Automating Battery Management System and Billing Using Machine Learning

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Abstract Battery Management System (BMS) is one of core parts of Electric Vehicles. The charging station/point and electric vehicles must both accurately track the charging and the billing. The billing will also help the upstream electricity generators estimate the power used by a single charging as well as total power used by a station or a group of stations in a time period. Machine Learning can automate BMS tracking and billing and also provide alerts if supplemented by communication systems. It can also help predict power needed in a given period and also number of charging points required in a given area. The paper proposes a BMS that uses machine learning. It starts with Battery Management System (BMS) conceptual diagram and its explanation. It then gives the parameters to be measured. This is followed by proposed system design and it will work along with the ML algorithms that can be used. This is expected to aid the design of practical BMS system using machine learning.

Keywords Battery management system · Electric vehicles · Supervised machine learning · Online machine learning · Data analytics

1 Introduction

Electric Vehicles consume electricity. However, electricity is not a free resource and there is a cost involved in production and distribution of electricity. This cost is recovered from consumers by raising invoices for electricity consumed. It is also imperative to keep a track of demand and supply of electricity at all times. Calculating and predicting the demand is not an easy task as demand varies in same day and also varies from season to season. Calculating supply involves keeping track of all areas where electricity is supplied and then totalling the supplied electricity. The gap needs computation and is different for times in day as well as seasons.

Different electricity consumption systems need different computations and demand and supply categorisation. One such upcoming system is electric vehicles. Government of India is promoting electric vehicles with curbing pollution and

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reducing dependence on fossil fuels as two of goals. Already policies, regulations and standards have been put into place [1, 2]. Electric vehicles will require also require billing and demand and supply computation systems. As the vehicles grow in number, setting up of infrastructure including electricity supply and charging stations will be needed. This will involve more monitoring on top of current monitoring systems. A system design is proposed in system that can help in automating monitoring and billing accurately and depends on communication infrastructure (IoT) and machine learning.

Before proceeding to design of such a system it is important to introduce the Battery Management System.

2 Battery Management System

The electricity storage and consumption in an electric vehicle is managed by a Battery Management System (BMS). It is responsible for monitoring the following parameters with respect to batteries in electric vehicles [3]:

a. State of Charge
b. State of Health
c. Charging and Output Current
d. Voltage of each cell in the battery
e. Battery Temperature
f. Automatic Cell Balancing.

The power consumption can be calculated from above parameters. It should be noted that the state of health of battery determines how much charge can the vehicle battery can hold and how frequently the battery needs to be recharged.

The block diagram is given below.

As seen in Fig. 1, the BMS consists of a master controller called Battery Controller which controls and coordinates the operation of the estimators. Each estimator uses a specific algorithm for its operation e.g. a State of Charge estimator may use Coloumb estimator along with Kalman filter to determine state of charge. The Battery controller along with its estimators is called the Battery Control Unit (BCU). The readings of estimators are then transferred to Electronic Control Unit (ECU). The ECU also receives data from motor controller for motor control system. The motor controller along with its estimators is called the MCU. The ECU coordinates and manages the MCU and BCU and the coordination amongst themselves.

3 The Proposed System

The diagram of proposed Charging Network System is given in Fig. 2.

The components of the proposed system are given in sub-sections below.

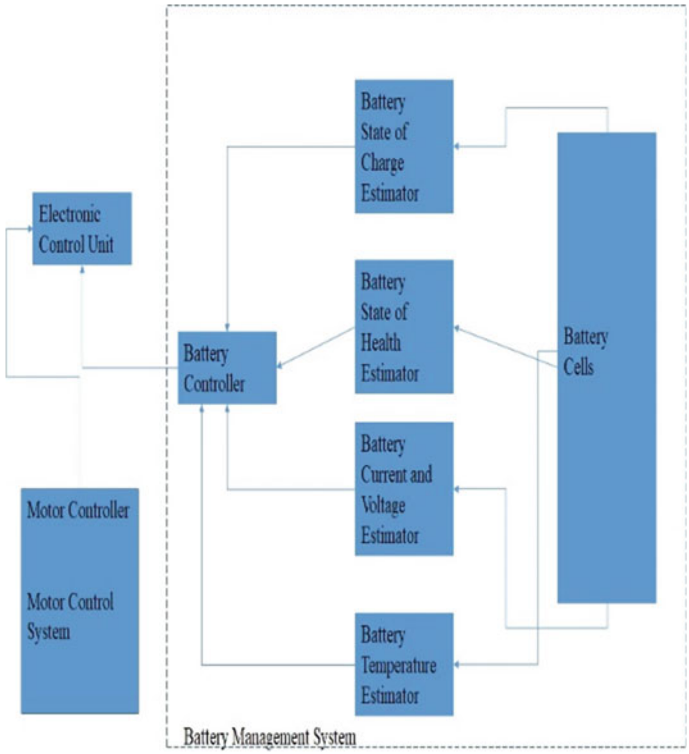

Fig. 1 Battery management system (derived from [4, 6, 8])

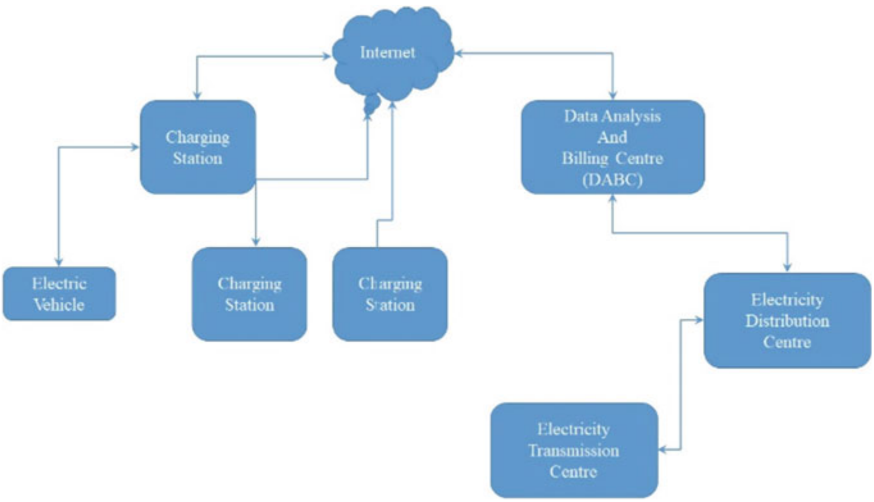

Fig. 2 The proposed system (derived from [4])

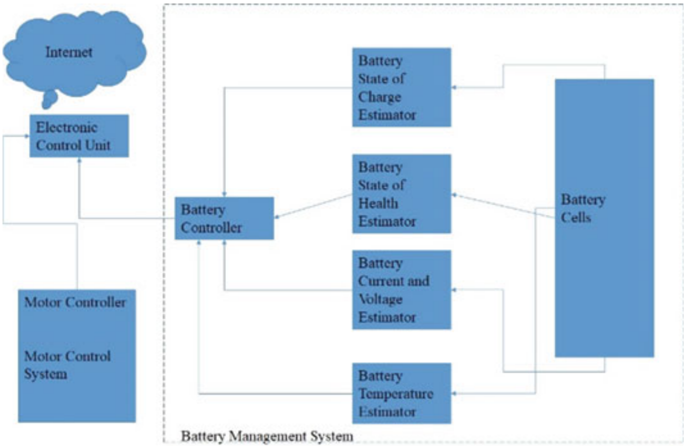

Fig. 3 System with network (derived from [4–8])

3.1 The Electric Vehicle

The electric vehicle has a set of batteries to be charged. Each battery has one or more cells. Each battery is 12 V. The battery set is managed by BMS. The ECU inside BMS will undergo a change in functionality as given in section below:

3.1.1 The Change in ECU Functionality

For ECU, the proposed system adds a networking capability at the hardware level. The new block diagram is given in Fig. 3.

At the software the ECU functionality changes. The description of changed functionality is given below.

3.1.2 Changed ECU Software Functionality

In the proposed system, the following functionality is added to ECU software to enable it to send data to Data Analytics and Billing Centre (DABC).

1. A Data formatting module: This module is responsible for formatting data received from BCU and MCU in CSV format for forward transmission. The data includes time spent in charging and total power consumed in charging.
2. Networking capability and network protocol stack. Fully functional network stack is added to ECU to enable support of HTTP over TCP. HTTP is chosen as all network systems allow HTTP protocol packets through firewalls. Other protocols may be stopped at firewalls.

3. An optional display for displaying statistics, analysis and billing from DABC. The DABC may also send this information to user defined email, phone or any other option specified. The display may be scrolling or page based.
4. An optional keypad connector to connect keypad for data entry and display control. The ECU controls operation of keypad and restricts data that can be entered through keypad (data read from BCU and ECU cannot be altered) and display control.
5. An optional support for printer to print analytics and bill if user requests so.
6. Each Unit comprising of ECU, BCU and MCU is programmed with a unique id that distinguishes it from other units. The unique id is assigned at factory time and cannot be changed at all. Any change in it results in unit invalidation and non-availability of BMS and MCU, i.e. vehicle cannot be used as electric vehicle.
7. Support for securing (with encryption and authentication) of data sent to DABC and response/data received DABC. This includes secure key management also.

3.2 The Charging Station

The Charging function functionality remains same. It gets vehicle registration number or unique id of BMS in vehicle and computes power/electricity consumed by electric vehicle and sends it over to the DABC. Optionally it may send other data if configured to do so. Other data may include photo of driver, location of charging station, etc. It also sends daily and weekly update for power consumed to the DABC.

The charging station may receive alerts and messages from DABC. It shall take action and send response to DABC acknowledging actions.

Additionally, a charging station may detect faults or have information for distribution centre e.g. loss of power, wiring faults etc. It shall send these messages to DABC for further transmission to distribution centre.

It is required by design to act on any messages received from DABC or the vehicle (optional and depends on vehicle) and acknowledge the messages with action taken.

3.3 Data Analytics and Billing Centre (DABC)

This receives data from charging stations. It is responsible for following

1. Computing bill for vehicle charged and send it to vehicle owner/operator as configured.
2. Predicting power requirement for vehicle.
3. Predict when vehicle owner/operator should change batteries using machine learning algorithms and pass on analysis to vehicle owner/operator. For this, the DABC uses BMS id, State of Health, State of Charge, Total battery capacity and

recharge period. This information can be used to predict battery requirements for zone of operation of DABC.
4. Store billing information in server of billing database along with unique id of BMS
5. Use the power consumption data received from all charging stations in its zone to compute total power and store total power in the database.
6. Send the total to Distribution centre for its analysis and storage.
7. Predict power requirement for its zone using machine learning algorithm (online learning for example) and pass on its prediction to Distribution centre.

A Cluster of charging stations is placed under a DABC. The number of charging stations under a DABC is chosen using following factors

1. The data transmission from charging station to DABC and versa is not long.
2. The DABC can process data and send response to charging station without any noticeable lag. The load on DABC is kept small enough to operate it efficiently and give quick responses.
3. The data transmission from DABC to distribution centre and vice versa is not long.

It is required by design to act on any messages received from distribution centre or charging station and acknowledge the messages with action taken.

3.4 Distribution Centre

The Distribution centre receives data from DABC. The data contains power consumption and predicted requirement for its zone. It may optionally use local analytics unit (a machine learning server) to analyse the data it receives to compute the total power consumed and predict the total power required in its zone. The computed power and required power are then sent to the Electricity Transmission Centre which may be a zonal centre or national centre.

The distribution centre can send alerts and messages to DABC if required. The alerts may include loss of electric supply or scheduled outage, emergency messages for charging station. The DABC passes these messages to charging station.

It is required by design to act on any messages received from transmission centre or DABC and acknowledge the messages with action taken.

3.5 Electricity Transmission Centre

It receives the data from distribution systems under its control and computes the demand and supply gap. It can also compute total transmission and distribution (T&D) losses if the network is lined up with sensors to track the transmission parameters like current, voltage (and resultant power), wire temperatures at various points.

The transmission centre can send alerts and messages to distribution if required.

It is required by design to act on any messages received from distribution centre and acknowledge the messages with action taken.

The Machine Learning Training ([9–11]).

The training for the system shall proceed in the following phases

1. Supervised Learning Period: In this period machine learning system shall be trained using pre-generated actual data. This data comprises training, validation and test set. The confusion matrix can be used along with least mean square and deviation to improve system
2. Online Training: The system above shall be trained using actual data and improvise its algorithm.

After above steps, the system shall be deployed and the data analysed for anomalies and deviations and the system improvised based on the analysis. This may result in re-training requirement steps if formula change is required.

4 Benefits from Proposed System

The following benefits are identified in the proposed system

1. Use of Machine Learning Systems will help automate power consumption calculation and prediction, and billing. It can also flag anomalies in system and even in power consumption patterns. This will help in freeing up persons involved in these task for important tasks such as system planning, operation, maintenance and help them by providing the required data. For example, if a charging station reports lower power requirements and other requires power, the distribution centre may readjust power supply.
2. The clustering of DABC and charging stations can give faster response time to both charging stations (and vehicles) and the distribution centre. The users can also get billing information details very fast.

5 Future Extensions

Additional features can be added to system easily if required, for example, user data drive may also be stored on user request. This information can be passed to municipal and traffic police who can then use it to identify difficult stretches. This data, with extensions to system, can be used by vehicle users to request assistance.

The system is easily extensible to allow battery swapping and this can also help calculating battery types and numbers in a zone in a given period.

References

1. Department of Heavy Industries Ministry of Heavy Industries and Public Enterprises, Government of India (2012) National Electric Mobility Mission Plan 2020
2. Department of Heavy Industries Ministry of Heavy Industries and Public Enterprises, Government of India (2018) Standardization of protocol for EV charging infrastructure Bharat public EV charger specifications
3. Xing Y, Ma EWM, Tsui KL, Pecht M (2011) Battery management systems in electric and hybrid vehicles. Energies 4:1840–1857. https://doi.org/10.3390/en4111840
4. Ministry of Law and Justice (Legislative Department): Electricity Act 2003, amended up to 2007
5. Meissner E, Richter G (2003) Battery monitoring and electrical energy management precondition for future vehicle electric power systems. J Power Sources 116:79–98
6. Renesas (2018) Battery management system tutorial. Retrieved from www.renesas.com/doc/whitepapers/battery-management/battery-management-system-tutorial.pdf on 25th Dec 2018
7. Hu R (2011) Battery management system for electric vehicle applications. Electronic Theses and Dissertations. Paper 5007. Retrieved through https://scholar.uwindsor.ca/etd
8. Kettles D (2015) Electric vehicle charging technology analysis and standards. FSEC Report Number: FSEC-CR-1996-15, U.S. Department of Transportation's University Transportation Centers Program
9. Chiu Y-W. (David Chiu) (2015) Machine learning with R Cookbook. Packt Publishing Ltd.
10. Raschka S (2015) Python machine learning. Packt Publishing Ltd.
11. Mitchell TM (1997) Machine learning. Mc Graw Hill