RIPPLE, NOISE, CHARGE AND DISCHARGE: TURNING UNWANTED SIGNALS FOR YOUR ADVANTAGE

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ABSTRACT

The designer of the battery monitoring system faces the difficult task of choosing the technology that will allow the extraction of information for the state of health of the battery while the battery is online. For the purpose of assessing the battery internal ohmic value, some battery monitoring manufacturers inject AC signals in to the battery strings, while others periodically apply a load pulse. Unfortunately, those signals are not always welcomed by the battery user or battery manufacturer.

The authors will present a passive method to measure and pinpoint a suspicious cell and extract battery performance information without injecting any signals to the battery by using the normally unwelcomed signals produced by charger/UPS equipment. Any AC power converter using the battery for the backup power source does inversely introduce the AC signals (often referred as the ripple and noises) across the DC link. The amplitude and frequency of these signals vary with UPS architecture. The authors will classify the source and properties of such signals in standby, on-line, 12-step, and PWM power conversion, with isolated and nonisolated battery placement.

The information should show performance down to individual cells without injecting any external signals to the battery link. The possibility of using the existing signals, in the form of ripple or white noise, will be discussed; however, AC signals across a battery are usually in low or very low amplitude; therefore a special noise elimination technique must be applied.

The concept of an instrument capable of measuring the signal below noise level, the technical obstacles, and results of the online test will be presented and discussed in detail.

INTRODUCTION

The existence and nature of the noises in the UPS system have been discussed in the past [1, 2, 3, 4]. Although they are not the subject of this paper, the authors will briefly discuss them for better understanding. The purpose of this paper is to revive the possible impact of the noises on the battery monitoring equipment and to propose a design concept utilizing the ripple and the noise, not only to extract the battery information, but also to eliminate the need for a power supply to such equipment.

AC COMMON MODE

AC voltage of the entire battery string, with respect to ground, is referred to as the common mode. When the battery is enclosed in a cabinet, installations without an input transformer are permitted. In such installations (Fig. 1), the battery will follow the potential of the incoming power line in unison with the switching charger device sequence and frequency. Since a 480V power line is commonly used in such applications, common mode voltages on the battery installation may reach 480V RMS and sometimes exceed 1kV p-p. The fundamental frequency of the common mode voltage may be as low as 60Hz, but it can reach 120kHz with considerable amplitudes present (Fig. 2).

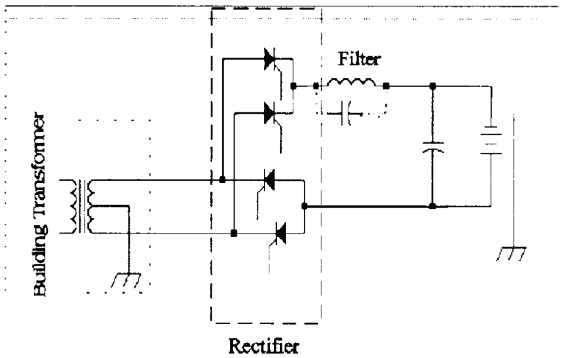

Figure 1: Common voltage (SCR type charger).

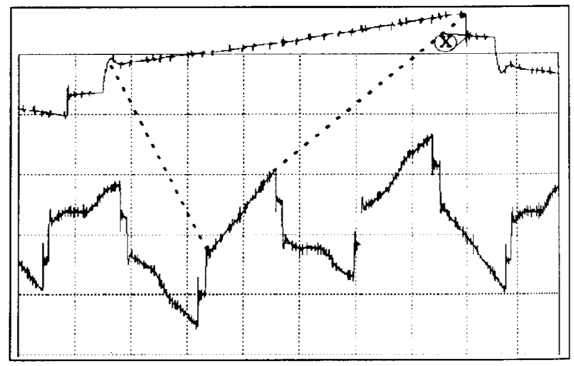

Figure 2: Common voltage SCR Charger.

A PWM type UPS has a more powerful noise and much higher frequency span than SCR controlled chargers (Fig. 3).

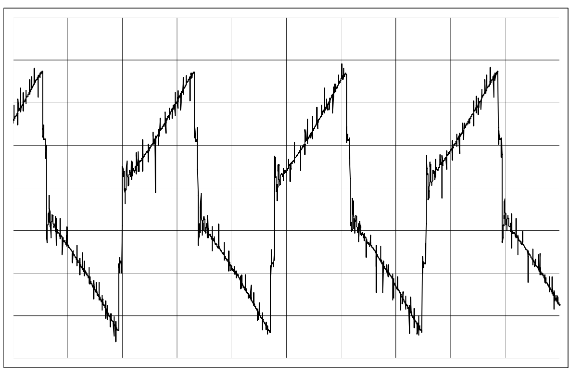
Figure 3: PWM UPS common mode. Scale: 100V/div

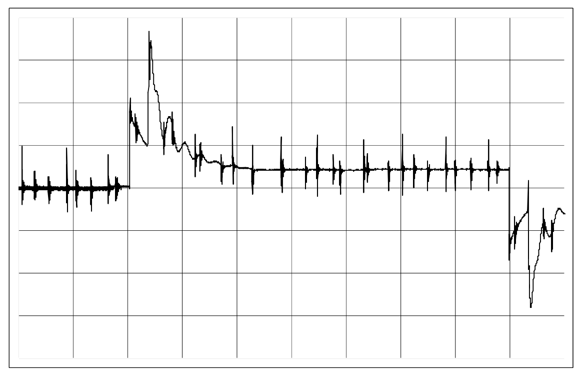
Figure 4: AC reading "air" with only ground of probe attached to the battery. Scale: 10V/div.

Common mode seems to produce no adverse affect on the battery itself. Although this type of noise may not affect the battery, the battery monitoring equipment can be affected. The common voltage range might be as high as 1kV and common mode frequencies can reach several MHz. Unfortunately, the amplitude, shape, and frequency vary not only due to charge/discharge conditions, but also from site to site.

The dramatic result of the HF noise influencing the readings can be seen when reading from the universal meter attached to the battery posts. The display of the ripple voltage across one of the cells (12V) will change when the universal meter is held at different spots, such as top, middle and bottom. The HF noise can also be observed when the probe is left unattached. A reading of about 80VAC p-p (Fig. 4) can be observed.

In summation, any battery monitoring device will be exposed to the high EMI signal, and any wire-like sensing or communication link can act as an antenna. Also, monitoring equipment that has undergone laboratory testing might refuse to work on the site after installation or, even worse, during the acceptance test or when it is needed the most: during a real battery discharge due to increased noise level in that condition.

RIPPLE VOLTAGE

Usually insufficient filtration of the charger is blamed for the ripple voltage across the battery posts. But besides the charger, other factors, such as the internal ohmic value of the battery, the nature of the load, the magnitude of the DC current or the interaction between charger and inverter will have an effect on the magnitude of the ripple voltage. Surprisingly, the character and magnitude of the load on the DC bus seems to have the largest effect [1]. The frequency, phase, and amplitude of the voltage ripple cannot be completely known prior to installation and may vary over time due to site changes. In addition to other possible negative effects on the load, the ripple voltage across battery terminals will make battery monitoring difficult [4].

Fig. 7 shows a sample of the ripple voltage across a 12V cell, from a selection of 40 cells in the PWM UPS installation, to be approximately 0.6V p-p. The sharp pulses that can be observed are a result of the PWM charger transitions. At first, those pulses seem to be unwelcome occurrences, which could upset a voltage reading device; however, those pulses can be used as start signals for integration of the voltage reading, which is essential for the RMS calculation

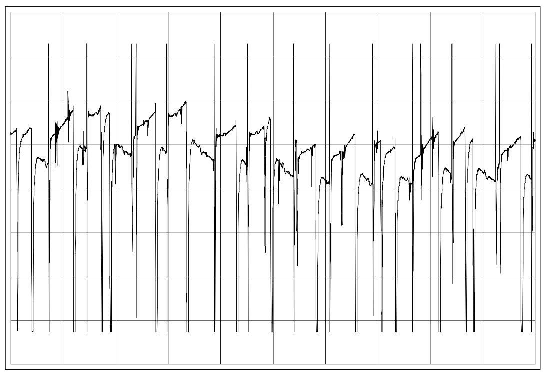

Figure 7: Ripple voltage across battery. Scale: 0.1V / 0.4mS

RIPPLE CURRENT

Ripple current is usually produced by the mutual interaction of the rectifier and the inverter with the battery. As part of the nature of converting AC to DC, and vice versa, both rectifier and inverter will produce the ripple current. The output/input of the converters will usually have a filtration capacitor. The purpose for the capacitor is to shunt the ripple current and to output ripple-free DC voltage; however, if the battery is connected directly to the equipment's DC bus, the ripple AC current will also flow through the battery. The magnitude of the ripple currents in the battery installation will depend on the existence and type of DC load [1] and on the ratio between the output capacitor and the capacitance of the battery. The last one is usually much bigger than filtration capacitor; therefore, by the Kirchhoff law, a much bigger current would be conducted by the battery than by the filtration capacitor. The frequency of the AC ripple current follows the frequency of the ripple voltage.

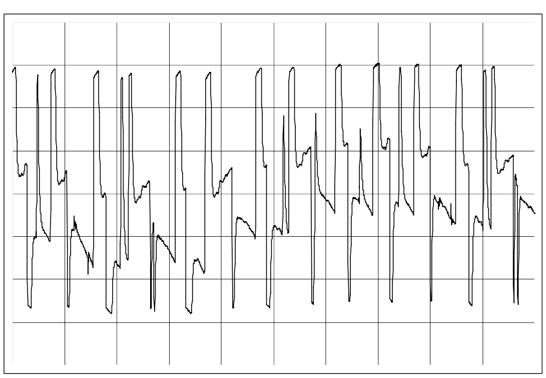

**Figure 8: Float current ripple PWM ups.
Scale: 5A / 0.4mS**

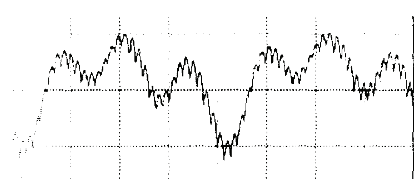

**Figure 9: Unbalanced AC load Discharge current.
Scale: 100A / 8mS**

Depending on the construction and the size of the UPS, the magnitude of this current may be as little as a few hundred mA and up to 20A or more in the larger UPS installations. It should be noted that, when a battery is floating, there is only a small DC float current that does not depend on the DC load; however, the load on the DC bus will dramatically affect the AC component of the float current. The authors observed as much as 60A peak-to-peak of the ripple current with a DC component of 400mA. The ripple current in the float condition could also dramatically change the amplitude and shape during a charge/discharge event (Fig 9).

PITFALLS AND BENEFITS OF HF NOISES

Noises in the battery cabinet are a nightmare for battery monitoring designers. Any wire could carry the high frequency signals of frequency and magnitude that are difficult to duplicate and impossible to predict. Some manufacturers learned this the hard way, while others who were aware of the problems went to the extreme in order to reduce the noise.

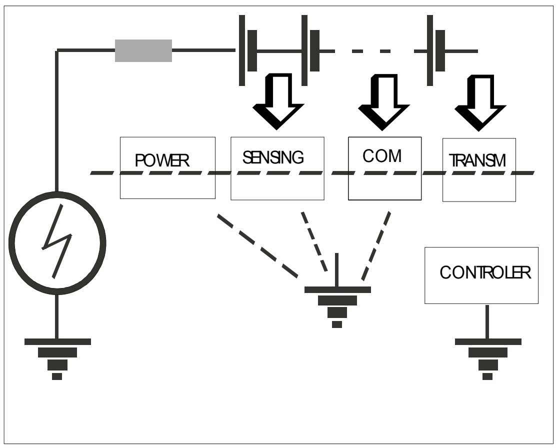

Figure 10: Noises entry.

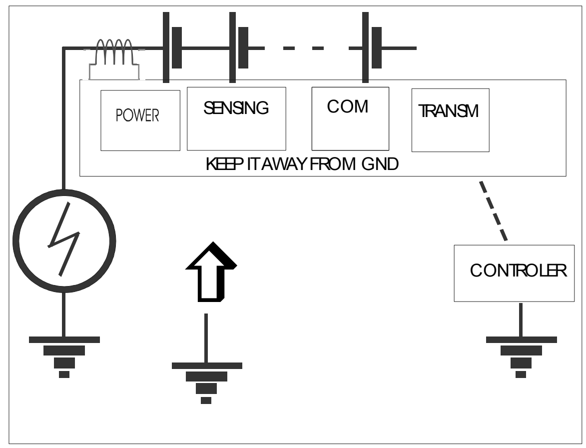

Figure 11: Reference to battery eliminates noises.

There are four channels of noises entering monitoring equipment: sensing wire, processing IC PCB, communication ports and power supply. With the exception of the controller, which is usually away from the battery, all of the elements of the monitoring system will see the noises as mentioned above.

In electronics design, the common practice is to place everything on ground and filter all incoming/outgoing signals. Some monitoring manufactures do that by enclosing equipment in the grounded box, using shielded wires to sense, and optocouples to communicate. There have been cases where an isolated power supply is also used to supply the sensing circuitry.

Shielding of the sensing wires will have the opposite effects, since increasing capacitance will conduct more HF current to the equipment “gnd,” which will prompt the noises to find a path as it would if there are two or more ground connections (the nightmare of an electronic designer). Extensive means and design considerations would be necessary to reduce the influence of “conducting” these types of noises.

Some monitoring companies isolate the sensors using optocouple. These little devices are good for high voltage, some of them 2kV, but their limited Common Mode Rejection (CMR) is well below the magnitude of the noises existing in the battery cabinet. Since these noises cannot be duplicated in the lab, the first test of the design is (unfortunately) sometimes done on the premises of the customer, or in certain cases, after installation during the first battery discharge.

Power supply of the logic can also be a problem. When the logic is connected to the cabinet ground at one end, it has to provide power at another noisy position. No matter how well it is isolated, there will always be some stray capacitance that will allow noises to enter the monitoring devices.

Ground level is a convention definition, and what is considered to be "gnd" inside of the monitoring equipment could be high voltage for another observer. In fact, positioning everything on the battery potential will make all battery monitoring parts (sensors, logic, and power) grounded to the source of the noises. As long as the equipment is joined, there should be no noises on the inputs and the noise source, as seen by the monitoring equipment, it is no longer the battery but the cabinet ground and the power supply.

To make EMI immunity complete, it is also necessary to deal with the power. The power can be drawn directly from the battery, which is what some manufacturers are already doing. This, however, is not always permitted or desirable, due to high voltage limitations or necessity of balancing power consumption by each battery segment being monitored. The presence of the ripple current does come in handy in solving the problem. (See Fig. 11.) The CT is placed somewhere within the battery string, then the voltage produced by the CT is rectified and used to power up the sensing device.

To measure the ripple current, the same or another type of current sensor might be used. First, the AC ripple current is sent to the logic, where it is possible to compare the signal to the preset limits. An alarm should be set to trigger when the ripple current deviates from the preset limits [5].

Monitoring ripple current alone will provide some information about the system; however, the ripple current is also affected by and in the greater extent by changes in the system (i.e.: load change) [1, 3]. It should be noted that a false alarm could be generated for reasons not associated with the battery condition at all.

The authors propose to use the AC ripple current and (simultaneously) AC ripple voltage to obtain the ohmic value of the battery or individual cells. The relation between the ohmic value of the battery and battery condition has been documented in numerous publications. Usually, the insertion of voltage or the current to the battery provides corresponding battery response, which is used to calculate the ohmic value. The utilization of AC ripple current and AC ripple voltage for this purpose were not reduced to the practice nor published as yet to the best knowledge of the authors.

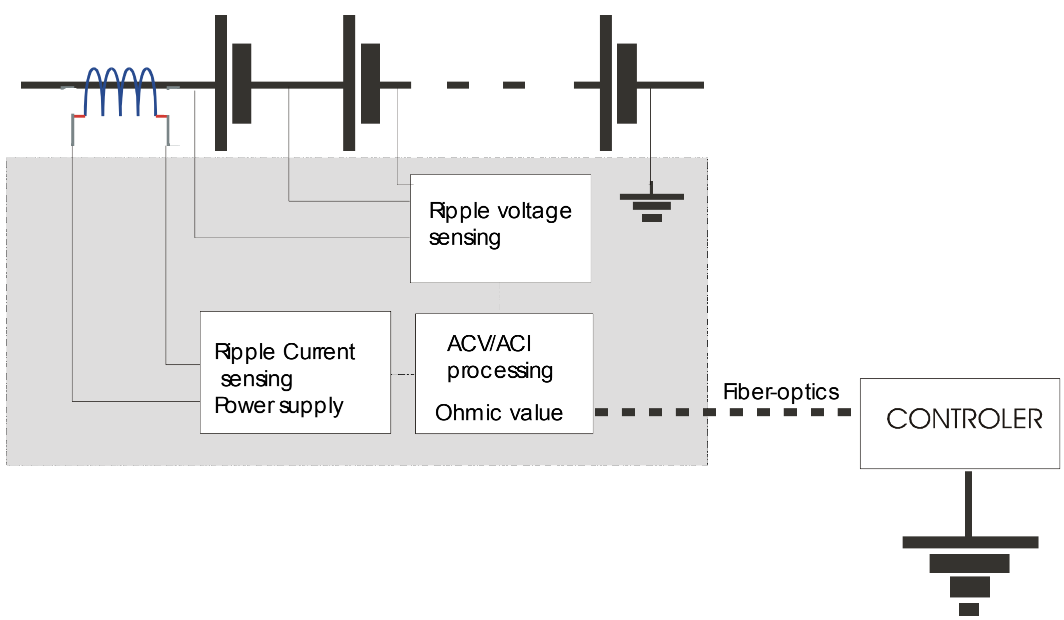

Figure 12: Extracting ohmic value from AC ripple

Measurements of low voltage in the presence of high noises can be a difficult task. Fortunately, the need to detect and measure the signal below the noise level for other application resulted in the developing the method now known as synchronized rectification. This method can be applied for repetitive occurrence, providing that the repetition rate and/or start/stop signals used for integration are known. In the UPS installation, there are plenty of signals that can be used for that purpose. (See amplitude of short pulses from the PWM conducting transition in Figures 7 and 8.) Since the repetition and timing of such pulses are well defined, it is possible to detect signals below noise level [4]. Either current or voltage HF pulse can be used as the trigger to collect and integrate the data until the next pulse resets the system.

With AC ripple voltage and AC ripple current available for calculation, the ohmic value of the string, or the individual cell, can be made (Fig 12). This value is corresponding to the battery condition only; it is fully passive and immune to other parameters of the system.

An optical communication link will provide the information to a central processor that can be placed on the ground potential without a worry to high voltage or high noise influence. Please note that all monitoring components are at full battery potential which, contrary to the first impression, provides the elimination of the EMI susceptibility. Additionally, in most of the cases, the ripple current also provides sufficient power to supply the logic.

CONCLUSION

This paper discusses the high frequency noises in UPS installations and its influence on the monitoring equipment. It was shown that noise immunity can be significantly reduced by placing all components of the monitoring equipment on the battery potential. The authors designed and tested the device using concepts discussed in this paper. The device was capable of producing a value proportional to the ohmic value using the ripple voltage and current existing in UPS installations.

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