Battery management system(BMS) of electrical vehicle

Pranay Dattani[a] Taylor & Francis, shantilal shah engineering collage, bhavnager, Gujarat,India

ARTICLE HISTORY
Compiled March 2, 2021

ABSTRACT
At the recent time, the improvement of the battery management system (BMS) is in demand, and nowadays a wireless communication or wireless system in BMS. CAN communication system is a very popular and more useful system compare to the other wireless system. In this paper various wireless battery management systems discuss and also a BMS system discuss. As EVs are becoming popular, the use of Lithiumion (Li-Ion) batteries is exponentially increasing due to their good charge/discharge performance, high energy, and current density, and optimum power support. For safe operation of the battery, precise estimation of the State of Charge (SOC) is necessary[24]. In Evs, various type of chargers is available AC, DC, CCS, DC fast charger, etc. in Gujarat regain CCS charger are very common to use in a private or commercial charging station. ultimately the EVS charging system is dependent on a BMS of the system, when the BMS system is very advance the charging of the EVs is fast and efficient. Keep upgrade the BMS system of an electric vehicle is necessary to improve the charging and whole system performance and BMS also benefit in fast charging in Electric vehicle(EV).

KEYWORDS
battery management system(BMS), EV charging system, BMS of Electrical vehicle, Internet of vehicles, smart battery management system, wireless battery management system(WBMS).

1. Introduction

Today The use of vehicles is very high, which leads to an increase in the consumption of nonrenewable fossil fuels, and it also plays a big role in contributing to increasing the pollution level. So, this issue makes us think of an alternative energy source for vehicles. Moving towards renewable energy. The Electric vehicle is the best option in the vehicle sector because it operates on electricity and its a non-polluted. in the electric vehicle, the battery is the heart, and the battery management system is a very important aspect of the electric vehicle.The battery management system is a very necessary part and core component of an electric vehicle battery system. most of the vehicles are on road are powered with petrol or diesel, and based on this greenhouse effect are produce, and due to this the environment is polluted, that's why at this time electrical vehicle(EV) are in demand and the government are a support of electrical vehicle(EV). in an electrical vehicle, the power source is changed and its a rechargeable, and its a nonpolluted or eco friendlily. Here many types of electrical vehicle and each type have its own function and its a different to other but all types are nonpolluted and types are,

CONTACT Pranay dattani. Email: dattanipranay.11@gmail.com

- BEV - Battery Electric Vehicle
- PHEV – (Plug-In) Hybrid Electric Vehicle
- HEV – Hybrid Electric Vehicle
- FCEV – Fuel-cell Electric Vehicle

At this time many companies have their own EV charging station and many companies have provided a public charging station. They provide onboard charging, off-board charging. and also have different connectors like type 1, type 2, CHAdeMO, Combined Charging System (CCS)[17]. The charger has AC or DC both types of charging. in India many companies charging station use CCS(combined charging system)[19]. The increasing use of electrical drivetrain sources in passenger vehicles is relying more heavily on Battery Management Systems (BMS) to ensure battery pack efficiency over a wide range of driving styles and uses. The BMS uses internal battery pack sensors to measure the voltages and temperatures of individual cells within the pack to ensure that all cells are charging, or discharging, at level rates and are operating at an acceptable State of Health (SoH), which is vital to optimum battery performance. This improves the overall performance of the battery pack[27].

Different charging station company in India have provided a charging facility to a private vehicle or government vehicle, TATA Power, Fortum India, Mass-Tech, Exicom, Delta Electronics India, Bright Blue, ABB India, magenta group, Panasonic, this is top Indian company have their own charging station in India. and charging station is charge electrical vehicle from grid charging. BMS can be revolutionized as a result of further investigation of the Internet of Things (IoT) technologies [21] and cloud computing resources [22] to identify battery cell's health condition and to enhance scalability, cost-effectiveness, adaptability, safety, reliability, and flexibility of the largescale Li-ion BESS[9].

With the development of wireless communication technologies, it's possible to eliminate the complex wire setup and bulky hardware implementation. The Lithium-ion battery is protected properly otherwise it will large problem occurs. the efficiency of a battery in terms of how much power it can give output concerning size and weight has drastically improved [3]. The main reason for the growth in battery pack energy storage shows that can ensure maximum performance, safe operation, and optimal lifespan under diverse charge-discharge in different environmental conditions[14].

2. Ease of Use

The EVEV charging system is too easy. this is not complicated to charge, discharge, pay bills, overcharge, it is on the online server and its connection to the mobile wireless system. electric vehicles plug into the charging point and track energy from the grid. they store energy in a battery to supply energy to the motor wheel to rotate. electric cars accelerate faster than traditional fuel engines, and the EV has a smart control and various function made by the automated system, due to this it's very easy to use all the functions in the EV car like operating a cell phone.

3. Battery management system (BMS)

Battery is the main core part or main source of power for Electrical vehicle. the energy consumption by EV is more effect on battery performance. there are many functions which include in the battery management system(BMS),

- cell protection
- charge control
- SOC determination
- SOH determination
- cell balancing
- Authentication and identification
- Temperature protection
- communication

In the battery management system, the cell is a very important part of a battery, and based on the requirement of the vehicle the battery cell are connected in series or parallel. Each battery cell want to measure the temperature and we assure each of batter cell completely charges at 100 percent and also protects from the overcharging of a cell.

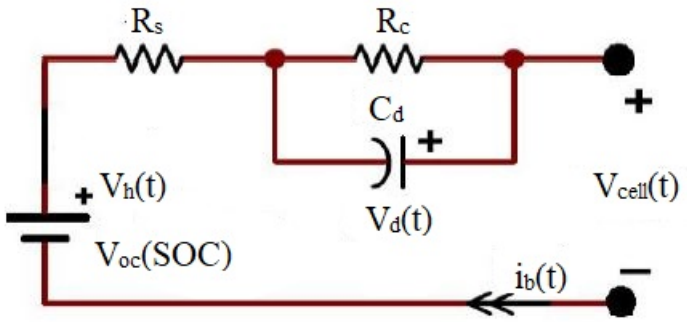

Figure 1. equivalent circuit of cell

In an advanced way of BMS, wireless BMS a significant breakthrough that offers the potential for improved reliability, weight, and lower cost (reduces wiring complexity, saves galvanic isolations and connectors) for large multi-cell battery stacks in electric and electric/hybrid vehicles[2]. The batteries are generally categorized based on the ability to charge that is primary and secondary batteries. The primary battery is disposable or used once while the secondary battery has the capability of charging when fully discharged. In EVs and HEVs, the secondary type of batteries are used, lithium-ion(Li-ion), lead-acid, nickel-cadmium (NiCd), and nickel-metal hydride (NiMH), etc[3].

The most common type is a battery monitoring system that records the key operational parameters such as voltage, current, and the internal temperature of the battery along with the ambient temperature during charging and discharging[4]. The system provides inputs to the protection devices so that the monitoring circuits could generate alarms and even disconnect the battery from the load or charger if any of the parameters exceed the values set by the safety zone.The battery is the only power source in pure electric vehicles. Therefore, the BMS in this type of application should include battery monitoring and protection systems, a system that keeps the battery ready to deliver full power when necessary, and a system that can extend the life of the battery[17]. The BMS should include systems that control the charging regime and those that manage thermal issues. In a vehicle, the BMS is part of a complex and fast-acting power management system. Also, it must interface with other onboard systems such as the motor controller, the climate controller, the communications bus,

the safety system, and the vehicle controller.

3.1. block diagram of battery management system

There are various Battery Management Systems available, either by the available Integrated IC or even customize our own battery management system(BMS) and have three different types of the battery management system(BMS) available. They are differentiated based on their topology[4]. The three available battery management system(BMS) are,

- Modular battery management system(MBMS)
- Centralized battery management system(CBMS)
- Distributed battery management system(DBMS)

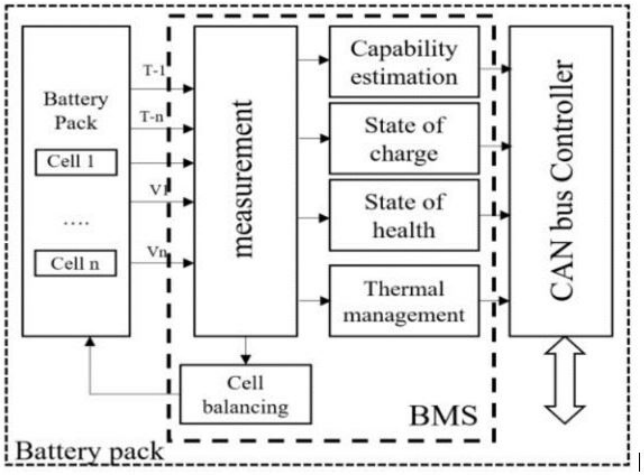

Figure 2. Block diagram of BMS system

The CAN bus is the single serial bus communication medium connecting all the Electronic control units across the vehicle. As we know the BMS is the primary control unit for the battery pack of the vehicle that supplies the power to the motor for its running that ultimately produces torque and rpm for the wheels to rotate and thereby generating motion[5]. The can bus is responsible for all the information and command to transmit from the electric vehicle control unit(ECU) to other systems or subsystems. The important part is the pedal subsystem which is connected via can bus to motor controller ECU and dashboard ECU. this subsystem work when the fault or error signal occurs then the immigrant driver stop or restarts the vehicle.

The main purpose of the BMS is the monitoring, control, safety, of the battery life and the system performance. in a data system, a few things are monitored or observed,

- Monitor individual cell voltages in the battery.
- Measure overall battery voltage and current output.
- Measure the temperature of the battery and its surroundings.
- Control the charging of the battery.
- Monitor the discharge of the battery.
- Monitor overvoltage or undervoltage conditions.
- Determine the condition of the battery.

4. Wireless battery management system(BMS)

Advance technique of BMS is a wireless BMS system. it is a very reliable, lower cost, and reduce the wiring complexity. there are many types of the wireless battery management system,The advanced technique of BMS is a wireless BMS system. To overcome the shortcomings of a wired BMS, a wireless communication-based system can be implemented. The architecture of MCU includes a Control module directly interfaced to the cells and is used for monitoring voltage, current, temperature, and other diagnostic parameters. The other unit the Communication module connected to the former using serial communication protocol includes a low power radio transceiver which will be used for data transmission between the CMU and CMBU[10].

it is a very reliable, lower cost, and reduce the wiring complexity. there are many types of the wireless battery management system,

- CAN communication for BMS
- IoT based wireless BMS
- Zig-bee based wireless BMS
- Bluetooth based wireless BMS
- Cloud based wireless BMS

4.1. CAN communication

The full name of CAN communication is controller area network(CAN). it is a serial communication bus design for hard, robust, and flexible performance in harmful environments, and its particularly automotive application. The CAN defines the data link and physical layer of the open system interconnection(OSI) model, to provide basic level networking solutions and high speed in electric vehicle communication. ECU and CAN both are together[6].CAN communication is extremely robust, efficient, simple and lowest in cost, and fully centralized.

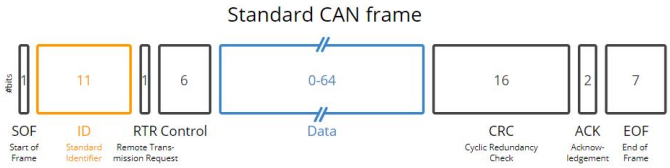

Figure 3. CAN communication

- SOF: The Start of Frame is a 'dominant 0' to tell the other nodes that a CAN node intends to talk
- ID: The ID is the frame identifier - lower values have higher priority
- RTR: The Remote Transmission Request indicates whether a node sends data or requests dedicated data from another node
- Control:: The Control contains the Identifier Extension Bit (IDE) which is a 'dominant 0' for 11-bit. It also contains the 4-bit Data Length Code (DLC) that specifies the length of the data bytes to be transmitted (0 to 8 bytes)
- Data: The Data contains the data bytes aka payload, which includes CAN signals that can be extracted and decoded for information
- CRC: The Cyclic Redundancy Check is used to ensure data integrity

- ACK: The ACK slot indicates if the node has acknowledged and received the data correctly
- EOF: The EOF marks the end of the CAN frame

The main advantage of that system compared with the existing systems was that it provided a fault-tolerant capability and battery protection. It consisted of several smart battery modules, and each module provided the functions of battery equalization, monitoring, and battery protection to a string of battery cells[19]. Today CAN is used in most of all automotive industry with an ISO standard (ISO11898). It is a twisted pair of wires having high transmission speed with combine error handling and fault confinement facilities[8]. The main advantage of the CAN bus is inexpensive, support auto re transmission of lost messages works in various environmental condition, etc. Considering the disadvantage of CAN bus it is applicable for 64 nodes in electrical loading, maintenance cost and time is high[9].

4.2. cloud based battery management system

Many research in IoT technology to improve and use IoT in all sectors, due to warm research IoT is used in many platforms and by use of IoT in battery management system its very grate advantages of all EV sector. IoT components contain data acquisition and wireless communication components which help to communicate with cloud components[9]. The Module Management System receives State of Health (SOH) and controls command from cloud battery management system from cloud BMS. Data transfer can be done by any device like low power Bluetooth, Wi-Fi, Zigbee with the help of IoT protocols[2].

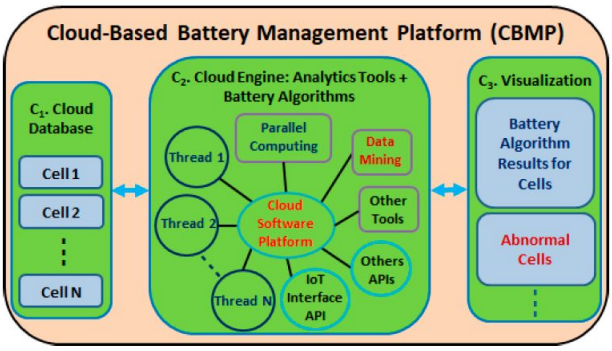

Figure 4. cloud based battery management system plateform

In cloud based condition monitoring system which contain a large set of batteries, Wireless Module Management Systems (WMMS)s in addition with IoT devices and Cloud Battery Management Platform (CBMP) contain cloud storage, analytics tools, battery calculation and visualization in display[25]. The data acquisition part such as sensor measure data at a sampling time of 1second, the measuring data are battery cell voltage, current and temperature. These data are stored in IoT communication devices which help to send data to cloud data storage in cloud server.

In this system by use of Raspberry pi, all systems are properly run without any complications. in the market various raspberry pi available, raspberry pi2, raspberry pi 2B+, raspberry pi3, raspberry pi3B+, raspberry pi4. various raspberry platforms in different ranges and capacities.

4.3. Bluetooth based wireless BMS

Bluetooth wireless technology is used in small devices like mobiles, computers, laptops, headphones, etc. The IEEE 802.11 b/g communication protocol. The range of these Bluetooth devices is approximately 20-100 meters. it's a very common device to use in wireless Bluetooth systems [13]. Bluetooth provides a flexible and inexpensive solution for remote applications[10].It operates in the 2.4GHz band in a piconet topology with a data rate of 1 Mbps. It uses 3 advertising channels to search for other devices and activates for 0.6 to 1.2 ms. After connection, it utilizes Adaptive Frequency Hopping in a pseudo random manner to avoid interference. The data rate is less as compared to standard Bluetooth as it is designed to fit devices that send data a few times a second, or less[26].

The UART is a communication protocol that enables the communication between computers and micro controls or micro controls and peripherals. The USART can carry data between 5 and 9 bits of data length. However, in general, 8 or 9-bit uses are preferred[11]. The sensed data from the battery cell is sent to the Microcontroller unit then data is sent to the GUI using the Bluetooth module. The flowchart for Arduino and data sending[2].

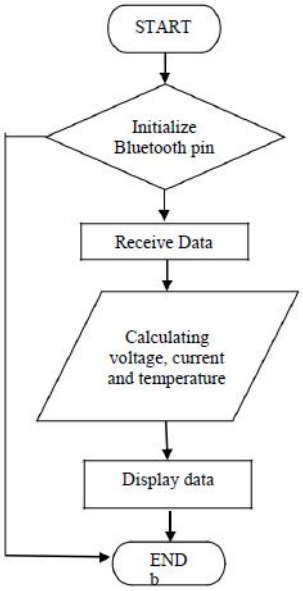

Figure 5. Flow chart of Bluetooth system

4.4. IoT based wireless BMS

wireless communication is a typical data transfer wirelessly. Here voltage sensors measure the voltage of lithium-ion batteries. By using SIM808 GSM/GPS/GPRS locate the vehicle exactly in the interface computer. The sensed voltage is sent to the Arduino Uno microprocessor after processing data is sent to the computer via SIM808 shield[2]. Also, the balancing algorithm based on the state-of-health (SOH) and the state-of-charge (SOC) can balance battery cells with any number, different aging states, and reasonable capacity deviation[6].

The sending data stored in the communication in the IoT devices which id respon-

sible for the sending the stored data to the cloud data storage in the cloud server wit assured security, ideally in real-time using transmission control protocol/ internet protocol via IoT gateway. on the other hand, the module management system receives the comprehensive health monitoring result equipped with a short-range radio such as WIFI, Zigbee, and low power Bluetooth, which transfer data or signal to other modules or a concentrator using IoT protocols[27].Due to the IoT and cloud support the WBMS can reduce the wire harness issue, simpler onboard controller, resulting in increase battery module scalability and improved manufacturing productivity.

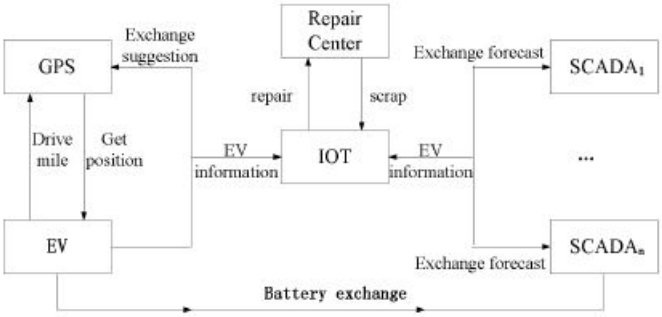

Figure 6. Block diagram of IOT system based BMS

4.5. softwere design for wireless BMS system

The purpose of developing the high-performance software architecture of BMS is to standardize, modularize, develop and maintain the BMS efficiently according to the inter-national popular AUTOSAR(Automotive Open System Architecture).

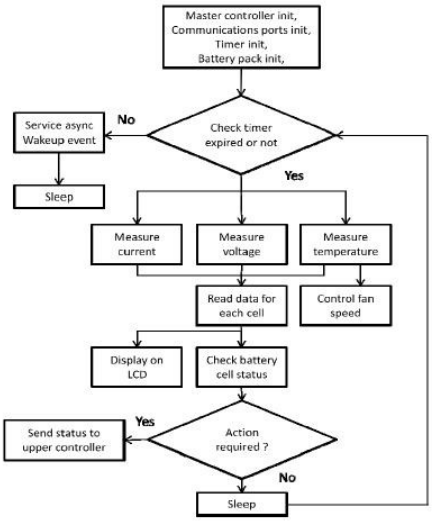

Figure 7. flow chart BMS softwere

In the application layer, the main functions of the BMS include online diagnosis, security protection, state estimation, balance control, thermal management, and charging flow control. Each function consists of several small sub- function modules[12]. The

MPC5775B battery management controller (BMC) plus MC33771 battery cell controller (BCC) system illustrates how to implement a simple high-voltage (HV) battery management system (BMS) in an efficient and easy-to-implement solution including hardware and software enablement. this MPC5775B battery management controller is very high speed with CAN flexible data transmitter and receiver system. It has also a voltage measurement, cell output, individual cell voltage measurement, temperature sensor, etc.

Future scope

Many battery models do not simulate the discharging behavior of actual batteries. When batteries are nearly fully discharged, and the load is removed from the battery, the voltage of the battery will increase; when the load is connected to the battery, and the current resumes, the voltage of the battery will drop to the nominal value. Such discharging behavior should be simulated in future battery models. Also, the performance of battery models could be further improved.

The results using the FLC reveals that it can be used to evaluate the energy-saving using several EV models; this way, it will be possible to improve the fuzzy set that composes the FLC and extends the energy-saving percentages. The hardware, software, and control strategy model of the battery management system are developed based on AURIX multi- core micro-controller. The minimal BMS system is developed by using AURIX265 + LTE35584 chip which meets the functional safety requirements. The dual-core processing of control strategy and individual information acquisition is realized, and the processing efficiency is improved.

conclusion

This paper explains various types of Wireless Battery Management System implemented so far along with its working and key finding of each system. We get to know that Bluetooth and Zigbee are two wireless communication having low power consumption. Bluetooth becomes more popular in the automotive industry while comparing with other wireless technologies. Cloud and IoT-based technology make wireless communication in broadway by adding with the google internet platform. Wireless technologies are updating day-by-day so it will be the future of Battery Management systems in electric vehicles. Usage of CAN communication will reduce in the future if an effective Wireless BMS unit came into the automotive industry. WSBMS is used to manage battery cells for EVs. The advantages of high fault tolerance and sufficient scalability compared with the traditional modularized BMS.

CAN Bus communication is indispensable when it comes to electric vehicle communication because of data transmission speed, reliability by reducing complications, accuracy in error detection along lower hardware costs for multi-signal processing techniques. Due to varying situations in real-world applications, a standard solution was not wanted. Based on the specific situation, different strategies should be applied to improve and optimize the performance of BMS in future EVs.

References

[1] M. Furat, "Electric Vehicle and Charging Strategies for Upcoming Demand," 2019 3rd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), Ankara, Turkey, 2019, pp. 1-5, doi: 10.1109/ISMSIT.2019.8932790.

[2] V. K, R. K. Nema and A. Ojha, "Various Types of Wireless Battery Management System in Ev," 2020 IEEE International Students' Conference on Electrical,Electronics and Computer Science (SCEECS), Bhopal, India, 2020, pp. 1-5, doi: 10.1109/SCEECS48394.2020.115.

[3] F. A. Shah, S. Shahzad Sheikh, U. I. Mir and S. Owais Athar, "Battery Health Monitoring for Commercialized Electric Vehicle Batteries: Lithium-Ion," 2019 International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET), Istanbul, Turkey, 2019, pp. 1-6, doi: 10.1109/PGSRET.2019.8882735.

[4] J. S. Lokhande, P. M. Daigavhane and M. Sarkar, "A Critical Approach Towards a Smarter Battery Management System for Electric Vehicle," 2020 4th International Conference on Trends in Electronics and Informatics (ICOEI)(48184), Tirunelveli, India, 2020, pp. 232-235, doi: 10.1109/ICOEI48184.2020.9142869.

[5] T. S. Lee, D. W. Lee, Y. H. Kim and J. H. Kim, "Enhancement of Bridge Management System (BMS) with Mobile Communication Technology," 2005 First International Conference on Semantics, Knowledge and Grid, Guilin, China, 2005, pp. 78-78, doi: 10.1109/SKG.2005.70.

[6] F. Kong, L. Zhang, J. Zeng and Y. Zhang, "Automatic Measurement and Control System for Vehicle ECU Based on CAN Bus," 2007 IEEE International Conference on Automation and Logistics, Jinan, China, 2007, pp. 964-968, doi: 10.1109/ICAL.2007.4338706.

[7] V. Vaideeswaran, S. Bhuvanesh and M. Devasena, "Battery Management Systems for Electric Vehicles using Lithium Ion Batteries," 2019 Innovations in Power and Advanced Computing Technologies (i-PACT), Vellore, India, 2019, pp. 1-9, doi: 10.1109/i-PACT44901.2019.8959965.

[8] V. K, R. K. Nema and A. Ojha, "Various Types of Wireless Battery Management System in Ev," 2020 IEEE International Students' Conference on Electrical,Electronics and Computer Science (SCEECS), Bhopal, India, 2020, pp. 1-5, doi: 10.1109/SCEECS48394.2020.115.

[9] A. Adhikaree, T. Kim, J. Vagdoda, A. Ochoa, P. J. Hernandez and Y. Lee, "Cloud-based battery condition monitoring platform for large-scale lithium-ion battery energy storage systems using internet-of-things (IoT)," 2017 IEEE Energy Conversion Congress and Exposition (ECCE), Cincinnati, OH, 2017, pp. 1004-1009, doi: 10.1109/ECCE.2017.8095896.

[10] A. Kurt, U. Dolu, B. Kaya and G. Poyrazoglu, "Design of the Circuitry, Battery Management System, and Wireless Communication of an Electric Vehicle," 2019 1st Global Power, Energy and Communication Conference (GPECOM), Nevsehir, Turkey, 2019, pp. 233-237, doi: 10.1109/GPECOM.2019.8778553.

[11] "Basics of UART Communication", Circuit Basics, 2016. [Online]. Available: http://www.circuitbasics.com/basics-uart-communication/. [Accessed: 25- Jan- 2019].

[12] X. Wang, D. Huang, Y. Wang and L. Zhou, "Battery Management System Based on AURIX Multi-core Architecture," 2019 IEEE 4th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), Chengdu, China, 2019, pp. 1790-1794, doi: 10.1109/IAEAC47372.2019.8997570.

[13] X. Huang, A. B. Acharya, J. Meng, X. Sui, D. -I. Stroe and R. Teodorescu, "Wireless Smart Battery Management System for Electric Vehicles," 2020 IEEE Energy Conversion Congress and Exposition (ECCE), Detroit, MI, USA, 2020, pp. 5620-5625, doi: 10.1109/ECCE44975.2020.9236279.

[14] D. Ranawat and M. P. R. Prasad, "A Review on Electric Vehicles with perspective of Battery Management System," 2018 International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT), Msyuru, India, 2018, pp. 1539-1544, doi: 10.1109/ICEECCOT43722.2018.9001321.

[15] Hyeon-Chyeol Hwang, Bong-Kwan Cho, Yong-Kuk Oh and Jae-Ho Kwak, "Battery monitoring and management system for battery-driven public transit using wireless communication," 2013 International Conference on ICT Convergence (ICTC), Jeju, Korea (South), 2013, pp. 185-186, doi: 10.1109/ICTC.2013.6675334.

[16] Subhashree Choudhury, Nikhil Khandelwal, Ankit Kumar, Anshika Shukla, Anshu Jha, Monalisa Mohanty, Taraprasanna Dash. (2020) A Supervisory State of Charge and State of Power Management Control Strategy among Hybrid Energy Storage Systems through Thermal Exchange Optimization Technique. 2020 IEEE Calcutta Conference (CALCON), pages 323-327.

[17] S. Rumale, H. A. Ashkar, T. Kerner, F. Koya and M. Eitzenberger, "Design and Implementation of an On-Board Vehicle CHAdeMO Interface for Vehicle-to-Grid Applications," 2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE2020), Cochin, India, 2020, pp. 1-6, doi: 10.1109/PESGRE45664.2020.9070445.

[18] z. liu, Q. Wu, M. Shahidehpour, C. Li, S. Huang and W. Wei, "Transactive Real-Time Electric Vehicle Charging Management for Commercial Buildings With PV On-Site Generation," in IEEE Transactions on Smart Grid, vol. 10, no. 5, pp. 4939-4950, Sept. 2019, doi: 10.1109/TSG.2018.2871171.

[19] Z. Moghaddam, I. Ahmad, D. Habibi and Q. V. Phung, "Smart Charging Strategy for Electric Vehicle Charging Stations," in IEEE Transactions on Transportation Electrification, vol. 4, no. 1, pp. 76-88, March 2018, doi: 10.1109/TTE.2017.2753403.

[20] M. Khalid, S. S. Sheikh, A. K. Janjua and H. A. Khalid, "Performance Validation of Electric Vehicle's Battery Management System under state of charge estimation for lithium-ion Battery," 2018 International Conference on Computing, Electronic and Electrical Engineering (ICE Cube), Quetta, Pakistan, 2018, pp. 1-5, doi: 10.1109/ICECUBE.2018.8610969.

[21] E. A. Bostan and V. Sezer, "State of Charge Estimation for Lithium-Ion Batteries In Electric and Hybrid Vehicles," 2019 11th International Conference on Electrical and Electronics Engineering (ELECO), Bursa, Turkey, 2019, pp. 34-38, doi: 10.23919/ELECO47770.2019.8990474.

[22] G. C. P. Mallikarjuna, R. Hajare, C. S. Mala, K. R. Rakshith, A. R. Nadig and P. Prtathana, "Design and implementation of real time wireless system for vehicle safety and vehicle to vehicle communication," 2017 International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT), Mysuru, India, 2017, pp. 354-358, doi: 10.1109/ICEECCOT.2017.8284527.

[23] S. N. Hewalekar and S. Y. Gadgune, "Progression of Smart Metering Infrastructure for Electric Vehicle Charging Stations," 2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT), Tirunelveli, India, 2020, pp. 370-375, doi: 10.1109/ICSSIT48917.2020.9214248.

[24] M. Khalid, S. S. Sheikh, A. K. Janjua and H. A. Khalid, "Performance Validation of Electric Vehicle's Battery Management System under state of charge estimation for lithium-ion Battery," 2018 International Conference on Computing, Electronic and Electrical Engineering (ICE Cube), Quetta, Pakistan, 2018, pp. 1-5, doi: 10.1109/ICECUBE.2018.8610969.

[25] Kim, Taesic Makwana, Darshan Adhikaree, Amit Vagdoda, Jitendra Lee, Young. (2018). Cloud-Based Battery Condition Monitoring and Fault Diagnosis Platform for Large-Scale Lithium-Ion Battery Energy Storage Systems. Energies. 11. 125. 10.3390/en11010125.

[26] P. Bansal and P. R. Nagaraj, "Wireless Battery Management System for Electric Vehicles," 2019 IEEE Transportation Electrification Conference (ITEC-India), Bengaluru, India, 2019, pp. 1-5, doi: 10.1109/ITEC-India48457.2019.ITECINDIA2019-83.

[27] M. Ramesha, V. DankanGowda, K. Jeevan and B. M. Sathisha, "Implementation of IoT Based Wireless Electronic Stethoscope," 2020 Third International Conference on Multimedia Processing, Communication Information Technology (MPCIT), Shivamogga, India, 2020, pp. 103-106, doi: 10.1109/MPCIT51588.2020.9350476.