1. Introduction

Fossil fuels are dwindling in nature day by day and prone to increase air pollutions are the main reason for searching alternative energy sources for vehicles. Presently some plug-in type electric and hybrid vehicles are already in the market. Electric vehicles and hybrid electric vehicles are powered by rechargeable batteries have shown great potential to become vehicle of the next generation.

In an electric car industry several types of batteries are used to power the vehicle. Essentially the battery should be strong enough to power the car. There is main difference between the requirements in the battery of a gasoline car and the electric car. In gasoline engine car, the battery will be able to sustain power for a few minutes and then becomes recharged by its alternator. The regular battery used in car is a single, holds power for a short time and is charged by the alternator when the engine starts. When electrical vehicle is powered by battery or generators then these vehicles shows drastically change in average i.e. kilometer per liter costs compared to gasoline cars. However, a more wide-spread use of EVs are still trapped by limited capacity of the battery and cruising ranges of only hundreds of kilometers. Hence accurate prediction of remaining cruising range and energy-optimized driving are the important issues for EVs in the foreseeable future. Hence in the automobile field and battery powered vehicles, the research is mainly focused on fuel saving or energy efficient concept.

Many researchers and industries are working on battery technologies for increasing battery capacity, reducing recharge time, decreasing weight and cost. In recent days in automobile field more research is concentrated on fuel efficient vehicles and battery
operated vehicles. The present research work is focused on estimation of electrical parameters of the battery in the electrical vehicle, which is the most important factor to get information about possible available driving range. If the amount of remaining battery capacity can be displayed for the driver then it is possible to make decision on the time of recharging the battery. To know battery behavior under different conditions, it is necessary to know various battery performance parameters. In the present research, the battery performance parameters for efficient electrical vehicles have been determined experimentally as well as using simulation and compared. These parameters are also verified using hardware in the loop (HIL) setup. The present work is organized in six sections and is presented in the form of six chapters in the thesis.

1.1 Aim and objectives

The aim of the research work is to carry out modeling and simulation of battery performance parameters for efficient electrical vehicles and its verification using hardware-in-loop (HIL) setup.

The main objectives of the research are:

1. To identify mathematical models for batteries of electrical vehicles.
2. To do modeling and simulation of Battery Performance Parameters with different electronic load using MATLAB, SIMPLORER and LabVIEW
3. To perform experimentation on rechargeable battery to study the effect of active loads on battery parameters
4. To design Battery Monitoring System (BMS) for electrical vehicles and measure performance parameters.
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5. To measure Battery Performance Parameters (BPP) for efficient electrical vehicles and verification using Hardware in the Loop (HIL)

1.2 Significance of the work

Environmental issues are the major deciding factor in acceptance of electric vehicles. Leaded petrol are already been prohibited in some country. Therefore there have been attempts in some country to force zero emission vehicles. The fairly complex nature of the rules and regulations in the country may enhance to very fascinating development in the battery, fuel cell and electric vehicles.

This research work has been focused on measurement of battery performance parameters, development of battery management system and verification of BPP using hardware in the loop (HIL) in electrical vehicles. The mileage estimation of Electric Vehicles (EV) is possible through a method which predicts the state of charge (SOC) and efficiency which is close to vehicle's control strategy. The battery model takes into account the temperature, state of charge (SOC), terminal voltage and specific gravity parameters of the battery. Modeling and Simulation results show that SOC of the battery fatalities significantly and depending on amount and type of discharge current. Type of discharging current indicates charging current or discharging battery current.

In electrical vehicles and hybrid electric vehicles, performance of the battery plays a vital role. Any advanced car consists of many electrically operated sections and parts of the car with different power requirements. In electrical car or hybrid electric vehicle, battery decides cars mileage, its pick up, and designing of all electrical systems like power steering, power window, air conditioner (AC), heater and many more. Determination of various parameters like power consumption, efficiency, average, pickup,
charging and discharging time and maximum distance travelled are essential for any fuel efficient vehicle. Modeling and Simulation of electrical parameters of the battery and its estimation for electrical vehicles are key parameters for the user or driver to get detailed information about the health condition of battery. Every device or electrical system consumes some power hence system designer should know power requirement and its management. Every electrical system consumes some portion of power for functioning of the systems. After some countable time, battery will discharge and need to be recharge and maintain sufficient power to the car, which can drive all electrical appliances as well as car. Hence, it is necessary that user or operator should get information of cars status in terms of mileage. The estimation of batteries parameter gives factual information from the designed system. The data base of the battery performance parameters will be taken in to account to estimate some physical parameters, which are commonly used for layman. Through these parameters, layman can take decision on distance of travel and technician may get detailed information about battery performance parameters and ultimately electrical vehicle performance.

For the enhancement of the capability of the automotive industry, simulation and modeling of dynamic systems are essential for future safety and critical applications. Present research work will setup future direction of research in the field of battery and electrical vehicle. Battery ratings are based on long time testing and secondary data of manufacturer which can help in defining battery parameters or battery functions. This will help to know battery performance characteristics in an electric vehicle. The goal of present research work is to adjoin into standard information that will expand to encompass system demands and requirements. Some ideas are planned for modeling and simulation
of battery related electrical parameters for better understanding of a rechargeable battery used electrical car or dynamic applications..

1.3 Outline of the thesis
The present work is presented in six chapters in the form of thesis. The outlines of all these six chapters are discussed below.

The chapter 1 includes aim, objectives and significance of the work.

Chapter 2 takes a literature review in the field of battery powered electrical vehicles. The review of research carried out by earlier researcher has set up direction for further work in this area. Understanding the importance of the battery in this field, an overview of battery technology and battery management systems has been studied. In this chapter, an account of various topics of battery i.e. battery chemistry, batteries for electrical car, power backup calculations, etc. has been taken. The literature review has provided a foundation for secondary data to validate the results obtained in the pilot experimentation. The major challenges in the electrical vehicles are also studied in this chapter with special reference to battery performance parameters. An overview of recent trends in EV is a special highlight of this chapter. This chapter also describes various battery models like electrochemical model, equivalent circuit model, simple battery model, advanced simple model, Thevenin battery model, mathematical model etc. for better management of performance parameters. This forms the sound background for studying battery performance parameters and its management for optimum utilization and safety of the electrical vehicles.
Modeling and simulation are used for testing system conditions that might be difficult to reproduce with hardware prototype and chapter 3rd mainly focuses on it. In early phase of the design process modeling and simulations are used before the availability of hardware. Iterating modeling and simulation can improve the quality of the system design early, thereby reducing the number of errors found later in the design process.

Modeling is nothing but representation of a real-world system with the help of software, hardware, or its combination. If the software components of any model driven by mathematical relationships then that model can be simulated under various conditions to verify the system.

Battery is a heart of the electrical car. Predicting the mileage or remaining battery back is of prime importance to the driver of all electrical vehicles. In this chapter, efforts are made to understand the battery performance parameters and their role in deciding the breakeven point before charging. Modeling and simulation for rechargeable battery has been carried out to study the performance parameter. For this research work, scientific tools like MATLAB, Simploter® and LabVIEW tools are used effectively for simulation, modeling, control purposes, data acquisition, storage, estimation and monitoring.

MATLAB based battery simulator has been used for finding battery capacity and battery discharging time for different active loads. The rechargeable battery circuit with active load / DC motor is simulated in Simploter® for transient state of analysis. The simulation of electrical DC motor of Electric Vehicle has been carried out with the help of LabVIEW tool in the further chapters. The effect of load variation and battery terminal voltage has been studied to see the effect of RPM, electrical energy and heat energy of
the motor. The developed motor simulator is further used for hardware in the loop for battery parameter measurement, management and control purpose.

Developing a smart electronic system for an electric car is often about making the right choices of the system architecture for efficient design. Chapter 4 elaborates different stages of hardware designs and developments of battery management system using microcontroller for portability and LABVIEW for further processing and analysis.

Initial experiments have been carried out to understand the battery handling, reading electrical parameters, charging and discharging, self discharging, active load and passive load discharging and capacity testing for flooded and VRLA batteries. For all electrical vehicles, battery pack and its precise management is an essential component of the design process. This chapter also describes development of portable embedded battery management systems for electrical vehicle. In addition, an extensive battery performance parameter monitoring and management using LabVIEW tool has been developed. The microcontroller based battery management system has advantage over LabVIEW based system that design is low cost, simple to use, easy to install and portable for electrical car for displaying battery performance parameters. The different experiments are carried out for displaying battery performance parameters (BPP) like VOC, discharging current, temperature ,specific gravity, SOC, DOD, internal resistance or impedance using LabVIEW. A new approach to for on line detection of state-of-charge of lead acid battery a fiber optic sensor for state of charge (FOS-SOC) has been implemented. Monitoring the state of charge (SOC) of any battery is important to understand the remaining or residual electrical energy. Usage of the battery reduces the charge content in the active electrolyte which in turn changes its refractive index. The SOC of battery is monitored for
different loads. Mainly terminal voltage, temperature and depth of discharge have been measured using a LABVIEW based data acquisition system.

Chapter 5 describes the development of integrated hardware and software system is key step in for testing the electrical vehicles. Adoption of Hardware in the Loop (HIL) is the standard method for testing any efficient electrical vehicle before final deployment. Battery being a major energy source in EV, hence verification of battery performance parameters has been implemented using in-house developed HIL setup. This developed system is useful in every battery powered systems and electrical vehicle for knowing battery capacity in terms of fuel status, driving range and other specifications.

This developed system monitors important battery performance parameters i.e. temperature, terminal voltage, charging/discharging current, ampere-hour, state of charge, depth of discharge and etc. Knowing state of charge, terminal voltage and temperature of the battery is important to understand amount of energy left in the battery. The real time monitoring system for measurement of battery parameters are implemented with the help of software Lab VIEW and DAS USB 6009 with extra modules for high current sensing and temperature sensing. The signal conditioning circuits for reading various electrical parameters of the battery has been designed and presented in this chapter. The battery monitoring system is configured as intelligent driver intelligent system (DIS). The performance parameters are not directly displayed in terms of voltage and current but displayed using fuel gauge and temperatures according to the driver perspective. Therefore this system is useful in efficient electrical vehicles.

To get better efficiency of electrical vehicle, attention must be given on mileage, cost, weight, management and technology. The battery parameter monitoring, battery man-
agement and estimation of BPP will help to improve vehicle efficiency. Estimation of BPP will help driver to know battery discharging profile and battery efficiency. User can avoid deep discharging, fast discharging and fast recharging of the battery. These handling precautions will definitely extends life of the battery. The alarm system is also included in the BMS of electrical vehicle so that car user will get alarms for different condition of the battery.

Outcome of this research work may be benefited to automotive industry in general and electrical vehicular sector in particular. Chapter 6 includes summary and direction of the future research. In the summary section brief layout of completed research work is described. Whereas in the future direction of research, hardware in the loop for battery management system are discussed using advanced virtual instrumentation.

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