ELECTRICAL NOISE IN BATTERY INSTALLATIONS

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Abstract
In this paper, the authors will discuss the AC ripple during float, charge and discharge states of batteries in UPS installations. There are three types of AC signals capable to make some monitoring system useless. The magnitude and sources for each signal will be explained later. The typical AC waveforms for various installations as well as the load supplied by the batteries will also presented and discussed.

Introduction
Some battery monitoring equipment requires injection of AC components across a battery. However, the response will not always produce the expected results since the existing ripple components on the battery terminals often mask the required measurements that the equipment was designed to capture. Usually, the source of AC in the battery room originates from the equipment producing or using the battery power. There are three types of AC signals present that can be attributed to such equipment: differential, where AC voltage can be measured across two battery posts; common mode, with high voltage between any and all battery terminals in respect to ground; and dynamic, which produces frequent, short and shallow charges/discharge cycles of the battery.

Differential AC Voltage
This is usually produced by the mutual interaction of the rectifier and the inverter connected to the battery. If the battery is connected directly to the equipment's DC bus, the ripple AC current will flow through the battery. The magnitude of ripple currents in the battery installation depends primarily on the existence and type of DC load [1].

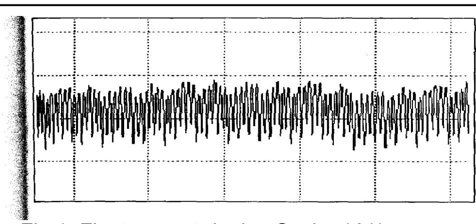

Fig 1. Float current ripple. Scale: 1A/1s

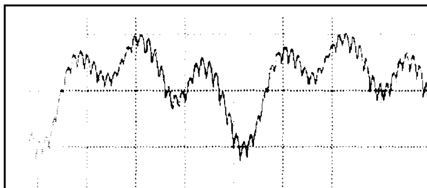

Fig 2. Discharge current ripple. Scale: 100A/8mS

The best example of a ripple free installation is the telecommunication system demanding a well-filtered DC power source. On the other end of the scale are UPS and Electrical Vehicle (EV) applications. Since the battery is part of a larger system in which only system parameters are specified, the designers of UPS systems often take the liberty to use the battery not only as an energy storage device, but also as a large capacitor bank. As a result, in some UPS installations the ripple current might reach unexpected high values. We have observed as much as 380 A of ripple current during a 1100 A discharge. The shape and amplitude of ripple currents vary greatly from site to site depending on the type of equipment connected to the battery. Some example waveforms captured during normal operation and discharging are presented in the figures above.

The significance of the AC current and voltage present on the battery are not well understood. There is a consensus though, that large ripple currents through the battery cells may cause overheating and accelerate its aging by producing additional chemical processes. This issue is of special importance for VRLA batteries that were designed for a well-balanced internal environment.

AC presence across the battery significantly complicates the extraction of the battery conditions from on-site voltage and current measurements. Battery monitoring equipment, in particular, is prone to this problem especially since the frequency, phase and amplitude of the AC is not known before installation and may change with time.

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, the battery will follow the potential of the incoming power line in unison with the switching charger device sequence and frequency. Since a 480 V power line is commonly used in such applications, common mode voltages on the battery installation may reach 400 V. The fundamental frequency of the common mode voltage may be as low as 60 Hz, but it can reach 120 kHz with considerable amplitudes present (Fig. 3).

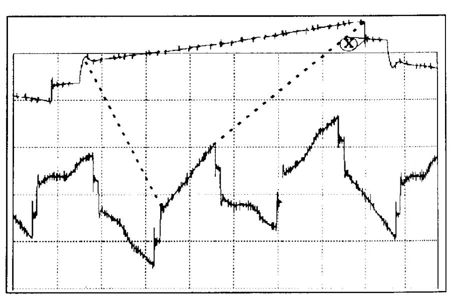

Fig 3 Common voltage (SCR type charger)

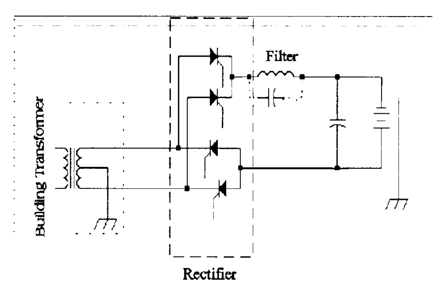

Fig. 4 Transformer-less UPS

Note the presence of high frequency ripples along the straight line of the graph. These are the result of the PWM switching in the inverter. The high frequency components can be observed in the battery current as well. A similar shape and, surprisingly, amplitude can also be observed when the current probe is placed across the two conductors supplying the battery.

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 certainly is. The common voltage range might be as high as 1 kV and common mode frequencies can reach a several MHz. The bad news is that the amplitude, shape and frequency vary not only due to charge/discharge conditions, but also from site to site. The net result is that monitoring equipment tested in the laboratory often do not work after installation during power outages, when they are needed most.

For rack-mounted batteries, the high voltage battery installations usually require isolation. Safety regulations further require that DC leakage above a 5 mA current must be detected. However, a permissible AC leakage current over the common voltage producing it, has not yet been specified. Since the battery is connected to a DC bus, it seems to be taken for granted that only DC voltages might exist between the battery and ground.

When an isolation transformer is used, one can expect that no DC or AC common mode voltage will be present. Although this is true for DC and, in most cases, for 60 Hz, it is not true when high frequencies are considered. The presence of high frequency common mode voltages can be understood when the high frequency model of the input transformer is considered. There will always be capacitance between windings in the real transformer (C1). If the transition of the conducting device occurs in soft mode (like in the full bridge, full wave rectifier), the output voltage will be free of high frequency components since they were not generated in the first place. When the charger employs active switches however, high frequencies are generated and they find their way through C1 via common filters and inductance of the cables into the battery. The battery itself also has capacitance with respect to ground.

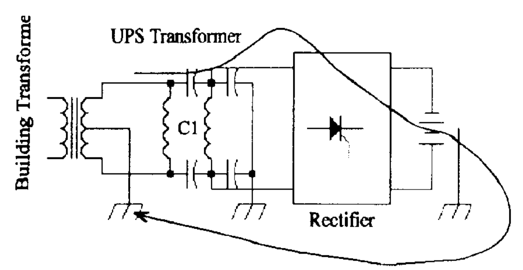

Fig 5. High frequency current loop

Since there are many stray inductances and capacitances in the circuit, prediction of the magnitude and frequency of ringing after each switch event is difficult. It is also difficult to assess the magnitude of the high frequency ripple current passing from the battery to ground, through its casing. Up to 80 mA at l20 kHz was measured in installations of 120 cells

Monitoring of a few µV (as required for detection of the degradation of the intercells) under such conditions presents a considerable challenge for the electronic circuitry designer. The monitoring equipment subject to such a high common mode must be able to deal with the **C**ommon **M**ode **R**ejection **R**atio (**CMRR**) in excess of 100 dB over a wide frequency range.

The existence of AC ripple current raises concern among of many battery manufacturers and users. The main concern seems to be the battery temperature increase due to ripple currents [2, 3] and the possible detrimental effect on the battery life [1]. In addition, the system losses produced by ripple current are significant enough to draw the attention of EV system engineers. Bypass super capacitors have been proposed to deal with this in spite of the cost and weight increase.

Dynamic

Batteries require well controlled DC voltages. 1% or better is required not only by battery manufacturer but also the DC equipment connected to it. Electronic engineers designing the charger must keep in mind these requirements and usually do much better when they do so. Since many users do not know about the AC presence on the battery, and even fewer who suspect battery operations, when sensitive power monitors monitoring the input to the charger record no power outage or disturbances. The net result is that batteries are called for service much more frequent than one would expect.

To explain fully this phenomena, we need to reach for closed loop tool analysis used for calculation of the stability of a high gain control systems This analysis is beyond the scope of this paper, however results of such presented in Fig 6. should be convincing enough. From this drawing it becomes evident that insignificant input voltage variation, which are not recorded by any power monitoring equipment, will produce the same effect as short duration shallow discharges of the battery. This is good news for battery monitoring manufacturers, since such events are quite frequent and the behavior of the battery under real load can be observed without any injection of the external load or current pulses [4]

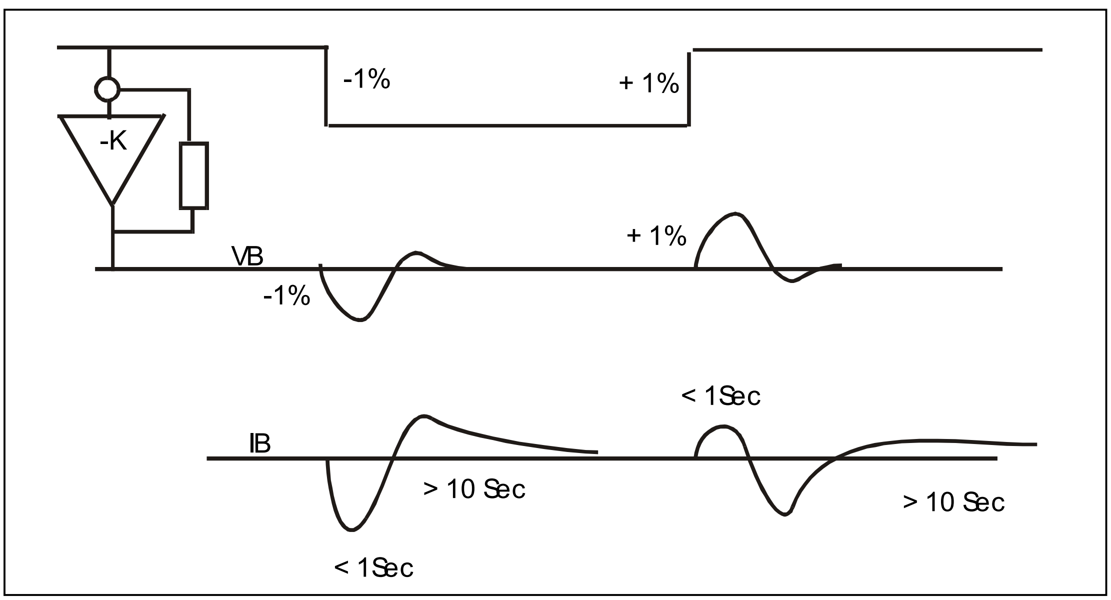

Fig. 6 Response of the high stability charger to the input voltage variation and resulting battery current

Conclusion.

The presence of the electrical noises in the battery room of UPS installation is much higher than any DC engineer would expect. Batteries mounted in the tight cabinets are often are serviced without powering the system down, which is evidently life hazard. The presence of the high AC ripple current may elevate the temperature, which may its lifespan and high frequency common mode noises upsets the sensitive monitoring equipment.

Good news is that in UPS application there are frequent discharge/charge events permitting battery monitoring equipment to capture real data, the bad news is that such equipment may simply refuse to work after installation or during a discharge/charge event due to the monstrous noise level existing at such time.

References

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