Advanced energy storage systems: electric and hybrid vehicles

Science, Physics

Voltage and current constraints on the system: Voltage: Generally, the Hybrid Electric vehicle requires voltage supply of 250-400 V for meeting their power requirements. In our case, the maximum voltage designed for the battery is 350V and the minimum is 195 V. However, the voltage limit will be different considering the requirements of the electric motors and the power control system. For example, during regenerative braking the voltage generated in fraction of seconds can be significantly high. Therefore, proper voltage control will be required to maintain the efficiency of the system. In our project, the maximum voltage allowed to generate in the system must not exceed 375 V considering the capability of the electric motor. However, for the design safety, the electric motor will be capable of sustain voltage supply up to 400 V. Similarly, minimum operating voltage should not drop below 195 V for sound working of electric system (electric motor, converters etc.) and longer life. Current: Current is also one of the most important criteria for determining the operational capabilities of the energy storage system in our project.

The value of maximum allowable current can be calculated from the formula; Pmax = Imax x Vmin The allowable discharge power from the battery pack is 60KW in 10s and during regenerative breaking the power generated will be less than 50KW and the minimum voltage should not drop below 195 V. Therefore, Imax = 60, 000/195 = 307. 69 A And for the power of 50 KW (the design power of battery), Imax = 256 A Therefore, maximum value of current allowed is 307. 69 A. However, system including power controller, electric motor will be capable of withstanding current value up to 325 A. 12. Design of battery pack for the vehicle: The battery is designed to provide maximum discharge voltage of 350 V. Each cell of the battery selected for our project ($LiMn_2O_4$) is capable of providing 3. 8 V of electric supply. Therefore, to develop voltage of 350 V, the number of cells required in series; Number of cells in series = 350/3. 8 = 92. 5 or 93 cells Consider each battery module consists of a rowof 5 cells in series and 2 rows in parallel containing total of 10 cells. Therefore, total number of cells = 93 x 2 = 186 cells Module Design: Assuming a module consisting of two rows of 5 cells in parallel, containing a total of 10 cells. Therefore, number of modules required is, 186/10 = 20 modules. Cell specifications:[12] Prismatic Lithium-ion Battery Cell: 5. 3Ah*2,[12] Items Specifications*1 Dimensions (mm) 120 × 85 × 12. 5 Weight (kg) 0. 25 Nominal Voltage (V) 3. 6 Rated Capacity (Ah) 5. 3 Specific Power (W/kg) 3, 400 Specific Energy (Wh/kg) 76 Efficiency 80-85 % Figure: Typical Prismatic Lithium Ion Battery cell Table 4 : Prismatic Lithium Ion Battery Cell specifications [12] Module specifications: Each module consists of 5 cells in series & 2 rows in parallel. Therefore, width does not change. However, due to packing/casing the width of module will be increased by 10-15 mm on each side. Let us say the final width of module is 120 + 20 = 140 mm As there are 2 cells in parallel, therefore, the height of the module would be more than double of height of cell. Hence, 85 x 2 = 170 mm, Adding space required for packing, the height of module should be 190 mm. As there are 5 cells in series, the length of the module will be 5 times thickness plus extra space required for casing. 12. 5 x 5 = 63, adding thickness of pack, 63 + 20 = 83mm Figure: Battery Specification Figure: Module Specification Battery Specification Calculating the volume of the battery for the above mentioned dimension, Volume = 200 x 840 x 290 (without excluding the vacant part) = 48, 720, 000 mm3 or 48. 72 Litre In our project, we had assumed the volume constraint to be 50 Litre.

Therefore, the design of battery will meet the requirements of the project, considering 2 litre volume allowances for calculation mistakes, measurements or manufacturing errors etc. Battery management system: From convenient gadgets to electric vehicles (EVs), batteries are broadly utilized as a principle vitality source in numerous applications. Enthusiasm for batteries for EVs can be followed back to the mid-nineteenth century when the main EV appeared. Today, since EVs can decrease fuel utilization up to 75%, EV batteries have increased reestablished consideration in the vehicle showcase. Boston Consulting Group has revealed that, by 2020, the worldwide market for cutting edge batteries for electric vehicles is relied upon to contact US $25 billion, which is three times the span of the present whole lithium-particle battery advertises for customer gadgets. Besides, finished release causes diminished cell limit because of irreversible concoction responses. In this way, a BMS needs to screen and control the battery in view of the wellbeing hardware joined inside the battery packs. At whatever point any anomalous conditions, for example, finished voltage or overheating, are distinguished, the BMS ought to inform the client and execute the preset revision strategy. Notwithstanding these capacities, the BMS additionally screens the framework temperature to give a superior power utilization conspire and speaks with singular parts and administrators. At the end of the day, a complete BMS ought to incorporate the accompanying capacities:

- Data acquisition
- Safety protection
- Ability to determine and predict the state of the battery
- Ability to control battery charging and discharging
- Cell balancing
- Thermal management
- Delivery of battery status and authentication to a user interface
- Communication with all battery components
- Prolonged battery life

Now, there are two parts of BMS system. it shown as below: 1) Hardware 2) Software 13. Battery Thermal Management: As Li ion cells are said to have high power, they are prone to catching fire as cells heat up quickly. As liquid is a good facilitator of heat transfer, hence we decided to use liquid cooled battery thermal management system. The liquid that we decided to use would be 1: 1 mixture of water and glycol. The advantage of using water glycol solution over mineral oil would be that it has much lower viscosity and higher thermal conductivity. Working: The water glycol solution is first cooled by passing through the heat exchanger. Now, the cooled liquid absorbs heat from the cells through the parallel placed aluminium plates of the battery pack. The heated solution is then passed on to the AC and liquid/liquid heat exchangers through the cooling lines/hoses to be cooled and re-circulated again as shown in the figure below. The system has a variability in terms of its cooling range between -20 and 50°C. Figure 13. 1: Liquid based battery thermal management system (Active thermal management) Besides active thermal management, passive thermal management would also be a part of our system. Active thermal management uses phase changing material (PCM). It absorbs bulk of heat with only small volume of its usage. It helps to buffer against life reducing high temperature during battery operation. The Li-ion cells would be surrounded by graphite sponge which is saturated by PCM. The battery cells are in direct contact with the PCM. During intensive usage, the heat released by the cells melts the PCM.

Battery Management System: Various components that we decided to include in our vehicle as part of battery management system include: intelligent battery unit, monitoring system and balancing system. Monitoring system monitors the state of the battery in terms of its voltage, temperature, state of charge (SOC), coolant flow and current. Difference in voltage across the battery cells is equalised by the balancing system. Lastly, intelligent battery unit is the provider of parameters like SOH and SOC. Battery management system also deals with battery recharging by redirecting energy recovered from regenerative braking back into the battery pack. POWER ELECTRONICS AND INTEGRATION The components involved in control system includes computers and electronic control units. Data is collected from driver which is sent to the controller. Data includes amount of torque needed by driver, vehicle speed and PPS, engine speed, motor speed State of charge of battery and other parameters. The vehicle controller further gives the information in the form of signals to the Motor controller and Brake control system (Regenerative braking).

These controllers further control the motor and braking system.[Fig. 15] Figure 15. 1: Control system and integration of battery management system[15] Figure 15. 2: Overall control strategy layout[16] Different modes of working are achieved transmission system with the help of control system and power electronics. Transmission system consists of planetary gearing and lay shaft gearing. It consists of motor shaft as well which transmits power to and from motor. Lay shaft gears on input and motor shaft freewheel unless engaged by the shifter synchronizer Figure 15. 3: Power train and control of different hybrid modes [16] assemblies. Shifters are actuated by stepper motors and computers which control shifters according to the command from the vehicle controller. Planet carrier is coupled with input shaft to transmit power in different modes.

There are 5 different working modes of our fully hybrid vehicle. 1 Motor alone mode – vehicle always start in motor alone mode. In this mode motor shaft is engaged by motor shifter electric power is transferred to output shaft by motor gear. Vehicle can be reversed when motor controller reverses the direction of the motor rotation. This reduces emissions and improves fuel economy as emissions and fuel usage is maximum at low speeds and at the start of engine. 2Power assist mode – when vehicle is accelerating or when it requires high power boost motor shaft is engaged as well as one of the lay shaft gear is engaged by the shifters both ICE and motor powers the vehicle. 3 Electric CVT modes – In this mode engine drives vehicle and provides power to motor which becomes generator and charges the battery. Sun gear is coupled by shifter to motor shaft and fourth gear is coupled to ring gear. This achieves fuel economy as well by limiting the engine to work on optimized speeds according to the gear ratios. 4 Energy recovery mode: In this mode motor is coupled with output shaft by motor gear and motor becomes generator. This charges the battery whenever the battery is quite low. 5 Regenerative braking: In this mode when the car decelerates or brakes the motor act as generator and the torque applied to rotate the motor helps in stopping the vehicle. Total Cost Estimation and Bills of Materials: Table 5: (Note: Costs in this table are estimates) Part Material Percentage of total weight Weight (Actual) Cost ($) per Kg Total cost (CAD$) Anode Graphite 20% 12 Kg 20 240 Cathode LMO 34% 21. 5 Kg 15 322. 5 Separator Polymers 3% 2 Kg NA 50 Electrolyte Carbonates, LiPF6 15 % 9 Kg 21 189 Cell casing Steel 12% 9 Kg 7 63 Battery pack casing Steel 14 % 12 Kg 8. 3 100 Collectors and wiring Aluminium, copper 2% 1. 22 Kg 1. 5 (Average) 55 Total CAD $1020 Now, Total cost = Material Cost + Other Cost (Labor + Processing + Logistics etc.) Assuming the other costs to be approximately 55% of the purchase costs, Total cost = 1020 + 0. 55 x 1020 = $1581 ± 100

Therefore, cost ($) per power (kW) = 1581/55 = 28. 75 $ per kW And cost ($) per Energy (kWh) = 1581/5 = 316. 2 $ per kWh Expected Future Opportunities: Despite of the numerous challenges encountered in this project, there is huge scope of Hybrid Electric vehicles in the future. Following points justifies the need of development of this technology. 1) The cost of the product of this project can be significantly reduced in the future by making significant improvements in the battery technologies used for energy storage purpose. 2) As announced by the Hyundai, in their coming second generation model there will be full integration of the electric motor and all other power train components to the transmission. It will eliminate the need of torque converter, thereby improving efficiency and reducing cost. The same technique can be used in our project in future to cut down vehicle's cost. In future, there can be chances of integration of electric motor and turbocharger to boost the power output for running the vehicle. This concept of boosting the power by consuming energy from the battery and with combination of electric motor and turbocharger is called Honda's Integrated Motor Assist (IMA) system.[8] Conclusion: This report gives us a clear image that hybrid electric vehicle have numerous advantages over conventional IC engine vehicles.

Due to worldwide increase in the prices of gasoline, hybrid electric vehicle have become core segment of the automotive industry nowadays as people have shown significant interest in them. HEVs can however, only match the demand and popularity of the IC engine automobile segment, if there are continuous improvements. High maintenance costs, less power, high costs, and untimely battery replacement are major drawbacks of such vehicles which need to be dealt with. For this project, we first analyzed the need for the battery system to be designed for the car. Considering all the factors required for efficient performance of the hybridized electric vehicle we decided to choose lithium ion battery for this project. Its advantages over nickel metal hydride battery have also been mentioned in this report. The design of the battery has been prepared after taking into consideration all the factors which would influence its performance. Factors like vehicular power, safety, performance, etc. were taken into consideration which are essential factors to optimize the vehicle performance. The design prepared for the battery of this project is optimized to meet the requirements of the vehicle including high power, safety, energy etc., as well as considering the constraints on the design including weigh, volume & cost. The lab testing of the battery is recommended before use as it was not part of the project scope. Overall, this project report carries all the significant aspects of energy storage system in terms of its technical as well as design related aspects to hybridize Honda civic 2017(4dr CVT LX)”.