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TRACTION ASSISTANCE SYSTEM FOR FOUR WHEEL DRIVE ELECTRIC VEHICLE

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Abstract – ***The increasing prospect of electric vehicles has led to many different control schemes to be applied on the driving system. The Front and rear wheel drive electric vehicles are being developed as the next generation electric vehicle with ideal characteristics of driving performance of all types of propulsion systems and various driving conditions. By analysing the power distribution of the given driving cycle, the energy efficiency of the traction machine over the driving cycle can be characterized against a number of driving conditions and the control optimization can be carried out with respect to the conditions. The main objective is to analyse the condition of the driving mechanism and automatically convert the driving (2/4 wheel drive) mechanism during starting time, slope conditions, long driving and braking times. Also the parameters during various driving modes such as 2 wheel modes, 4 wheel modes and automatic drive changing modes are analysed and compared. The analysis and control actions are taken in LabVIEW software automatically and the data for various driving modes are recorded and the analyses for power consumption, efficiency, driving distance, etc., are validated.***

Key Words: *Electric Vehicle, LabVIEW, Traction, Virtual instrumentation.*

1. INTRODUCTION

1.1 Electric Vehicles

An electric car is an automobile that is propelled by one or more electric motors, using electrical energy stored in rechargeable batteries or other electrical sources. Electric motors give electric cars instant torque, creating strong and smooth acceleration. They are also around three times as efficient as cars with an Internal Combustion engine. Electric cars are typically easy to drive, perform well, and are significantly quieter than conventional internal combustion engine automobiles.

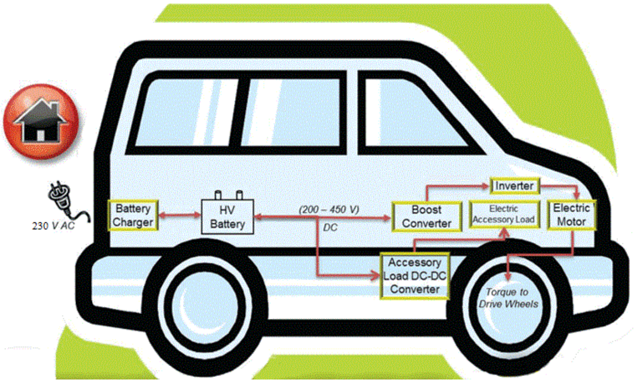


Fig -1: Structure of Electric Vehicle

They also do not emit tailpipe pollutants, giving a large reduction of local air pollution, and in many cases, a large reduction in total greenhouse gas and other emissions (dependent on the method used for electricity generation).

They also provide for independence from foreign oil, which in several countries is cause for concern about vulnerability to oil price volatility and supply disruption.

Nobuyoshi Mutoh in 2006 proposed a new type of electric vehicle drive system, which has independently driven front and rear wheels. The mechanism deals with the driving and braking torque distribution mechanisms at various load and running conditions. [1]

Donghyun Kim, Sungho Hwang, and Hyunsoo Kim in 2008 proposed a fuzzy-rule-based control algorithm which generates the direct yaw moment to compensate the errors of the side slip angle and yaw rate. They evaluated it using ADAMS and MATLAB co-simulations. [2]

Nobyoshi Mutoh in 2009 derived the mathematical model for the driving torque distribution of front and rear wheel drive electric vehicle. The mathematical model for the curved trajectories is analysed in simulation using CARSIM software. [3]

Nobuyoshi Mutoh, Osamu Nishida , Tatsuya Takayanagi in 2010 described the driving torque distribution method for electric vehicles for providing stable steering on a low friction coefficient road surface by distributing driving torque to the left and right wheels of the front and rear wheels. [4]

Nobyoshi Mutoh in 2012 described about various propulsion force generation mechanisms in conventional Electric Vehicle as

- Front or rear wheel drive type Electric Vehicle.
- Two or four in-wheel drive type Electric Vehicle.
- Front and Rear wheel Independent Drive Electric Vehicle. [5]

Brahim Gasbaoui, Abdelfatah Nasri in 2012 calculated the speed of four wheels independently during the turning with electronic differential system computations which distributes torque and power to each in-wheel motor. [6]

Xiaodong Wu, Min Zu, Lei Wang in 2013 proposed a Differential Speed Steering Control strategy for Four Wheel Independent Driving Electric Vehicle. This steering speed control method provided a steady turning performance during the acceleration and deceleration. [7]

Kuperman, U. Levy, J. Goren, A. Zafransky, A. Savernin in 2013 discussed about the battery charger for electric vehicle traction applications. They discussed various modes of charging and also provided simulation and experimental design to demonstrate the functionality of the device. [8]

Cheng Lin and Zhifeng Xu in 2015 developed a wheel torque distribution strategy based on multi-objective optimization to improve vehicle manoeuvrability and reduce energy consumption. [9]

Electric Vehicles now-a-days are running using different sources as follows.

1.2 Battery Electric Vehicles (BEV)

Battery Electric Vehicles (BEV) powered only by a plug in charged battery. Electric motors have high torque at a wide range of speeds and therefore do not generally require a gearbox. Electric motors have very high efficiencies ~90+% compared to internal combustion engines at ~30-45%.

1.3 Hybrid Electric Vehicle (HEV)

In Hybrid Electric (HEV) petrol or diesel engine is used to generate electricity, which then powers the electric drive motor. Surplus electricity is stored in a battery, reducing engine revving and idling losses. Two types of hybrid drive vehicles are available, series and parallel hybrids:

- A series hybrid is an all-electric drive-train which decouples the combustion engine (which then exclusively drives the electricity generator) from the drive shaft and allows the elimination of the gearbox.
- A parallel hybrid operates the combustion engine in parallel to the electric motors and uses an automatic gearbox; the vehicle can run on electric, fossil fuel or both in combination.

1.4 Plug-In Hybrid Electric Vehicle (PHEV)

Plug-in Hybrid Electric Vehicle (PHEV) similar to the hybrid, except it uses a larger battery store to enable a portion of its energy to come directly from the electricity grid, returning to petrol or diesel energy when the battery charge is depleted to a certain level. All these electric vehicles have common propulsion system and internal operations of the circuits. Some of the types of propulsion (traction) system are discussed below.

2. EXISTING SYSTEM

2.1 Existing Electric Vehicles

The major parts of the electric vehicles are driving motors, battery source and control units.The figure describes the position of the battery pack, converter and driver circuits and electric motors in the current system. The electric vehicles running majorly has the structure given as in Fig -2.

Fig -2: Existing System of Electric Vehicle

The current system has various modes or methods of operation. They are

- Two wheeled Driving Mode (Front or rear wheel drive mode)
- Four wheeled Driving Mode

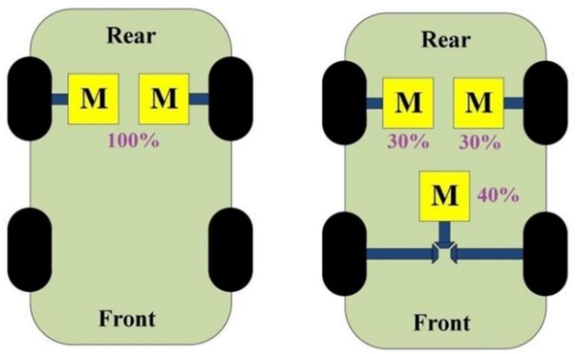
The power distribution in any method of traction system or mode of driving decides the power consumption and efficiency of the vehicle.

2.2 Power Distribution

Generally the power consumption or distribution of the front and rear wheel motors of any 4 wheel drive electric vehicle is given in the figure below.

Fig -3. (a) shows the Rear wheel power distribution mode. Fig -3. (b) shows the Front and Rear wheel power distribution mode.

The Fig. -3. (a) shows the power distribution of 2 wheel drive mode in which electric motors are connected to the rear wheels only. Hence the power is completely transferred to the rear wheels.



(a) (b)

Fig -3: Power Distribution Representation

The Fig -3. (b) shows the power distribution of 4 wheel drive system in which the each wheel is coupled to an electric motor. Here the power distribution is not uniform, where 40% of power is alone fed to the front wheel motors and the rest 60% of power I fed to the rear wheels. As like of the power distribution the rating of the rear motors are also higher than that of the front motors.

2.3 Constraints in Existing System

The dirving of the electric vehicles in plain roads are not difficult and also the operation will not face any constraints. But driving the vehicles in slope areas will cause problems in traction.

Similarly the starting time will also lag the required traction force in order to have a smooth start and reach a medium speed in lesser time. The constraints faced due to these driving modes are shown in Fig -4.

The above figure shows the various constraints that are being faced in the current roads. The constraints can be listed as

- Up Hill Slope
- Down Hill Slope
- Cross Directional Slope
- Flaw Corners (One wheel of the vehicle alone in slope)

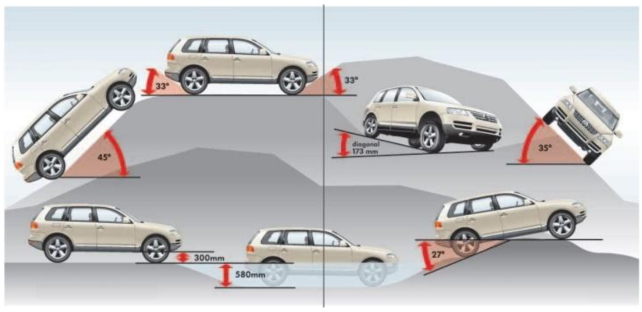


Fig -4: Constraints Faced in Electric vehicles

3. PROPOSED SYSTEM

3.1 Proposed Electric Vehicle System

The proposed system is a hybrid powered system where the source of power is acquired from battery and also from solar energy. The Fig -5 represents the model of the proposed system.

The proposed method is an automatic four wheels and two wheels drive changing mode. This drive changing mechanism provides the electric vehicle some additional propulsion power at times like starting and raising slope driving areas. There by providing the vehicle an extra power for smooth raiding.

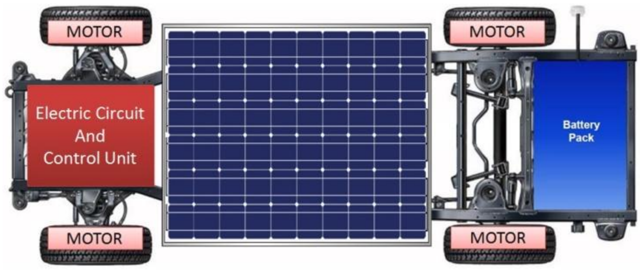


Fig -5: Proposed Electric Vehicle System

The excess power is compensated by the solar energy and so the battery life time can be increased. The proposed system will also provide some extra running time for the electric vehicle on a single battery charge.

3.2 Block Diagram

The block diagram of the proposed system is given below. The entire process can be categorized into four major parts.

1. Acqusition part.
2. Circuit part.

3. Transmitting part.
4. Controlling part.

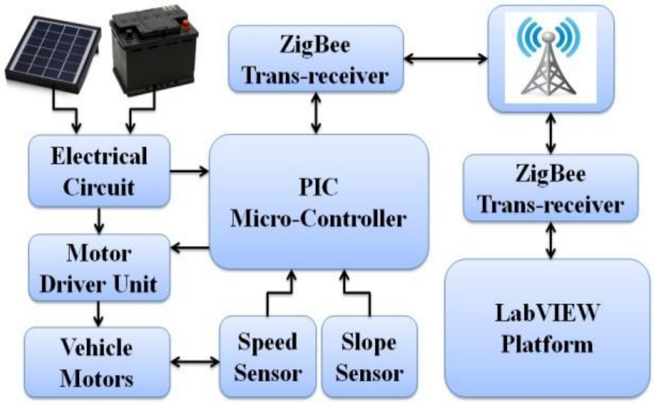


Fig -6: Block Diagram of the Proposed System

3.2.1 Acquisition Part

In the acqusition part the real time data are acquired from the system. Sensors are incorporated for the acqusition of the data. Sensors such as Groove type speed sensor is used to acquire the speed of the vehicle,

Horizontal type float sensor in a specific way of installation is used to get the exact slope condition, current transducers are also used to acquire the current consumption data. These sensors are incorporated with the microcontroller from which these sensor outputs are trransferes to the LabVIEW platform for analysis.

3.2.2 Circuit Part

The circuits for the electric vehicles are the major parts of the control unit. The circuits can be divided into electrical circuits and driver circuits. The electrical circuit includes the charging circuit. The charging is made possible using 230 V AC source and also the solar panel. Separate circuits are implementeed so that the interference of one on the other is limited. The driver circuit includes the control circuit of the motors. The driver circuit operates according to the signals received from the LabVIEW control unit through the microcontroller.

3.2.3 Transmitting Part

The PIC microcontroller and zigbee trans-reciever are the main units of the transmitting part. The PIC microcontroller converts the acquired data to digital format for transmitting it to the LabVIEW platform. One of the Zigbee trans-receiver unit is connected to PIC microcontroller and the other is connected to the LabVIEW installed computer. The data is transmitted in serial format.

3.2.4 Controlling Part

The speed of the motor is controlled by the controlling unit. This circuit operates based on the signal given by the LabVIEW platform. The cnangeover of the two wheel and four wheel driving mde is carried out in this circuit. The speed is controlled manually in this circuit.

4. ANALYSING METHODOLOGY

4.1 Driving Modes

The Proposed Automatic Drive changing system operates on

- Four Wheel Drive Mode
- Two Wheel Drive Mode

Based on the following considerations, the comparative analysis is carried out in LabVIEW.

4.2 Drive Mode Considerations

The following are the major considerations that are used in the mathematical analysis. The considerations factors are taken separately for various driving modes.

4.2.1 Automatic Drive Changing Mode

In this mode of operation both the two wheel drive operation and four wheel drive operations are incorporated.

4.2.1.1 Four Wheel Drive Mode – Auto Mode

For the four wheel drive mode the following considerations are taken into account for operation.

- The four drive mode is considered as the primary mode of operation of the electric vehicle during start and after limit conditions are exceeded.
- This mode is selected when the speed of the vehicle is under the maximum upper limit.
- This mode is selected when the uphill slope driving position is below the maximum angular value.

4.2.1.2 Two Wheel Drive Mode

For the two wheel drive mode the following considerations are taken into account for operation.

- The four drive mode is considered as the secondary mode of operation of the electric vehicle. This mode is switched only when certain conditions are met.

- This mode is selected when the speed of the vehicle exceeds the maximum upper limit.
- This mode is selected when the up-hill slope driving reaches certain maximum angular value.

4.2.2 Four Wheel Drive Mode

In this driving mode the vehicle is driven in the same mode without any change. The external parameters are not considered in this driving mode. In this mode all the four wheels are operated with variation in the power distribution between the front and rear wheels.

4.3 Vehicle Analysis

The analysis of electric vehicle is divided into two main parts

- Electrical Part
- Mechanical Part

The Electrical part deals with the electrical parameters associated with the vehicle such as Voltage, Current, Power, torque, Electrical Losses, etc. The Mechanical part deals with the mechanical parameters associated with the vehicle such as Mechanical forces, Mass, size, Mechanical design, Mechanical Losses, etc.

The electrical and mechanical analysis is carried out with certain considerations. The analysis is made by assigning certain constant and assumptions on the vehicle which is being simulated. The following are the parameters which are taken for the analysis. The analysis is mainly carried out for the motors. As in the simulation part the performance of the motors alone are considered. Various factors causing some variations in this are alone processed. Both electrical and mechanical factors are derived for the analysis.

4.3.1 System Parameters

- Size of the vehicle = 45 X 30 cm
- Radius of the Vehicle r = 4 cm
- Mass of the Vehicle m = 3 kg
- Internal Resistance of motor = 0.001 ohms
- Acceleration due to gravity = 9.8 ms^{-2}

4.3.2 Output Parameters

- Output of the PV panel I_{PV} = 0.1 A
- Drive Changing Speed = 25 Km/hr
- Maximum Up Slope angle = $+20^0$

4.4 Electrical Analysis

Electrically, permanent magnet brushed DC motors can be modeled as a series of three basic electrical components: a resistor, an inductor, and a source of electro-motive force (EMF), or voltage. This voltage source is commonly called the "back-EMF" or "counter EMF." The origins of the resistive and inductive components are easy to see. The resistor in the model is a result of the finite resistance per unit length of wire used to construct the coils in the armature. The inductor is a result of coils of wire that make up the armature windings. All coils of wire act as inductors.

Faraday's law is the effect that requires the inclusion of the back-EMF component in our electrical model of a permanent magnet brushed DC motor: the armature is spinning inside the field created by the stator. This induces a voltage (the back-EMF) across the coil as it spins. This voltage is opposed to the voltage placed across the coil that made the rotor spin in the first place. In short, the motor is acting as a generator at the same time that it is acting as a motor. The voltages are added by superposition, though they have different signs. The effect of this voltage is to reduce the voltage drop and current flow in the motor's terminals when the motor is running.

As a motor turns faster, more back-EMF is generated since the coils in the armature are moving faster through the stator's magnetic field. The magnitude of the back-EMF is related to the rotational speed through a constant Ke, called the speed constant or voltage constant.

$$E = Ke\,\omega \quad [V] \qquad (1)$$

Where,

$$E = \text{back-EMF} \quad [V] \qquad (2)$$

The speed in rpm is converted to rotational speed ω in rad/sec and is given by

$$\omega = \frac{2\pi N}{60} \quad [rad/s] \qquad (3)$$

The rotational constant Ke is determined by

$$K_e = \frac{V}{\omega} \qquad (4)$$

Torque T is the traction power that is generated in the motor. The torque is given as the product of the current and the rotational constant of the motor.

$$T = \frac{K_e}{I} \quad [Nm] \qquad (5)$$

We can use Kirchoff's laws to write a loop equation to describe the steady-state current flow in this circuit.

$$V = IR + K_e\omega \qquad [V] \qquad (6)$$

Where,

- V = voltage [V]
- I = current [A]
- R = resistance of motor coils [Ω]
- Ke = voltage constant or rotational constant
- ω = rotational speed [rad s]

The voltage drop across the motor's coils has an I·R term, as you would normally expect, plus the effects of the back-EMF generated by spinning the motor, expressed in the term $K_e * \omega$.

Some implications of equation are:

- ➢ The higher the rotational speed of the motor, the lower the current flow and therefore the lower the torque. This occurs because of the back-EMF.
- ➢ Maximum speed corresponds to 0 current flow and therefore 0 torque (we obviously can't achieve this with a real motor).
- ➢ When ω = 0 (a condition referred to as "stall") V = IR and current and torque will both be at a maximum. Hence the resultant power P is calculated by

$$P = (I\,R + K_e\,\omega)I \qquad [W] \qquad (7)$$

4.5 Mechanical Analysis

In addition to the electrical parameters the mechanical forces also act on the vehicle. The following are the various parameters that are involved in the analysis.

The total force acting on the vehicle at any moment in time is split up into several different forces as follows

$$F_T = F_a + F_g + F_d + F_r \;[Nm] \qquad (8)$$

Where,

- F_T Total tractive force at the wheels
- F_a Force due to acceleration
- F_g Force due to gravity
- F_d Force due to aerodynamic drag
- F_r Force due to rolling resistance of the tires

For simulation analysis Force due to acceleration and Gravity alone are considered, while other forces are neglected. Hence,

$$F_T = F_a + F_g \qquad [Nm] \qquad (9)$$

Where,

$$F_a = m\,a \qquad [Nm] \qquad (10)$$

$$F_g = m\,g\,\sin\theta \qquad [Nm] \qquad (11)$$

Where,

- m = mass of the vehicle [kg]
- a = acceleration of the vehicle [ms^{-2}]
- g = acceleration due to gravity [ms^{-2}]
- θ = angle of inclination of the vehicle

The Angular rotational velocity is given by

$$\omega = \frac{a + g\sin\theta}{r} \qquad [Rad/sec] \qquad (12)$$

The moment of inertia acting on the vehicle is

$$J = m\,r^2 \qquad [Kgm] \qquad (13)$$

The resultant torque generated is

$$T = J\,\omega = r\,F \qquad [Nm] \qquad (14)$$

With the above equations the performance of the vehicle are calculated and the simulation is implemented in LabVIEW.

5. RESULTS AND DISCUSSION

5.1 Simulation Analysis

The simulation is performed with the known parameters and giving some manual input to the other parameters. Speed and slope conditions are the two parameters which are given as the inputs. All the other parameters are pre analyzed and programmed in LabVIEW coding. The following is front panel design of the simulation part.

In the panel feed the speed and slope inputs in left end and the outputs in digital as well as graphical formats are viewed in the right end. Various tabs are created to present the digital output and the other graphical outputs of all the parameters such as current, power, torque, efficiency, and the provided inputs with respect to time.

The LabVIEW coding is done using state machine architecture in which there is a main program and the sub programs are incorporated in the main program. The main program calls the sub programs in times of requirements.

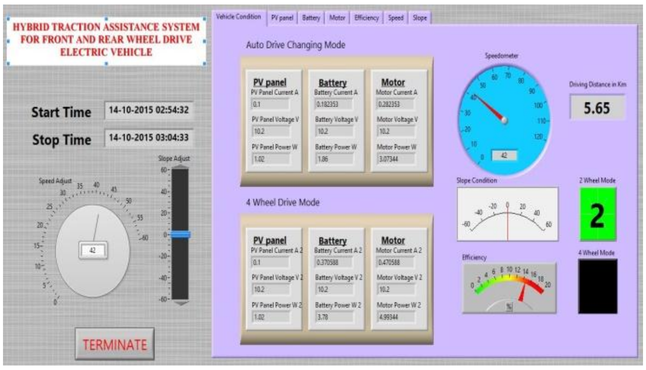


Fig -7: Front Panel with Digital Output

5.2 Graphical Output Analysis

The results are taken in the form of graphs for analysis. The parameters such as voltage, current, power, efficiency are provided in graphical formats to give the results at all instances. Individual graphs are published having the comparative results of both the driving modes.

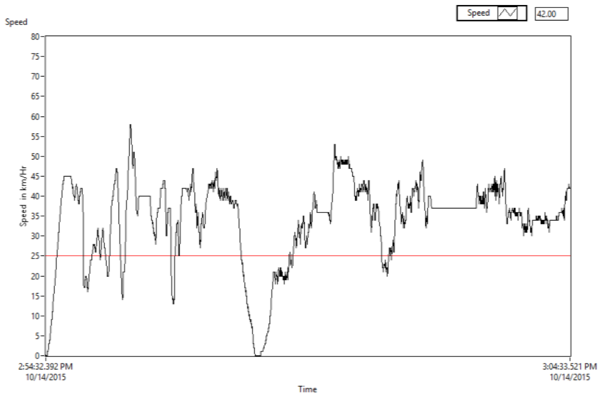


Fig -8: Speed vs Time Graph

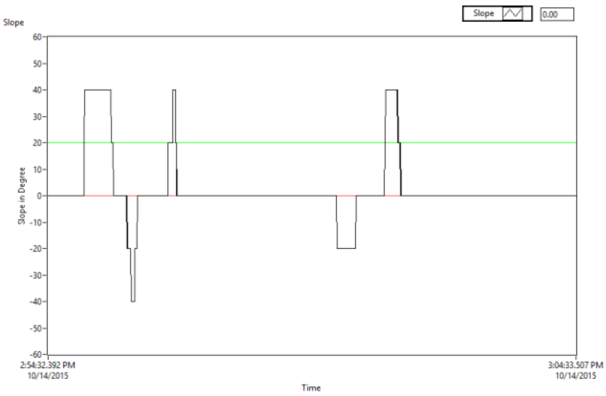


Fig -9: Slope vs Time Graph

Fig -8 and Fig -9 shows the inputs given to the simulation model manually. The speed of the vehicle and the driving slope conditions are alone given as the inputs for a specified period of time.

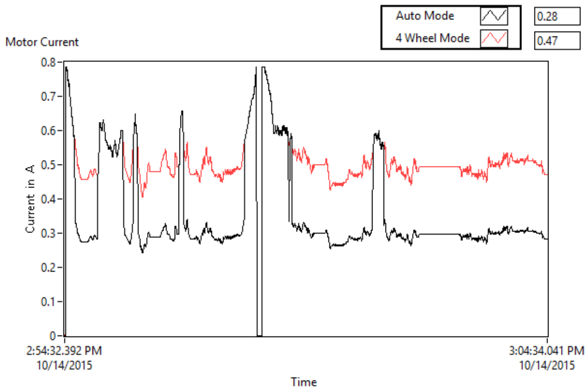


Fig -10: Motor current vs Time Graph

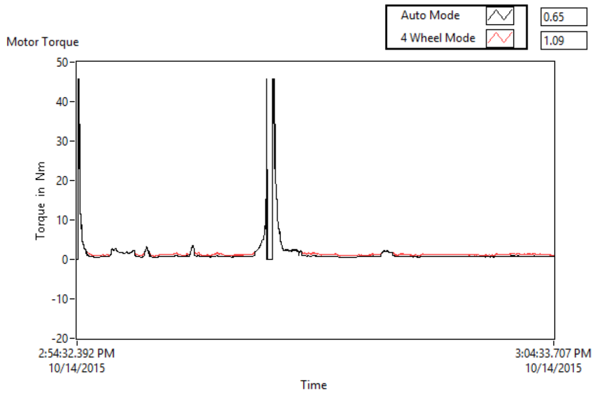


Fig -11: Torque vs Time Graph

From the graphs in Fig -10 and Fig -11 it can be seen clear that the current is proportional to the torque developed in the wheels. The torque is maximum at atarting times and it gradually increased based on the slope conditions. The same ratiometric increase is found in current.

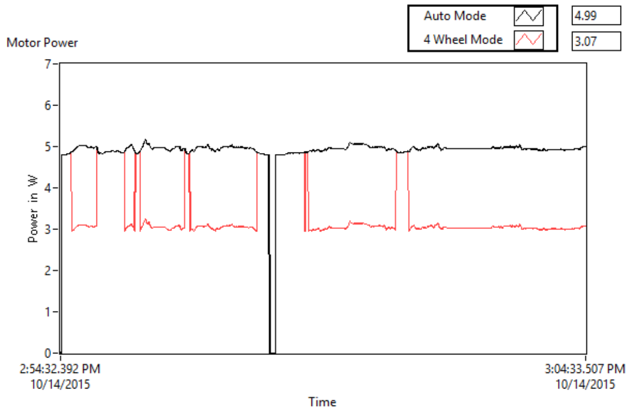


Fig -12: Total Power vs Time Graph

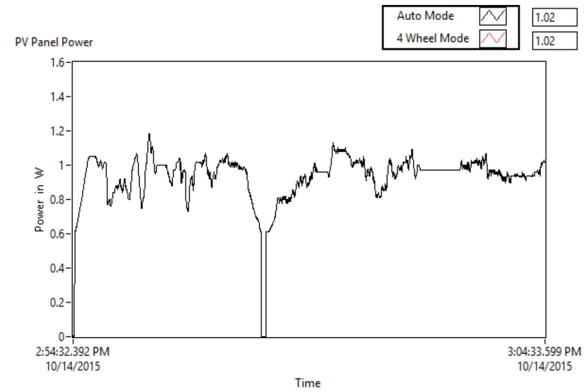


Fig -13: PV Panel Current vs Time Graph

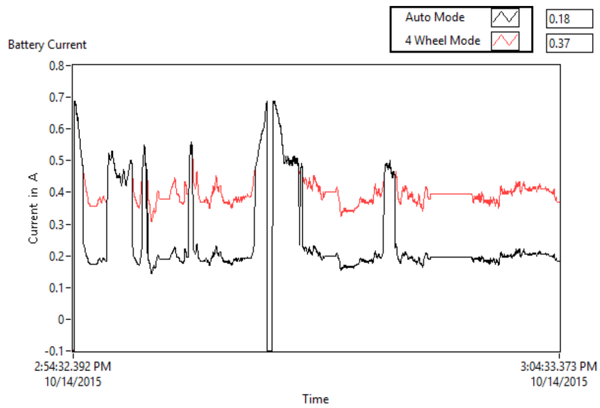


Fig -14: Battery Current vs Time Graph

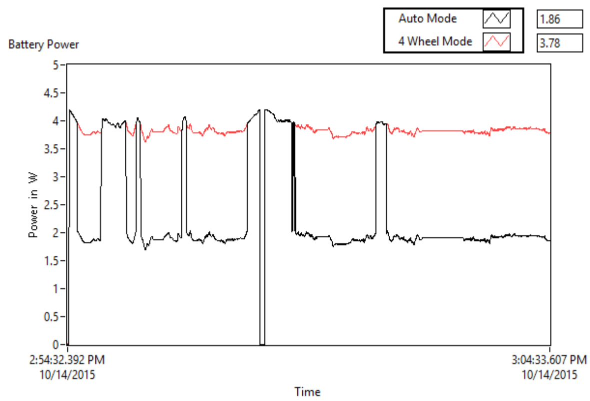


Fig -15: Battery Power vs Time Graph

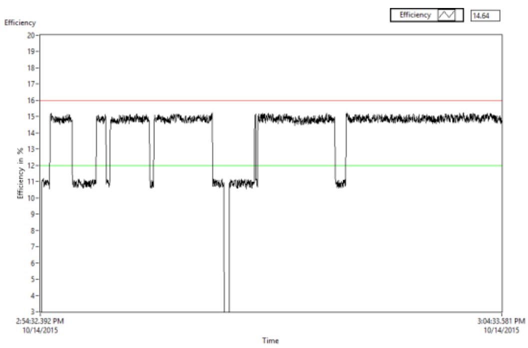


Fig -16: Efficiency vs Time Graph

5.3 Sample Analysis

Consider the following input parameters for the sample analysis.

Speed of the vehicle = 50 km/hr
Slope angle = 0^0

For the above input parameter values the following are the outputs obtained in the simulation for both drive mode are

Four Wheel Drive Mode:

Voltage V = 11 V
Current I = 0.4363 A
Load Power P = 4.482 W

Automatic Drive Changing Mode:

Voltage V = 11 V
Current I = 0.2618 A
Load Power P = 2.376 W

On comparing the consumed in both the modes the efficiency is found to be improved by 14.12%

From the graph of Fig -16, it is shown that in both the driving modes when the vehicle is operated in four wheel mode the power consumption is same. When the automatic drive changing mode switches the drive from four-wheel to two-wheel drive mode the efficiency is improved gradually.

7. CONCLUSION AND FUTURE SCOPE

7.1 Conclusion

The vehicle parameters are analyzed and the automatic drive changing and four wheel drive modes are simulated in LabVIEW. The analysis and control actions are taken by LabVIEW software automatically and the data for various driving modes are compared and the analyses for power consumption, torque developed, efficiency, driving distance are performed in LabVIEW. Based on the simulation results it is proved that Electric vehicles with independently driven front and rear wheels enhance the traction, drivability, efficiency and safety, which are essential for vehicles. Electric vehicle drive mode is altered in the automatic drive mode so that these requirements are achieved more effectively. The LabVIEW simulation results were analyzed and the proposed system is proved to be energy efficient in operation.

7.2 Future Scope

- The real time hardware of the simulated vehicle model can be implemented and complete comparative analyses can be analyzed.
- The analysis can be extended for turning conditions and yaw directions.
- Maximum power point tracking system for solar panels can also be incorporated.
- Regenerative braking systems can also be implemented in the system as separate driving motors are implemented in this system.

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BIOGRAPHIES

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