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BATTERY MONITORING SYSTEM FOR INDIAN SUBMARINE

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Abstract - The Battery Monitoring System (BMS), has been developed to remotely monitor the state of the batteries. The BMS monitors Voltage, Temperature and Level of the batteries, and using pre-defined algorithms provided by the Indian Navy, calculates the status of each battery. Apart from simply calculating the status of each battery, the BMS also notifies the user of the current state of the capacities of the battery, and as to how long can the batteries last, given the amount of discharge at the given time, proving to be a very useful tool during critical conditions.

1.INTRODUCTION

The purpose of the Battery Monitoring System is to provide the user an automated system to monitor the cell voltage, cell temperature, electrolyte level and health of the batteries on board a submarine. This document provides a technical guide to the user for the maintenance, repair and handling of the equipment for the Battery Monitoring System. In India we are able to see an exponential increase in the number of electric Rickshaws which use Lead Acid battery instead of the using a more efficient lithium-ion battery. The main reason being the cost of the lead acid battery which way lesser than the lithium-ion battery, hence it is important to build a battery monitoring and management system for lead acid battery. These lead acid battery works well in the ambient temperature but gives poor performance at lower temperature. The current system currently used are not adaptable to different atmospheric conditions and in a country like India temperature places an important role in determining the performance of the battery because the temperature here can go as high as 51.0 °C (123.8 °F) Phalodi, Rajasthan and as low as −45 °C (−49 °F) in Kashmir. Hence it is important to study the behavior of the battery at different temperatures which could help us design a system that more adaptive to the surrounding conditions. we have to keep a lot of factors in mind like Cell and Battery.

2.SYSTEM ARCHITECTURE

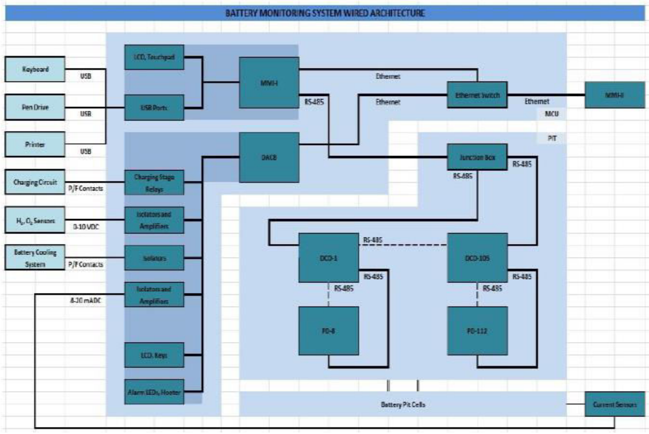

Figure No. 2.1Sytem Architecture

The Battery Monitoring System (BMS) has been developed to remotely monitor the state of the batteries. The BMS monitors Voltage and Temperature of the batteries, and using pre-defined algorithms calculates the status of each battery. Apart from simply calculating the status of each battery, the BMS also notifies the user of the current state of the capacities of the battery, and as to how long can the batteries last, given the amount of discharge at the given time, proving to be a very useful tool during critical conditions.

(a) Main Control Unit (MCU).
The MCU consists of the Main MMI, Status MMI Data Acquisition and Conversion board, Ethernet Switch, AC Power Supply Distribution Board, Three Phase SMPS, Single Phase SMPS, Keyboard and Printer. The MCU also accepts inputs from external systems such GSSCS, LCS and Battery Switchboard. The entire BMS is controlled and monitored by the MCU.

(b) Main Man Machine Interface (Main MMI). The Main MMI is the heart of the system, and it is where the user interface is displayed to the operator. It consists of a 10.1-inch touch panel. It is powered via a +24V DC input power and provides two USB ports and one LAN port interface. Detailed circuit description and operation of the Status MMI has been provided in the later sections of this document.

(d) Data Acquisition and Communication board (DACB).

This board, which is located inside the MCU, is used for acquisition of data from sensors present in various external systems such as Gas Subsystem and Cooling System and the Battery Switch Board. It sends the sensor data collected to Main MMI over Ethernet based on triggers received from Main MMI. It also drives the Annunciator panel and various control outputs, based on certain pre-defined alarm conditions. The DACB controls the charging stage relays, and monitors the Hydrogen and Oxygen percentages, Charging and Discharging currents and Battery Cooling System. It also consists of a 20 x 4-character LCD to display the above parameters. Detailed circuit description and operation of the DACB has been provided in the later sections of this document.

(e) Ethernet Switch.

The Ethernet switch is used to interconnect the Main MMI, Status MMI, DACB and BMS-II for communication.

(f) AC power Supply Distribution Board.

AC Power Supply Distribution Board received power from three AC-DC SMPSs. +24VDC is also received from the aforementioned SMPSs and a single 24V is passed to the system as the system supply.

(g) Three Phase SMPS.

An SMPS is an electronic power supply that incorporates a switching regulator in order to be highly efficient in the conversion of electrical power. This SMPS converts the 170-280VAC to 24 VDC. This output is then provided to AC power supply Distribution Board.

(h) Single Phase SMPS.

An SMPS is an electronic power supply that incorporates a switching regulator in order to be highly efficient in the conversion of electrical power. This SMPS converts the 170-280VAC to 24 VDC. This output is then provided to AC power supply Distribution Board.

(j) Upgraded PD.

A single PD caters to an entire column of 8 batteries. It is responsible for collecting voltage and temperature of all the 8 batteries. In all, there are 14 such PDs. These devices are located in the battery pit. The PD with mounting plate is mounted on top of a pre-determined battery of that row, using a clamp. The PD collects the data from the batteries and sends it to the Communication Board (CB) inside the DACB over RS-485 and then this data is given to the Main MMI over Ethernet.

(k) CH-DCH Module.

The Charging/Discharging module is used to sense the Charging/Discharging current of the whole battery bank. The sensor used provides 0-100mv output from Shunt as a reflection of 0-3000A charging/discharging current of the battery bank. The charging/discharging module gives an output of 0-20 ma for 0-100mv input to the BMS system.

2.1 Types of Components Proposed System Details.

2.1.1 Main Man Machine Interface (Main MMI) MMI

The MMI is the heart of the system, and is located as the top most component on the front side of the MCU. Every user interaction for the BMS is conducted through the MMI. All data from the battery pit and the DACB is processed and calculated in the MMI as per pre-defined algorithms.

Every 30 seconds, the MMI requests information from all PDs and DACB, processes the information and updates its display, LEDs and other outputs. Specifically, the MMI requests voltage, temperature, level and self-test information from 14Nos. PD/DCDs on RS-485. Each PD/DCD in turns requests the same information from 7Nos. PD/BMTx on RS-485. Each PD/DCD consolidates its own information along with the one received from PD/BMTxs and sends it to MMI.

Specification:-

- +24VDC Power Supply
- 12,1'' 800x600 Resolution
- Touch screen
- 2 Ports
- IP-54

2.1.2 Data Acquisition and Communication board (DACB).

DACB fascia carries 4 Line, 20 Character LCD, 29 Nos. LED indicators and 4Nos. Keys, as shown in **FIGURE 3.4** below, The DACB LCD when it is connected to the MMI. When the DACB is disconnected from the MMI, the DACB LCD shows only percentage of Hydrogen and Oxygen, Discharging and Charging Current. The remaining parameters are displayed as **'N/A'**.

Specification:-

- +24VDC Power Supply, <1Amp.
- Led indicators 29Nos.
- 24x4 LCD display character
- IP-54

When it is connected to the MMI. When the DACB is disconnected from the MMI, the DACB LCD shows only percentage of Hydrogen and Oxygen, Discharging and Charging Current. The remaining parameters are displayed as **'N/A'**.

The DACB is connected to the MMI via Ethernet and acts as a slave to the MMI on Modbus-RTU/TCP protocol.

Every 30 seconds, the DACB receives commands from the MMI. The command packet contains text to be displayed on the LCD, statuses of the 29 LEDs, On/Off status of the four Charging Stage relays and On/Off status of the hooter. Additionally, the command also requests external inputs such as percentage of Hydrogen and Oxygen, Charging and Discharging Current and Battery Cooling System statuses, so that the MMI can display these values to the user.

The feedback of the physical keys located under the LCD panel are sent to the MMI via the same interface as mentioned above. The DACB only handles the L/T (Lamp Test) key locally and turns on all LEDs as long as it remains pressed.

When the DACB loses connection with the MMI, it only displays the values of percentages of Hydrogen and Oxygen, Charging and Discharging Current parameters on its LCD. The values of all other parameters are displayed as 'N/A'. Also, the DACB only sets LEDs corresponding to the aforementioned parameters, and switches off all other LEDs, Relays and the Hooter. A DACB Utility is provided on the laptop for testing and calibration.

2.1.3Power Supply Module (PS)

The PS Module is located inside the MCU, and is the primary source of power for all the MCU components including the MMI, DACB and Hooter Module.

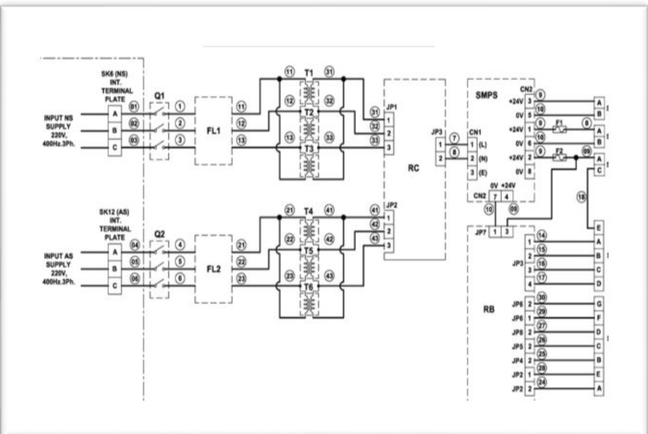

Figure No.2.2 Electrical Diagram Of Power Supply (PS)

PS module is mounted on the back plate of the MCU from inside. As shown in figure 3.5, the PS fascia has 2Nos. MCBs, 5Nos. connectors, 2Nos. fuses and a tally plate depicting electrical diagram of the MCU. The MCBs Q1 and Q2 receive input connections from the MCU Terminal Plate.

On the inside, the PS module contains 2 Nos. MCBs in the top right corner, Relay Board containing 4 Nos. relays in the top left corner, 2Nos. Power Filters just below MCBs and Relay Board, 6 Nos. transformers just below Power Filters, Relay Card in the bottom right corner and SMPS in the bottom left corner, as shown in figure 3.5 All the aforesaid components are accessible on opening the front plate of the PS.

2.1.3.1 Rectifier card (RC)

The Rectifier card rectifies an input of 120V AC, to a full wave rectified output filtered by a low pass filter.

A photograph of the Rectifier Card is shown in below

Figure No.2.5.2 Electrical Diagram Of Rectifier Card

The Rectifier Card receives two 3-phase, 120 VAC, 400 Hz inputs at JP1 and JP2. D1-D3 and D7-D9 are Diodes which implement full-wave rectification of 3-phase input at JP1. D4-D6 and D10-D12 are Diodes which implement full-wave rectification of 3-phase input at JP2.

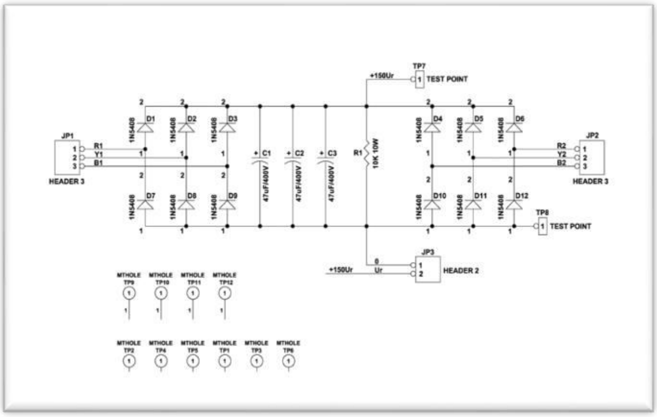

Figure No.2.3 Rectifier card (RC)

The full-wave rectified output is filtered by low-pass filter formed by Capacitors C1-C3 and Resistor R1. The Diodes also act as an OR-gate for Main and Alternate power supplies, thereby maintaining rectified-output in presence of either one of the input power supplies.

2.1.3.2 Relay Card.

The relay card consists of 4 relays for controlling charging stages. The relay card is driven by signals provided by the DACB. The photograph of the Relay Card PCB is shown in below

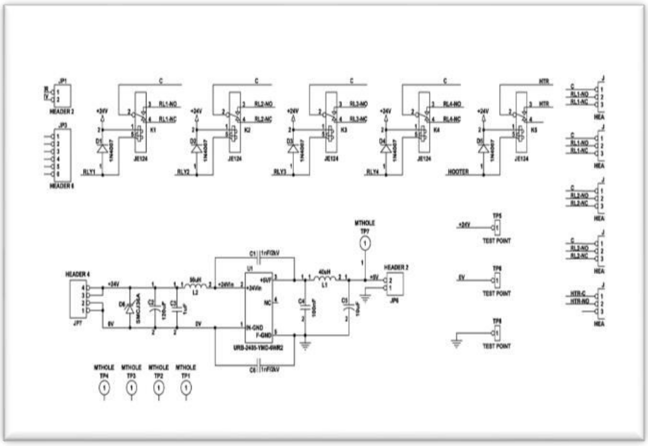

Figure No.2.4 Relay Card.

(i) The Relay card implements five potential-free outputs, four for Charging Stages and one for Hooter.

(ii) RLY1-RLY4 and Hooter are five digital inputs from the MCU. The Digital inputs drive the five relays (K1-K5), each of which has one NO (Normally Open, RL1-NO - RL4-NO and Hooter) and one NC (Normally Closed, RL1-NC - RL4-NC) contacts.

(iii) D1-D5 are freewheeling Diodes, which take care of inductive current during relay switching.

(iv) Relays are driven by 24 VDC power supplied from the MCU.

(v) U1 is a 24 VDC to 5 VDC converter. 5 VDC is an alternate power for Relays, but is not used.

2.1.4 Peripheral Device (PD-DCD and PD-BMTx)

The Peripheral Devices consist of both the PD-DCD and PD-BMTX. The Peripheral Devices reside inside the battery pit, and are mounted upon each battery. As such, a total of 224 Peripheral Devices are required to monitor the voltage, electrolyte temperature and electrolyte level of each battery. While PD-DCDs are mounted on the first battery of each of the 14 columns, PD-BMTx are mounted on the remaining batteries of all the 14columns. PD/DCD as well as PD/BMTx enclosures are sealed and cannot be opened or serviced. A damaged unit should be replaced.

Specification:-

- **Voltage:-**
  Range: 1.5 VDC to 3.0VDC
  Resolution: 0.001VDC
  Accuracy: ± 0.001VDC

- **Indicators:-**
  3 x LEDs: Power and Communication, Sick Cell and Level

- **Temprature:-**
  Range: 0°C to 100°C
  Resolution: 0.1°C
  Accuracy: ± 1°C

- **Level:-**
  Range: -25 mm to 25 mm
  Resolution: 1 mm
  Accuracy: ± 5 mm

- **Communication:-**
  2 x RS–485 Master and Slave Port (PD/DCD Only)
  1 x RS–485 Slave Port (PD/BMTx Only)

- **Power:-**
  Voltage: 1.5 VDC to 3.0 VDC
  Current: 200 mA DC Max

PD/DCDs and PD/BMTx are mounted on the service holes of the batteries located inside the battery pit of the submarine with the help of an Adaptor. The Adaptor is first screwed into the service hole and PD/DCD or PD/BMTx is mounted on the Adaptor using a locking Plunger. Illustrates that each PD/DCD has two Power Cables and two Communication Cables coming out of its top portion.

Each Power Cable has a terminal block at its other end. The terminal blocks, red for positive and black for negative, are attached to the positive and negative terminals of the battery respectively, on which PD/DCD is mounted. The Thumb Screws are used to tightly secure the contact with the battery. Each of the 2Nos. Communication Cables viz. COM1 and COM2 are further split into 2 parts - plug and socket. All PD/DCDs are looped on COM2 and each PD/DCD is looped with 7Nos. PD/BMTx mounted on the batteries of the corresponding column via COM1.each PD/DCD and PD/BMTx has a narrow, cylindrical stem which immerses into the electrolyte of the battery when the PD is mounted on the service hole of the battery. The stem contains a temperature sensor and uses value of the capacitance formed between core of the stem and electrodes of the battery to measure level of the electrolyte.

NOTE: It must be noted that only the PD/DCD consists of two COM ports viz. COM1 and COM 2. The PD/BMTx only consists of one COM port.
Each PD/DCD and PD/BMTx has 3 LEDs located on its cap, indicating various aspects of the battery and the PD itself Connectors attached to the other end of the cables of each PD/DCD and PD/BMTx have input and output connections Inside, each PD/DCD or PD/BMTx contains a set of 4 Nos. PCBs – two circular PCBs, one each at the base and top, and two rectangular PCBs, as shown in figure.

(i) The PCBs are not only soldered, but are also supported with metallic studs for firmness and stability.
(ii) The stem PCB is located inside the stem and wires coming from it are soldered to the circular PCB at the base.
(iii) The circular PCB at the top carries three LEDs surrounded by three Light Guides which protrude out of the cap.
(iv) The Power and the Communication Cables enter the enclosure just under the cap and are first secured and then soldered to the circular top PCB.
(v) The PCB assembly is surrounded on top, bottom and side by metallic shields to protect them from EMI/EMC interference

It consists of the microcontroller that drives the Peripheral Device. A photograph of the DCD-MUC-V3 is shown in figure.In accordance to the PCB schematic at, the details of the DCD-MUC-V3 PCB are as follows.

(i) U1 is the main micro-controller for the DCD and Y1 is its crystal oscillator.
(ii) U2 is the Radio Frequency Module for future wireless communication (not used in this design).
(iii) U3 is Single-Pole-Double-Throw (SPDT) Analog Switch for switching between receive lines of wired and wireless modules.
(iv) U4 is Double-Pole Quadruple-Throw (DPQT) Analog Switch used for switching between battery terminals, and internal reference and internal ground inputs to Analog-to-Digital-Converter (ADC). U4 allows auto-calibration.
(v) U5 is low voltage temperature reference for measuring temperature inside the enclosure.
(vi) U6 is a micro-power voltage reference diode used as reference for internal and external ADCs.

I.EXPERMENTS AND RESULTS

The Battery Monitoring System (BMS), has been developed to remotely monitor the state of the batteries. The BMS monitors Voltage, Temperature and Level of the batteries, and using pre-defined algorithms provided by the Indian Navy, calculates the status of each battery.

Apart from simply calculating the status of each battery, the BMS also notifies the user of the current state of the capacities of the battery, and as to how long can the batteries last, given the amount of discharge at the given time, proving to be a very useful tool during critical conditions.

3.CONCLUSION

The paper described the design and development of an battery monitoring system for Heavy rating batteries to ensure the battery performance degradation can be monitor on Single MMI. The objective is to proof that the concept of the idea can be realized. The development of the system consists of the development of the hardware for the battery monitoring device and a web-based battery monitoring user interface. The system is capable to show information such as Voltage, Temp, Electrolyte Level, H2-O2, Residual capacity, battery endurance, Data logging etc.

Further modification can be done to improve the system by adding more functions into the system. Ethernet can be used in this project we are going to monitor the battery level using current sensor and voltage sensor. When the battery level is getting low, the led will blink, as well as it will be also displayed in MMI.

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