e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:02/Issue:05/May-2020 www.irjmets.com

CONTROL OF AN ELECTRIC VEHICLE

Peram Chandra Sekhar Reddy[*1], Ramireddy Swarna[*2], Vikranth Chowdary Kondaveeti[*3], Buragadda Sandeep[*4], Eswar Raja Sayinathababu[*5]

[*1,3]Master student, Dept of Electrical Engineering and Computer Sciences, Hochschule stralsund, Stralsund, Mecklenburg-Vorpommern, Germany

[*2]Bachelor student, Dept of Electronics and Communication Engineering, VVIT, Guntur, Andhra Pradesh, India

[*4]Undergraduate, Dept of Electronics and Communication Engineering, NRIIT, Guntur, Andhra Pradesh, India

[*5]Master Student, Dept of Mechanical Engineering, Hochschule Stralsund, Stralsund, Mecklenburg-Vorpommern, Germany

ABSTRACT

The benefits of electric vehicles are more when compared with the conventional fossil fuel combustion vehicles. Some of them were the zero emission harmful substances. In the near future, the conventional fossil combustion engines are less chosen because of the extinction of fossil fuels and invention of various new types of battery vehicles. In this scenario, the electric vehicles are to be reliable and robust. These types of vehicles are not supposed to have drawbacks or setbacks when compared with the conventional fossil fuel powered vehicles. In battery powered electric vehicles, the controlling part is very difficult to understand when compared with the other parts like battery technology, range calculation. This paper aims mainly with the understanding of control of battery powered electric vehicles. It covers with various modules involved in the controlling unit of the electric vehicles

KEYWORDS: Control, Fossil fuel combustion vehicles, Reliable and Robust, Battery Technology.

I. INTRODUCTION

Due to the lack of proper knowledge regarding the control modules of electric vehicle makes it less choosable when compared with the conventional fossil fuel combustion vehicles.

The main modules involved in the control of electric vehicles are as follows

1. Electric Machine Control System(EMCS)
2. Battery Management System(BMS)
3. Driver Mode System(DMS)
4. Stability Control System(SCS)

All the modules are combined into a single module called Vehicle Control System.

In order to explain the above systems we need to have basic knowledge on what is happening inside a battery powered electric vehicle.

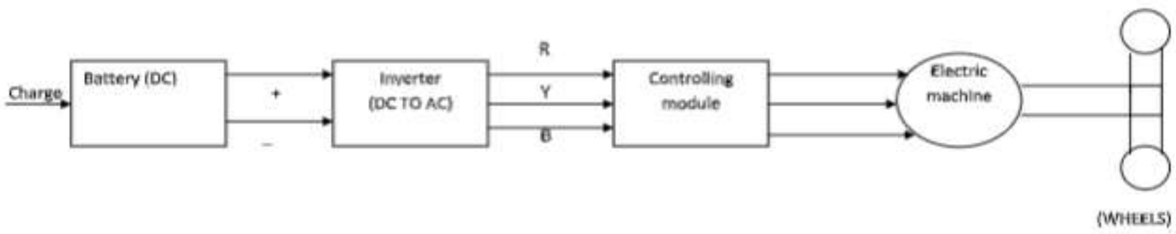

Fig-1

When we charge an electric vehicle, the first thing that happens is it stores the energy inside the battery as DC. Electrical machines used in the electric vehicles are the AC electrical machines. This is due to several reasons which will cover in another topic. For AC, the DC needs to be inverted so that it can be fed to the electrical machine.

Therefore with the help above basic knowledge in an electric vehicle we can get into the controlling of an electrical vehicle.

An electric vehicle contains the above mentioned modules called controlling modules which are explained below.

Electric Machine Control System (EMCS):

The main purpose of the electric machine control system is to convert the DC power stored in the battery pack into the required magnitude of the AC power that is suitable for the electrical machine. It is also the main unit which receives the information from the other modules such as DMS, BMS and SCS. By calculating the inputs received by the different modules the EMCS sends the required torque signal to the motor controller which controls the motor to produce the required torque. The functions of EMCS can be broadly understood by the following block diagram.

The examples of EMCS used in electric vehicles are pm100, pm150.

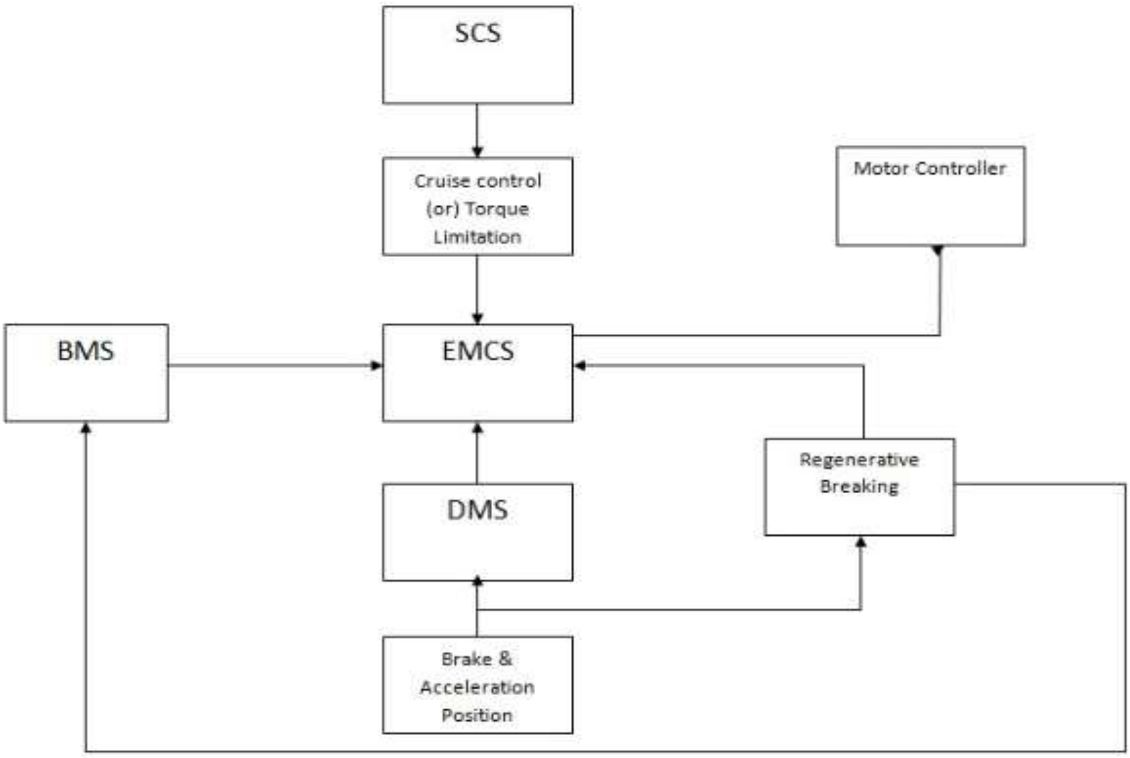

Fig-2

Battery Management System (BMS):

The Battery Management System mainly deals with issues related to the battery pack. The main issue in the battery pack would be the heating of batteries while charging and discharging. The Battery Management System is equipped with the heating sensors which sense the heat level of each module of the battery pack. When it senses the heat, it circulates the cooling liquid around the battery modules which consists of small battery cells. In addition to the battery pack cooling, it also senses the battery pack voltage and current ratings even for the individual cell charging current and discharging current. By monitoring the individual battery cell parameters we can keep the battery pack safe and hence it will be reliable. It also sends the required voltage and current to the EMCS module such that it regulates the electrical machine. In general as the name suggests Battery Management System (BMS) deals with the every minute problems faced by the battery packs.

The example of Battery Management System (BMS) used in electric vehicles is Orion BMS battery control module (Ewert Energy Systems).

The functions of BMS can be clearly understood by the following block diagram.

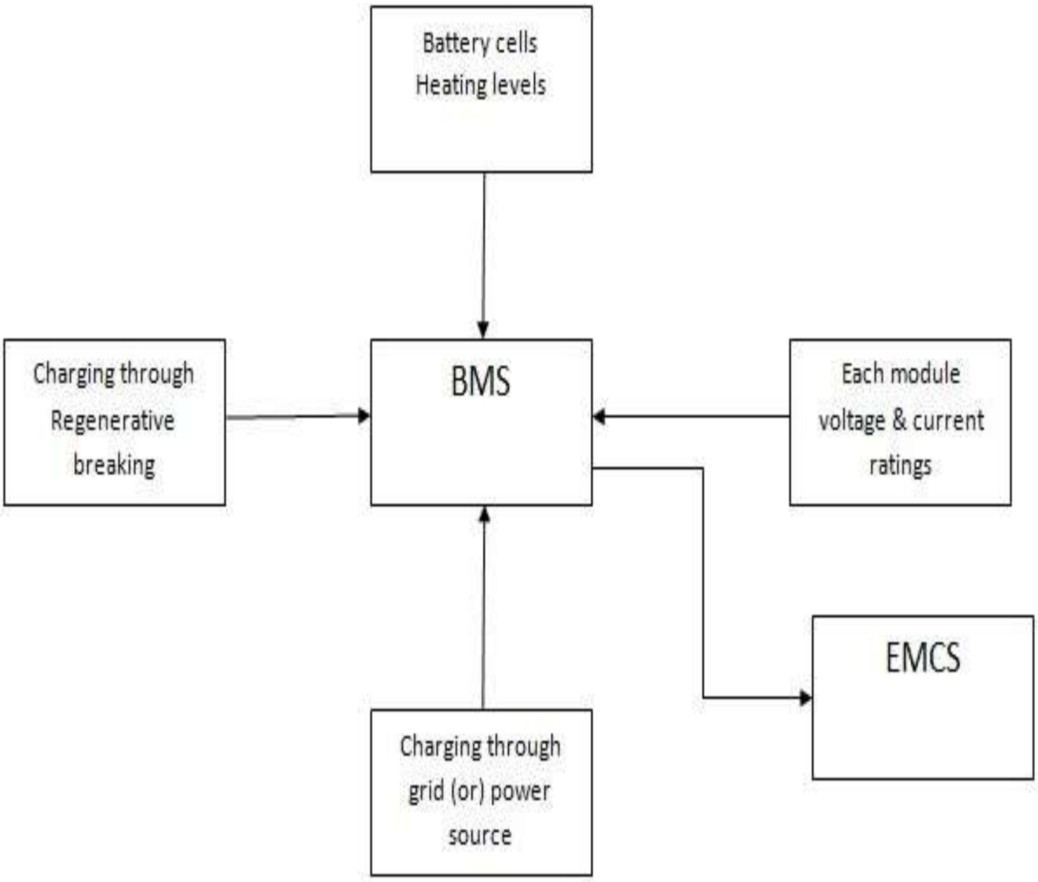

Fig-3

Driver Mode System (DMS):

As the name suggests it is the interaction between the driver and electric vehicle. The Driver Mode System module takes the inputs from the gear rod position and positions of both accelerator and brake. This processes the information and gives the output to the electrical machine control system (EMCS). Its style processing information can be clearly understood by the following flow chart. The DMS is associated with the driver inputs and gives the required outputs as ordered by the driver to the other components of the electric vehicle.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:02/Issue:05/May-2020 www.irjmets.com

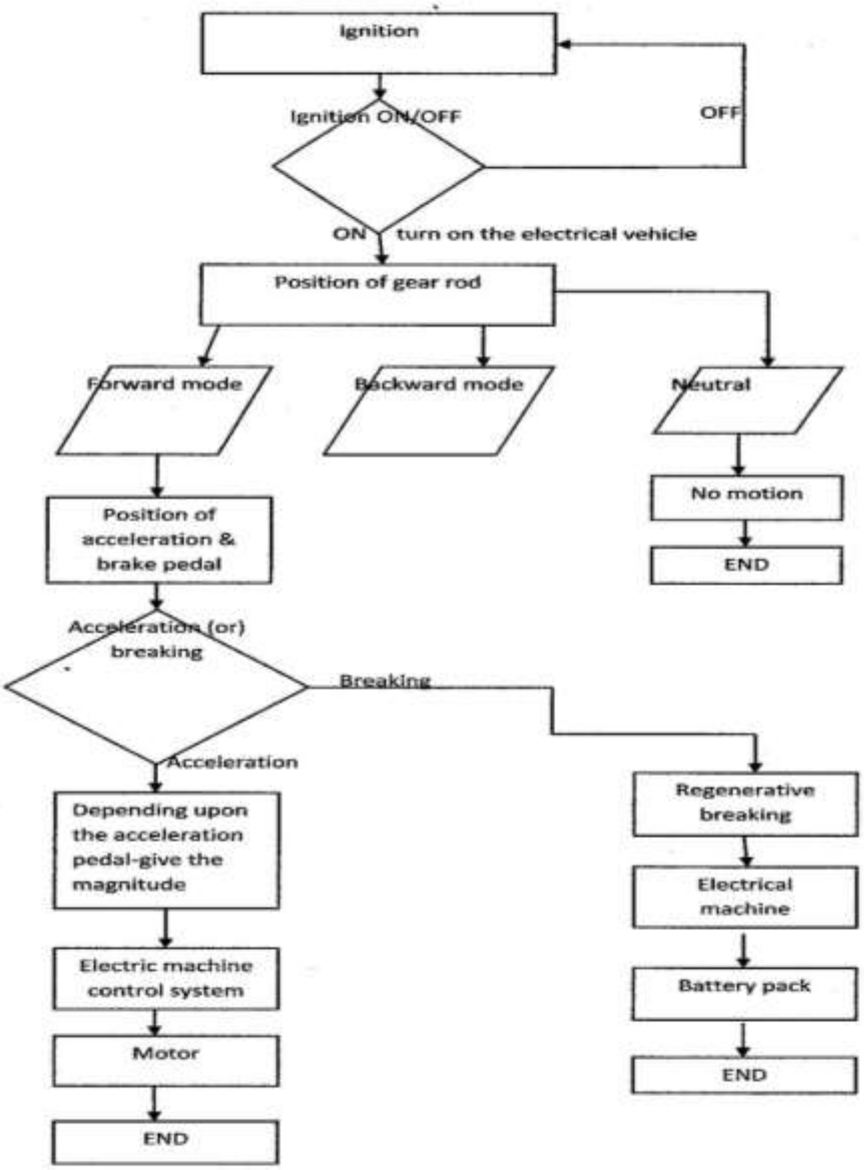

Fig-4

Stability Control System (SCS):

The SCS has many functions in the battery powered electric vehicle. The main function among them is the safety of the electric vehicle. Any aspect relating to the safety of the electric vehicle is to be dealt by the Stability Control System. One among the safety concerns in the electric vehicle is the limitation of torque. In the cruise control mode the vehicle is setup with a speed limited mode where the stability control system plays the main role in the torque limitation of the electric vehicle. For example, when an electric vehicle is moving on a low frictional surfaces like snowy land where the friction between the tyres and the land will be limited. At this instinct, the stability of the vehicle is the main problem therefore SCS plays the vital role. The functions of the SCS can be deeply understood by the following block diagram. In order to control the torque on the low frictional areas like snowy places, the Bosch brake pedal is used.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:02/Issue:05/May-2020 www.irjmets.com

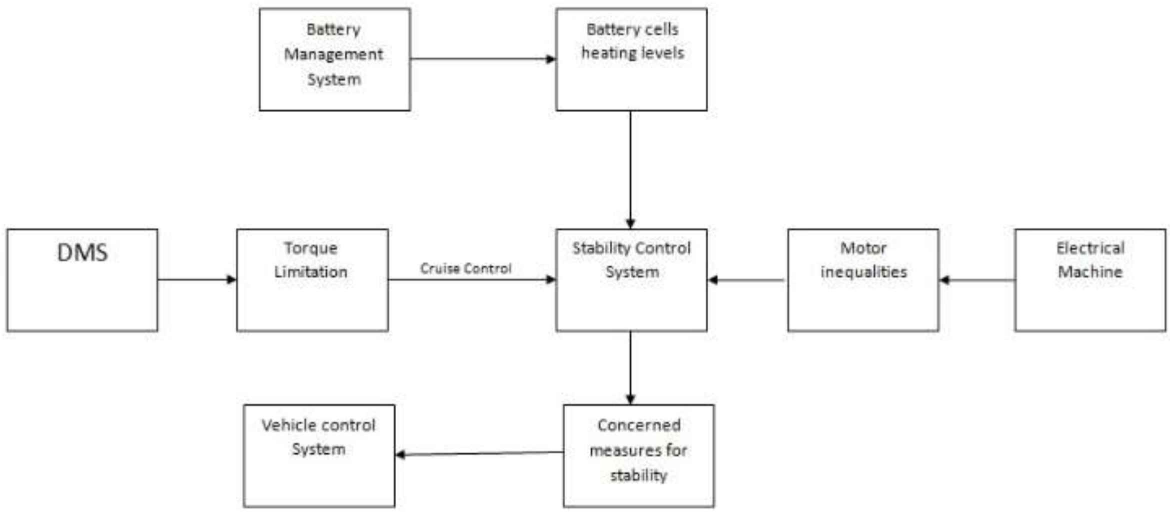

Fig-5

In order to get an overview of the control of a battery powered electric vehicle, the following block diagram gives a clear understanding of the process involved in the control of the electric vehicle.

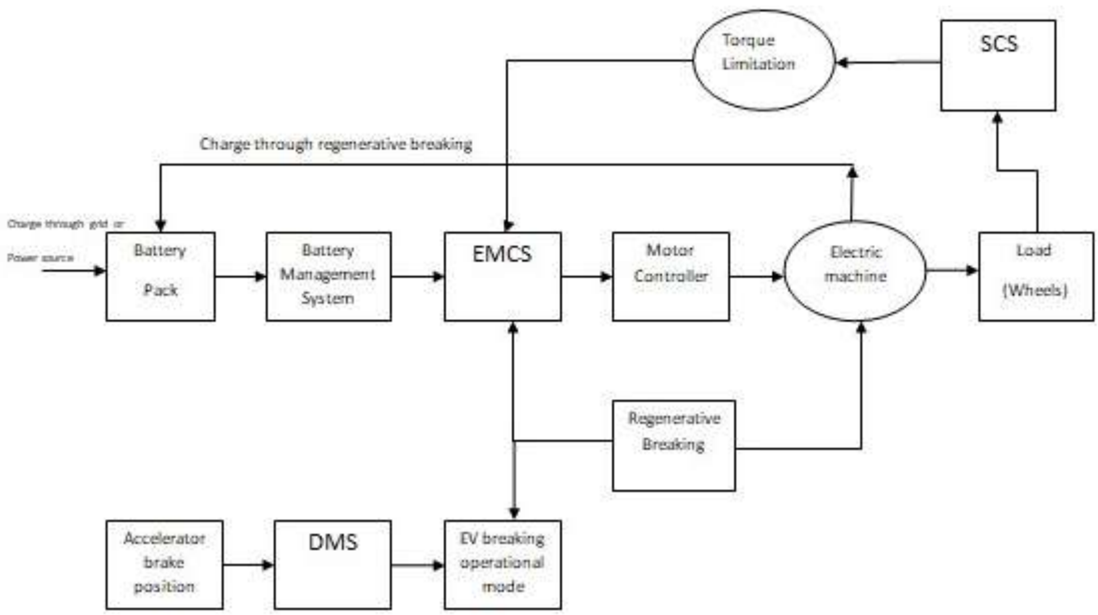

Fig-6

II. VEHICLE OPERATIONAL MODES

The battery powered vehicle has three operational modes. These three modes of operation are broadly divided based upon the running state of an electric vehicle. The three types of operational modes of a battery powered electrical vehicle is given by

1. Acceleration
2. Coasting state
3. Energy recuperation state

In order to fully understand the operational mode of battery powered electric vehicle, first we need to understand the DMS in detail. As said earlier the DMS consists of module which performs logical operation regarding the driver inputs (gear rod position and positions of both accelerator and breaking pedal). When the ignition of battery powered electric vehicle is turned ON and when the driver puts the gear rod to drive mode then logical module in the DMS checks for the position of accelerator and brake pedal. Depending upon the position of the brake pedal, the magnitude of the torque required is sent to the EMCS. Then according to the torque requested, the EMCS sends the signal of magnitude of torque requested the motor controller and hence the required torque is generated by the electric machine which is then fed to the wheels of the electric vehicle.

By having this basic knowledge about DMS the vehicle operational modes can be clearly understood.

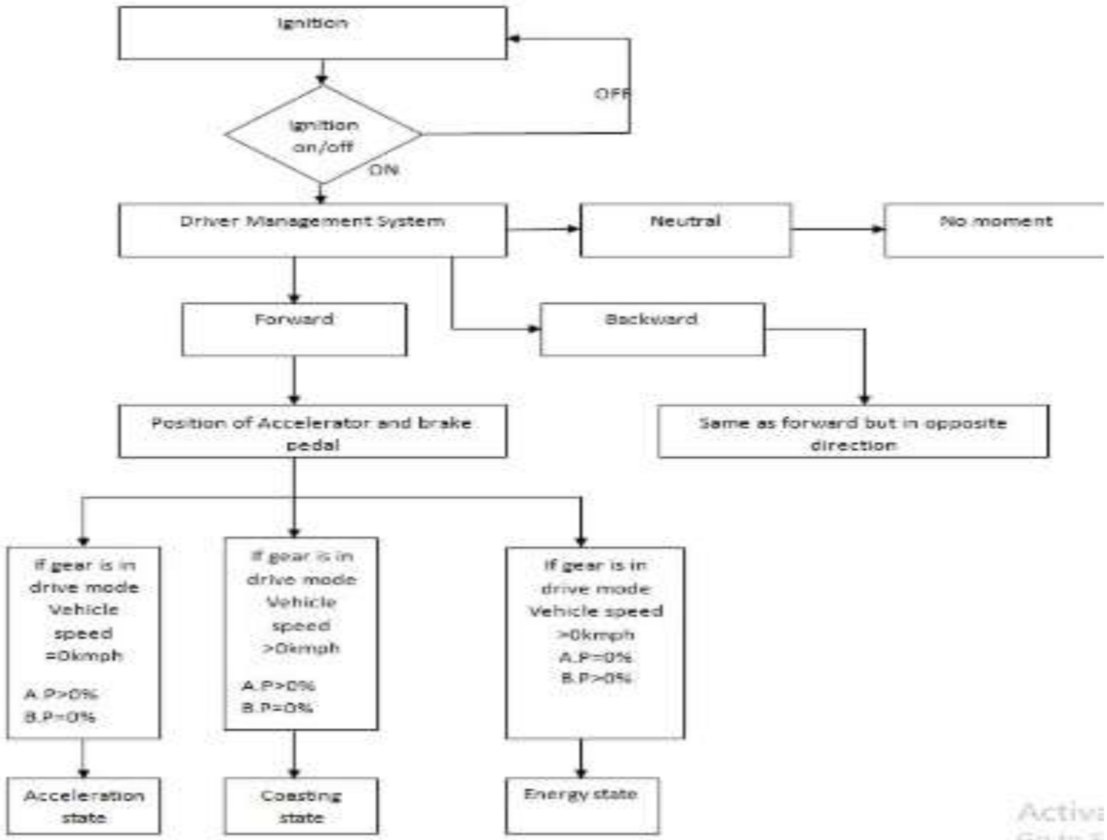

Fig-7

From the above flow chart of vehicle operational, we can easily differentiate between the three states of the electric vehicle. Therefore, the three modes states of an electric vehicle can be described as follows

1. Acceleration State:

In the acceleration state i.e. when the speed of the electric vehicle is zero (V.speed=0) and acceleration pedal has some value (i.e. A.P>0%) and brake pedal at rest (i.e. B.P=0%). The electric vehicle in this state has full acceleration. For this, the required torque signal is sent by the EMCS to the motor controller to achieve the full acceleration. But, in this state if there is any limitation torque set by the SCS the max torque obtained by the electric vehicle will be limited by that value of torque limitation.

2. Coasting State:

The coasting state is achieved when the following conditions are satisfied. The conditions are

1. Vehicle speed > 0kmph
2. Gear shift is in drive mode
3. Accelerator pedal = 0%
4. Brake pedal= 0%

If the above four conditions are satisfied then the electric vehicle is in coasting state. In this state, the vehicle uses kinetic energy obtained by the moment of vehicle in the acceleration state. Here the accelerating torque is not produced. Therefore, the energy can be saved even in the moment of electric vehicle.

3. Energy recuperating state:

The energy recuperating state is also called as regenerative breaking which can be achieved when the electric vehicle satisfies the following conditions.

1. Gear shift is in drive mode
2. Vehicle speed >0kmph
3. Accelerator pedal=0%
4. Brake pedal >0%

The regenerative breaking state (or) the energy recuperating state is a state in which the kinetic energy gained by the electric vehicle is used to power the electric vehicle by charging the battery.

III. TORQUE CALCULATION

In general, Torque can be defined as the product of force and distance. The Force (F) is the rotational energy developed by the electric motor and the distance is the diameter of the wheel used in the electric vehicle.

In the electric vehicle scenario, the Torque can be broadly divided into positive Torque and negative Torque.

The positive Torque of the battery powered electric vehicle is the Torque developed by the electric machine which is used to drive the vehicle.

The negative Torque of the battery powered electric vehicle is the Torque developed by the electric vehicle in motion i.e., Kinetic energy of the electric vehicle in motion. This negative charge is used to charge the battery by feeding back the Torque to the electrical machine which is then converts into the electric generator and produces the electric power that is to be stored in the battery. In simple terms it is also called regenerative braking.

When we consider the electric machine, the positive and negative Torque can be defined as follows:

The positive Torque in the electric machine is obtained when the machine shaft is rotated in the clock wise direction and the Negative Torque in the electric machine is obtained when the machine shaft is rotated in anti-clockwise direction.

Let us consider the following parameters,

Slip (S) = $(N_s - N_r) / N_s$

N_s– Synchronous speed of machine.

$N_s = (120 * f) / p$

f – frequency

p – Number of poles

If slip> 1 : The Torque is negative, and Torque is obtained by external motor (the Kinetic energy of the electric vehicle in this case)

If slip < 1 : The Torque is positive, and Torque is produced by the electric machine and is used to drive the load. In this case, electric vehicle.

In order to briefly understand between the positive and the negative Torque, just look at the following chart.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:02/Issue:05/May-2020 www.irjmets.com

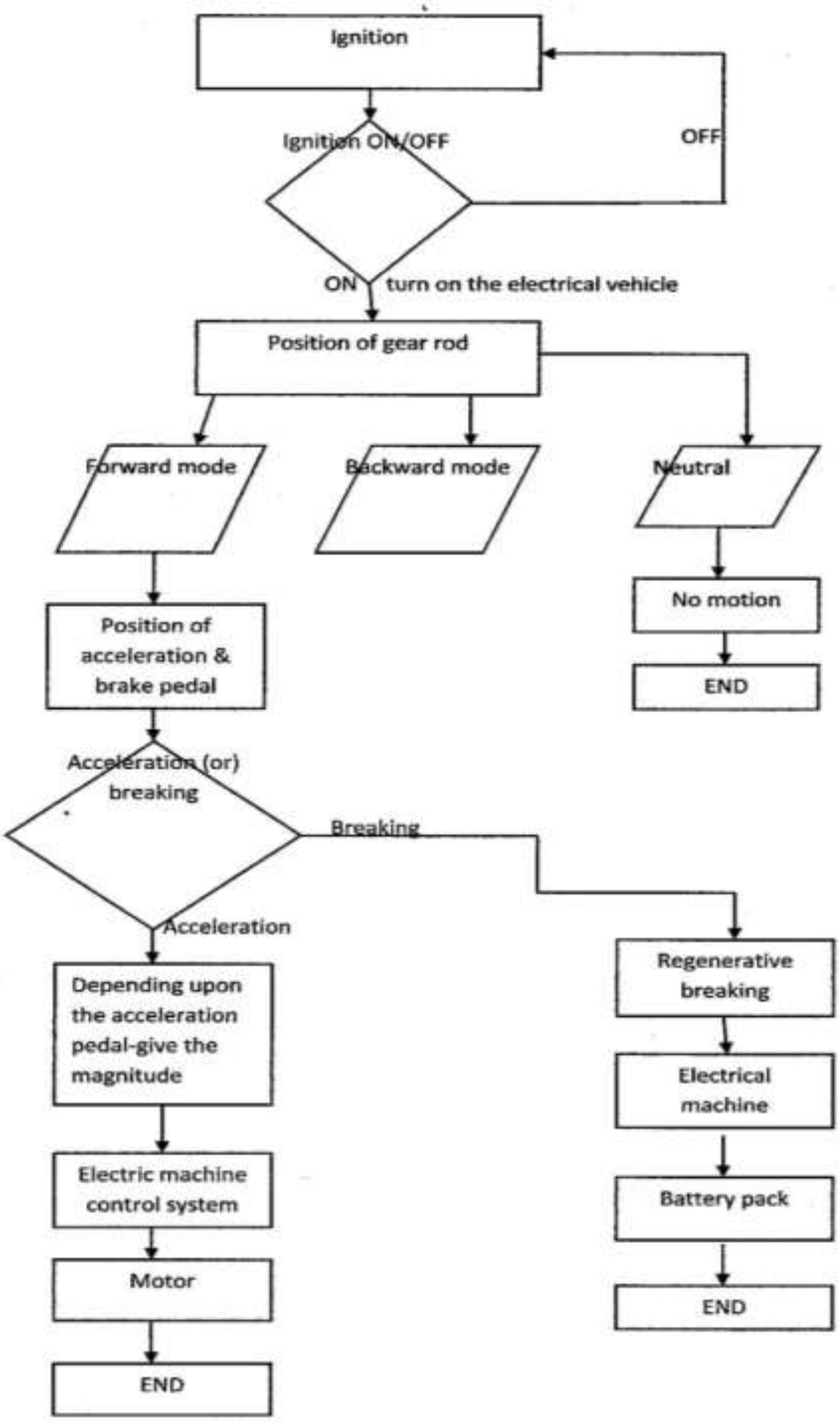

Fig-8

Now, let us calculate the torque required by the electric vehicle.

Consider,

Let W be the weight of the electrical vehicle

t be the time for the acceleration

a be the acceleration required by the electrical vehicle

V be the velocity of the electrical vehicle

F be the force required by the electrical vehicle

d be the diameter of the wheel of electrical vehicle

Firstly, calculate the velocity of the electrical vehicle

$V= U_{max}-U_{min}$ m/sec

V=u-at => v=at

a=v/t

Therefore F= Wa

The torque required by the electrical vehicle

$$\tau = F*d$$

τ is the maximum torque required by the electrical vehicle to accelerate from the minimum velocity U_{min} to the maximum velocity U_{max}.

Now, consider the mechanical parts used in the transmission of the power from electrical machine to the wheels. They are

1. Differential ratio
2. Transmission gear ratio

In general, the differential ratio and the transmission gear ratio for an electrical vehicle is 3:1 and 4:1 respectively. These values are approximate values taken by looking at the differential and transmission gears used in the moderate level electrical vehicles.

Total ratio = 3*4 = 12

In general, the moderate level electrical vehicles use EMRAX228 motor in the application.

The motor EMRAX228 can deliver 240 N-m peak torque and 120 N-m continuous torque.

Thus the peak torque on the wheels = 12*240 N-m = 2880 N-m

This peak torque will be used for the first gear at the strating of the motion of the electrical vehicle where the torque requirement will be more and the continuous torque will be used in the running condition where the torque requirement will be less when compared with the starting torque.

For example:

Consider the following values to calculate the torque required by the electrical vehicle

Let the weight of the electrical vehicle be W = 1780 kg

The acceleration time required to accelerate from initial velocity to the final velocity be t = 5 sec

Initial velocity U_{min}= 0 kmph

Final velocity U_{max}=100 kmph

Therefore velocity of the electrical vehicle is given by

$V = U_{max} - U_{min}$ m/ sec

= 100 – 0 kmph

= 100 kmph

= 100* 1000 mph

= 100* 1000/ (60*60)

= 27.78 m/sec

The acceleration can be calculated by-

$V = at$

$a = V/t$

$= 27.78/5$

$= 5.55 \ m/sec^2$

The force of the electrical vehicle can be calculated by

$F = W*a$

$= 1780*5.55$

$F = 9879 \ N$

Therefore the torque required by the electrical vehicle can be calculated by

$\tau = F*d$

Consider the diameter of the wheel of an electrical vehicle be

$d = 0.64 \ m$

Radius of the wheel = d/2 = 0.32 m

$\tau = F*d$

$\tau = 9879*0.32 \ m$

$\tau_{max} = 3161.28 \ N\text{-}m$

The τ_{max} is the maximum torque needed for the electrical vehicle to accelerate from 0 kmph to 100 kmph in just 5 seconds. This torque will be mainly used in the first gear of transmission where the torque requirement will be more when compared with all the other transmission gears.

IV. CONTROL MODULES USED IN THE ELECTRIC VEHICLES

The practical examples of types of control modules used in the electrical vehicles is given in this section. If you want a deep knowledge in the every control module involved in the control of an electric vehicles we would recommend you to look at the following examples of practical control modules used in the control of an electric vehicle.

1. Electrical Machine control system (EMCS):

The practical examples of the EMCS control modules used in the electric vehicle are PM family inverters they are, **PM100** and **PM150**. Some of the specifications of this control modules are given below.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
Volume:02/Issue:05/May-2020 www.irjmets.com

Table-1

ELECTRICAL SPECIFICATIONS			
CONTROLLER MODEL	PMX100DX	PMX100DXR[1]	PMX100DZ
Maximum DC Voltage Operating	400 V		800 V
Maximum DC Voltage Non-operating	500 V		840 V
Motor Current (Continuous)	300 A		150 A
Motor Current (Peak)[2]	350 A_{RMS}	450 A_{RMS}	200 A_{RMS}
DC Bus Capacitance	440 uF		280 uF
Size and Volume	200 x 87 x 314 mm 5.5 L		
Weight	7.5 kg		
Minimum Conductor Size	4 AWG		
Maximum Conductor Size	1 AWG		
Minimum Cable O.D.	9 mm		
Maximum Cable O.D.	16.5 mm		

2. Battery Management System:

The practical examples of the battery management system module used in the control of electrical vehicle is **ORION BMS BATTERY CELL**. Some of the specifications of this control module are given below:

Table-2

Features	Applications
▪ Designed specifically for high EMI immunity ▪ Low power sleep mode ▪ Redundant design for improved reliability ▪ Highly programmable / flexible	▪ Electric Vehicles (EV) ▪ Plugin Hybrid Vehicles (PHEV) ▪ Hybrid Vehicles (HEV) ▪ Solar / Wind Energy Storage Systems ▪ Battery Backup Systems ▪ Racing Vehicles

Electrical Specification Item	Min	Typ	Max	Units
Nominal Supply Voltage	10		16	Vdc
Supply Current – Active *		250		mA
Supply Current – Sleep (Rev C) *		650		uA
Operating Temperature	-40		80	C
Cell Voltage Measuring Range	0.5		5.0	mS
Number of Cells Supported In Series	4		180	cells

3. Stability control system:

The practical examples of the stability control system used in the control module of an electric vehicle is **BOSCH BRAKE CONTROL MODULE**. Some of the specifications of the stability control system can be viewed in below link.
https://www.bosch-mobility-solutions.com/en/products-and-services/passenger-cars-and-light-commercial-vehicles/driving-safety-systems/electronic-stability-program/esp-value-added-functions/

4. Driver Management system:

This module is a theoretical understanding control module. Its operation will also be carried out by other control modules used in the controlling of an electric vehicle and comes under vehicle control system.

V. CONCLUSION

The overall brief understanding of the controlling the electrical vehicle is met in this paper. All the control modules used in the electric vehicle are presented but this is in general. Some of the control modules may be different for different varieties of the electric vehicles but in general these modules are same as far as the controlling of the electric vehicle is concerned. The deep understanding of the control modules can be achieved by looking at the last section of this paper i.e. modules used in the electric vehicle. A general overview of the process in the control modules is presented in this paper.

VI. REFERENCES

[1] https://x-engineer.org/automotive-engineering/vehicle/electric-vehicles/ev-design-mode-management-vehicle-control-system/

[2] https://www.irejournals.com/paper-details/1702221.

[3] Quddus, A.; Kabli, M.; Marufuzzaman, M. Modeling electric vehicle charging station expansion with an integration of renewable energy and Vehicle-to-Grid sources. Transp. Res. Part E Logist. Transp. Rev. 2019, 128, 251–279. [CrossRef].

[4] Wang, D.; Saxena, S.; Coignard, J.; Iosifidou, E.A.; Guan, X. Quantifying electric vehicle battery degradation from driving vs. V2G services. In Proceedings of the 2016 IEEE Power and Energy Society General Meeting (PESGM), Boston, MA, USA, 17–21 July 2016; pp. 1–5...

[5] Zhang, Y.; Wang, W.; Kobayashi, Y.; Shirai, K. Remaining driving range estimation of electric vehicle. In Proceedings of the 2012 IEEE International Electric Vehicle Conference, Greenville, SC, USA, 4–8 March 2012; pp. 1–7..

[6] Liu, H.; Zhang, Y.; Zheng, S.; Li, Y. Electric Vehicle Power Trading Mechanism Based on Blockchain and Smart Contract in V2G Network. IEEE Access 2019, 7, 160546–160558.

[7] Sun, X.; Yamamoto, T.; Morikawa, T. Charge timing choice behaviour of battery electric vehicle users. Transp. Res. Part D Transp. Environ. 2015, 37, 97–107.

[8] Shi, R.; Li, S.; Zhang, P.; Lee, K.Y. Integration of Renewable Energy Sources and Electric Vehicles in V2G Network with Adjustable Robust Optimization. Renew. Energy 2020, 153, 1067– 1080.