CHAPTER NO. 5

Measurement of BPP using Hardware in the loop

(HIL)

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5.1 Hardware in the Loop

The main purpose of Hardware in the loop system is to simulate the real world as closely as possible. Simulating the analog signals and digital signals that will go into the control unit and receiving signals from it as accurately as possible are two of the major challenges in designing such a system. In this research work data acquisition card is used to acquire analog signal of current and voltage from the battery. The analog signals of the battery are used to measure battery performance parameters of the battery and these signals are given to the control unit of the LabVIEW based system. The hardware used should have a sufficient number of inputs and output channels therefore eight channels for analog input, two analog output, 8 pins for digital out and 4 pins for digital input are used from USB 6009 data acquisition system. The required electronic hardware should have ability to generate a wide variety of complex signals as accurately and deterministically as possible.

The development of integrated hardware and necessary software is the key step for testing of 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 electrical vehicle (EV), hence verification of its 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 important specifications. The battery monitoring system is configured properly with proper changes so that it acts as Intelligent Driver Intelligent System (DIS). The battery performance parameters are not directly displayed in terms of voltage and current but very few battery parameters like fuel gauge and temperature are displayed on the DIS according to the driver perspective. Therefore this system is
useful in efficient electrical vehicles. In addition the front panel of HIL system provides a Graphical User Interface (GUI) with different panel views. The graphical programming code of Lab VIEW has been developed for intelligent battery monitoring system for electrical vehicle. The required electronics for reading various electrical parameters of the battery has been designed and used for monitoring battery performance parameter.

5.1.1 Fundamentals

In recent scenario, HIL simulation becomes an unavoidable means of performing real time experimentation, testing in critical conditions and validation of models and prototypes. This method then provides tests for the control system to prevent costly breakdowns and damaging. Indeed, many groups in the automotive industry have used the HIL simulation for testing electronic control units [1].

Embedded systems play an important role in controlling the different mechanical, electrical and thermal systems. A small error in the design may cause a serious problem during traditional testing. Hence software simulation is not always helpful before actual testing of the system because this simulation doesn’t run in real time with actual analog and digital types of the signals. This dilemma is responsible for adoption of HIL simulation as a standard method for testing any efficient electrical vehicle before final deployment. Hardware in the loop is a real time simulation. It differs from pure real time simulation by the addition of a real component in the loop. This component may be an electronic control unit or actual car engine. Currently industry definition of a HIL system is shown in following figure 5.1. It shows that the plant is simulated and the electronic control unit is real. The purpose of HIL system is to provide all of the electrical stimuli needed to fully exercise the electronic control
unit. In the effect, fooling electronic control unit into thinking that it is indeed connected to a real plant. The traditional testing knows as static testing, in which functionality of a particular system is tested by providing known number of inputs and measuring the outputs.

![Diagram of Hardware in the Loop (HIL) simulation](image)

**Fig. 5.1:** Hardware in the Loop system

Hardware-in-the-loop (HIL) simulation is achieving a highly realistic simulation of equipment in an operational virtual environment. A typical HIL system includes sensors to receive data from the control system, actuators to send data, controller to process data, a human-machine interface (HMI) and a development post simulation analysis platform. The offline simulations were used within the early phases of the development process are often called Model-in-the-Loop simulations. In software development phases module test and system test are accompanied by MIL or Software-in-the-Loop (SIL) simulations. These established simulation method increases the overall test coverage. In the SIL simulation the functional model of an electronic control unit is replaced by LabVIEW code. But in order to use the HIL simulation, real-time capable simulations are needed. After the software tests are successfully passed the calibration of the ECUs can be done on the test-bench of the vehicle.
Now today’s everybody is very much eager to launch product faster with reduction of research and development time or cycle time. Therefore such types of demands are leading for dynamic testing. Dynamic testing encompasses a big range of test conditions as to compare to static testing of the systems. Use of this strategy for dynamic testing is called as Hardware in the Loop simulation.

![Diagram of HIL system](image)

**Fig. 5.2:** General block diagram of HIL system

Hardware in the loop is an integrated part of the design cycle. The design cycle of embedded control applications are in common to automotive, aerospace, and defense industries. The control design cycle consists of several different stages of design and testing. The system definition step documents the needs and requirements of the system. The rapid prototyping step involves development of prototype controllers to test the basic ideas and concepts in an actual system. The actual system can be simulated using software or a combination of software and hardware. The idea of HIL testing is similar in concept to rapid prototyping in that part of the system is simulated while connected to the rest of the real system. The developed driver information system gives information to the driver about how far he can drive the car and also gets real time information of battery on dash board. This will enable a simple real-time...
processing in vehicles to determine the ability of a battery to deliver energy over its life.

5.1.2 Need and advantages

The main idea with the Hardware in Simulation Loop (HIL) is to test the hardware device on a simulator before we implement it on the real process. Hardware in the loop setup is generally used in development and testing of sophisticated and dedicated real time embedded systems. HIL is useful to test a controller function with a simulated process before the controller applied to the real process. If the mathematical model used in the simulator is an accurate representation of the real process, you may even tune the controller parameters using the simulator. It is useful for the process operator and he may learn how the system works and operate by using the hardware-in-the-loop simulation [2]. An additional benefit of Hardware-In-the-Loop is that testing can be done without damaging electric equipments.

In embedded real time system, small errors in any design of embedded systems prone to the serious problem in a system. In many cases, the most effective way to develop an embedded system is to connect the embedded system to the real plant or system. In other cases, HIL simulation is more efficient. The metric of development and test efficiency is typically consists of factors i.e. cost, duration, safety and feasibility. The ability to design and automatically test sophisticated systems with HIL simulations will reduce development cycle, increase efficiency, and improve reliability and safety of these systems for large number of applications. There are a least three strong reasons for using hardware-in-the-loop simulation for electric vehicles i.e. reduction of development cycle, demand to extensively test control hardware and software in
order to meet safety and quality requirements, and need to prevent costly and dangerous failures.

Every time software simulation may not be useful prior to actual testing of the system, because this simulation does not run on real time mode. Therefore Hardware in the loop (HIL) system is adopted as a standard method for testing any efficient electrical vehicle before final deployment. The hardware in the loop simulations are real time simulations. This system comprises of real time platform and electrical emulation of sensors and actuators for read, process, monitor, control and stores the acquired data for analysis. This system monitors important battery performance parameters of the battery 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. With the help of this knowledge user can get approximate information about mileage and distance could cover by the electrical vehicle. This developed system is useful in every battery powered systems and vehicle in finding mileage, fuel status or battery capacity and other specifications. The battery parameters are monitored in real time situation. Virtual instrumentation software and actual hardware are placed in the loop to monitor and control each other requirements. The HIL systems are used to test electrical vehicles before final deployment. The above electrical vehicle system consists of various electrical sections and devices. The main component of the system is high voltage battery pack and battery management system. The BMS manages almost every section which is linked with battery. In the further topic more focus is given on development of HIL for battery operated systems or vehicles.
5.1.3 Development of HIL Setup

The HIL systems for rechargeable lead acid battery of electric vehicle is developed using virtual instrumentation platform. A small error in the design may cause a serious problem during traditional testing. Therefore many times software simulation is not helpful before actual testing. The HIL system comprises real time platform and electrical emulation of sensors and actuators for read, process, monitor, control and stores the acquired data for analysis. This system monitors important performance parameters of the battery i.e. Temperature, Terminal voltage, charging/discharging current, ampere-hour, state of charge, depth of discharge and etc.

![Diagram of HIL Setup]

Fig. 5.3: Developed HIL setup for electrical vehicle

Knowing state of charge, terminal voltage and temperature of the battery is important to understand amount of energy left in the battery. The electrical vehicles are
propelled by electrical motor hence it is necessary to simulate and study the performance of the motor for various load conditions. The counter electromotive force, temperature, speed, torque, thermal energy and kinetic energies, armature currents are simulated for various battery terminal voltages. Fig 5.3 is the conceptual block diagram of developed hardware in the loop setup for car battery and car motor. In this motor parameters are modeled using mathematical formulae’s. This developed model has been used in motor simulator. LabVIEW tool is used to develop motor simulator and this can be used in studying the performance of the motor using Hardware in the loop. The developed HIL setup displays rotation per minute (RPM), electrical energy, heat energy with respective discharging time of the battery.

5.1.3.1 DC motor modeling

Electric motor finds a place in conventional vehicles as starter and alternator. The former boost of the engine reach its idle speed and to start delivering torque. The latter produce electricity to charge the 12V battery and to feed the electric auxiliary loads. In electric and hybrid vehicles, the electric machine is a key component. Usually it is a reversible machines ,which can operate in different ways (1) convert the electrical power from battery into mechanical power to drive the vehicle (2) convert mechanical power from the engine in to electrical power to recharge the battery and (3) recuperate mechanical power available at the drive train to recharge the battery i.e. regenerative braking. The latter two modes are generator modes. In parallel hybrid vehicles and in electric vehicles the two functions can be fulfilled in principle by a single machine.
In series hybrid vehicles and in combined hybrid vehicles two different machines are needed, the generator usually being a second reversible machine, smaller than traction motor. The dynamic models generally used for specific control and diagnostics purposes. It is also used in hybrid-electric vehicle simulator. In dynamic model of motor or generator input variables are motor shaft rotational speed (ω) and DC link voltage (V) and output variables are current exchanged at the DC link (I) and torque (Ṫ) at motor shaft. The counter-electromotive force (E₀) is known as back electromotive force and is the voltage, or electromotive force, that pushes against the current which induces it. The counter-electromotive force is caused by a changing electromagnetic field. Back electromotive force is a voltage that occurs in electric motors where there is relative motion between the armature of the motor and the external magnetic field.
One of the practical applications of counter electromotive force is to measure motor speed and position indirectly. The counter-electromotive force is a voltage developed in an inductor network by a pulsating current or an alternating current.

In a DC motor using a rotating armature and, in the presence of magnetic flux, the conductors cut the magnetic field lines as they rotate. The changing field strength produces a voltage in the coil and motor acts like a generator. This voltage opposes the original applied voltage; therefore, it is called counter-electromotive force with a lower overall voltage across the armature, the reducing the current flowing into the motor coils.

![Diagram of electric motor or generator with battery](image)

**Fig. 5.6:** Electric motor or Generator with Battery ($E_s$) connected

The counter electromotive force ($E_0$) is calculated from the following equation

$$E_0 = \frac{ZnF}{60}$$  \hspace{1cm} (1)

Where $n$ is the speed of rotation, $F$ is the flux per pole and $Z$ is the constant depending upon number of turns on armature and type of the windings. The polarity of $E_0$ always acts against source voltage $E_s$ and depends on difference $E_s-E_0$ and the sum $E_s+E_0$ of
battery voltage $E_s$ and $E_0$. Current flowing into the motor coils can be calculated using the following formula

$$I = \frac{E_s - E_0}{R}$$  \hfill (2)

When motor is at rest condition, the counter electromotive force $E_0$ is zero and current passing through motor is

$$I = \frac{E_s}{R}$$  \hfill (3)

The electrical power $P_a$ of DC motor is nothing but multiplication of Battery voltage $E_s$ and armature current ($I$)

$$P_a = E_s \times I$$  \hfill (4)

Now with

$$E_s = E_0 + I \times R$$

We have

$$P_a = (E_0 + I \times R) \times I$$

$$P_a = E_0 \times I + I^2 \times R$$  \hfill (5)

The term $I^2 \times R$ represents thermal power dissipated from the motor or generator and term $E_0 \times I$ represents the electrical power converted into mechanical power

$$P_m = E_0 \times I \quad \& \quad P_{heat} = I^2 \times R$$
Torque (T) responsible for rotation and can be calculated from Mechanical power (P_m) is given below

\[ P_m = \frac{n \times T}{9.55} \]  

(6)

where ‘n’ is speed of DC motor

\[ E_0 \times I = \frac{n \times T}{9.55} \]

From this we get,

\[ T = \frac{E_0 \times I \times 9.55}{n} \]  

(7)

Therefore the torque of the motor is directly proportional to the generator voltage (E0). These formulae are used in designing of DC motor simulator for Hardware in the loop testing.

5.1.3.2 Development of DC Motor Simulator for HIL

The electrical vehicles are propelled by electrical motor hence it is necessary to simulate and study the performance of the motor for various load conditions. The simulator for electrical motor has been developed in LabVIEW for studying the performance of the motor. LabVIEW is a powerful software system that accommodates data acquisition, instrument control, data processing and data presentation.

A powerful tool often used in HIL is a hardware-in-the-loop simulator. It is a computer program or device that fools the hardware or embedded system into thinking that it's operating with real-world inputs and outputs, in real-time. Therefore
Hardware in the Loop Simulator is designed for electric car motor. The mathematical model of DC motor is worked as simulator section and rechargeable battery would be real component in this developed prototype. The designed DC motor simulator shows important performance parameters of the DC motor i.e. Armature current, Rotation Per Minutes (RPM), heat energy and electrical energy and total power of the simulator as shown in figure 5.7.

This LabVIEW based simulator gives graphical representations of important parameters of the DC motor given in the result and conclusion section of this chapter.

**Fig. 5.7**: DC Motor Simulator for HIL (actual screen)

This simulator tells user how much heat energy is generated and how it can be reduced by varying counter electromotive force. The clockwise and anticlockwise
rotation can be seen on graph of the simulator, knowing these parameters and rechargeable battery voltage value simulator can connected in the loop for verification and testing of the battery in electrical car or battery operated systems. The system comprises real time platform and electrical emulation of sensors and actuators for read, process, monitor, control and storing the acquired data for analysis.

5.1.4 Performance Testing

The metric of development and test efficiency is typically consists of factors i.e. cost, duration, safety and feasibility. Every time software simulation is not useful prior to actual testing of the system, because simulation does not run on real time mode. Therefore Hardware in the loop (HIL) system is adopted as a standard method for testing any efficient electrical vehicle before final deployment.

In embedded real time system, small errors in any design of embedded systems prone to the serious problem in a system. HIL simulation is more efficient. There are at least three strong reasons for using hardware-in-the-loop simulation for electric vehicles i.e. reduction of development cycle, demand to extensively test control hardware and software in order to meet safety and quality requirements, and need to prevent costly and dangerous failures. The simulation of electrical DC motor of electrical vehicle has been carried out with the help of LabVIEW tool. The effect of load variation and battery terminal voltage has been studied to see the effect of rotation per minute 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. The simulated result in terms of graphs gives idea about how RPM changes with electrical energy and heat energy.
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Modeling and Simulation of BPP for Efficient Electrical Vehicles

Fig. 5.8: Electrical energy distribution of DC Motor

The developed motor simulator is further used for hardware in the loop for battery parameter measurement, management and control purpose. The positive PRM value means clockwise rotation of shaft and vice versa. The simulated results for different values of battery voltage and counter electromotive are also shown in the graphs. The motor parameters variations are shown in the figures i.e. 5.8, figure 5.9 and figure 5.10. These results are produced by DC motor simulator using real time simulator software.

Fig. 5.9: Heat energy variation of DC Motor
The system developed here is useful in every battery powered systems and electrical vehicle in knowing motor performance, approximate mileage, fuel status or battery capacity and other specifications.

### 5.2 Battery Performance Parameters using Hardware-in-Loop

Generally battery performance parameters for electrical vehicle are not directly displayed in terms of voltage and current. Therefore these parameters can be displayed in another form on the car dash board. Very few but important battery parameters like status of battery fuel, electrical parameters and temperature are displayed on the Driver Information System (DIS) according to the driver perspective. Therefore measurement of BPP system is useful in every efficient electrical vehicle. In addition to this system HIL system provides a Graphical User Interface (GUI) with different panel views to the user. Hence research is carried out to study and measure electrical parameters of the battery and its estimation for electrical vehicles. Through estimation of the battery parameters user or driver of the car will get detail information of the health of the battery and through this decision can be taken for car operation.
5.2.1 Experimentation

The real time battery monitoring system for measurement of battery parameters are implemented with the help of software LabVIEW 8.5 and DAS USB 6009 with some additional electronics for high side current sensing section and temperature sensor circuitry. The high side current circuit is designed with suitable gain of the amplifier. The load current is converted in to corresponding voltage using differential amplifier. The differential voltage is amplified up to certain value and given to the DAS card i.e. USB 6009. The DAS driver software is needed to work DAS hardware on PC or Laptop.

![Block diagram for measurement of Battery Performance Parameters](image)

**Fig.5. 11:** Block diagram for measurement of Battery Performance Parameters

The device driver performs low-level register writes and reads on the hardware, while exposing a standard API for developing user applications. In this work LabVIEW tool is used for data storage in particular file for reference and for comparison of previous and current data. Furthermore, the resolution should be kept less than eight bits...
because the peak amplitude is a critical parameter for unit classification. Moreover, under persistent high-speed acquisition, the amount of data could be massive and difficult to handle. Hence, utilizing the technique of on demand sample acquisition may resolve this problem. The front panel of developed system is given below in figure 5.12, with different panel views. The measurement and automation explorer driver is used to select number of channels used for reading data and selected channel are saved with some file.

**Fig. 5.12:** Battery Performance monitoring system for electrical vehicles

This file is called while starting task with DAQ and through which coding starts. The DAQ read section is connected at the output of the DAQ start part. The total output data is stored in array and through index array the data is separated. Figure 5.12 and 5.13 are the front panels of battery performance parameters of the battery and corresponding graphs which are required for electrical vehicles and battery operated...
systems.

![Battery Management System for Electrical Car](image)

**Fig. 5.13:** Graphical display of SOC, A-H, Load Current and Terminal Voltage

### 5.2.2 Results and Discussion

The designed system has given information about backup time or system running time and consumed ampere-hours value on the front panel system. Simultaneously all battery parameters and other physical battery parameters like temperature and calculated backup time are stored in separate excel file format. With the help of stored data analysis can be done for finding further more parameters which are linked to the electrical vehicle. This system is configuring from developed hardware in the loop which is previously explained. Following is the sample table given for understanding purpose. The lengths of tabular values are very much wider but for simplicity few of them are given in the following table 5.1.
Table 5.1: Battery parameters with Hardware in the loop setup for 7.5AH battery

<table>
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<th>Sr. No</th>
<th>Total Time (Sec)</th>
<th>Terminal Voltage (V)</th>
<th>Discharge Current (A)</th>
<th>Temp ($^0$C)</th>
<th>AH</th>
<th>SOC (%)</th>
<th>DOD (%)</th>
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This table shows terminal voltage, discharging current, battery temperature, AH, SOC, DOD and system run time while discharging of the battery. The variation of SOC, AH and terminal voltage has shown from 100% to 13%, 0.01 AH to 4.32AH and 12.37V to 10.22V respectively. The metric of development and test efficiency is typically consists of factors i.e. cost, duration, safety and feasibility.

![Graph showing terminal voltage, discharging current versus discharging time](image)

**Fig. 5.14:** Terminal voltage, discharging current verses discharging time

Every time software simulation is not useful prior to actual testing of the system, because simulation does not run on real time mode. Therefore Hardware in the loop (HIL) system is adopted as a standard method for testing any efficient electrical vehicle before final deployment. In embedded real time system, small errors in any design of embedded systems prone to the serious problem in a system. HIL simulation is more efficient. There are a least three strong reasons for using hardware-in-the-loop simulation for electric vehicles i.e. reduction of development cycle, demand to extensively test control hardware and software in order to meet safety and quality requirements, and need to prevent costly and dangerous failures. This developed

system is useful in every battery powered systems and vehicle in finding mileage, fuel status or battery capacity and other specifications.

Figure 5.14 shows the relation of terminal voltage and discharging current in Ampere with the discharging time. When the external electrical load is connected to the battery it is observed that there is sudden change in terminal voltage of the battery. The external load value decides decrement value of the terminal voltage. When there is sudden change in load value it also reflects on terminal voltage of the battery. This graph gives total profile of discharge current and terminal voltage with respective to the discharging time of the battery.

Figure 5.15 shows variation of state of charge and depth of discharge with the discharging time of the battery. The values of state of charge and depth of discharge are considered in percentages. The state of charge is calculated from consumed ampere hour value of the battery. The ampere hour values are continuously recorded and added in the previous values to get current value of ampere hour. Through current value of ampere value state of charge and depth of discharge is decided and shown in LabVIEW front panel and graph.
**Fig. 5.15**: SOC, DOD verses Discharging time

**Fig. 5.16**: Consumed AH verses discharging time
The consumed ampere hour of the battery is recorded and stored in the separate file and accordingly SOC and DOD are calculated. This relation of consumed ampere hour and discharging time is shown in the graph of figure 5.16.

The further graphs are given here to understand temperature and battery parameters variation according to the discharging time. It is observed that the battery temperature is an approximate constant throughout discharging of the battery. This temperature variation depends on many parameters but discharging current value is one of them. Hence it is necessary to study and record the values. The graph of temperature against discharging time is given in figure 5.17. The all parameters of the battery are also given in the succeeded figure 5.18 to know accumulative effect of all battery parameters against discharging time of the battery i.e.50 minutes.

![Graph](image)

**Fig. 5.17**: Temperature verses Discharging time
Figure 5.19 shows the system setup photographs of hardware in the loop for battery performance measurements purpose. This setup has been included different electrical loads, data acquisition card and LabVIEW software.

**Fig 5.18:** Battery parameters verses discharging time

**Fig. 5.19:** Prototype of hardware in the loop for battery performance measurements
Various experiments were carried out and results are analyzed and presented in various forms. This prototype can be used for measurement of battery performance parameters for electrical vehicle or battery powered system. In this laboratory setup, available electrical loads like incandescent lamps, fan, DC to AC converter and powerful DC lamps are taken along with developed electronics for experimentation. The graphical results are also shown on the front panel of the HIL and it is seen in the different figures.

5.3 Implementation of Driver Information System (DIS) using HIL

The ambitious prototyping effort included to design driver information system on electrical car dashboard. The designing focus is given on the development of an interior driver information system using designed hardware and configured DIS software. User of this system would find attentive, approachable, easy to use, and compatible with developed portable system.

5.3.1 System Description

The DIS system is mainly developed for electrical vehicles or battery operated systems. Driver information system is very much useful in electrical vehicle for knowing current battery parameters.

The driver information system tells the driver what is happening under the different load conditions to the battery.

This designed electronics with software is connected to all the vital moving components of the car which interacts with the different electrical loads and displays the battery parameters on car dash board.
This system monitors various parameters of the battery on the car dashboard. The parameters like fuel status i.e. state of charge, terminal voltage, temperature and consumed ampere hour are mainly displayed. The estimation of mileage range could be done from fuel status of the electrical vehicle. In any type of batteries in electrical car, the full energy stored in the battery cannot be withdrawn or cannot be fully discharged without causing serious and often irreparable damage to the battery. Various battery parameters like terminal voltage, discharge current, backup time, temperature and number of cycles will decide deliverable power/energy/capacity. Through these important parameters layman can calculate travelling range of vehicle and refuel or recharging information of the battery. Cold cranking current capacity is also decided by the condition of the battery.
Therefore these battery parameters have to be monitored on the dashboard of the electrical vehicle. Thus this monitoring system is called as intelligent DIS (Driver intelligent system).

Following are the battery parameters used to decide battery deliverable power and energy with the help of drawing current, run time, terminal voltage, and temperature and age factor of the battery. With these parameters it is simple to predict status of battery health and battery real time parameters in context of the electrical vehicles. Here its nomenclature is an intelligent driver information system (DIS) shown in the following figure 5.20. The designed hardware and developed software is used to read these battery parameters for driver information system. Followings are different front panel windows for data storage, fuel gauge, SOC, DOD, AH, temperature and consumed backup time in the succeeded figures.

![Monitoring SOC, drawn current using gauge diagram](image)
The system flow diagram gives details about battery performance parameters and estimation of the mileage and how they are interlinked with each other and how they are dependent on each other. This flow diagram shows how the battery terminal voltage, discharging current and discharging time depend on battery condition and life of the battery. Through battery condition deliverable charge, power and deliverable power is decided.

5.3.2 Result and Discussion

The intelligent driver information system (DIS) continuously reads the battery parameters and displays battery information according to the driver perspectives on the car dashboard. With the help this flow diagram the driver information system is
developed for electrical vehicle using LabVIEW and developed electronic hardware and data acquisition system. The front panel diagrams of the developed systems are given below.

Fig. 5.23: Driver information system for Data storage

Through this system, driver can understand how far he can drive the car and also get detail information about battery parameters on the electronic dash board, here referred as DIS system. This will enable a simple real-time processing (model-based diagnosis) in vehicles to determine the ability of a battery to deliver energy over its life.
With the added functionality of these characteristics will develop new insight to system performance. The results of the developed research system are expected to lead to the development of user information system for electrical cars.

By knowing these parameters driver information system gives information related to mileage and fuel gauge related information to the driver. The designed system monitors battery related all parameters and provides useful information to the user.
about health of the battery. Through this battery performance parameters and necessary preventive action are suggested through the developed prototype.

### 5.4 Applicability of HIL for Efficient Electrical Vehicles

To get better efficiency of electrical vehicle, main center of attention must be given on mileage, cost, weight, management and technology. The battery parameter monitoring, battery management and estimation of battery performance parameters (BPP) helps in improving vehicle efficiency. Estimation of Battery performance parameters helps driver to know battery discharging profile and battery efficiency. This battery information helps user to understand upper load and lower load limit. Therefore user can avoid deep discharging, fast discharging and fast recharging of the battery. These handling precautions will definitely extends life of the battery. Through developed system user will get energy status, operating cycles, temperature, cold cranking current, drawing current etc. on the electrical dashboard. Effective use of hardware-in-the-loop (HIL) simulation leads to improvement in the quality and efficiency of electric vehicle (EV). The concept and development process of HIL simulation has been studied and presented in previous sections of this thesis. The adoption of modular design and CAN bus technology with the HIL simulation technology help in flexibly and applicability in the field of electrical vehicle. This will help to use multi-body dynamics theory to establish more accurate simulation models of the EV components [3]. The advanced control strategies will help to speed up system response and minimize simulation errors.

Application of switched reluctance machines in a power hardware-in-the-loop (PHIL) environment. The switched reluctance machine (SRM) is the subject of PHIL experiments that has been observed operation of the SRM in a simulated electric
vehicle (EV) system [4]. The PHIL setup has been used to control the DC-Bus voltage of the SRM and to simulate a driving profile by applying a dynamic load to the SRM. With the help of this setup electrical car range for single battery charge could be determined and effectively to understand requirement of the battery pack for specific car and particular distance. The uniqueness and practicality of using switched reluctance machines in a PHIL environment is emphasized.

There are two interesting things are to be considered when evaluating the efficiency of a vehicle. These things are energy efficiency and emissions. An electric vehicle (EV) starts with an enormous advantage over an internal combustion engine (ICE) vehicle. The ICE vehicles generally run at about 20% efficiency, meaning that 80% of the energy content of their fuel is wasted, versus EVs which put about 80% of their input energy into turning the wheels. This percentage of energy efficiency could be improved by optimizing battery performance parameters and battery health improvising techniques. In other hand extension of battery life will improve the energy efficiency of the electrical vehicle.

Normally Electrical vehicles get their charge from an external power source and these sources could be from a clean, renewable energy source like wind or solar. Most of the people uses current electrical grid to recharge the battery. As our electrical grid gets cleaner so do EVs, but even when powered from today's electric grid, EVs reduce both greenhouse gas emissions and pollution that causes smog [5-9]. Electric Vehicles have no tail pipe because it does not emit polluting gasses when it is driven. But they do increase load on the electrical grid, which in turn causes more emissions at polluting power plants. This is called as the long tailpipe. That same study found that overall greenhouse emissions would decrease by up to 27%. Emissions of volatile organic gases and carbon monoxide would drop over 90%. Without improving
generation technology, particulate and SO$_x$ emissions would also increase. With the increased energy efficiency and ability to be powered from green energy sources, EVs offer significant long-term environmental benefits. Replacing ICE vehicles with EVs powered from the current electric grid has immediate considerable upside on average, and massive benefits in regions with electric grids that take advantage of green energy sources.

Once an EV has been recharged, how far will it go before it needs to be recharged again? This kind of situation depends on a number of factors, including the type of battery. The EVs using lead-acid batteries has given the shortest range of distance i.e. around 128 km on a single charge whereas Ni-MH batteries turn in a better performance, with a range of about 193 km per charge. This is where lithium-ion batteries do extremely well, with a range of more than 354 km per charge. The range of an EV can be extended even further with a technology known as regenerative braking, which uses the kinetic energy of the car's brakes to recharge the battery on the fly. Under optimum driving conditions, regenerative braking can extend the driving range up to 50 percent.

The results of the developed research system are expected to lead to the development of user information system for electrical cars. Through this battery performance parameters system preventive action are suggested through the developed prototype. The battery parameter monitoring, battery management and estimation of battery performance parameters helps in improvement of vehicle efficiency. Estimation of BPP will help driver to know battery discharging profile and battery efficiency. This battery information will help user to understand upper load and lower load limit. User can avoid deep discharging, fast discharging and recharging of the battery.
References


2. Telemark University College, 'Hardware-in-the-Loop Simulation', Faculty of Technology, Norway, Web, 11 July 2014, online


