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High Voltage Battery Monitoring System

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Abstract: Battery monitoring system (BMS) is used in battery operated industrial and commercial equipments to avoid any failures and increase running hours of equipments. A Lead acid battery string (LAB) is a set of lead-acid cells connected in series. This paper presents High Voltage Battery Monitoring System can monitor LAB of 112 cells (2V each) connected in series thus an effective string voltage of 224 VDC. The proposed system is a low cost individual cell monitoring system suitable for LAB. The system has two main parts: one part is the main control unit (MCU) that stores, analyses cells data in a battery monitoring system software and presents cells data in the graphical form and the other is 14 peripheral devices module (PD) one for eight battery cells that measures voltage and electrolytic temperature of eight cells and sends data to the MCU. The MCU could connect the PD on the RS485 bus. Through the modbus communication, the battery data is transmitted to the monitoring system software and it will be stored in the database for the estimating of state of charge. It also provides signals to the Battery Charger panel.
Keywords: Battery Monitoring System, Battery string, Lead Acid Battery.

1 INTRODUCTION

Lead-Acid batteries (LAB) are widely used in industry to store energy in chemical form and deliver it as electricity. LABs can be found in electric vehicles, submarine operation, power plants and backup systems in critical installations such as hospitals, computer centers, telecommunication sites, oil-rigs and emergency bays in roads. However, their electrochemical nature gives them a very short useful life. Much research has been conducted to understand the phenomena during its charge and discharge cycles; phenomena that affect in the long term the battery useful life. These studies have provided two conclusions:

a) The selection of the right charging algorithm can extend the useful life of a battery and,

b) A continuous monitoring helps to estimate the LAB's state-of-health (SOH) and hence, it is useful to locate the batteries that are about to fail.

This allows maintenance person to take action before a problem arises. A LAB is a set of lead-acid cells connected in series. In this paper the acronym LAB will be used to refer to lead-acid battery bank (string). LABs are very fragile devices whose useful life mostly depends on factors such as terminal voltage of cell, temperature of cells, charge and discharge regimes and connections with other elements. In energy backup systems, cells are connected into arrays to achieve operational voltage and current levels. Connecting cells in series elevates voltage. High current rates are achieved by connecting cells in parallel. Reliable operation of a cell-array depends on every element functioning correctly.

In a series array, if one cell fails, then the complete array fails causing maintenance costs and the consequent drop in system reliability. The useful life of a particular cell in an array depends on several factors such as:

- Difference in the ability to accept charge with respect to other identical cells
- Excessive electrolyte loss
- Thermal stress if the cell is located at the end of the array.

Individual and continuous monitoring of LABs can detect elements with higher fail-probability, allowing their replacement before system breakdown, hence increasing the reliability of the backup system.

Some benefits of monitoring the LAB-banks are:

- Increase in system reliability
- Reduction in maintenance costs
- Personnel safety
- Extension of LAB's useful life

The parameters that are commonly monitored to determine the LAB's SOH are:

- LAB-bank voltage
- Individual LAB voltage
- Temperature (environment and at the LAB)
- Number of charge-cycles

Typically, these parameters are registered for every 30 seconds; but depending on the application, longer sample rates could be recorded.
This paper presents High Voltage Battery Monitoring System can monitor LAB of 112 cells (2V each) connected in series thus an effective string voltage of 224 VDC.

2 SYSTEM DESCRIPTION

The system has two main components: one module is the main control unit (MCU) that stores, analyses cells data in a battery monitoring system software and presents cells data in the graphical form and other module is 14 peripheral devices one for eight battery cells that measures voltage and electrolytic temperature of eight cells and sends data to the MCU using modbus protocol. In this way we can achieve the monitoring of 112 cells of battery bank (LAB).

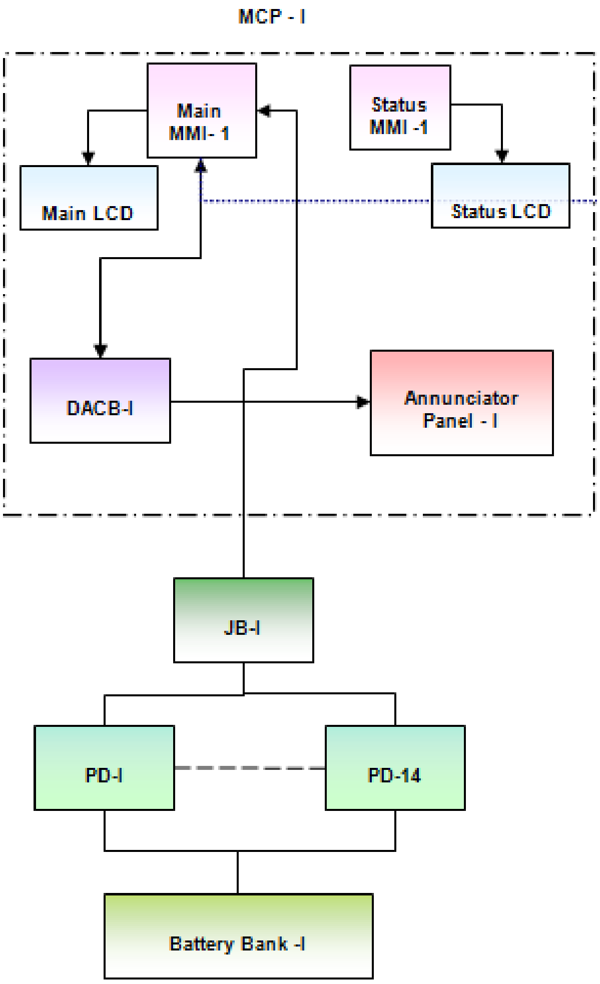

Fig.1 Block Diagram of the Battery Monitoring System

2.1 Peripheral Devices

This system has 14 PDs, depending on its size. There must be one PD for every 8 array of cells connected in series. Each peripheral device registers voltage and temperature of the corresponding cell. The PD is also a microcontroller-based board and have a low-cost, low-power, commercial microcontroller each. The microcontroller performs the data acquisition and the communications with main control unit. Fig.2 shows a photograph of a peripheral device without its case.

Fig.2 Photograph of Peripheral Device

Every module takes its power from the MCU. An RS-485 network is used to communicate all the peripheral devices in a bank with the corresponding MCU. In order to avoid the problems associated with differential power supplies, every PD has an isolated power supply for its communications circuitry. Communications are carried out using a modbus protocol that reduces overhead in order to save the high-energy demands that occur during transmissions.

Every PD in the system will perform the following functions:

- Measuring the voltages of 8 cells in the bank.
- Measuring the temperatures of the same 8 cells.
- Communication with the MCU via a serial channel that is RS-485 bus.

2.2 Main Control Unit

The main control unit must be a computer with enough processing power and disc space to store, analyze and display all data collected by the peripheral devices. The Main Control Unit controls the entire functionality of the BMS. The system can store data up to 112 LABs. Data are stored in a commercial database located at the MCU. This scheme assumes that the PDs are located in the same room as the LABs being monitored, and that the MCU is located in a control room.

MCU requests for cells data to 14 PDs. The user sets the sampling rate at which the MCU reads data from the PDs. Faster sampling rates require the use of larger databases. For small, non-critical applications, slow sampling rates are recommended.

The main control unit performs the following functions:

- Periodic data collection from its associated PDs.
- Serial communication with the PDs using a modbus protocol.
- Monitoring of bank's current.
- Monitoring of room's temperature.
- Database management and updating.
- Monitoring-system administration.
- Estimates SOH of each LAB in the system.
- Graphic display of collected data.
- Report generation.

The MCU houses the following system components:

(i) Main MMI
(ii) Status MMI
(iii) DACB
(iv) Keyboard
(v) Printer

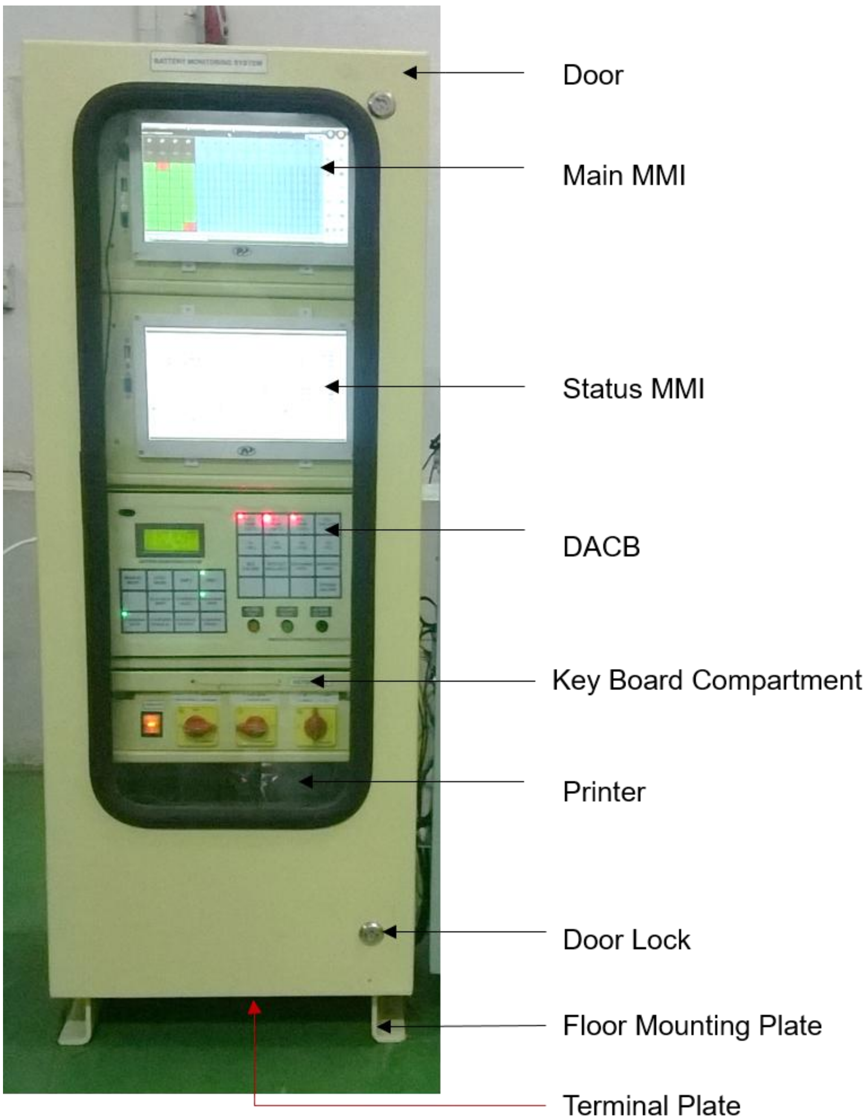

Fig.3 Photograph of Main Control Unit

The programs of the main control unit are written in MPLAB compiler by Microchip. This programming tool permits adapting the program to any particular user need. It is also possible to make the LAB-bank's data available over the Internet, so that remote supervision can be achieved.

3 DATA VISUALIZATION

The main control unit presents data in graphical form on Main MMI (man machine interface) application software. We use QT software for application development. It creates powerful applications and UIs that run on any screen and any platform. The Main MMI is the heart of the system, and is located in the first compartment of

MCU enclosure. Every user interaction for the BMS is conducted through the Main MMI. All data from the battery pit and the DACB is processed and calculated in the Main MMI as per pre-defined algorithms. Every 30 seconds, the Main MMI requests information from DACB to get data of 14 PDs, processes the information and update its display, LEDs and other outputs.

The Main MMI application window is divided into the Dashboard Panel, the Main Body and the Status Bar. The Dashboard Panel displays the most crucial elements of the batteries. These elements are known as Dashboard Parameters. The Main Body of the BMS software is where the user can adjust, modify or view various aspects of the BMS software. Any section's major user interface is shown by the Main Body of the BMS Application Software. The Status Bar is located at the bottom most section of the BMS Application Software. The Status Bar provides very brief information to the user, along with Date and Time.

Upon booting into the BMS, the user is first greeted to a welcome screen, as shown in the Fig.4. The software shall automatically jump to the monitoring screen if no input is given by the user within 30 seconds.

Fig.4 BMS Application Software Screen

The Monitoring Mode is the crux of the BMS software. This is where the user can monitor the voltage and temperature of the batteries, and view each battery's status. This is also the default mode that is displayed when the user clicks the  button. The Fig.5 illustrates a typical view of the Monitoring Mode. Each battery has its Serial No. shown below its icon. If the user clicks on any of the batteries, a dialog shall be displayed to the user showing the said battery's Voltage and Temperature. If the user clicks on the  icon on the top right, a zoomed in view showing the Serial No, Voltage and Temperature of each battery is displayed to the user, as shown in the Fig.6. The user can use the scroll bar to view the other batteries.

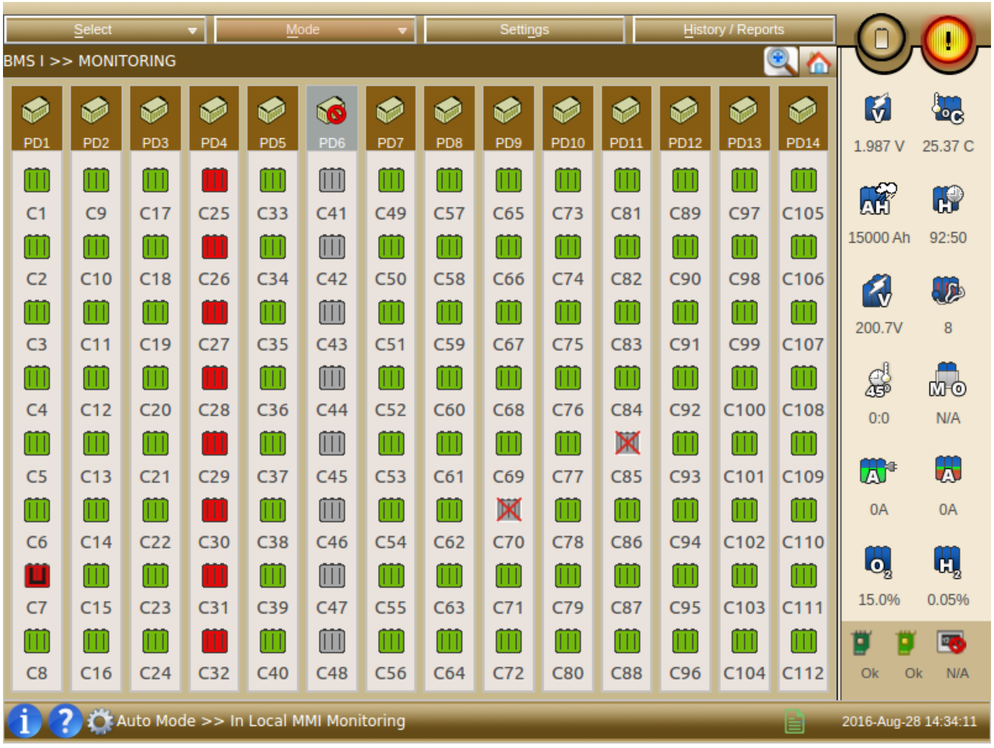

Fig.5 Monitoring Mode, Zoomed out

Fig.6 Monitoring Mode, Zoomed in

The application window’s main body presents data of 112 cells. Data consist of the voltage and temperature registered in each cell at a particular date and time. This can help system operators to detect a particular cell whose voltage or temperature is prominently lower or higher than the rest of the cells in the same bank. When looking for abnormal behaviors, it is desirable to display data from many cells at the same time. If the user is monitoring the batteries in zoomed in mode, both invalid and sick batteries shall show up in RED color.

The information provided by this window can help an experienced system operator to detect those cells more prone to fail and take the corresponding preventing maintenance actions.

Although there is a difference of a couple of degrees, it is obvious that none of the cells has suffered thermal stress during the time of monitoring. Exact measurements are not necessary, as long as the monitoring in one particular LAB is consistent.

If one cell behaves differently, it should be marked as suspicious and the appropriate diagnosis procedure applied. The voltage and temperature sensors used have a tolerance of +/-1%. Hence differences between the values read in different cells seem significant. However, the purpose of the system is to detect abnormal changes in LAB’S behavior, therefore, the exactness of a sample is not relevant as it is its consistency.

4 CONCLUSION

A monitoring system for big battery-banks has been presented. All components (hardware and software), were developed. The system provides the following benefits:

- Detection of failing cells: With this, preventive maintenance actions can be scheduled, which is cheaper than corrective maintenance during emergencies.
- Longer useful life of LAB: By observing the trend in the voltage of a cell, it is possible to determine if some maintenance action is needed, for example, replenish electrolyte or check the connections. Opportune maintenance actions can make the LAB’S useful life longer.
- Low cost.
- Adaptability: Since all hardware modules are programmable, it is possible to adapt the system to particular user requirements.

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