014
    - ✓ Deployment of hybrid systems to remainder of off-grid sites
      - o 174 – 35 = 139 sites
      - o Expected savings in fuel per day (50% * 139 * 4.38 * 24h) = US$ 7,305.84
      - o Savings across portfolio 1 - ((28,426.2 – 2,145.79 – 7,305.84) / (28,426.2 – 2,145.79)) = **27.8%**

Uganda specific – OPEX efficiency

- Security
  - Hardening of current site conditions by:
    - ✓ Implementing stringent access control processes
    - ✓ Deployment of high security locks
    - ✓ Diesel storage and fuel lines
    - ✓ Implement as part of the site monitoring system intrusion detection
  - Replacing wire mesh and steel palisade fences with block walls allowing security guards to be removed from site.
  - Possible deployment of CCTV surveillance to reduce presence of physical guards and/or drive by patrolling
  - Installation of panic buttons on site
    - ✓ Reduce the presence of physical security guards
    - ✓ Provide immediate response from security companies when required
  - Continual assessment of guards and drive by patrols to ensure optimal placing and utilisation of security forces

Uganda specific – OPEX efficiency

- Operations and Maintenance
  - ➢ Evaluation of current preventative maintenance program and optimising by introducing more stringent controls
  - ➢ Correctly dimensioning headcount and location of field support teams
  - ➢ Deployment of site monitoring equipment
  - ➢ Through the SMC measure equipment performance and proactively repair or replace where needed
  - ➢ Stabilising the current situation by either repairing or replacing faulty and end of life equipment
    - ✓ Automatic Transfer Switches (ATS) to ensure automated load transfer between AC-grid and generator supply
    - ✓ Air conditioning units to ensure optimal cooling
    - ✓ Generator control panels to ensure that generator start/stop function is fully automated
    - ✓ Generator starter batteries to ensure minimal to zero failure during AC-grid interruptions
    - ✓ Site earthing refurbishment and/or enhancement to reduce the impact from lightning strikes
    - ✓ Installation of Class1 surge arrestors to reduce the impact of lightning strikes and surges on the AC-grid
    - ✓ Replacement or refurbishment of exhausted diesel generators will reduce the operational expense with regard to maintenance and fuel consumption
    - ✓ All generators replaced/refurbished will be fitted with oil management systems to increase service intervals
  - ➢ Power optimisation deploying power management systems
    - ✓ Correction for loss of phase voltage
    - ✓ Correction of abnormal grid voltages
    - ✓ Utilise ETKL newly installed batteries to the maximum by utilising all available power sources
      - o During AC grid power failures which PMU cannot rectify, only start the generator when a battery recharge is needed or when the room temperature reaches a critical high

Uganda specific – OPEX efficiency

- Site Management

  - Key to managing site OPEX is to have a strong management tool in order to track performance and evaluate the key initiatives that are implemented. Eaton will install INALA Site Management which provides both O&M function as well as Administrative function. The three main functions of the INALA Management system are:

    - ✓ Alarm Management
      - Eaton can more effectively manage passive network performance, respond faster to system failures and reduce unnecessary call outs. Eaton's SMC automatically detects network alarms and generates trouble tickets. A team of NOC personnel ensure the trouble ticket is efficiently and effectively manage. All escalation is automated up to senior management. Eaton is well positioned to manage its SLA to ensure SLA penalties are avoided
    - ✓ Power Management
      - Eaton produces monthly power reports for all tenants of the site, based on contractual arrangement, Eaton can increase power consumption tariffs charged to tenants for high usage. Eaton also monitors the monthly averages trend to ensure that power consumption is controlled and maintained
    - ✓ Fuel Management
      - Eaton will have a comprehensive view of fuel consumption, fuel deliveries and fuel theft. The fuel management system automatically reports on fuel theft (via email) and provides graphical reports on the theft.
      - When crosschecking for fuel delivery the Administration team validate against the fuel report, this will show clearly the precise time and volume of the delivery.







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