Case Study: Hybrid Power System for UNHCR

Presently in Operation - Study covers Sept 28th, 2024 to Feb 17th, 2025

Polar Power is pioneering technologies that can radically change the production, consumption, and environmental impact of power generation

POLAR POWER INC.

Nasdaq: POLA

BACKGROUND

- UNHCR submits an RFQ with the purpose of reducing fuel usage and emissions for their utility backup systems.
- Most UN locations have 2 AC gensets, typically one of the two being larger to handle varying site loads.
- In poor grid areas with critical loads, it's typical to have more than one backup generator on site to manage the extended run times.
- Additional requirements included: Portability, ease of installation, remote access for configuration and control with advanced telemetry.
- UNHCR selected Polar Power for DC genset efficiency, innovation, lower cost and field experience in hybrid systems.

- The most common backup power solutions in Nigeria are diesel fueled AC generators operating continuously during a power outage.
- What is creating a demand for change?
  - Increasing diesel costs
  - High fuel consumption
  - Increasing diesel fuel theft
  - Loud noise
  - High Maintenance costs due to continuous operation
  - Reliability issues with automatic transfer switch (ATS)
  - Lack of automation (runs longer than necessary)

BACKGROUND

Polar's Hybrid power system is cost effective solution in both off-grid and bad grid sites, and cuts diesel fuel costs by up to 85% while providing considerable savings in maintenance costs. A two-cabinet modular design, or an all-in-one single shelter solution, allows for high reliability and ease of installation. Polar's Hybrid works as a fuel-solar-grid-battery solution. Fuel options include diesel, LPG and natural gas (LNG, CNG, and pipeline). Battery options include a wide range of chemistries.

Polar's DC Generators are designed and optimized to deliver efficient charging power at wide range of battery voltages and charging currents. Due to genset's DC output, battery chargers or power supplies are not required. Generator controls have built in charging algorithms, or can receive charging instruction from the battery BMS.

Polar Power generators are customized to client needs pertaining to packaging, climates, power outputs, voltage ranges, and fuel types. DC generators can be simply paralleled for increased power and redundancy.

Polar offers LPG and Natural Gas generators with maintenance service intervals exceeding 4,500 hours of usage along with 60,000 to 90,000 engine life. Generators' service life can exceed 100,000 hours

Polar Power's fully integrated power generation and energy storage True Online Hybrid Solutions are more efficient than a typical backup system. Whether it's a complete loss of grid, or frequent power outages, or dirty grid, our solution protects the site and its functions.

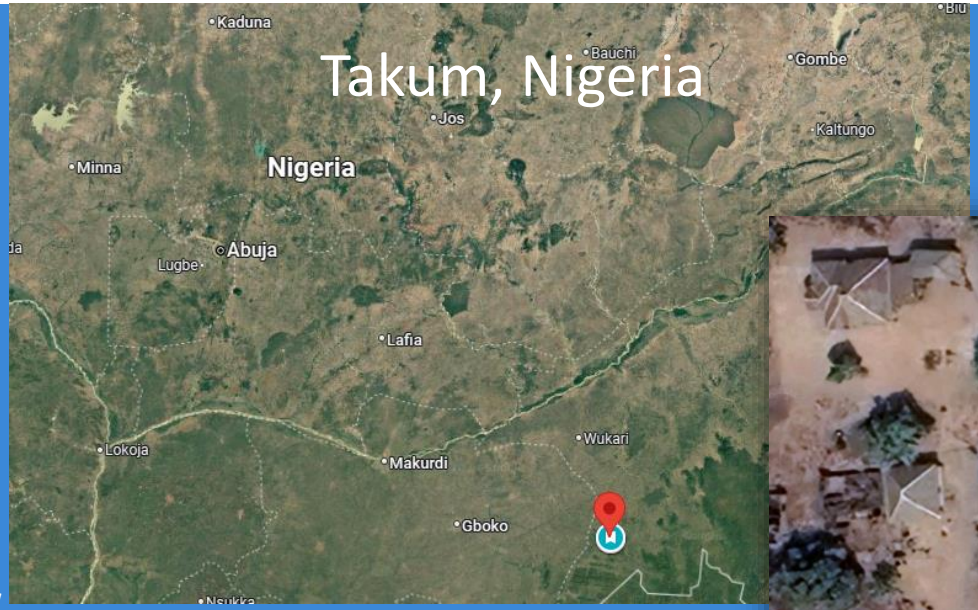
Typical AC generator or battery backup UPS systems have a power delay in restoring power to the load anywhere from milliseconds to minutes. Interruptions of milliseconds can cause computers and servers to reboot. Breaks in power can cause surges and voltage spikes in equipment, causing equipment failure over time.

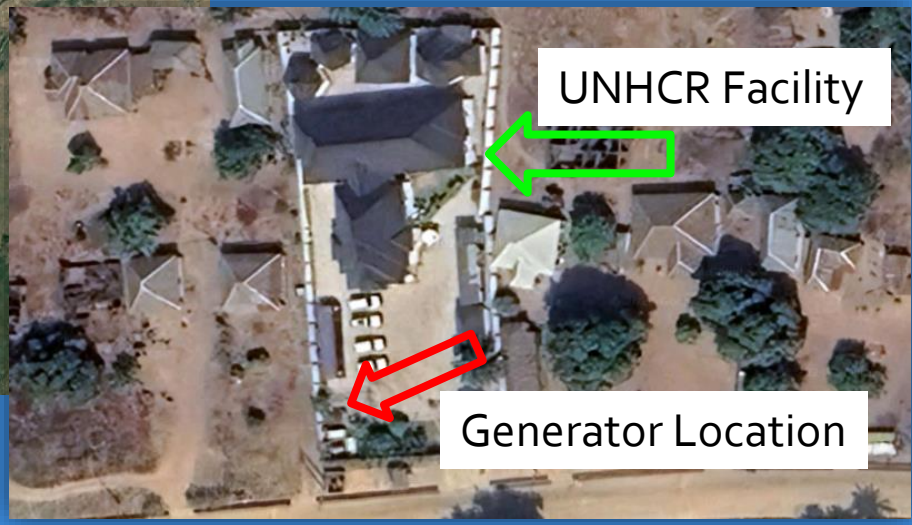
Polar's True Online backup does not have any interruption in power, regardless of grid availability or intermittent grid conditions. It uses multiple technologies including battery, grid, solar, and DC generator to overcome issues with the use of single backup technologies. High level system integration makes significant improvements in fuel efficiency, emissions reduction, reliability, and lifetime cost of ownership.

Polar Power offers a wide range of generator sizes and fuel types to support sites globally, and provides the most efficient means of maintaining power to the site.

LOCATION AND ENVIRONMENT

- Site loads:
  - Office and Hotel accommodations
  - Security living quarters
  - Fitness center
  - Kitchen
  - Laundry
  - Water pump
  - Server and UPS system (5kWh)
  - Split AC systems
  - 2 AC Generators on site (100kVA / 70 kW and 50kVa)

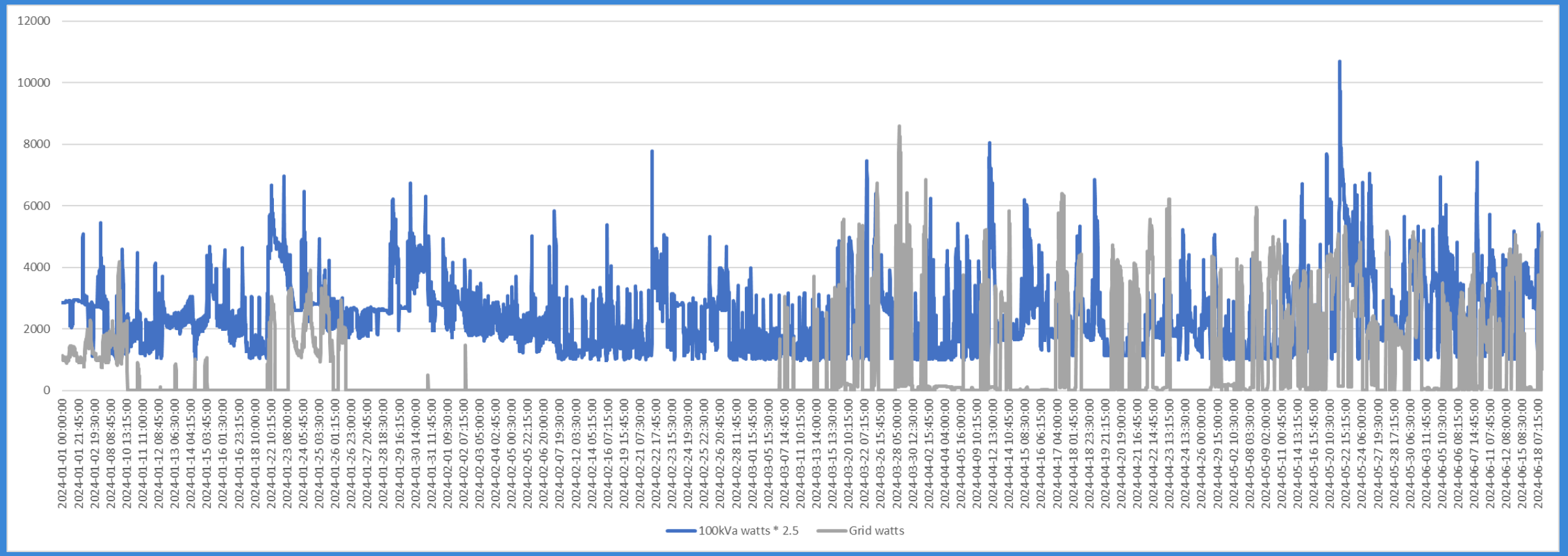




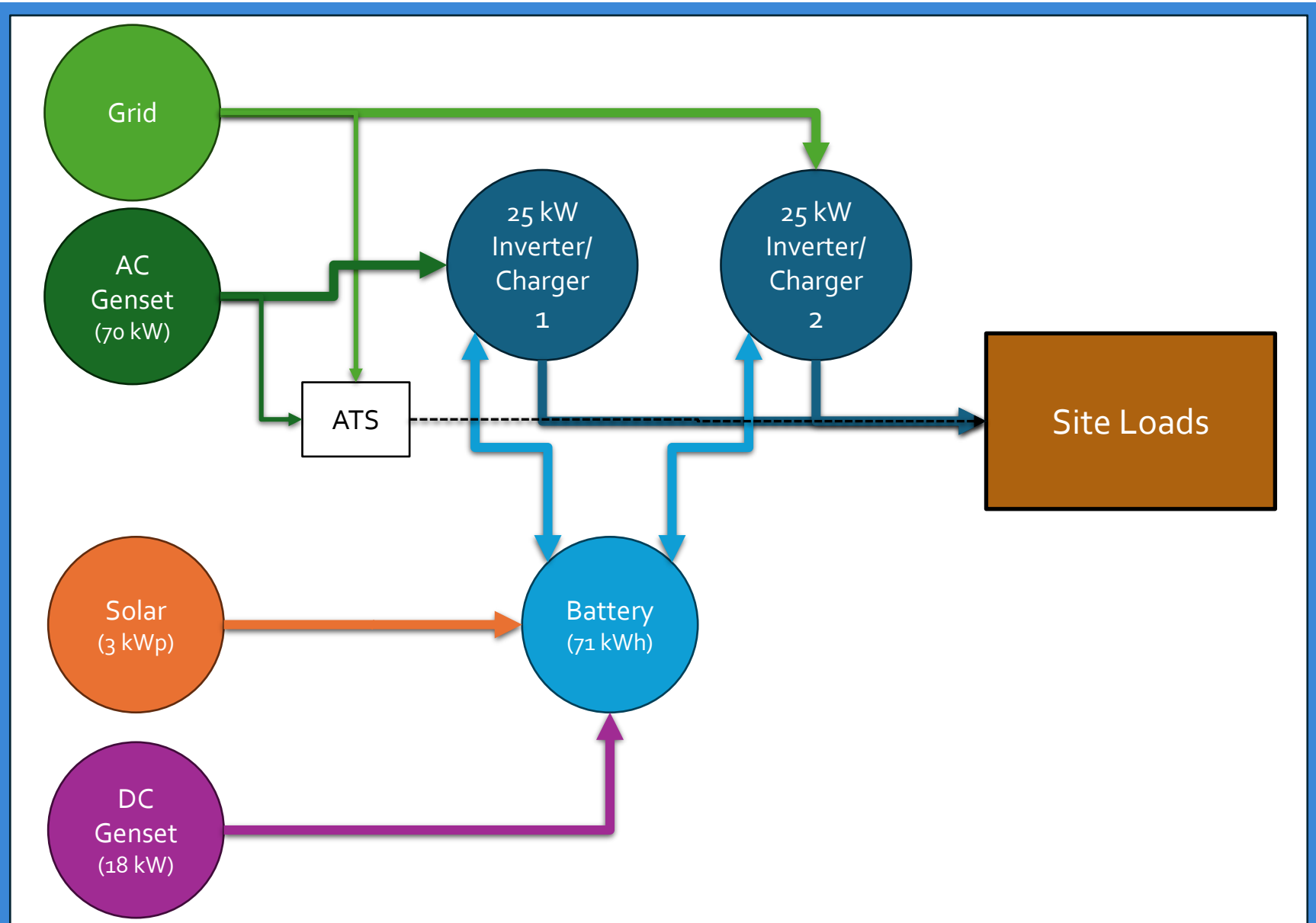
INITIAL SITE DATA - ESTIMATES

Original data analysis (provided by UNHCR)

- Data was known to be incomplete, therefore some initial estimations were made. Actual site load requirements (kWh) turned out to be much higher than estimated.
- Collection of site data is challenging, and it was found that the sensors for data monitoring on site were not complete, for example, data from all 3 phases was not available. Data from only 1 phase was accurate for the AC generator. Also, data was overlapping, so the assumption was made that the grid was not available when the AC generator was running.



DESIGN PROPOSAL



System capabilities

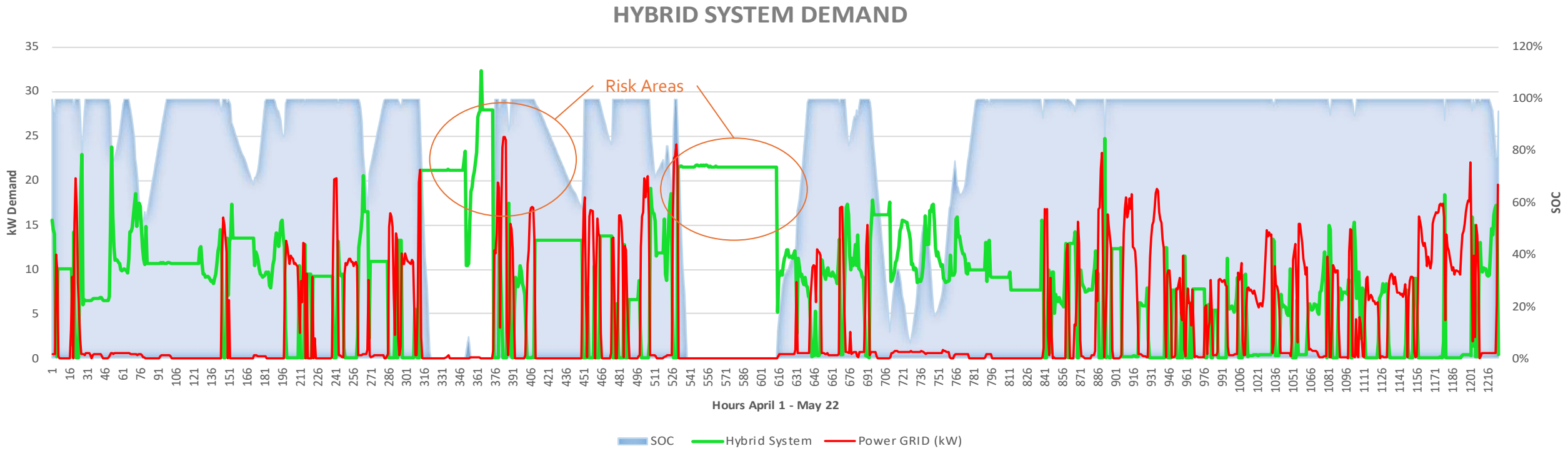
- True online system
- Powers loads up to 50 kW, expandable.
- 3 kWp of Solar, expandable
- Polar DC Gen 18 kW, additional DC generators can run in parallel
- Customer's optional AC Gen 70 kW
- LiFePo4 Battery 71 kW expandable to 142 kWh

True online system provides clean and uninterrupted power to the site for loads up to 50 kW.

Beyond 50 kW, the grid will connect directly to the site, or if grid is unavailable, the AC gen will run and connect directly to the site.

PROJECTIONS

BASED ON UNHCR RECORDED DATA



A simulation was performed against actual recorded data to show the projected performance of a hybrid system. The hybrid system would use the DC genset and Grid to charge the batteries.

Projections show that a 12.5 kW DC genset paired with 71 kWh of Lithium batteries would cover the loads for the site, with possible risk during the periods of missing data and in certain conditions where batteries are low, and load is exceptionally high. (As a safety margin for this project, an 18 kW DC genset was selected.)

Power usage: The DC generator starts charging when either the State of Charge (SOC) of the battery pack goes below 30% and stops when SOC reaches 90%. Or the DC generator starts when loads exceed the ideal discharge rate of the battery.

Projections Summary			
Grid Uptime	377	hours	
Hybrid Runtime	1058	hours	
Days	52.0		
AVG Load	12.7	kW	
Peak Load	28.0	kW	
Longest grid outage	156.0	hours	
Highest Hybrid Demand	62h @22.2kW		AC Gen Required
	< 18.1	hours of battery	
	313 - 375		
Battery Capacity	71.7	kWh	
Generator Capacity	**12.5**	**kW**	

PROJECTED COST AND SAVINGS

Projection Summary			
Grid Uptime		225	hours
Hybrid Runtime		190.5	hours
Days		17.3	Days
AVG Load		4.3	kW
Peak Load		12.6	kW
Longest grid outage		28.5	hours
Original Fuel Usage		655.4	Liters
Hybrid Fuel Usage		260.5	Liters
AC Fuel Usage		0.0	Liters
Fuel Savings		**60%**	
April fuel cost	$	0.96	$ 629.17
December fuel cost	$	0.91	$ 599.03
Projected April cost	$	0.96	$ 250.06
Projected December	$	0.91	$ 238.07

- Cost with AC generator solution: ₦862,415.90 per 190hrs with an average of 4.3 kW
- Cost projections with hybrid system: ₦343,502.43
- This estimation is based on April and May data.
- Estimated 60% fuel savings with Polar Hybrid system.
- **Note:** The actual collected data since the installation Sept 27, 2024, to February 17, 2025, shows fuel saving of 59% as determined by UNHCR program staff.

INSTALLATION PHOTOS

REMOTE MONITORING AND CONTROL

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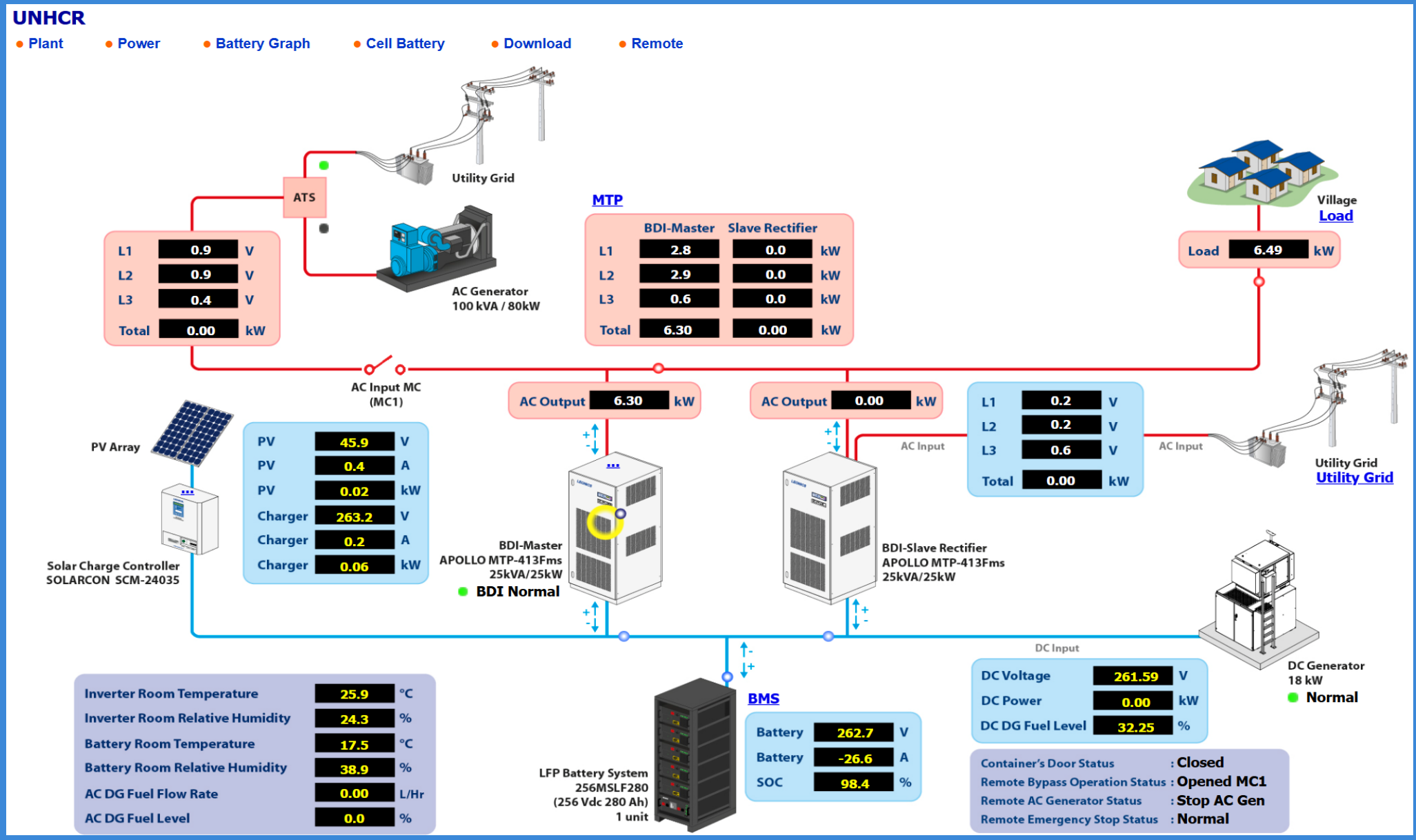
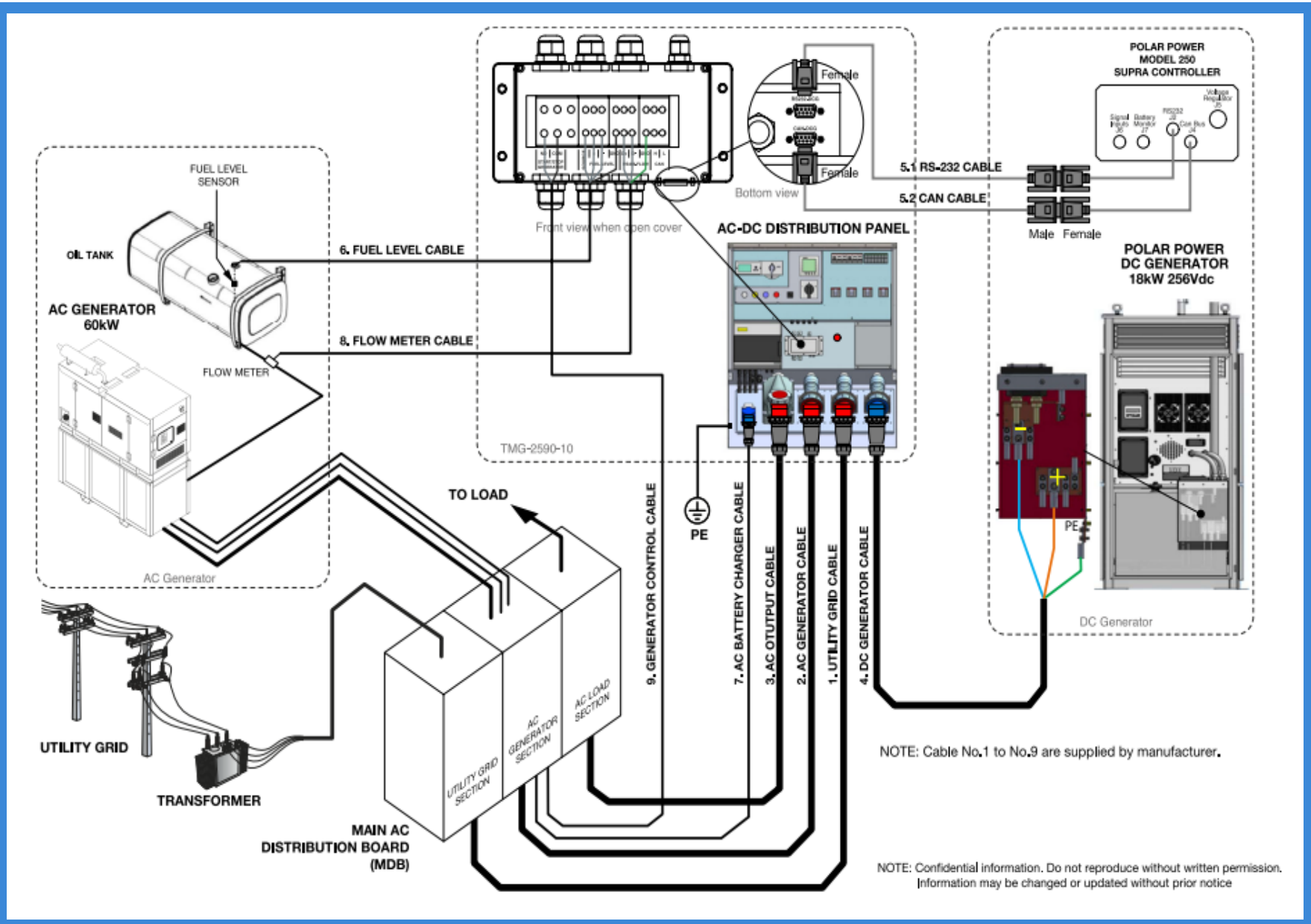
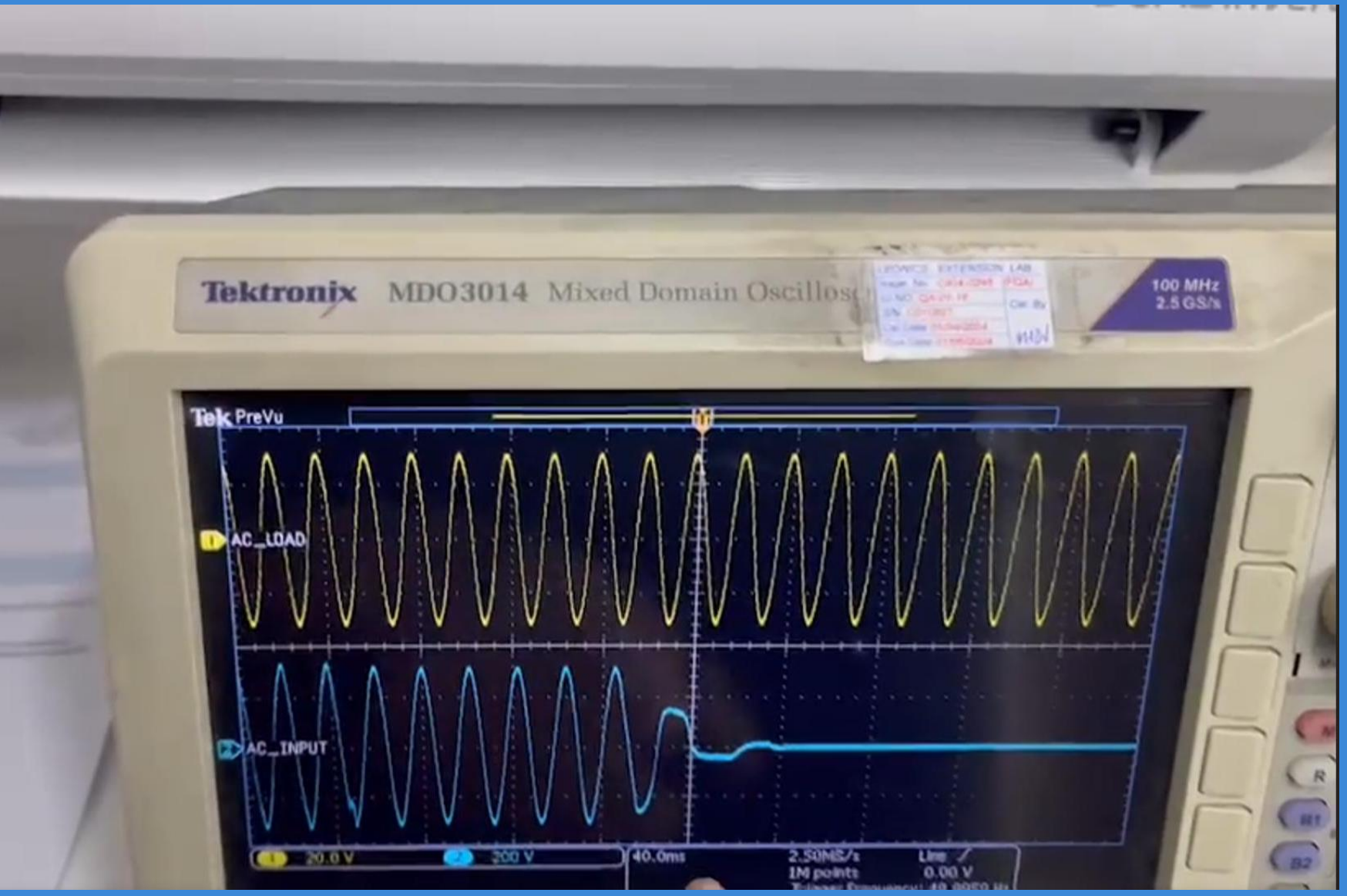


CONNECTION DIAGRAM



Quick disconnects for portability

TRUE ONLINE PERFORMANCE



The image shows True Online Hybrid operation. When the AC grid is lost, the output of this hybrid system goes unaffected, as there is no momentary loss of power as shown by the oscilloscope.

The grid is not connected to the load, but instead is converted to DC to charge the battery and provide power to the inverter. The inverter is always powering the load and providing cleaner power than the grid.

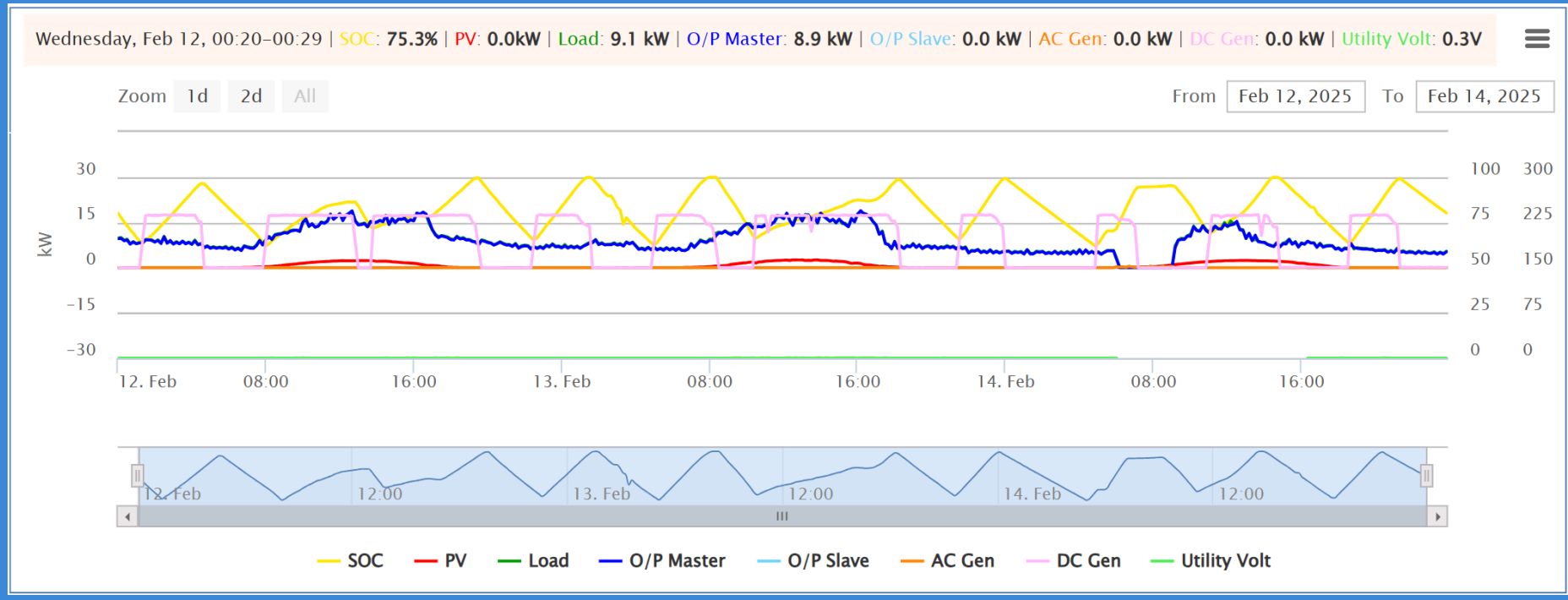
The hybrid system provides a high degree of isolation from the grid and its disturbances from voltage spikes, shifts in frequency, and loss of phases (dirty power)

Inverters supported with batteries can provide more stable power than the typical AC Generators.

RESULTS

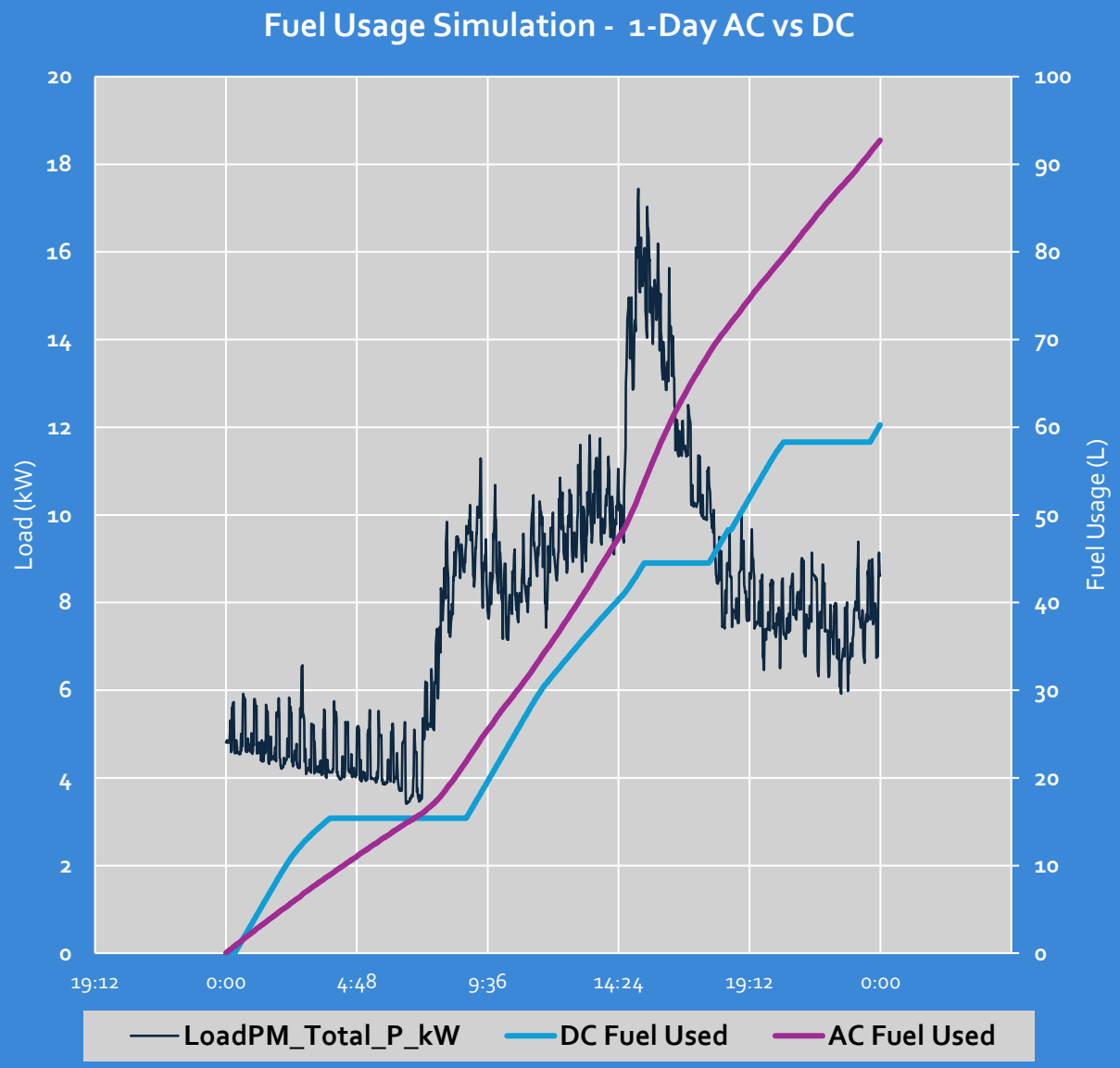
- Portable system as a theft-resistant, plug-and-play containerized package simplifying logistics and installation
- Installation time (5 hours)
  - 5 people / 3 hours to initial power on
  - 2 people / 2 hours solar installation
- Site power stability
  - Users report consistent power
  - No “light dimming” when grid fails
  - No computer reboots when grid fails
  - No outages for 4 months other than during testing
- Fuel usage (DC Genset): 3.24 kWh/L

Assisting Polar on this project: Leonics Ltd. (supplier of inverters and lithium batteries), Biohenry Ltd. (provided installation and maintenance services), and the Greening and Sustainability Team at UNHCR assisted in the system design and evaluation.

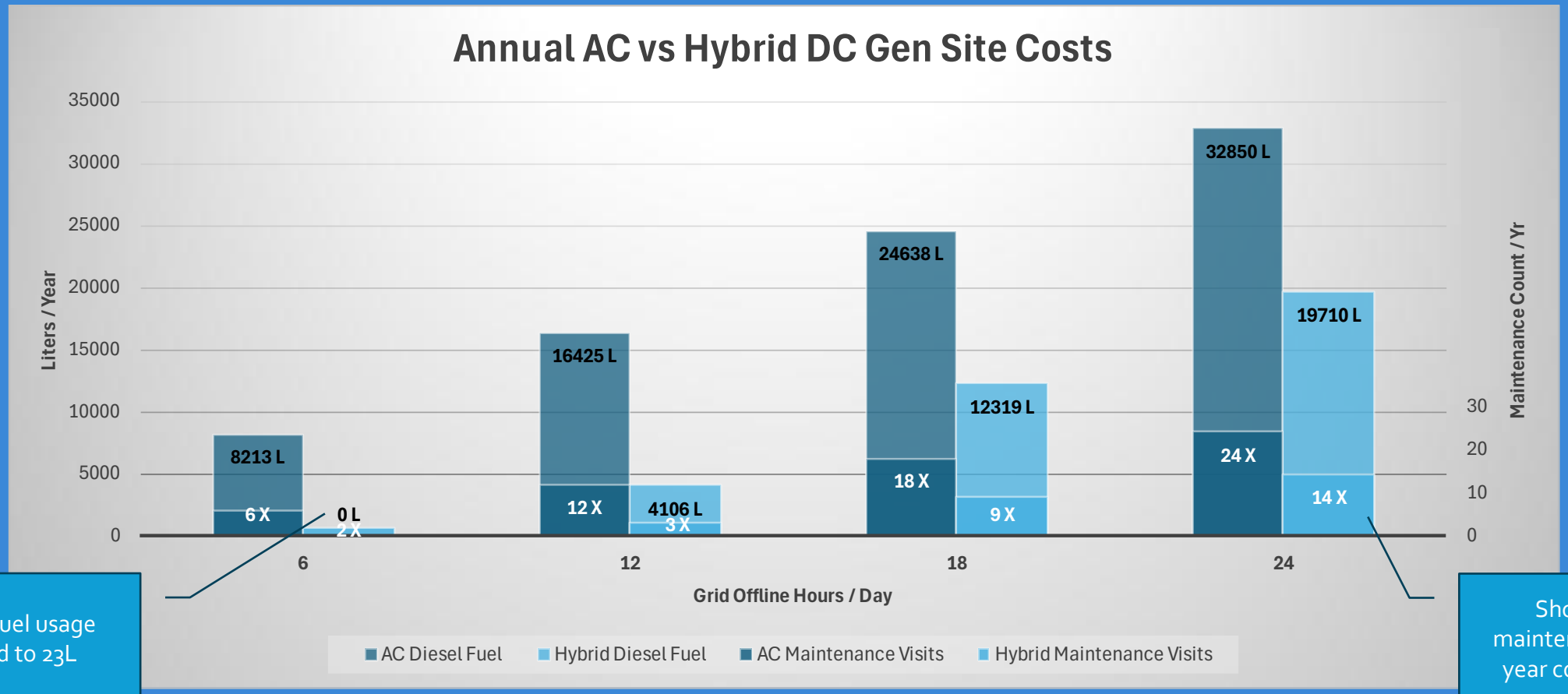


RESULTS – 24 HOURS NO GRID

- Comparing a 24-hour AC gen backup from April to a comparable 24-hour period in December where there was no grid entire day.
- We found the following
  - DC genset 50.6% runtime (subject to further improvement with software update)
  - AC genset 100%
  - Fuel savings 59.28% (kWh/L)
- In summary, during a 24-hour power outage the DC generator in the hybrid system had 50.6% runtime, compared to the AC generator's 100% runtime.
- In addition, the diesel fuel consumption per hour for the 70kW AC generator was considerably higher than the more efficient smaller 18 kW DC Generator.
- The DC generator used 60% less diesel fuel to service the same loads, or deliver the same amount of kilowatt hours.
- There is a greater reduction in fuel consumption for partial-grid situations, where battery covers load until grid returns. Thereby eliminating the need for the DC generator to run.



RESULTS – ANNUAL COSTS



Shows no fuel usage compared to 23L

Shows only 14 maintenance visits per year compared to 24

- Chart shows fuel savings and annual maintenance visits for AC backup vs Polar Hybrid system
- 6X annual maintenance represents 6 maintenance visits per year

CASE STUDY CONCLUSION

Events encountered from September 28th, 2024, to Feb 17th, 2025

- Faced 7+ hours daily grid downtime for first month of operation.
- Phases rotated by utility company in October. Note: Other competitors' hybrid sites were non-operational for over 3 months after this event.
- Supported over 2,240 hours of continuous grid down from Nov 16, 2024 to Feb 17, 2025

- Generators in rural areas need to be super quiet.
  - Generator Runtime switched Off for 6 hours during the night from midnight to 6am. Scheduling can be enabled to ensure generator remains off throughout the night.
  - Daily Generator run time during extended grid outage, 9 to 10 hours on a day with light-to-medium site load.
  - LPG DC generators are super quiet, and not easily noticed by neighbors or animals.

- Logistically not prepared for frequent oil changes and inspections
  - There was a V-belt failure, leading to an oil seal failure. DC generator was down for 3 days. During this time, power was cycled on the inverters and improperly turned ON, which caused a fuse to fail before the 24th. The system continues to operate with 50% capacity as we wait for the fuse to arrive. Still no grid during 3 months.
  - During the DC generator downtime, the AC generator was not able to assume the load due to the ATS failure.

- Faced unusual grid quality problems. Utility power to the grid is 3 phase, 240 VAC. How bad the grid could get was underestimated. A redesign on the utility input to the battery is being evaluated by Polar.
  - Phases dropped out, Grid voltages 224V, 147V, 112V
  - Large voltage swings, Grid Voltage reached 300V for 15 minutes
  - Huge changes in frequency. Grid frequency changing from 40 to 47 Hz when rated at 50 HZ +/- 10%

RECOMMENDATIONS / NEXT STEPS

- Having an AC generator as backup to the Hybrid System introduces the same Automatic Transfer Switch (ATS) problem that affects the standard backup systems. ATS switches can fail due 500-hour voltage spikes from the grid or AC generator, changes in grid phasing, large frequency fluctuations, and voltage deviations from phase to phase. During operation all the aforementioned events occurred. For backup, a second DC generator is recommended with an additional inverter.

- Presently the largest parasitic load is the Air-conditioner for the batteries. Air-conditioner draws between 400W to 750W and operates 24/7 at the test site. A redesign of the cooling air flows within the enclosure could reduce the air conditioning load.

- At only 3 kWp the solar array is undersized, but its original intention was to demonstrate the practicality of combining solar with diesel fuel and utility grid. Increasing the solar array size will reduce both diesel fuel consumption and utility costs. The solar PV arrays can provide convenient shading for car ports, and solar on the roofs of the cottages / offices will reduce the air conditioning load by shading the roofs and generating electricity.

- To reduce noise pollution, diesel smell, and the 500 hour oil service interval we recommend use of LPG fuel gensets in place of diesel gensets. Polar's LPG DC generators based on the Toyota prime power engines have oil change intervals of up to 4,500 hours, and have eliminated V-belts and engine coolant pump for increased reliability.

- LPG DC generators are extremely quiet. In many areas LPG fuel cost is lower than diesel and the LPG is harder to steal.

- Recover the waste heat off the generator and use it for space heating, bathing, laundry, and washing. Also use the LPG directly for cooking. This will lower the cost of batteries, inverters, generators and reduce fuel consumption. In the process of using fuel to generate electricity about 20% to 30% of the fuel converts to electrical energy, and 80% to 70% of the fuel energy goes off as heat.

ADDITIONAL RESOURCES

- https://polarpower.com/
- https://polarpower.com/products/dc-alternators/ac-vs-dc/
- https://polarpower.com/products/dc-generators/
- https://polarpower.com/hybrid-power-systems/
- https://ir.polarpower.com/press-releases/detail/78/polar-power-completes-installation-of-unhcr-nigeria-contract