An Online Method of Estimating State of Health of A Li-Ion Battery

R.Gopi[1], K.Gowdhaman[2], M.Ashok[3], S.Divith[4], S.Saravanan[5], G.Dineshkumar[6]
UG scholars[1234], Professor[5], Assistant professor[6], Department of Electrical and Electronics Engineering
Muthayammal Engineering College -Tamil Nadu

Abstract - A reformulated model is capable of predicting the internal states of battery with a full simulation running in milliseconds without compromising on accuracy. This paper demonstrates the feasibility of using this reformulated model for control-relevant real-time applications. The reformulated model is used to compute optimal protocols for battery operations to demonstrate that the computational cost of each optimal control calculation is low enough to be completed within the sampling interval in model predictive control (MPC). Observability studies are then presented to confirm that this model can be used for state-estimation-based MPC. A moving horizon estimator (MHE) technique was implemented due to its ability to explicitly address constraints and nonlinear dynamics. The MHE uses the reformulated model to be computationally feasible in real time.

Keywords: EV (Electrical vehicle), BMS (Battery Management System), LIB (Lithium ion Battery), IOT (Internet of things).

I. INTRODUCTION

Electric vehicles are playing a key role because of its zero-emission of harmful gases and use of efficient energy. Electric vehicles are equipped by a large number of battery cells which require an effective battery management system (BMS) while they are providing necessary power. The battery installed in electric vehicle should not only provide long lasting energy but also provide high power. Lead-acid, Lithium-ion, -metal hydride are the most commonly used traction batteries, of all these traction batteries lithium-ion is most commonly used because of its advantages and its performance. Battery management system (BMS) makes decisions based on the battery charging and cell voltage, temperature, etc. To ensure safe operation of the battery pack, the Battery Management System (BMS) has to make sure the cells remain in this safety window. Electric vehicles are becoming more commonplace as the technology matures and gas prices remain higher than in previous decades. While the internal combustion engine still dominates much of the world's roads, electric vehicles and hybrids (vehicles with both an internal combustion engine and some form of electric motor) are more prevalent in urban areas than previous decades. Electric vehicles do not have any on board power generation and rely solely on stored energy in batteries to power the electric motors during operation.

This paper outlines a scalable method of determining the voltage across each battery in an electric vehicle charging and an eventual path for the development of a real-time battery monitoring for use in the Department Electric Vehicle. The Internet of Things (IOT) is the network of devices such as vehicles, and home appliances that contain electronics, software, actuators, and connectivity which allows these things to connect, interact and exchange data. An IOT ecosystem consists of web-enabled smart devices that use embedded processors, sensors and communication hardware to collect, send and act on data they acquire from their environments. IOT devices share the sensor data they collect by connecting to an IOT gateway or other edge device where data is either sent to the cloud to be analyzed or analyzed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another. The devices do most of the work without human intervention, although people can interact with the devices -- for instance, to set them up, give them instructions or access the data. The connectivity, networking and communication protocols used with these web-enabled devices largely depend on the specific IOT applications deployed.

II. EXISTING SYSTEM

The existing system for an IOT-based battery monitoring system in an electric vehicle would typically describe the limitations and drawbacks of current battery monitoring systems and highlight the need for a more advanced and comprehensive solution. Here's a possible section on the existing system. Nowadays, electric vehicle (EV) is becoming popular since the fuel prices becoming more expensive. Due to this scenario, many vehicle manufacturers looking for alternatives of energy sources other than gas. A real-time Battery Monitoring System (BMS) using the coulomb counting method for SOC estimation and messaging-based MQTT as the communication protocol, based on ease of implementation and less overall complexity. The BMS is implemented using sufficient sensing technology, central processor, interfacing devices, and Node-RED environments on the hardware platform.

III. PROPOSED SYSTEM

Our proposed system consists of three main components: battery sensors, a gateway device, and a cloud platform. The battery sensors are placed in each battery cell to measure key parameters such as voltage, current, temperature, and state of charge. These sensors transmit data wirelessly to the gateway device, which aggregates and processes the data before sending it to the cloud platform. The cloud platform hosts a database and analytical tools to process the battery data and provide actionable insights to vehicle owners, manufacturers, and service providers. Users can monitor the health and performance of their batteries through a web or mobile application, receive alerts for potential issues, and access historical data for trend analysis and predictive maintenance.

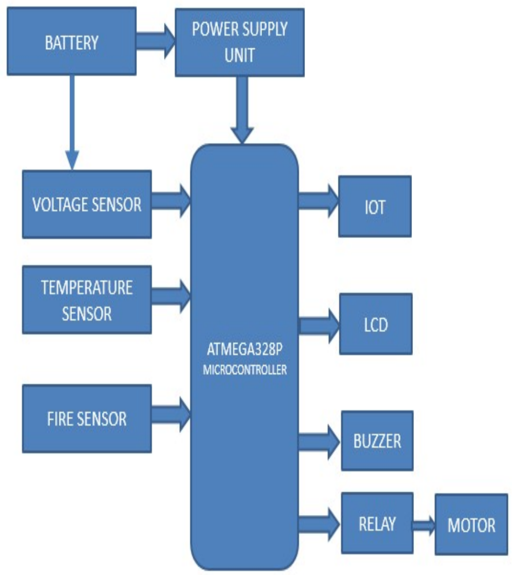

Fig.1 Proposed Block Diagram

The IOT based battery management system for electric vehicle is proposed. This system consists of voltage sensor to detect the voltage and update in IOT. The temperature sensor is used to sense the battery temperature; if there is increase in temperature buzzer alert is given and displayed in LCD. For safety purpose the system is interfaced with fire sensor that detects the fire in the battery and gives alarm. The overvoltage button indicates when the voltage exceeds certain level. The measured parameters are updated in IOT and displayed in LCD display. Previous battery monitoring system only monitors and detects the condition of the battery and alarmed the user via battery indicator inside the vehicle. Due to the advancement of the design of notification system, internet of things (IOT) technology can be used to notify the manufacturer and users regarding the battery status. The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino board. Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board.

IV. METHODOLOGY

The objective is the battery health estimation of battery management an effective method to predict the battery aging process with accurate battery health estimation SOH and RUL of a Li-Ion 18650 cell which are based on various factors like state of charge, discharge voltage transfers characteristics, internal resistance and capacity. To identify an optimal SOH and RUL machine learning based estimation approach, various batteries' statistical models are developed and implemented on a standalone hardware platform. In existing system Kalman filter based scheme has been implemented in existing system Fuzzy logic based health condition of battery system has been implemented Series and parallel cell balancing based health condition of battery has been implemented.

V. SIMULATION

A neural network (NN) is a mathematical model whose parameters have no direct reflection of the physical or chemical structures of the original model. Feed forward and recurrent are the types of NN architecture design. They utilized a time series prediction system. Yang et al. used maximum available capacity to indicate the battery's SOH based on a back propagation neural network. A direct parameter extraction method was employed to identify the parameters of the first-order ECM. Then, a three-layer back propagation neural network was proposed to estimate SOH, whose inputs were the parameters of the first-order ECM and output was the current value of SOH. From the experiments, it was found that when ohmic resistance increases SoH reduced and when SOC ranges between 20% and 90% ohmic resistance increases and SoC decreases. Artificial neural network (ANN) is known for its simplicity. It can handle nonlinear data, and it is not necessary to take all the details of the battery during modeling. For data-driven model, the feature extraction is a crucial part to determine the input variables.

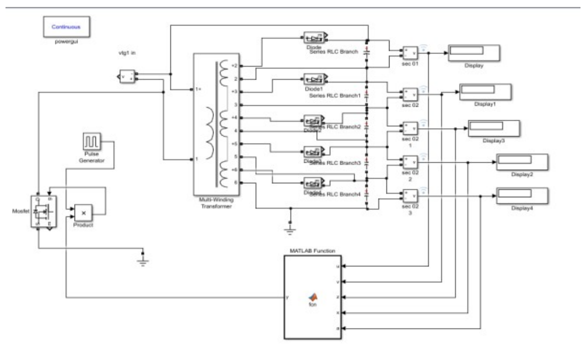

Fig.2 Passive Cell Balancing Method

Feed Forward Neural Network (FFNN) is adopted to capture the correlation between extracted features and capacity degradation. First of all, data platform has no limitation of calculation effort unlike onboard application, and the database is large enough for creating the sample dataset with sufficient quality and size. Furthermore, as the inherent property, FFNN has great superiority for multidimensional non-linear problems and high fault-tolerance FFNN model are comprised of the interconnected neurons distributed in multiple layers.

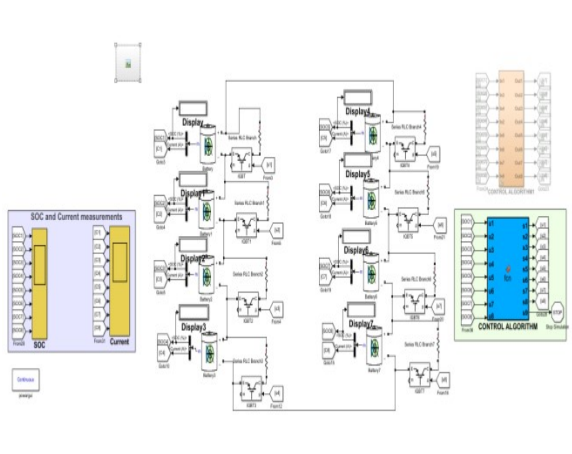

Fig.3 Active Cell Balancing Method

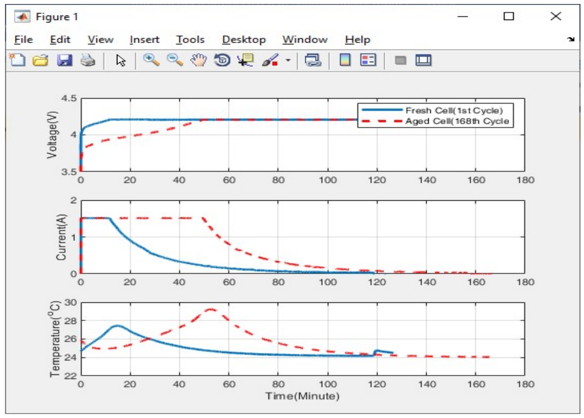

Fig.4 Performance Curve

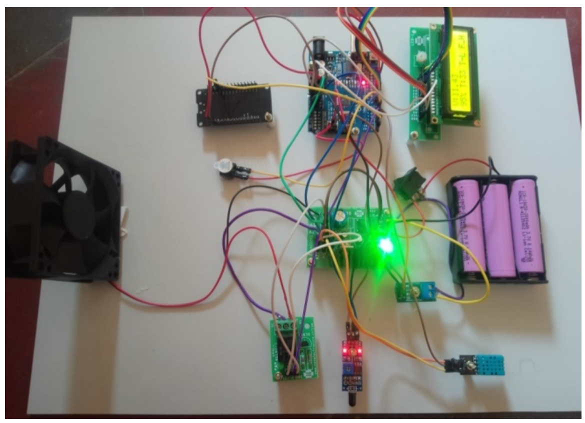

Fig.5. Hardware

VI. CONCLUSION

In this paper, we have proposed an IOT-based battery monitoring system for electric vehicles that leverages wireless communication and cloud computing to collect and analyse battery data in real-time. Our system offers granular and accurate insights into battery health and performance, real-time monitoring and analysis capabilities, cloud-based analysis, and enhanced safety. Through our experiments and evaluations, we have demonstrated the effectiveness and reliability of our system in detecting potential issues and providing actionable insights to users. We have also shown that our system can be easily integrated into existing electric vehicle infrastructure and can scale to accommodate large fleets of vehicles.

REFERENCES

[1] Cunanan, C.; Tran, M.-K.; Lee, Y.; Kwok, S.; Leung, V.; Fowler, M. A Review of Heavy-Duty Vehicle Powertrain Technologies: Diesel Engine Vehicles, Battery Electric Vehicles, and Hydrogen Fuel Cell Electric Vehicles. Clean Technol. 2021, 3, 474–489.
[2] Tran, M.-K.; Fowler, M. Sensor Fault Detection and Isolation for Degrading Lithium-Ion Batteries in Electric Vehicles Using Parameter Estimation with Recursive Least Squares. Batteries 2020, 6, 1.
[3] Liu, K.; Li, K.; Peng, Q.; Zhang, C. A brief review on key technologies in the battery management system of electric vehicles. Front. Mech. Eng. 2019, 14, 47–64.
[4] Gabbar, H.A.; Othman, A.M.; Abdussami, M.R. Review of Battery Management Systems (BMS) Development and Industrial Standards. Technologies 2021, 9, 28.
[5] Cui, Y.; Zuo, P.; Du, C.; Gao, Y.; Yang, J.; Cheng, X.; Yin, G. State of health diagnosis model for lithium ion batteries based on real-time impedance and open circuit voltage parameters identification method. Energy 2018, 144, 647–656.
[6] V.Dhinesh, T.Premkumar, S.Saravanan and G.Vijayakumar," Online Grid Integrated Photovoltaic System with New Level Inverter System" International Research Journal of Engineering and Technology (IRJET), Vol.5, Issue 12, pp.1544-1547, 2018

[7] J.Vinoth, T.Muthukumar, M.Murugagndam and S.Saravanan," Efficiency Improvement of Partially Shaded PV System, International Journal of Innovative Research in Science, Engineering and Technology, Vol.4, Special issue 6, pp.1502-1510, 2015
[8] M.B.Malayandi, Dr.S.Saravanan, Dr. M.Muruganandam, "A Single Phase Bridgeless Boost Converter for Power Factor Correction on Three State Switching Cells", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Special Issue 6, pp. 1560-1566, May 2015.
[9] A.Sasipriya, T.Malathi, and S.Saravanan, "Analysis of Peak to Average Power Ratio Reduction Techniques in SFBC OFDM System" IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), Vol. 7, No.5, 2013.
[10] P.Ranjitha, V.Dhinesh, M.Muruganandam, S.Saravanan, "Implementation of Soft Switching with Cascaded Transformers to drive the PMDC Motor", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Special Issue 6, pp. 1411-1418, May 2015.
[11] C.Sowmiya, N.Mohanandhini, S.Saravanan and M.Ranjitha,"Inverter Power Control Based On DC-Link Voltage Regulation for IPMSM Drives using ANN" International Research Journal of Engineering and Technology (IRJET), Vol.5, Issue 11, pp.1442-1448, 2018.
[12] N.Yuvaraj, B.Deepan, M.Muruganandam, S.Saravanan, "STATCOM Based of Adaptive Control Technique to Enhance Voltage Stability on Power Grid", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Special Issue 6, pp. 1454-1461, May 2015.
[13] P.Manikandan, S.Karthick, S.Saravanan and T.Divya," Role of Solar Powered Automatic Traffic Light Controller for Energy Conservation" International Research Journal of Engineering and Technology (IRJET), Vol.5, Issue 12, pp.989-992, 2018.
[14] R.Satheesh Kumar, D. Kanimozhi, S. Saravanan, "An Efficient Control Scheme for Wind Farm Using Back to Back Converter," International Journal of Engineering Research & Technology (IJERT), Vol. 2, No.9, pp.3282-3289, 2013.
[15] K.Prakashraj, G.Vijayakumar, S.Saravanan and S.Saranraj, "IoT Based Energy Monitoring and Management System for Smart Home Using Renewable Energy Resources," International Research Journal of Engineering and Technology, Vol.7, Issue 2, pp.1790-1797, 2020.
[16] J Mohammed siddi, A. Senthil kumar, S.Saravanan, M. Swathisriranjani, "Hybrid Renewable Energy Sources for Power Quality Improvement with Intelligent Controller," International Research Journal of Engineering and Technology, Vol.7, Issue 2, pp.1782-1789, 2020.
[17] S. Raveendar, P.M. Manikandan, S. Saravanan, V. Dhinesh, M. Swathisriranjani, "Flyback Converter Based BLDC Motor Drives for Power Device Applications," International Research Journal of Engineering and Technology, Vol.7, Issue 2, pp.1632-1637, 2020.
[18] K. Manikanth, P. Manikandan, V. Dhinesh, Dr. N. Mohananthini, Dr. S. Saravanan, "Optimal Scheduling of Solar Wind Bio-Mass Systems and Evaluating the Demand Response Impacts on Effective Load Carrying Capability," International Research Journal of Engineering and Technology, Vol.7, Issue 2, pp.1632-1637, 2020.
[19] T.R. Vignesh, M.Swathisriranjani, R.Sundar, S.Saravanan, T.Thenmozhi," Controller for Charging Electric Vehicles Using Solar Energy", Journal of Engineering Research and Application, vol.10, Issue.01,pp.49-53, 2020.
[20] V.Dhinesh, Dr.G.Vijayakumar, Dr.S.Saravanan," A Photovoltaic Modeling module with different Converters for Grid Operations", International Journal of Innovative Research in Technology, vol.6, Issue 8, pp.89-95, 2020.
[21] V. Dhinesh, R. Raja, S. Karthick, Dr. S. Saravanan," A Dual Stage Flyback Converter using VC Method", International Research Journal of Engineering and Technology, Vol.7, Issue 1, pp.1057-1062, 2020.
[22] G. Poovarasan, S. Susikumar, S. Naveen, N. Mohananthini, S. Saravanan," Study of Poultry Fodder Passing Through Trolley in Feeder Box," International Journal of Engineering Technology Research & Management, vol.4, Issue.1, pp.76-83, 2020.
[23] C. Sowmya, N. Mohananthini, S. Saravanan, and A. Senthil kumar," Using artificial intelligence inverter power control which is based on DC link voltage regulation for IPMSM drives with electrolytic capacitor," AIP Conference Proceedings 2207, 050001 (2020); https://doi.org/10.1063/5.0000390, Published Online: 28 February 2020.
[24] M.Revathi, S.Saravanan, R.Raja, P.Manikandan," A Multiport System for A Battery Storage System Based on Modified Converter with MANFIS Algorithm," International Journal of Engineering Technology Research & Management, vol.4, issue 2, pp.217-222, 2020.
[25] D Boopathi, S Saravanan, Kaliannan Jagatheesan, B Anand, "Performance estimation of frequency regulation for a micro-grid power system using PSO-PID controller", International Journal of Applied Evolutionary Computation (IJAEC), Vol.12, Issue.4, pp.36-49, 2021.
[26] V Deepika, S Saravanan, N Mohananthini, G Dineshkumar, S Saranraj, M Swathisriranjan, "Design and Implementation of Battery Management System for Electric Vehicle Charging Station", Annals of the Romanian Society for Cell Biology, Vol.25, Issue.6, 17769-17774, 2021.
[27] A Senthilkumar, S Saravanan, N Mohananthini, M Pushparaj, "Investigation on Mitigation of Power Quality Problems in Utility and Customer side Using Unified Power Quality Conditioner", Journal of Electrical Systems, Vol.18, Issue.4, pp.434-445, 2022.
[28] V Kumarakrishnan, G Vijayakumar, D Boopathi, K Jagatheesan, S Saravanan, B Anand," Frequency regulation of interconnected power generating system using ant colony optimization technique tuned PID controller", Control and Measurement Applications for Smart Grid: Select Proceedings of SGESC 2021, pp..129-141.
[29] C Nagarajan, B Tharani, S Saravanan, R Prakash," Performance estimation and control analysis of AC-DC/DC-DC hybrid multi-port intelligent controllers based power flow optimizing using STEM strategy and RPFC technique", International Journal of Robotics and Control Systems", Vol.2, Issue.1, pp.124-139, 2022.
[30] G Vijayakumar, M Sujith, S Saravanan, Dipesh B Pardeshi, MA Inayathullaa," An optimized MPPT method for PV system with fast convergence under rapidly changing of irradiation", 2022 International Virtual Conference on Power Engineering Computing and Control: Developments in Electric Vehicles and Energy Sector for Sustainable Future (PECCON), pp.1-4.
[31] C Nagarajan, K Umadevi, S Saravanan, M Muruganandam, "Performance Analysis of PSO DFFP Based DC-DC Converter with Non Isolated CI using PV Panel", International Journal of Robotics and Control Systems' Vol.2, Issue.2, pp.408-423, 2022.
[32] VM Geetha, S Saravanan, M Swathisriranjani, CS Satheesh, S Saranraj, "Partial Power Processing Based Bidirectional Converter for Electric Vehicle Fast Charging Stations", Journal of Physics: Conference Series, Vol.2325, Issue.1, pp.012028, 2022.
[33] M Santhosh Kumar, G Dineshkumar, S Saravanan, M Swathisriranjani, M Selvakumari, "Converter Design and Control of Grid Connected Hybrid Renewable Energy System Using Neuro Fuzzy Logic Model", 2022 Second International Conference on Computer Science, Engineering and Applications (ICCSEA), pp.1-6, 2022.
[34] C Gnanavel, A Johny Renoald, S Saravanan, K Vanchinathan, P Sathishkhanna, "An Experimental Investigation of Fuzzy-Based Voltage-Lift Multilevel Inverter Using Solar Photovoltaic Application", Smart Grids and Green Energy Systems, pp.59-74, 2022.
[35] C Nagarajan, K Umadevi, S Saravanan, M Muruganandam, "Performance investigation of ANFIS and PSO DFFP based boost converter with NICI using solar panel", International Journal of Engineering, Science and Technology, Vol.14, Issue.2, pp.11-21,2022.

[36] K Priyanka, N Mohananthini, S Saravanan, S Saranraj, R Manikandan, “Renewable operated electrical vehicle battery charging based on fuzzy logic control system”, AIP Conference Proceedings, Vol.2452, Issue.1, pp.030007, 2022.
[37] Tran, M.-K.; Mathew, M.; Janhunen, S.; Panchal, S.; Raahemifar, K.; Fraser, R.; Fowler, M. A comprehensive equivalent circuit model for lithium-ion batteries, incorporating the effects of state of health, state of charge, and temperature on model parameters. J. Energy Storage 2021, 43, 103252.
[38] Sui, X.; He, S.; Vilsen, S.B.; Meng, J.; Teodorescu, R.; Stroe, D.-I. A review of non-probabilistic machine learning-based state of health estimation techniques for Lithium-ion battery. Appl. Energy 2021, 300, 117346.
[39] Kim, T.; Makwana, D.; Adhikaree, A.; Vagdoda, J.; Lee, Y. Cloud-Based Battery Condition Monitoring and Fault Diagnosis Platform for Large-Scale Lithium-Ion Battery Energy Storage Systems. Energies 2018, 11, 125.
[40] Li, W.; Rentemeister, M.; Badeda, J.; Jöst, D.; Schulte, D.; Sauer, D.U. Digital twin for battery systems: Cloud battery management system with online state-of-charge and state-of-health estimation. J. Energy Storage 2020, 30, 101557.