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Modelling of Battery Data Acquisition System for Vehicles

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ABSTRACT

Modern automobile system is leaping towards automation. In this process the health of battery plays key role during cranking engine or sending command to stop engine when it is idling. The dynamics of Battery Management System (BMS) is complicated and the information helps in operating automobiles. The Start-Stop system used in automobiles enables automatic shut down and restart of Internal Combustion Engine in order to decrease the amount of time that engine spends idling and thereby reducing the fuel consumption which also reduces the emission. An attempt is done in this paper to model battery data acquisition for start/stop system in automobile with variation in vehicle operating conditions using ASCET environment. This module provides enabling or disabling condition of auto start stop feature based on the robustness of the battery system. Time Partition Testing (TPT) is used to test the results, with different operating conditions.

Key words: State of Charge, State of health, State of Function, Controller Area Network

INTRODUCTION

A Battery Management System (BMS) in electronic system accomplishes a battery that is rechargeable, and protects battery from functioning outside its Safe Operating Area, monitors its state, controls its environment, authenticates it and / or balance it. Battery technology has been used from long way since invention of first voltaic cell in the 1800s. It has developed as one of the primary components in automobile since from the time when the interest in hybrid vehicles has been increased. Automotive BMS is extremely challenging, because of the need of it working in real-time and in rapidly varying charge-discharge conditions depending on vehicle operating condition such as when vehicle accelerates and breaks, in addition its working in uncontrollable and severe environment. Apart from this it must also interface with other on-board systems, such as climate controls, engine management and safety systems.

Automotive electrical power systems that address the demands of increased electrical power, improved fuel economy and reduced emissions. Considerations related to high-efficiency automotive electrical power systems such as the selection of the types of electrical machines and power converters, selection of system voltages, battery voltage equalization, load management, energy management, regenerative braking, centralized and distributed power system architectures, DC and AC power distribution systems, and multiplexing [1].

BMS are used in many battery-operated systems to make the battery operation more efficient and the estimation of battery state non-destructive. The existing BMS techniques are examined in the paper and a new design methodology for a generalized reliable BMS is proposed. The main advantage of the proposed BMS compared to the existing systems is that it provides a fault-tolerant capability and battery protection. The proposed BMS consists of a number of smart battery modules (SBMs) each of which provides battery equalization, monitoring, and battery protection to a string of battery cells. An evaluation SBM was developed and tested in the laboratory and experimental results verify the theoretical expectations [2].

To realize a stable supply of electric power in an automobile, an accurate and reliable detection method of SOC (state-of-charge) in a lead acid battery is required. The characteristics of the battery greatly change due to its degradation. Moreover, an automobile has many driving patterns, which are unknown beforehand. Thus it is not easy to detect the

SOC analytically. In the paper, to overcome this problem, a new on-line SOC detection method using both neural network, online identification and multiple detectors is proposed. In order to increase the detection accuracy of degraded batteries, a detector is changed on-line in correspondence with a voltage-current characteristic of a battery. The detection accuracies for different sized batteries and various degradation states are investigated [3]. BMS is an integral part of an automobile. It protects the battery from damage, predicts battery life and maintains the battery in an operational condition. The BMS performs these tasks by integrating one or more of the functions, such as protecting the cell, controlling the charge, determining the SOC, the state of health (SOH), and the remaining useful life (RUL) of the battery, cell balancing, as well as monitoring and storing historical data.

The paper discusses a BMS that estimates three critical characteristics of the battery (SOC, SOH, and RUL) using a data-driven approach. The circuit parameters are estimated from electrochemical impedance spectroscopy (EIS) test data using nonlinear least squares estimation techniques. Predictions of remaining useful life (RUL) of the battery are obtained by support vector regression of the power fade and capacity fade estimates [4].

Global automakers are accelerating the development of fuel efficient vehicles, as a part of meeting regional regulatory CO_2 emissions requirements. The micro hybrid vehicles with auto start-stop functionality are considered economical solutions for the stringent European regulations. Flooded lead acid batteries were initially considered the most economical solution for idle-stop systems. However, the dynamic charge acceptance (DCA) at lower SOC was limiting the life of the batteries. While improved lead-acid batteries with Absorbed Glass Mat (AGM) and valve-regulated lead-acid (VRLA) features have improved battery longevity, they do not last the life of the vehicle. The United States Advanced Battery Consortium (or USABC, a consortium of GM, Ford, and Chrysler) analysed energy storage needs for a micro hybrid automobile with start-stop capability, and with a single power source. USABC has analysed the start-stop behaviours of many drivers and has developed the requirements for the start-stop batteries. The testing procedures to validate the performance and longevity were standardized and published. The guideline for the cost estimates calculations have also been provided, in order to determine the value of the newly developed modules. The analysis effort resulted in a set of requirements which will help the battery manufacturers to develop a module to meet the automotive Original Equipment Manufacturers (OEM) micro hybrid vehicle requirements [5].

Many drivers of vehicles believe that turning the vehicle off and on frequently instead of idling will cause premature wear of the starter system (starter motor and starter battery). As a result, they are concerned that the replacement cost of the starter motor and/or battery due to increased manual engine cycling would be more than the cumulative cost of the fuel saved by not idling unnecessarily. A number of variables play a role in addressing this complex concern, including the number of starting cycles per day, the time between starting cycles, the intended design life of the starting system, the amount of fuel used to restart an engine, and the cumulative cost of the saved fuel. Qualitative and quantitative information from a variety of sources was used to develop a life-cycle economic model to evaluate the cost and quantify the realistic factors that are related to the permissible frequency of starter motor cycles for the average vehicle to economically minimize engine idle time. Annual cost savings can be calculated depending on shutdown duration and the number of shutdown cycles per day. Analysis shows that cost savings are realized by eliminating idling exceeding one minute by shutting down the engine and restarting it. For a typical motorist, the damage to starting system components resulting from additional daily start cycles will be negligible. Overall, it was found that starter life is mostly dependent on the total number of start cycles, while battery life is more dependent on ensuring a full charge between start events [6].

The already existing energy problems in today's world are leading to the research and discovery in the area of energy management system. Hybrid electric vehicles (HEVs) are found to be the remarkable solutions for the worldwide environmental and energy problems caused by automobiles. Unlike fuel gauge in IC driven vehicles EVs do not have any direct method of measuring distance to charge. EVs, however makes use of SOC. The problem is that SOC cannot be measured directly but requires model of the battery for estimation. The model of the battery can be developed by obtaining charge and discharging characteristics of the battery at various currents. The main objective of the paper is to present the experience of development of a battery testing kit consisting of a charger, a discharging network and data acquisition (DAQ) to capture the data onto a PC. The Simulink model of the battery test kit is presented along with the prototype been developed as the part of the project. At last for capturing and storing the battery characteristics, Data Acquisition System (DAQ) is developed using ARM7 processor. The charging and discharging characteristics of battery at various constant current is observed through digital oscilloscope and Lab view software tool [7-8].

Battery Management Systems

Understanding battery health and state of its charge are essential in present day vehicles. Advances in automobiles like drive-by-wire, stop-start, and transformation of the hydraulic system to electrical system increases the load even more to the vehicle electrical battery system, on which motorists are previously trusting for the safety of themselves and also others around them. Intelligent Battery Sensor permits the vehicle to arrange all electrical loads on a scale from ‘comfort related’ to ‘safety critical.’ The vehicle can then turn these systems off in a logical order and notify drivers of a forthcoming battery trouble, while keeping them in safe and secure environment [Fig. 1].

A study is performed to obtain the data such as SOC, SOH, Battery temperature and SOF by implementing sensors. The Communication will be here either through CAN or LIN. This module provides enabling or disabling condition of auto start stop feature based on the robustness of the battery system. Auto stop should be enabled if the health of the battery system allows engine to restart without any doubt. If a vehicle is in auto stop and the health of the battery system deteriorates beyond certain level to the point that engine cranking is not guaranteed, then auto start signal has to be issued. Battery sensors are available in the system which provides data such as SOC, validity of SOC signal, Battery temperature, SOH and SOF. Switches are provided to read the sensor values either through Control area network (CAN) or local internet network (LIN) such that there is no constraint while choosing the type of sensor being used.

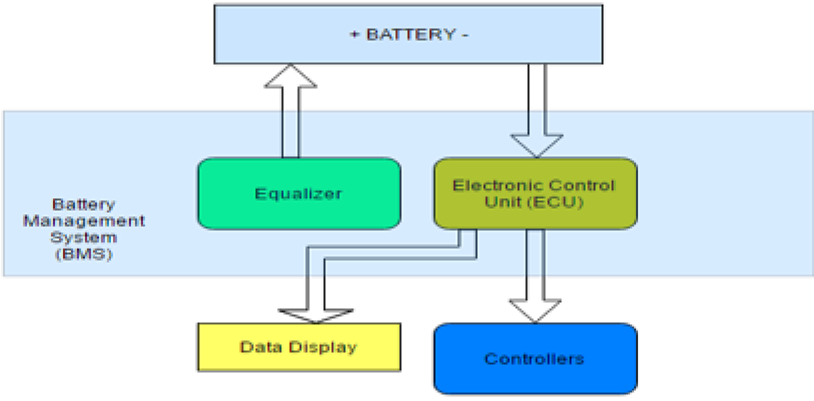

Fig. 1. Battery Management System

To develop Battery data acquisition model Automotive Simulation Control Engineering Tool, (ASCET) developed by one of the entity of BOSCH group, based environment is used. ASCET tool that is used to develop the model based on the logic. The family of ASCET product supports development of application software based on model and provides facility of generating code automatically from these models. ASCET is particularly developed to convene certain requirements of automotive to embedded software with constraints of real-time, efficiency and safety. From initial component design including block diagrams, state machines up to the generating code automatically for microcontroller target, the ASCET components perfectly fit in the processes.

BATTERY DATA ACQUISITION SYSTEM

A. Modelling of Battery Data Acquisition System

First, the battery data acquisition is to obtain the data from the battery sensor about state of health of battery and based on this input to provide signals whether to start the engine or stop the engine in a start/stop system enabled car. The battery sensor can be placed near to the electronic control unit (ECU) and there can be direct communication between ECU and sensors through CAN or LIN communication. Another way is that these sensors are placed in separate Energy Management ECU and the communication between two ECUs may be done in order to obtain the inputs from the sensor. The flowchart for battery data acquisition model is shown in the figure 2. This module works only when start-stop functionality is enabled and battery sensors and made available. The mathematical modelling of battery data acquisition system is done in ASCET environment and working is shown in flow chart. The following section B shows the ASCET model for the system.

B. Battery Data Acquisition System Model

The module provides enabling or disabling condition of auto start stop feature based on the robustness of the battery system. Auto stop should be enabled if the health of the battery system allows engine to restart without any doubt. If a vehicle is in auto stop and health of the battery system deteriorates beyond certain level to the point that engine cranking is not guaranteed, then auto start signal has to be issued. [Fig.2] Auto stop is enabled if the battery state will allow restarting engine without any doubt. Auto start is forced if restart capability is reduced by battery state.
All the calculations are done only if the start/stop- functionality are active (StartStop_Funcn_SY > 0). If a battery sensor is available, the state of charge will be used to enable start-stop functionality. These two are basic condition to enable the testing of entire model.

The model is divided into four hierarchies as shown in the figure 3. They are:
(1) Battert_Data (2) Sof_V_Correction (3) Start_request (4) Stop_enable

First hierarchy i.e. Battert_Data is modelled to check how the inputs are being received. The battery sensor inputs can be directly sent to the main ECU via CAN communication or Battery state can be received from Energy management (EEM) module and sent to main ECU. In both the cases state of SOC and percentage of SOC is received. A Calibration Calb_forCANorEEM_C is used to choose between CAN or EEM module, depending on its value the inputs are taken.

In the second hierarchy, the voltage showing State of Function (SoF) is calculated based on inner resistor of the battery. The Sof_V_Correction hierarchy output enables to adjust offset which gets added to the incoming Supply voltage drop while cranking to shift it above the safe value. The function allows defining different offsets for first 4 engine starts. The aging of sensor will decrease the accuracy of SoF and accordingly the offset value is set.

The main hierarchies are to get the auto start request or to enable stop when engine is idling. The inputs for this hierarchy are taken from above hierarchies and some inputs come from other ECUs in the car. Depending on all the inputs it checks whether it needs an auto start in order to maintain the health of battery or the battery is healthy and auto stop signal can be sent.

The output from Start_request or Stop_enable is received in a variable StartRequest_by_BattSensor and StopEna_by_BattSensor respectively. These messages are in the form of logic, if StartRequest_by_BattSensor is set as 1 then there is need for auto start. Similarly, if StopEna_by_BattSensor is set to logical 0 then the stop request cannot be allowed because of some error. If StopEna_by_BattSensor is logical 1 then auto stop can be enabled and battery is in good condition.

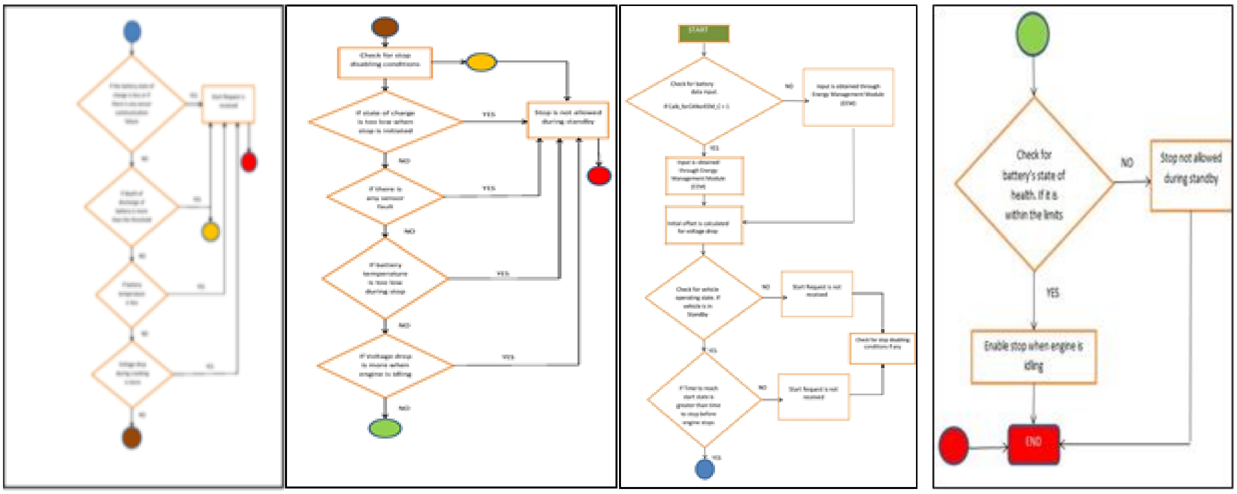

Fig. 2 Flow charts of Battery Data Acquisition System

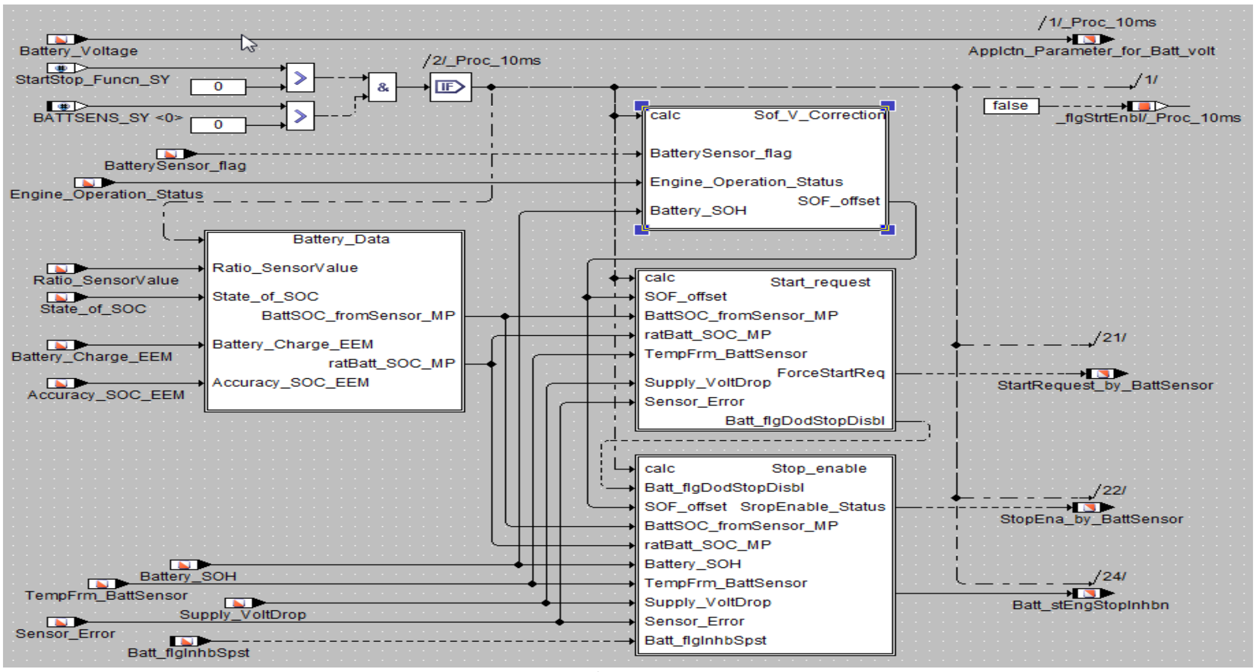

Fig. 3 Overview of battery data acquisition

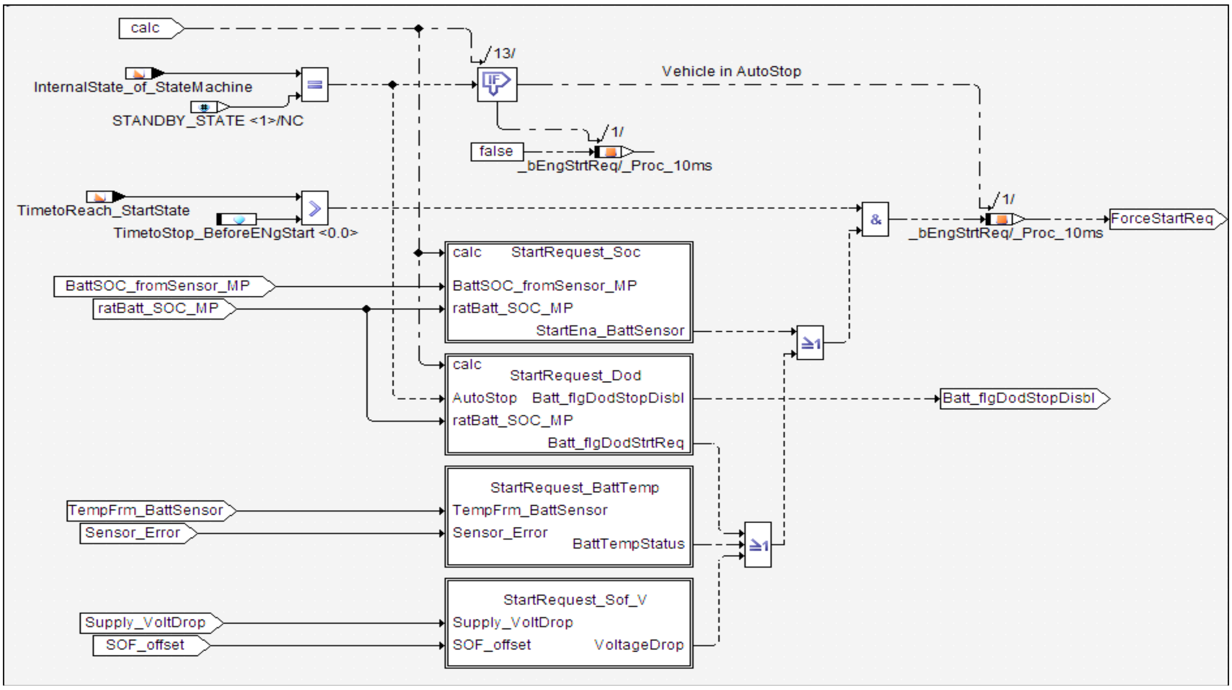

Fig. 4 Start Request hierarchy

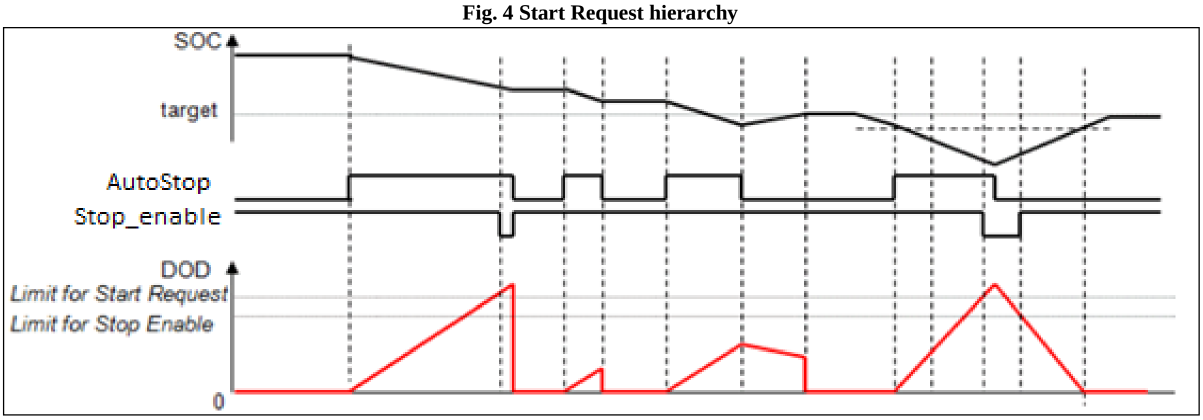

Fig. 5 Start request based on high DOD

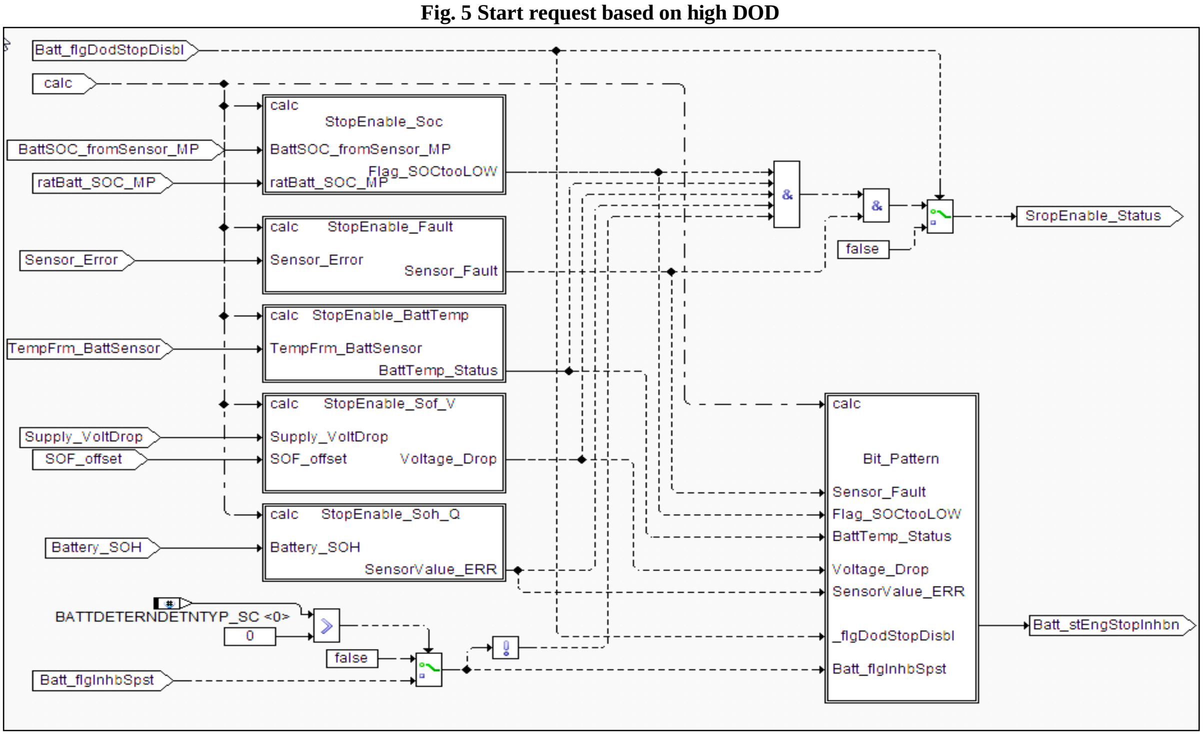

Fig. 6 Stop enable hierarchy

The start request is received again based on different conditions. Here the state of car is checked first to see whether car is in standby, and the time elapsed in reaching start state should be greater than the time spent in stop before starting engine. Both of these conditions are checked first before going to check other required conditions.

Start request hierarchy is also divided in 4 sub-hierarchies where check for State of Charge (SOC), Depth of Discharge (DoD), battery temperature and voltage dip based on state of function. [Fig. 4]

(1) StartRequest_SOC (2) StartRequest_Dod (3) StartRequest_BattTemp (4) StartRequest_Sof_V

Each hierarchy performs its own function. The StartRequest_SOC checks for the state of charge, StartRequest_Dod checks the depth of the charge. Depth of Discharge (DOD) is an alternative method to specify the battery's state of charge (SOC). The DOD is opposite to SOC: as one of them increases, the other decrease. Auto start is forced when the limit of discharge is reached. If the SOC is lower than the target SOC the stop enable will be enabled only if a minimum charge is restored in battery. This is indicated by DOD lower than limit for stop enable. [Fig.5]
It again has three hierarchies: (1) Dod_Off (2) Dod_Increase (3) Dod_Decrease

Each hierarchy performs its own function. Next is StartRequest_BattTemp which monitors the battery temperature. StartRequest_Sof_V monitors the supply voltage.

For Stop_enable hierarchy again different conditions are checked in order to decide whether to stop the engine or keep it running when the vehicle is not moving. Similar to Start_request hierarchy even Stop_enable hierarchy is also divided into 6 sub-hierarchies.

(1)Stop Enable_SOC (2)StopEnable_Fault (3) StopEnable_BattTemp
(4)StopEnable_Sof_V (5)StopEnable_Soh_Q (6)6.Bit_Pattern

In stop_enable, it is again checked for state of SOC, communication failures, battery temperature, supply voltage and sensor state of health. Depending on the input received from Start_request hierarchy check for stop enable condition. As shown in figure 6, if Stop disable on DOD (Batt_flgDodStopDisbl) is set true then stop enable message is set to false and is updated in the variable Batt_bEngStopEna else different other conditions are checked in order to enable Autostop.

RESULTS

This includes few of the case studies with different operating situations. If there is any error Bit_Pattern is used, each logical inputs that come from hierarchy is taken and mapped to a bit, these bits are again mapped to respective message which helps driver to know why stop is not enabled when engine is idling. The table I indicates reason to inhibit the stop function. As discussed battery data acquisition is a process where in through this method, the state of charge of battery and other reasons for which start stop functionality fails to work. By executing battery data acquisition model, various cases are taken and accordingly results are studied.

Case 1: To check whether the input from sensor is obtained from CAN communication or EEM module
In many cars/ automobiles battery sensors are either placed near to the ECU and there will be direct communication between Battery sensor and ECU through CAN communication or the battery sensors may be encapsulated in Energy Management Module which itself is another ECU in the automobile and communication may be between these two ECUs. It all depends upon OEM's decision in which place to mount the sensor. But the algorithm developed here for this module should perform in either of the situation. Hence, a calibration is provided which decides what communication is chosen to obtain the battery data. The OEM will provide this calibration and depending on it the battery data will be taken. If the calibration value is set as 1, then the battery data is obtained from CAN communication; else if the calibration value is set as 0, then battery data us obtained from EEM module. This is shown in graphical representation below, which is obtained as a result of TPT execution. If the calibration value is set as 1.CAN communication is choosen to take battery data. If the calibration Calb_forCANorEEM_C = 1, then second input State_of_SOC is chosen which is obtained directly from battery sensor. And this value is set to the variable BattSOC_fromSensor_MP.

Thus, you can see from the graph that the variable BattSOC_fromSensor_MP follows State_of_SOC. Similarly, from second mux the second input is chosen i.e., Ratio_SensorValue and this is set to the variable ratBatt_SOC_MP. This is shown in the graph that the variable ratBatt_SOC_MP follows the input variable Ratio_SensorValue. If the calibration Calb_forCANorEEM_C is set 0, then LIN communication is chosen.

Case 2: When Battery Temperature is Not Correct
For say around 22th second in the graph the battery temperature is low. Hence the stop is not allowed during this condition. The bit message '4' is set at the end and this means that battery temperature is too low according to the table -1.

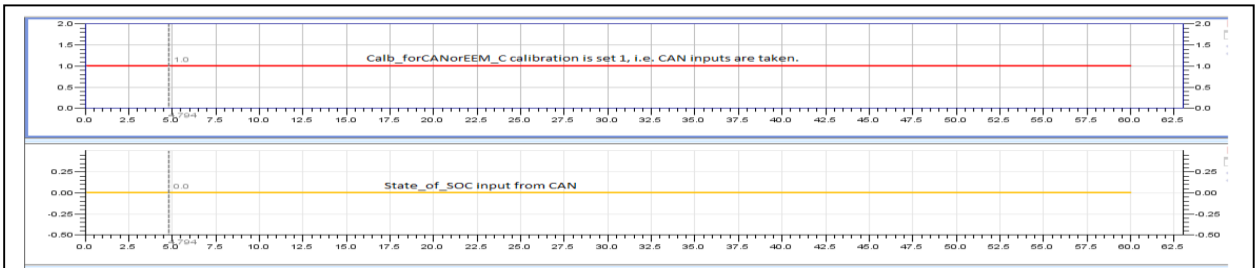

Fig.7 Battery data obtained from CAN communication

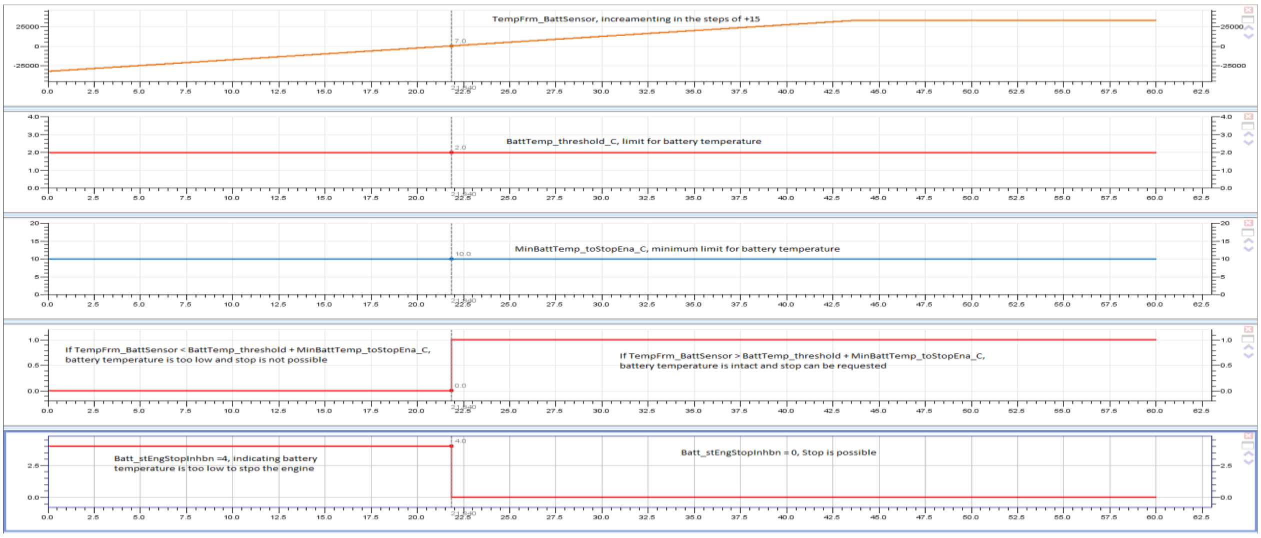

Fig.8 Fault due to Battery temperature

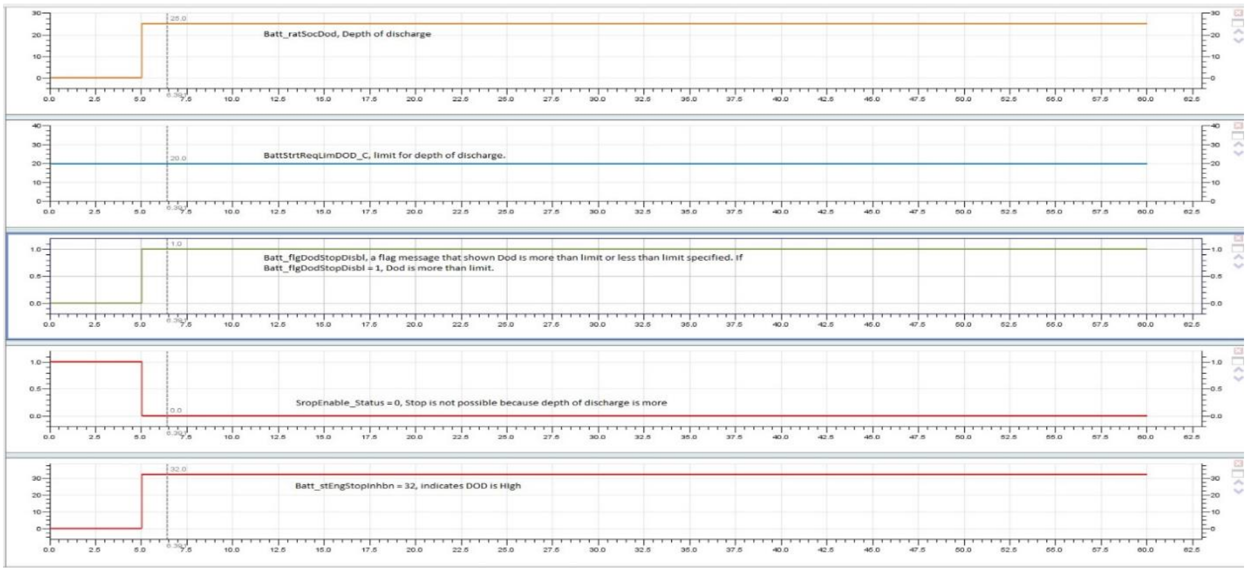

Fig. 9 Stop not allowed due to DOD too high

Table -1 Error Messages for Particular Bit Display

Bit Message	Description
0	Problem in sensor values.
2	SOC too low
4	Battery temperature too low.
8	Estimated voltage drop for engine restart below limit
16	Aging leads to SOH too low
32	Delta SOC limit (DOD) inhibits stop function
64	External reason inhibits stop function

As shown in the figure 8 and 9, when depth of discharge (Batt_ratSocDod) becomes more than the calibrated limit. Then StopEnable_Status message is set to zero indicating stop is not possible and corresponding bit message '32' is set which means Delta SOC limit (DOD) inhibits stop function from table I. Similar states can be studied for other errors mentioned in table -1.

CONCLUSION

For enabling start/ stop functionality in automobile the battery status is very important.

- If there is any error detected including battery temperature, or its SOC may be low, any sensor error then the ECU will not enable the stop functionality even if the vehicle is in standby state.
- If vehicle is in standby and stop functionality is already enabled, later if the software detects any of the error from battery data acquisition system like say temperature of battery is not in limit or depth of discharge may increase above limit, at that time ECU sends a message for force restart of the engine.
- Hence from this model of battery data acquisition, it is possible to monitor the status of start/stop functionality also the status of battery which plays important role when start/stop system is been used. Development had brought in many new technologies in all the fields, this even includes in automobile also.
- In automobile though dealing with small voltages and current but still electrical energy is most important and necessary part for it to work right from cranking engine to run all the other loads in the car.
- The performance and efficiency of the power source required for automotive applications is very important, which in turn support the overall strategy of many original equipment manufacturers toward the market introduction of more fuel-efficient vehicles.

REFERENCES

[1] IA Khan, Automotive Electrical Systems: Architecture and Components, *Proceedings of 18th IEEE Digital Avionics Systems Conference*, St Louis,MO, **1999**, 2, 8-10.

[2] J Chatzakis, K Kalaitzakis, NC Voulgaris and SN Manias, Designing a New Generalized Battery Management System, *IEEE Transactions on Industrial Electronics*, **2003,** 50(5), 990 – 999.

[3] Yoshifumi Morita, Sou Yamamoto, Satoshi Kakogawa and Naoki Mizuno, On-Line Detection Systemn of State-of-Charge in Lead Acid Battery Using Multiple Detectors, *33rd Annual Conference of the IEEE Industrial Electronics Society,* Taipei , **2007,** 2493 – 2498.

[4] Bharath Pattipati, Krishna Pattipati, Jon P Christopherson, Setu Madhavi Namburu, Danil V. Prokhorov and Liu Qiao, Automotive Battery Management Systems, *IEEE Autotestcon*, Salt Lake Cirty, UT, **2008**, 581 -586.

[5] Harshad Tataria, Oliver Gross, Chulheung Bae, Brian Cunningham, James A Barnes, Jack Deppe anmd Jeremy Neubauer, USABC Development of 12 Volt Battery for Start-Stop Application, *IEEE Electric Vehicle Symposium and Exhibition*, Barcelona, **2013**,1 – 8.

[6] Paul R Windover, Russell J Owens, Terry Levinson, M Laughlin and D Michael, Stop and Restart Effects on Modern Vehicle Starting System Components: Longevity and Economic Factors, Department of Energy, National Technical Information Service, 5301 Shawnee Road Alexandria, VA 22312 US, **2012**.

[7] Adil Usman, P Pavan Kumar and BP Divakar, Battery Charging and Discharging Kit with DAQ to Aid SOC Estimation, *IEEE International Conference on Computation of Power, Energy Information and Commuincation,* Chennai, **2015.**

[8] AUTOSMART, Natural Resourcecs Canada, Resources naturelles Canada. Learn the Facts: Ideal Start Stop Technology and Its Effect on Fuel Consumption, as represented by the Minister of Natural Resources Canada, **2014.**