Smart Charging Of BMS In Electric Vehicle

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Abstract:

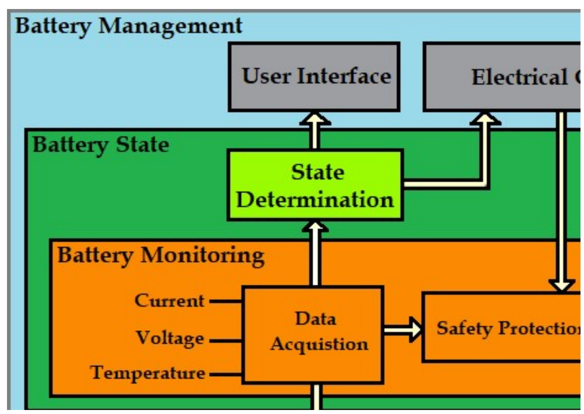
The usage of Lithium-ion (Li-ion) batteries has increased significantly in recent years due to their long lifespan, high energy density, high power density, and environmental benefits. However, various internal and external faults can occur during the battery operation, leading to performanceissuesandpotentiallyseriousconsequences,suchasthermalrunaway,fires,orexplosion. Fault diagnosis, hence, is an important function in the battery management system (BMS) and is responsible for detecting faults early and providing control actions to minimize fault effects, to ensure the safe and reliable operation of the battery system.

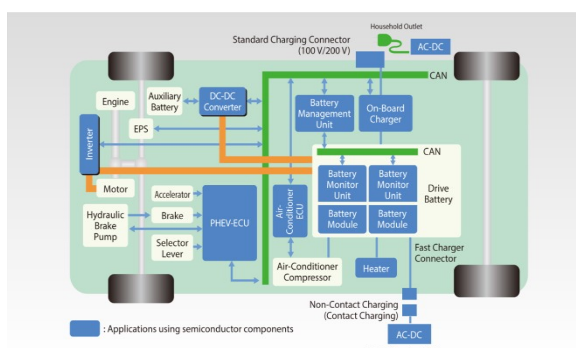
Keywords: **lithium-ion battery; battery faults; battery safety; battery management system; fault diagnostic algorithms**

1. Introduction

Lithium-ion (Li-ion) batteries play a significant role in daily applications due to their important advantages over other energy storage technologies, such as high energy and power density, long lifespan, and low self-discharge performance factors under improper temperatures[1]. Li-ion batteries have gained a significant amount of attention in recent years, showing promise as an energy storage source in electric vehicles(EVs)due to the a fore mentioned advantages[2]. They are also widely used in many electronics and stationary applications. Although Li-ion batteries have had reported accidents causing public concern, the advent of safety features over time has decreased the associated risk factors and improved battery operation [3,4].

Advantages of BMS **1. Maintains battery in a state in which it can fulfill its functional design requirements. 2. Protects the safety of the battery operated device's and Detects unsafe operating conditions and responds. 3. Protects cells of battery from damage in abuse/failure cases. 4. Prolongs life of battery (normal operating cases). 5. BMS is to keep track of the state of charge (SOC) of the battery. 6. Simple in Coulomb counting. 7. Simple and easy to predict capacity fade and internal resistance increment.**





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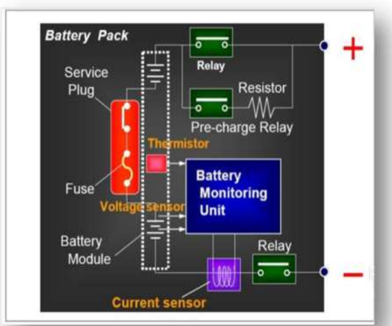
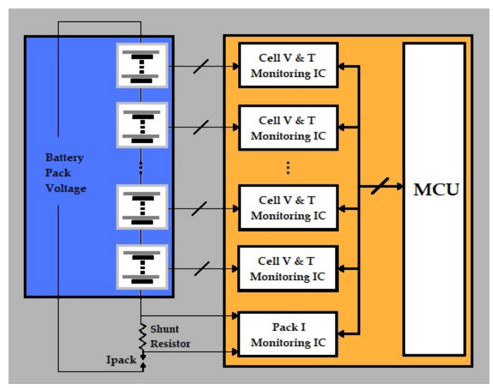
METHODOLOGY A battery management system is used to ensure the optimum use is made of the energy inside the battery and to minimize the risk of damage inflicted upon the battery. This is achieved by monitoring and controlling the battery's charging and discharging together with working temperature. The function of a BMS can be divided into the following tasks. A. Data acquisition B.Battery state determination C.Electrical management D.Thermal management E.Safety management F. Communication

BATTERY PROTECTION Li-ion batteries are applied for energy storage systems in EVs with a number of series-connected battery cells in a pack .EV batteries may be charged from the external source and discharged to run the EV driving motor and systems. The consecutive charge-discharge cycle may cause a voltage and charge imbalance among the battery cells because of changes in their physical characteristics. This imbalance happens due to manufacturing, temperature, and cell ageing problems.

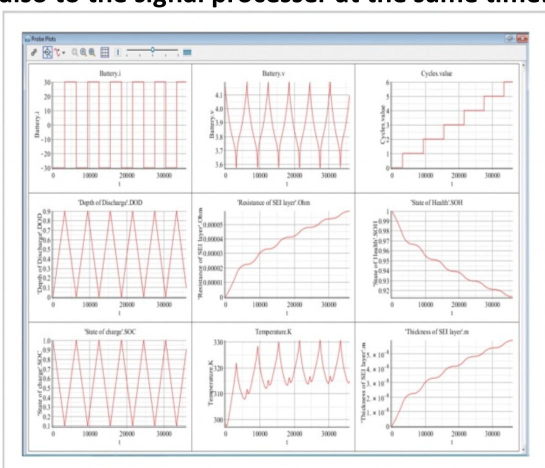




Battery cell monitoring systemThe EVs use a series Li-ion battery cells in a pack. The battery cell may behave differently during the run-time. Therefore, continuous battery cell monitoring is needed for investigating the cells' conditions. The battery cell monitoring results might aid the system performances by managing, protecting, equalizing and controlling operations. It indicates the necessity of the charge and discharge control, the protections from the overcharged and undercharged cell conditions, the control of the temperature and heat, the communication and interface for data acquisition, and the fault diagnosis and assessment, etc.

LITHIUM ION BATTERY Desirable to use Li- ion battery 1. Good heat conduction: The cell shows better heat conduction than cylindrical cells, because it has wide planes on both sides. 2. Efficient packing configuration: The cell packing efficiency allows for a smaller assembled battery as compared with cylindrical cells. Experienced assembly methods like those used for prismatic Ni-Cd batteries can be applied for our Li-ion battery because of the similar shape .3. High productivity:The cell has high productivity because its elements are easily manufactured by winding the electrodes and the separators. The productivity is higher than that of stacked electrode type cells.4. Low internal short-circuit possibility : The cell has never caused internalshort-circuitexceptundertest conditions as such nail penetration abuse testing. The cell uses a one-piece positive and a one- piece negative electrodes, this gives much fewer "electrode edge portion" than stacked electrode type cells.

BATTERY HARDWARE IN LOOP SYSTEM The battery HIL system can provide the signals into the BMS just as the signals from a real battery in vehicle. The Signal Generator output all signals including voltage of cells, temperatures, current, commands from Vehicle control unit(VCU), etc. The output signals be delivered not only to the BMS but also to the signal processer at the same time.



BMS verification with Hardware in loop system

A general test process of BMS with HIL system includes the following steps. As shown

1.Analyzing battery electrochemical to modeling, at the same time Battery charge and discharge experiments be done for parameters.

2. Refine the battery model.

3. Generate Battery signals, that including battery cell voltage, battery temperature, battery current, and command from Hardware control unit(HCU).

4. Output of the battery signals to both BMS and signal processor.

5. Data logging analysis output the performance of the BMS.

The main functions of the HIL are: 1. Evaluating the BMS performance, such as accuracy, linearity, signal collecting unit;. 2. Evaluating the accuracy of BMS algorithm of estimating SOC, SOH, etc. 3. Battery diagnostics method tests. 4. BMS algorithm parameters calibration. 5. Standardizes validation of major releases and incremental algorithm changes. 6. Lowcost:- does –not require expensive pack cyclers or environmental chambers. 7. Identifies areas of sensitivity to direct focused efforts in future development.

Table Quantitative analysis of various methods for state-of-health estimation of Li-ion battery

Method	True SoH (experimental) (%)	Estimated SoH (approximately) ()%	Prediction error (approximately) (%)
Coulomb counting	63.85	69.78	<10
Electrochemical impedance spectroscopy	85	86.27	<2.1
Neural network	82	82.3	<0.5
Support vector machine	60.35	59.19	<2
Kalman filter	84.36	86.57	≤5
Sliding mode observer	90.13	90.261	<2.5
Fuzzy logic	88	91.625	1.4–9.2

Integration of Mechanical Aspects With Temperature Related Problems: It is also known that the temperature is the main enemy of the battery. The temperature-related problems such as thermal runaway, rupture, explosion, etc. can be well integrated with the existing research on safety design of the battery/battery pack.

2.1. Internal Battery Faults Internal battery faults are difficult to detect since the operation within a Li-ion cell is still not fully understood [11]. Some examples of internal battery faults areovercharge,overdischarge,internalandexternalshortcircuit,overheating,accelerateddegradation,andthermalrunaway.

2.1.1. Overcharge Overcharge is a fault that can lead to more severe faults, such as accelerated degradation and thermal runaway. It may occur in Li-ion cells due to the capacity variation of cells in the pack, incorrect voltage and current measurement, or inaccurate SOC estimation from the BMS [13]. A normal battery pack can also get overcharged when the charger breaks down.

2.1.3.ExternalShortCircuit

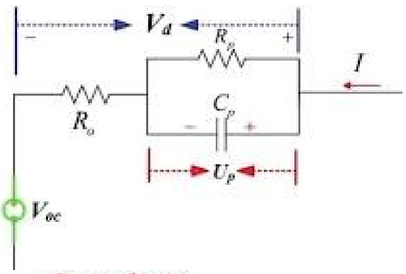
Anexternalshortcircuitgenerallyoccurswhenthe tabsareconnectedbyalowresistancepath[11].A nothercauseiselectrolyteleakagefromcellswelli ngduetogasgenerationfromsidereactionsduring overcharge [22]. It can also occur due to water immersion and collision deformation. An external short circuit specifically transpires when an external heat-conducting element makescontactwiththepositiveandnegativeterm inalssimultaneously,causinganelectricalconnec tionbetweentheelectrodes to occur [23].

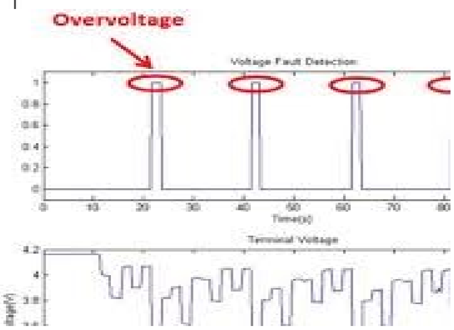
2.1.4. Overheating A Li-ion battery can overheat if an alternator's voltage regulator fails, sending a high amount of voltage back to the battery and causing overheating [24]. overheat, external and internal short circuit, and, most importantly, thermal runaway. Sensor faults include failure of temperature, voltage, and current sensors. Sensor faults are caused by vibration, collision electrolyte leakage, and other physical factors [35].

The Role of BMS in Fault Diagnosis One of the main functions of the BMS is to minimize the risks associated with the operation of a

functions of the BMS should minimize the likelihood of occurrence and the severity of these faults. Sensors, contactors, and insulation are common features added to the battery system to ensure its safety [13]. These algorithms serve the purpose of detecting

lithium-ion battery pack to protect both the battery and the users. Hazardous conditions are mostly caused by faults, and the safety

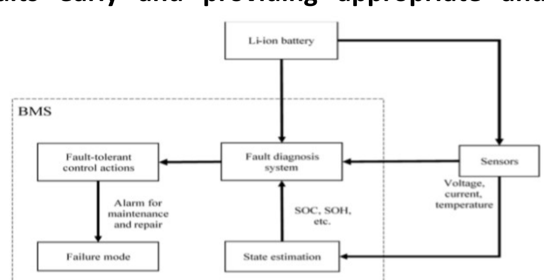




2.2. External Battery Faults External battery faults can have a significant effect on the other functions of the BMS and cause internal battery faults to occur. There are several types of external faults, which are temperature, voltage and current sensor faults, cell connection fault, and cooling system fault. The cooling system fault can be considered the most severe fault because it leads to a direct thermal failure, specifically thermal runaway, as the system fails to provide adequate cooling [34].

2.2.1. Sensor Fault It is crucial to have a reliable sensor fault diagnostic scheme to ensure battery safety and performance. It also helps to prevent internal faults, such as overcharge,overdischarge

faults early and providing appropriate and



Fault Diagnostic Algorithms for the Li-Ion Battery System

2.1Coulomb Counting Method. The Coulomb counting method is associated with monitoring the input and the output current continuously. Since capacity is the integral of current with respect to time, by measuring the input and the output current, change in capacity or capacity degradation of a battery can be measuredeasily[47].Inthismethod,SoHiscalculatedbydividingmeasured capacity (after discharging the battery to 0% SoC value) to its rated capacity. It is an extensively used method by researchers for its simplicity[48–50].But,theaccuracyofthismethodisnotveryhigh

2.2 Internal Resistance and Impedance Measurement Method.

The relationship of battery internal resistance and the actual measured impedance with battery aging leads a way to battery SoH estimation [52–55]. As the aging process occurs gradually, the impedance value of the battery under different frequencies changes. Electrochemical impedance spectroscopy (EIS) helps in this context by measuring the actual impedance of the battery pack [56–61].

2.3 Kalman Filter.

Kalman filtering is a well-designed and time-proven method to filter the measurements of system input and output to produce an intelligent estimation of a dynamic system's state. In the KF method, both input and output data are experimentally measured which help in obtaining the minimum mean square error assessment of the true state [75]. In KF, linear optimal filtering happens. If the system is nonlinear, extended Kalman filter (EKF) is used. In this method, its nonlinearity is linearized by using a linear time varying system [75–83]. SoC estimation was achieved with reduced order observer using OCV-SoC characterization. Yuan and Dung [126] had worked offline for the SoH estimation of high power lithium-ion batteries by a three-point impedance extraction method. As reported, this methodology was found to be computationally fast and efficient.

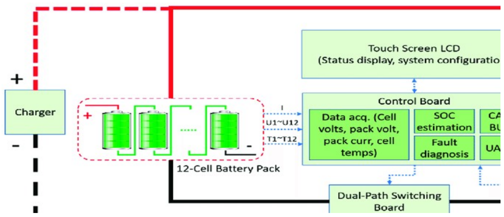
4.1. Internal Battery Fault Diagnosis

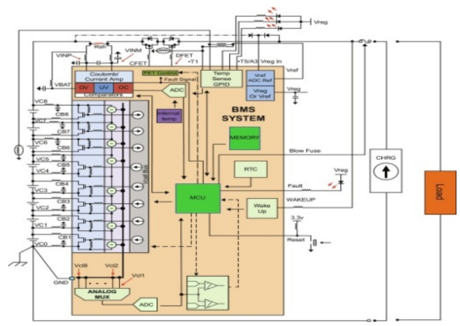
4.1.1. Model-Based Methods :The main principle of model-based fault diagnosis is the use of battery models to generate residuals which are monitored and analyzed to detect faults. There are several types of battery models,including electrochemical, electrical, thermal, and combinations of interdisciplinary models (electro-thermal,etc.)[45]. Each model can be used to assist fault diagnosis, depending on the requirementsoftheLi-ion battery application. Model-based methods are often used in fault diagnosis for their simplicity and cost-efficiency. Model-based methods include state estimation, parameter estimation, parity equation, and structural analysis. This method eliminates noises effectively, but the use of multiple models makes it too complex and computationally inefficient.

4.1.2. Non-Model-Based Methods Non-model-based methods include signal processing and knowledge-based methods. These methods primarily rely on battery data collection, although still using battery modeling to an extent. They can improve fault diagnostic accuracy but might require a largeamountoffaultdata,whichisoftennotavailable,orhaveveryhighcomputationalcost,whichisimpracticalforusage in the BMS.

4.3. Current Progress and Future Challenges of Li-Ion Battery Fault Diagnosis

Model-based methods can quickly detect and isolate a fault in real-time but require high modeling accuracy. Therefore, further research needs to be conducted to reach a better understanding of the internal battery operation to develop a precise, but not overly complicated, battery model.





Hardware Setup Rechargeable battery frameworks are to be an essential part of energy storage system in smart grids. Monitoring of battery performance is one of the key issue in control and management of a battery management system. The measurement part of BMS records cell voltages, battery current, and converts them into the digital measure.

1 Node-Red The estimation algorithm was implemented in the Node-Red environment. NodeRED is a graphical means for connecting various hardware appliances, Application Programming Interfaces (APIs) and real-time facilities together– to equip the Internet of Things. Using a browser based flow editor, Node-RED offers an extensive range of nodes to simply connect the flows which can be executed to the runtime with minimal effort. The light-weight runtime is built on Node.js, taking maximum benefit of its event-driven, non-blocking model [15].

2 MQTT MQTT (Message Queuing Telemetry Transport) is a messaging based communication protocol that affords the lightweight network with an easy means to deliver data. The protocol is used for machine-to-machine (M2M) communication and plays an imperative part in the IoT. It uses a publish/subscribe communication model. MQTT is a useful selection for wireless systems which undergo fluctuating levels of latency because of bandwidth restrictions or fickle connections. In publish/subscribe model, communication is straight from client to an endpoint.

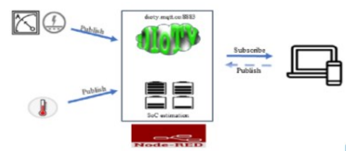


Fig. : BMS Hardware Block Diagram

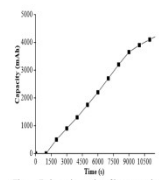


Fig. Estimated capacity of battery packs

Fig. Battery pack temperature across different platforms

Smart Charging :Optimal scheduling of EVs charging is a necessity to counter the increasing burden on grid. If not done in advance, it will lead to imbalance of voltage as well as frequency, which ultimately may lead to grid failure and blackout. The uncertainties involved in the EV fleet characteristics, DA electricity market operations as well as in generation, transmission, and load may be represented by Monte Carlo simulation. Risk involved with the financial as well as economical aspects of the EV aggregator in uncertainty environments can be managed by conditional value added risk analysis (CVaR) as given in [19].

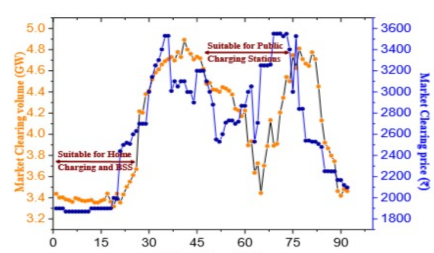


Fig. Demand profile for one day

CHALLENGES IN BMS A literature review has revealed that BMSs are still in a premature stage. Even if state-of-the-art algorithms and monitoring methods were developed and applied in EVs, the reliability of BMSs would still make end users suspicious.

5. Conclusions

The safety of the Li-ion battery system has attracted a considerable amount of attention from researchers. Battery faults, including internal and external faults, can hinder the operation of the battery and lead to many potentially hazardous consequences, including fires or explosion. One main function of the BMS is fault diagnosis, which is responsible for detecting faults early and providing control actions to minimize fault effects. Therefore, Li-ion battery fault diagnostic methods have been extensively developed in recent years. Non-model-based methods are less reliant on battery modeling.

FUTURE SCOPE

1. The BMS optimization algorithm could be further improved by considering the cost of each charge of each cells as an techno economical and discharge cycle of battery to prevent excessive activities that could shorten the battery life.

2. Algorithms can be developed to predict power usage and generation in the microgrid, Such algorithms can be integrated with optimization-based power flow control method for real time energy management in the microgrid.

3. New transmission capacity and better operating practices, such as greater automation controller, forecasting, renewable energy visibility, and transmission planning methods, market integration and implementation of smart energy management systems can resolve the problems and challenges for grid operators, often circumventing the need for curtailment.

4. Current BMSs have limited data cataloguing functions to update the state of charge. The data cataloguing function classifies each data generated by the BMS. 5.IOT Integrated with Grid has to be emphasised more so that status of the battery is given to the user.

6. Monte Carlo simulation., conditional value added risk analysis (CVaR) has to be more concentrated. work has to be conducted on above.

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