EAGLE EYE TECHNICAL NOTE

Title	Battery Power and Monitoring Considerations for Remote Locations
Document No.	TN-042723-1

Revision History

Date	Revision	Change Description	Author(s)
04/27/23	0	Original document	JAB

Abstract

On the evening of Thursday August 14, 2003, a software bug in an alarm system at a First Energy Facility in Ohio coupled with some operator error, set off a series of events which caused a major power outage over a large part of the northeast United States which was started by an overloaded transmission line touching some trees. At the peak of the resultant power outage more than 508 generating units at 265 power plants were forced to shut down and approximately 50 million customers were affected, some without power for up to four days. The estimated cost was more than sixty billion US dollars.

Just over two years later, on August 29, 2005; hurricane Katrina barreled into Louisiana and the surrounding Gulf States which resulted in over three million people without power. Many areas did not have power restored for several weeks. On December 11, 2008, Hurricane Ike caused about 7.5 million to lose power from Texas to New York State. A major snow and ice storm on January 11, 2007, caused over 1 million homes and businesses to lose power in the central USA. And it goes on. Think about the great Texas freeze out of February 2021 where over 4 million customers lost power and nearly 250 died. There were freeze driven power outages in Texas as late as February of this year.

Weather, accidents, and human error are not the only source of widespread power outages. Recently the CIA has warned that cyber attacks may have caused some power outages already and are a great possibility in the future in the USA. During many of these outages, people and agencies relied on the cellular telephone network and the microwave network for communications. Most of these networks had some battery backup, albeit limited, and many had engine generator backup. Think 911 service and emergency responders.

A national power quality study conducted by the National Power Laboratory between 1990 and 1995 indicated that the average location would experience 15.24 power outages per year. The study looked at 135 random locations in the United States and Canada. This author took part in that study. There is a belief within the industry that power quality is getting worse as the electrical generation and distribution system ages, becomes overloaded and the load equipment is getting more complex and more susceptible to power quality issues.

All the above are a clear indication that close attention needs to be paid to electrical power at remote locations and some form of power back-up needs to be provided. Stationary batteries are used extensively for reserve power in the mobile radio network and remote locations because they are still the most economical form of reserve power. All too often, the selection, installation and maintenance of these critical batteries are handled by personnel who are not too familiar with batteries and the associated charging equipment. Equally, the battery suppliers, installers and maintainers may be unfamiliar with remote locations and environments. Handling the selection, installation and the maintenance process is of prime importance to battery quality, performance, and reliability.

This article addresses some of the issues and requirements that need to be considered to assure a reliable battery back-up.

Battery Type.

There are two main stationary battery types, lead-acid and nickel-cadmium. Although the nickel-cadmium battery is an excellent battery for locations that are subject to temperature extremes and can cope well with charging abuse, they initial cost is very expensive when compared to lead acid and consequently they are not prevalent in most remote locations. Of the lead acid-batteries, there are two different types which are Vented Lead-Acid (VLA), also called “flooded” or “wet” cells, and Valve-Regulated Lead-Acid (VRLA), also erroneously called “sealed” or “maintenance-free batteries. They are neither sealed or maintenance-free as they have pressure relieve valves that can open to the outside atmosphere, and they certainly require maintenance. The great majority of batteries deployed in remote locations are the VRLA types which employ an immobilized electrolyte design. In other words, the liquid dilute sulfuric acid electrolyte is immobilized in such a way so there is no free or spillable electrolyte. There are two types. One being an absorbed glass mat (AGM) design also referred to as “starved electrolyte,” where the electrolyte is absorbed in a sponge like woven glass plate separator. The other type is the “gelled electrolyte” where a gelling agent is added to the liquid electrolyte in order to immobilize it.

Selection.

In many cases, battery selection is driven by cost and the user may not get the most suitable battery for the application. The user may also depend on the advice and offerings of a battery vendor that does not fully understand the requirement. There are some important details that should be taken into the battery selection process.

- Physical size. The selected battery should consist of cells or modules that can easily be moved, installed, and replaced as it is quite likely that the battery will have to be replaced during the life of the remote location.
- Electrical size. There are several considerations regarding the electrical size (capacity) of the battery mainly driven by the load and the autonomy (reserve time).
- Overestimation of the load power requirements will not only increase the battery cost and size but will also start a domino effect. When load power requirements are oversized, this will result in the over sizing of the battery but also the charging equipment and the HVAC equipment not to mention the extra space that has to be allocated.
- What is the actual load? Equipment manufacturers typically overstate the input power requirements. The figure stated on the nameplate is typically 25 to 50 percent higher

than actual. Find out the real input power requirement by consulting the manufacturer or measuring actual maximum load, or talking to users of similar equipment. On the other hand, one may want to oversize the battery if the expansion of the load equipment is likely.

- What reserve time is required? This can depend upon several factors such as:
    - Is a minimum reserve time mandated by a legislative authority such as a Public Safety Commission or The Federal Communications Commission?
    - Is there another form of power back-up on site such as an engine generator?
    - How important is the site in terms of reliability or revenue?
    - Is the site environmentally controlled?
    - What is the space available?
    - How accessible is the site?

All too often a user will simply request a battery that will provide, for example, 8 hours reserve time, without any consideration as to what will happen during a battery discharge. For example, if the is no air conditioning or if the air conditioning and air handling systems are not backed by generators, then the load equipment may well shut down because of high temperature long before the full capacity of the battery is ever utilized.

Projected Battery Life.

- What is the design life of the site? If it is only 5 years, then it does not make much sense installing a 20-year design life battery. Besides, if a lower life battery is selected, then it will not only cost less and take up less space, but it will be cheaper to replace should it become defective.
- What is the real life of the battery? Remember that a so called 20-year VRLA battery will realistically last 7 to 9 years, a 10-year battery is really a 3 – 6-year battery and a five-year battery may last only 2 – 3 years.
- Heat has a detrimental effect on a VRLA battery, and the life will be reduced when operated at a high temperature. If the battery is to be operated at an elevated temperature, then plan for a shorter battery life. Remember the rule of thumb, for every 10°C (18°F) above the nominal of 25°C (77°F) the battery live be cut in half.

Configuration.

Once the reserve time has been determined then the battery configuration can be addressed. Here the important decision is whether to have a redundant battery or not. In many cases, going with two or more parallel battery strings allows for smaller, more manageable individual battery modules. Also, parallel redundant batteries not only provide redundancy but greatly assist in managing battery maintenance and testing because a battery string can be taken off-line and isolated, without disrupting the power back-up capability. If fully redundant battery reserve is required, then obviously two or more parallel strings will be required.

Battery Containment.

The means of housing and containing the battery is often determined by the battery type, location, and space available. The preference should be an arrangement that assists airflow or ventilation around the battery such as open battery racks or frames. Where possible avoid battery cabinets which may hinder ventilation and cooling. Spill containment is recommended if not mandated for VLA batteries, and in most cases, Authorities Having Jurisdiction, (AHJ's) will determine if spill containment is required for VRLA batteries. AHJ's and seismic zone locations will determine if seismic restraints may be necessary. Forced air ventilation may also be required. Always check with the AHL and the national state and local codes as to all of these and other possible requirements.

Battery Controls.

Although considered by some as a "single point of failure," battery disconnects and low voltage disconnects can greatly assist with the safe operation of the site, protect the load and battery, and prolong battery life. A battery disconnect is a means or removing and isolating a battery from the charging system and load. The coordination of the electrical size of the battery disconnects and any over-current protection devices with other power system elements and the power system capacity, battery size, and interconnecting cabling, is of prime importance.

A Low Voltage Disconnect (LVD) is a means of automatically disconnecting the battery from the load at a preset discharge voltage in order to prevent the battery from being over discharged. Although the use of an LVD is purely the system designer's choice, it does protect the battery from being over-discharge and thus suffer permanent damage.

A power system can also incorporate remote controls that can reboot the system if for some reason it gets "hung-up." A means of measuring the battery voltage and load current should be provided. A permanently wired, full feature monitor may also be advisable for hard to access or critical locations.

Battery Alarms.

It is always advisable for remote locations to have both local and remote alarms. The remote alarms should incorporate enough information to enable the user to determine the status and health of the battery. This is discussed further below.

Battery Charging.

It is usually recommended that a new battery receive a freshening charge for a period of time after it is first installed. It is essential that the battery receive this charge and that the voltage level and ongoing float voltage are set at the manufacturer's recommended voltage level. Any levels outside the recommended limits will damage the battery and reduce life. Battery charging systems that can compensate the float voltage for temperature variations, particularly above the 77°F optimal operating temperature, are important as they can reduce the charging voltage and consequently the charging current at higher temperatures, thus avoiding overcharging and the possibility of thermal runaway of the battery. It is also advisable to have a high voltage shutdown feature on the charging system that will disconnect the charger from the battery in the event of a charger system failure resulting in too high a voltage being applied to the battery. Redundant chargers are also strongly recommended. This is usually stated as a N + 1 requirement where N is the number of chargers required to support the load plus one redundant charger. When sizing the charging system, it is also important to consider the following:

- Any high inrush current that may be required by the load.
- Sufficient capacity to recharge the battery in a specific time.
- Adequate local and remote alarming capabilities.

Battery Installation.

- The location and orientation of the battery plant when installed in a separate battery room is normally dependant upon the shape of the room and the achieving the shortest cable length and this voltage drop between the battery and the load. In remote locations it is rare to have a separate battery room and the space for the battery is all too often determined by the space that remains after all the other equipment is positioned. In many cases that battery system is an afterthought. There are four major considerations in positioning a battery plant.
    - The battery should be kept away from heat producing sources and direct sunlight.
    - It should not be in the direct path of HVAC equipment which could affect battery temperature or cause dust to accumulate.
    - It should always be installed in a way that the individual cells or modules can easily be removed and replaced.
    - Sufficient space should be left in front of the battery to allow for maintenance. Note. Minimum space is specified in the Nation Electrical Code, NFPA 70.
- Because of the close proximity of all of the equipment in a typical remote location, it is very important that be battery terminals are protected from accidental contact. It is also equally important that access to battery terminals for testing purposes be provided. One might want to consider using front terminal batteries if space constraints do not allow

for access to a traditional top terminal battery. These are typically easier to test and usually save space as they can be mounted on top of each other.

- The bonding and grounding of the battery system is important. Some load equipment manufacturers may have specific requirements but in general the battery rack, frame or cabinet should be grounded by bonding it to the building or structurral grounding system. The battery itself can be either positively or negatively grounded according to the load equipment requirement. For example, some equipment requires a negative voltage in which case the battery positive is grounded while others operate of a positive battery voltage which means that the battery negative must be grounded. Grounding methods for equipment can be complex and will be dealt with in a future technical note.

Standards, Codes, Methods, and Practices.

These can apply across the across the board, covering installation methods, equipment standards, maintenance procedures and safety. Care must be taken that all applicable standards, codes, etc. are followed and they do not conflict with any other building or load equipment standards that may apply. Equally, there should be an awareness of which standards, etc. do apply. In all cases, the AHJ has the final say.

An Eagle Eye Power Solutions Technical Note gives an extensive listing of the documents that apply to battery selection, installation, maintenance, and testing.

Maintenance.

There is probably no other word that can mean so many different things to so many people as the word “maintenance” when used in association with batteries. The problem is that there is perception that battery maintenance requires a physical act such as the addition of distilled water. Many users have been sold on the fact that the batteries are of the maintenance free type and require no maintenance. If one is talking about primary (single use) batteries that may be the case but for all VRLA batteries some form of maintenance is required. So why is maintenance important? The obvious answer is to keep the battery in a condition in which it will function properly, but there are other, not so obvious reasons.

- To protect the capital investment.
- To protect the user’s reputation.
- To comply with warranty requirements.
- To comply with mandated requirements.
- To ensure the proper functioning of the complete system.
- To extend the life of the battery and control aging.
- To rectify defects.
- To try to predict and preempt failure.

- To provide peace of mind.

Within the industry it is estimated that 85% of all battery backed power system failures are due to lack of maintenance or the improper management of batteries. One thing that all agree upon is that because of the chemical changes within the battery which start the moment the battery is manufactured, that all batteries will eventually fail and the period from manufacture to failure is very dependant upon the manner and conditions under which the battery is operated and maintained.

Testing.

Most would agree that that the ultimate test of any battery plant is a closely monitored load (discharge) at the maximum system load for the period of back-up time required and an equally observed recharge. If this testing is carried out at regular intervals, the data collected can be used to trend the discharge characteristics of the battery and predict battery failure and the end of useful life. What most agree upon is that it is not possible to fully identify battery characteristic changes and trends based only upon the measurement and analysis of cell voltages. Charge current, temperature and the use of portable or integrated monitoring equipment to measure the individual cell or module ohmic values helps to obtain data on which the trending can be based. Ohmic values can be obtained by measuring the internal resistance, impedence or conductance of a battery. When these values are trended, they can be very indicative of the battery state of health. A load test as described above is the only real way to establish a battery's capacity. As far as remote locations are concerned, the conduction of a full load test may not always be possible or practical, so reliance on locally and remotely monitored data is a good alternative. There is equipment on the market from several manufacturers that does a pretty good job in predicting battery failure. It is essential that all data collected is properly analyzed by personnel familiar with battery operation.

Conclusion.

It is repeatedly claimed by users that batteries are not performing well in remote locations. Well, they can certainly be the Achilles heel if not properly applied and maintained.

The battery manufacturers have certainly received their share of blame concerning battery performance and life and some of the complaints may have been justifiable. However, the integrators, installers and users are also largely to blame for poor battery performance because of less than an adequate battery selection, installation, operation, and maintenance. Close cooperation between manufacturers, suppliers, integrators, and users in the battery selection process, based upon a knowledgeable approach, is required. Proper installation and meaningful maintenance are a must if the battery system is to provide adequate service. An ongoing dialog between the battery provider and the user is necessary to promote understanding and confidence.