COMMUNICATION NETWORKS

Advanced Connected Energy:

A New Technique for Making Lead-Acid Batteries Intelligent

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INTRODUCTION

Batteries are the foundation of energy storage in communications and data networks. Batteries ensure wireless and wireline networks remain on even during grid failures. In areas where electrical grids are not available, batteries are essential to storing energy generated by weather-dependent renewable sources such as solar and wind. These fundamental solutions to energy storage are ubiquitous, helping to keep the world connected and functioning.

Despite the essential role batteries play in ensuring network continuity, network operators are often blind to their status. Frequently, operators find out that batteries are unable to support the load only after they receive an alarm, which is typically too late to ensure network continuity. External battery monitoring systems can provide awareness of the battery's status, but the cost and installation efforts are not trivial. A new approach is the advent of Advanced Connected Energy (ACE), a technique which embeds a low energy communication or Internet of Things (IoT) device into the battery which can communicate via Bluetooth® Low Energy (BLE) either at the site or remotely via a smartphone app, SDK (Software Defined Kit), or controller. The chip not only provides real-time access to performance when the battery is in service, but also enables the user to know the charge status during shipping or while stored in a warehouse.

The purpose of this paper is to introduce this new Advanced Connected Energy technique, explain how it works and present its benefit for various use cases.

MONITORING BATTERY PERFORMANCE – PRESENT MODE OF OPERATION

While lead-acid batteries are renowned for their ability to store and deliver energy, they are not so good at letting users know how they are performing. To obtain battery health status, some users deploy external devices called battery monitoring systems to assess battery performance. However, there are drawbacks to these external systems. They occupy additional space in the facility, add cost to the installation, and increase the installation complexity due to additional wiring requirements.

THE ADVANCED CONNECTED ENERGY TECHNIQUE ADDS INTELLIGENCE TO THE INDIVIDUAL BATTERY

The external wiring may also add "false alarms" due to wires coming lose or being disturbed during operation. Most external monitoring devices measure a battery's internal resistance, conductance, and impedance. These numbers are very small and can be affected by state of charge, parallel string connections or the resistance, conductance, or impedance of the charging system or load.

In many applications where there are just a few batteries or battery strings, the benefit of the external battery monitoring system does not justify the cost. However, when no battery monitoring system is employed, the only way the user knows the status of the battery is to be present with the battery and test it. Otherwise, the user is unaware if the battery is capable of performing its designed task.

The Advanced Connected Energy technique adds intelligence to the individual battery with information that can be obtained wirelessly. The ACE method eliminates the need for a permanently mounted monitoring system – it does not require rack space or floor space for mounting, it doesn't add wiring complexity, and it lowers the overall cost for assessing battery health.

ADVANCED CONNECTED ENERGY DEFINED

With the ACE technique, a battery is matched to a sensor at point of manufacture. The sensor is intrinsic to the battery, which helps ensure that the sensor cannot be removed or replaced. An ACE-equipped battery measures temperature, voltage, and time. In addition, it contains manufacturing information such as the battery model, unique battery serial number, manufacturing date, and origin of the battery. This data can be stored and reviewed to determine trends in the battery. For security purposes, an embedded ACE sensor has a unique ID that cannot be changed thus ensuring the integrity of the data.

Applying a communications device that consumes energy from the battery might seem counter intuitive. If the chip consumes too much energy, it could actually decrease life during storage. Obviously, it is important to use a device that consumes very little energy. The use of BLE transmitting technology consumes microamps and thus, does not degrade performance of the battery during storage.

This stored information is transmitted via Bluetooth to a special smart phone app or to any industrial computer or controller using SDK. The connected battery allows a continuous flow of battery data which can be used for fact-based decisions on short- or long-term improvements. In essence, the ACE technique makes a conventional battery smart..

Ultimately, a controller such as a power system controller, will provide users the utmost value. This functionality will enable users to access valuable battery data across their entire network from a remote location.

ADVANCED CONNECTED ENERGY – HOW DOES IT WORK?

Using Advanced Connected Energy technology is a straightforward process.

1. The ACE chip monitors the voltage and temperature of the battery. The chip rapidly samples the data, which is then averaged into one second values for storage. The voltage and temperature log form the battery matrix such as the one shown in Figure 1.

	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	5.7h	44.5h	39.4h	149.0h	1.1h	4.6h	86.9h	25.5h	0	0	0
	0	0	0	0	0	0	9.9h	10.7h	17.3h	3.7h	0.7h	25.7h	9.6h	0	0	0
	0	0	0	0	0	0	13.9h	36.9h	42.3h	20.2h	5.2h	82.6h	37.1h	0	0	0
	0	0	0	0	0	0	0.4h	1.7h	1.7h	1.3h	0.3h	6.7h	0.9h	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	205	728	1508	1300	386	188	1804	1687	0	0	0

V

Figure 1. Battery Matrix

Currently, sensors are designed for 12V monobloc batteries. Expansion to 2V cells and other battery voltages is expected to follow. In addition, the accuracy of today's sensor technology is best around 20-25°C (68-77°F), though it can measure from -30°C to +85°C (-22°F to 185°F).

2. Inside the sensor are additional logs and information. For example, a datalog can store around 20,000 voltage and temperature data points. Major events, such as a low/high voltage or temperature, are saved into an eventlog. The log always maintains the latest 20,000 data points, overwriting the data with time. When the ACE chip is connected to an SDK computer or controller, the events are synched so that all the events link to a real time clock. An example of a datalog is shown in Figure 2.

DATALOG		
Time Stamp	Temperature	Voltage
74027226	21,3	10,45
74027593	21,4	10,40
74049193	21,5	10,39
74070793	21,8	10,39
74075951	21,9	10,42
74076311	21,8	10,46
74076671	21,7	10,46
74077031	21,8	10,46

Figure 2. ACE Datalog

3. The chip uses Bluetooth® Low Energy, a technology with widespread adoption. That data can be accessed via a smart phone using an ACE-compatible app. It will also connect to a separate system controller or any computer using the SDK.

When connected to an industrial computer or controller with integrated SDK, the ACE chip will enable the operator to keep track of products in storage and when entering or leaving a location. This will also help to check the status of batteries being dispatched to operation. A controller or computer installed on site in a large data center or warehouse will connect to every installed battery on the site. It will also monitor all installed products, perform simple tasks and store limited historical data over an air interface. The data can then be transmitted over the operator's network for detailed analysis. An example of this network arrangement is shown in Figure 4.

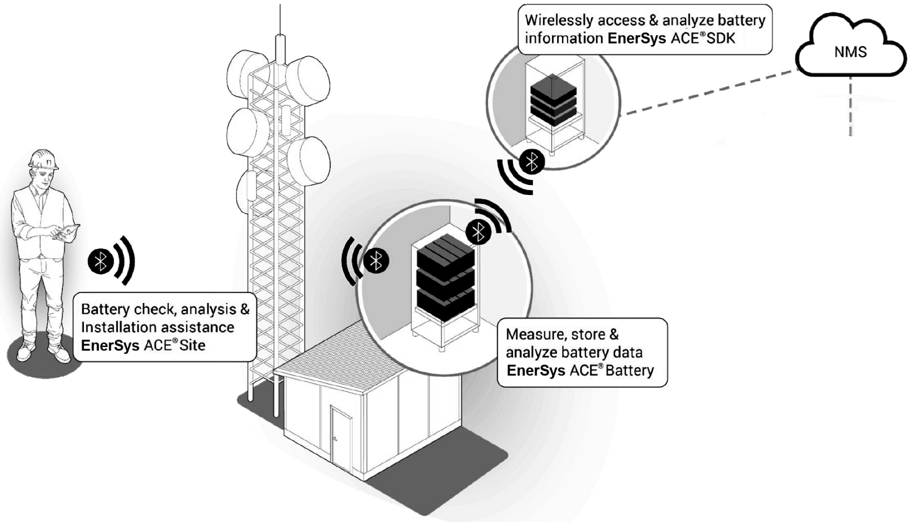

Figure 3. ACE Network Connectivity

ACCESSING THE BATTERY DATA

There are two ways of accessing the data about the battery performance and status.

The first method is to use a smartphone equipped with an ACE-compatible app. This smart phone tool enables the user to directly access the battery as the mobile device picks up the BLE signal from the battery. The app will guide users to ensure best practices during installation and provide a documented installation report, which can be accessed for future trouble shooting. The app also allows for a quick status check of the battery without lifting or touching the battery. The result is efficiency, quality and safety for anyone handling the batteries on site.

A second access method requires SDK and integration into the operator's network. This allows operators to review continuous data from battery performance and conditions. This aids in drawing conclusions and making decisions on replacement, need for service, outages etc. At a regional level, multiple sites can be reviewed. Site energy status reports can be extracted for further analysis.

Another view is for warehouse and storage. This ensures full control of batteries and their charging status, which helps eliminate risk for sending poorly charged batteries in the field.

BENEFITING THE END USER

The ACE technique offers several benefits for the end user. Some of the primary causes of battery failures include:

- Wrong setting or installation
- Incorrect battery selection
- Temperature
- Storage
- Theft and vandalism

1. SOLVING PRE-MATURE FAILURES

Many premature battery failures are caused by poor handling in selecting or installing the battery. Other failure causes are connected to the conditions in which the battery is stored or operated. When an SDK/controller is available and integrated into the operator's network, the ACE technique enables the user to address most of the main failure reasons before they happen.

THE APP ALSO ENABLES THE USER TO SCAN BATTERIES DURING INSTALLATION, THUS PROVIDING USERS A COMPLETE VIEW OF PHYSICAL INVENTORY DOWN TO THE EXACT POSITION ON THE SHELF.

Most power systems use factory default settings for batteries. These are a limited number of settings that do not always consider the type of battery chemistry or grid conditions. Integrating the connected battery to the power system will enable the application of automated charge settings based on actual conditions and product type. If the charge settings change over time as the battery ages or conditions change, the app will continue to monitor and enable the power system to adapt.

The app also enables the user to scan batteries during installation, thus providing users a complete view of physical inventory down to the exact position on the shelf. The integrated sensor in the battery enables it to report the battery's core temperature. By combining these two data points (location and temperature), one can determine battery abuse and detect poorly performing cabinets and air conditioners. This will help prevent end users from mistakenly replacing batteries and instead focus on addressing the root cause of the problem such as poor installation, airflow or under-dimensioned climate systems.

ACE technology can also reduce storage-related failure. An ACE system can provide an alert for batteries in need of recharging and inform logistics personnel which product is nearing the end of shelf life to help plan dispatch orders.

Incorrect selection of chemistry is not easily solved by the ACE technique as it involves other parameters judged by humans. Battery selection is a decision made by procurement and through technical evaluations. However, automated tools can point out recommended changes in the networks to prepare for replacement.

2. VISUALIZE ENERGY STORAGE KEY DATA POINTS

Many users apply a schedule for replacement or spend lots of money hiring service people to measure OCV (open cell voltage) levels of installed batteries to determine if a replacement is needed. Using the SDK connection, the user can see the list of batteries that have reached or are nearing end-of-life. Once this data is known, the service provider can be dispatched to perform the actual work.

An additional benefit of having visibility of the installed base is the ability to check if the correct products are being used. This is accomplished by applying filters combining the number and duration of grid losses with selected battery types. Also, actual backup time on every site can be monitored to ensure that regulations and wanted service levels are obtained over time.

3. INCREASING SAFETY & INSTALLATION QUALITY

Safety is very important when dealing with energy storage. All types of batteries can fail and cause damage to material or worse to personnel if not installed or treated as intended.

An ACE App will guide the installer to make sure the batteries to be installed are in good condition and installed correctly. Installing a degraded battery can cause rapid failure, overheating and elevated hydrogen gas emissions. If this happens and ventilation is not up to standards, there is a risk of hydrogen explosions.

Another safety feature is the system's ability to monitor battery abuse. High temperature, high voltage and under-dimensioned battery banks resulting in deep cycling are some types of abuse. Other situations may relate to power systems, software settings, cabinet/shelter cooling systems or over-allocated installations. Analyzing the battery in a methodical manner can further safety even further and improve network performance.

USE CASES

There are four primary types of uses cases for the Advanced Connected Energy technique. They range from battery operation to installation to inventory management. Synopses of these use cases are provided below.

USE CASE #1: BATTERY OPERATION – ON-SITE MAINTENANCE

The battery matrix tracks what the battery has endured during its lifetime, e.g., high temperature or low voltage. The data is summarized by the app in the report which enables quick analysis. If needed, the report can be analyzed by the battery vendor in situations where there is a unique issue.

For each maintenance visit, the technician can easily check the status of the batteries on site. The data enables the tech to rapidly spot potential issues. A maintenance report can quickly be generated and shared with the operations and engineering teams. The app maintains the history of the site which further aids in troubleshooting.

A maintenance report can identify who visited the site and when. It also provides the status of the batteries and whether any battery has been exposed to low / high voltage or high temperatures.

USE CASE #2: BATTERY OPERATION – REMOTE PERFORMANCE ASSESSMENT

When connected to an operator's network and Network Operations Center (NOC), the performance of the batteries can be assessed without needing to visit a site. The ACE technique gathers the data from all the batteries in the facility and systematically reports it to the NOC. If analysis indicates there is a need to visit the site to maintain or replace a battery, the technician can be dispatched with the right equipment, tools, and batteries to ensure a single trip can address the problem.

USE CASE #3: WAREHOUSE AND INVENTORY MANAGEMENT

Batteries are heavy and usually shipped across the world using surface transport. On top of this, they can wait for weeks or even months to get installed. When installed, they must be fully charged. By using the app to wirelessly scan the ACE batteries, the need to open the battery crates and remove them from their packaging is eliminated. All the batteries can be checked at once instead of one-by-one, saving much time and effort.

In addition, there is no need to use voltmeters to see the Open Circuit Voltage (OCV). This can also be done wirelessly with a scan that will in seconds show the OCV and signal strength of all batteries within Bluetooth/radio range. An additional benefit of this feature is that it reduces the level of expertise required of an installation engineer.

USE CASE #4: SIMPLIFYING BATTERY INSTALLATION

The ACE feature can provide a step-by-step installation guide to help installers. It generates a PDF report which can easily be shared through emails and captures the status of the batteries at installation, ensuring the work is done in a standardized way. It can also include a photograph of each step. This report provides a broad overview – who did the work, where the battery was made, which batteries were installed, and the initial battery status at the time of installation.

The ACE functionality not only simplifies the process by providing a guided installation, but also improves quality by providing guidance so the installation can be done correctly. Moreover, it reduces the time required for the installation by generating reports automatically through the app.

CONCLUSION

The introduction of a low-energy onboard sensor for lead-acid batteries can change the way batteries are installed, maintained, inventoried, and replaced. The intelligence added to these batteries approaches that of newer chemistries such as lithium. This innovation helps maintain continuous network performance by ensuring working batteries are installed and ready for service. It also can lower operating expenses by avoiding the placement of under-charged batteries into service and by minimizing truck rolls when site visits are required. The intelligence added to batteries by the ACE technique allows operators to improve quality of service to the end user.

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