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Design and Development of Differential For Electric Vehicle

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ABSTRACT

In vehicular Technology electric vehicle (EV) is innovative Technology. This paper present technique of imple- menting traction traction drive system for electric vehicle with two seperate DC motors. In this paper, an electric differential is developed. Electric differential is advancement in electric vehicles. Technology along with the more traction control. The electric differential provide required torque for each driving wheel and allow different wheel speed during cornering risky maneurs. The system uses the steering angle, linear displace- ment and wheel speed for calculation of velocity of other wheels. The effectiveness of control method is validated using matlab/ simulink environment. The priliminary result shows that new ED control system has the advantages of being linear ensuring the stability of vehicle either in straight or curve lane.

Keywords: Electric Vehicle(EV), Electric Differential System (EDS), cornering, Torque, Steering geometry.

INTRODUCTION

Electric vehicles are the future transportation elec- tric mobility has become an essential part of energy transition. The market and consumers are in need for cheaper personal transportation and even on top of that the government has started supporting electric vehicles through its policies Electric vehicles offers one of the best solution for reducing the air pollution as well as reliance on fossil fuels to power vehicle. In almost all system currently in market use fourth wheeled system for front and rear traction with mechanical differential instead of heavy mechanical differential to handle EV stability while cornering or under slippery road condition. Therefore the convention heavy gearbox can be superseded by ED therefore with the help of these not only the overall mass of electric vehicle is reduced but also performance improves satisfactory due to fast response time of electric vehicle is reduced but also performance improves satisfactory due to fast response time of electric motors. In some vehicle arrangement a chassis mounted motor connected to the wheel through gear reduction or gear motor assembly is mounted inside the wheel. ED in automotive engineering the electrical differential is a form of differential which provides the required torque for each driving wheel and allows different wheel speeds. It is used in place of the mechanical differential in multi-drive system when cornering the inner and outer wheels different speeds because the inner wheels rotates at different speed because the inner wheels describe a smaller turning radius. The electronic differential uses the steering wheel command signal and the motor speed signals to control the power to each wheel so that all wheels are supplied with the torque they need. The classical automobile drivetrain is composed by a single international combustion engine providing torque to one or more driving wheels. The most common solution is to use a mechanical device to distribute torque to the wheels. This mechanical differential allows different wheel speeds when cornering with the emergence of electric vehicles new drive train configurations are possible Multi drive systems usually with one motor per driving wheel need an additional top level controller which performs the same task as a mechanical differential.The ED scheme has several advantages over a mechanical differential such as simplicity, reconfigurable and faster response time.Despite of having these advantages one of the main challenge in designing of these EV without me- chanical differential is to ensure vehicle stability in particular while cornering or under normal driving condition ED system must guarantee that the four wheels.The ED system having ability to roll the four wheels at exactly same speed when EV drives in a straight line path. The ED system is having capacity into adjust torque which is generated from the motors and that have capacity to prevent the slipping of wheels in that adhesion coefficient are different when the steering angle does not equal to zero.

1. The drive wheels are not mechanically linked
2. By using speed controller traction power is separately applied to each wheel
3. The speed controller having capacity to apply less controller having capacity to apply less power on inner sided wheel.
4. When the front wheels are drives on straight path ED stimulates a differential lock.

DEFINATION OF DIFFERENTIAL

In automotive engineering the electrical differential is form of differential. Which provides required torque for each driving wheel and allows different wheel speeds. When cornering, the inner and outer wheels rotate at different speeds, because the inner wheels describe a smaller turning radius than the outer wheels turning radius. The electrical differential uses the steering command signal and the motor speed signals to control the power to each wheel so that all wheels are supplied with the torque they need.

METHODOLOGY

A. *Configuration of Two-wheel-Drive EV*

The vehicle considered in the analysis is a two-rear-wheel drive electric vehicle navigating between the districts in urban. Two motors are coupled in each of rear wheels. The energy source of the electric motors comes from NiMH batteries placed under the seats.The propulsion and control system schema of the EV. The vehicle controller accepts the wheel speeds and the driver demand from the two motors and the driver, respectively. All gating signals for power switches are determined at every sample instant by single microcontroller, which collects and analyzes the data from the steering angle, the voltage and current from each motor in order to adjust the real speed of rear wheels.When the vehicle drives on straight line, the speeds of the two driven wheels must be equal in order to keep the vehicle going ahead directly. On the other hand, when the steering angle does not equal to zero or adhesion coefficients between the driven wheels and ground are not the same, the vehicle will make a turn. Under these conditions, the outer wheels must run faster than the inner ones in order to maintain vehicle stability and reduce the tire abrasion.

B. *Steering Geometry*

The Steering geometry is a geometric arrangement of linkages in the vehicle steering. This can be used to calculate the speed of wheels on the different radius of a turning circle. In the electronic differential system the two rear wheels are directly driven by two separate motors. Consequently in the event of turning, the speed of the outer wheel motor will require higher speed than that of the inner wheel motor. In this work widely used steering geometrical model proposed by Ackerman and Jeantand is used which determines the vehicle's driving trajectory. The geometry of the model is shown in the

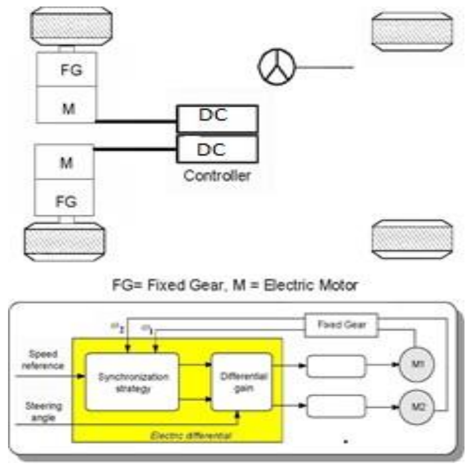

Fig. 1. Two wheel Electric Vehicle

fig.1. The main assumptions in regard to the vehicle movement in this analysis are firstly, the front wheels are considered passive. Secondly, the total torque will equally be distributed on the two actuated wheels in absence of slipping. Fig.1 shows the vehicle structure describing a curve, where L represents the wheel base, the steering angle of the reference wheel, d the distance between the wheels of the same axle and L and R the angular velocity of the left and right wheels respectively. The linear velocity of the left and right wheels VL and VR are functions of the radius of curvature of their respective paths along which they move.

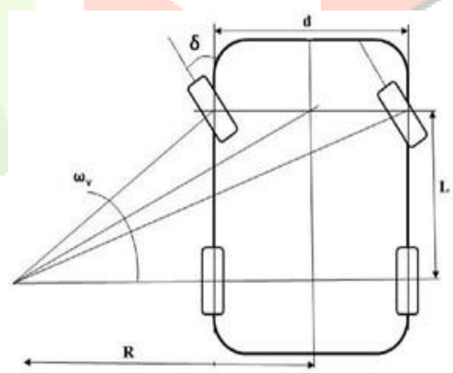

Fig. 2. Ackerman steering geometry[8]

C. *Working Principle*

The block diagram of the electronic differential developed in this work is shown in fig.4.3.Here microcontroller read the speed of the DC motor through the optical encoder, frequency to voltage converter and finally interfaced through analog to digital (A/D) converter. After reading the speed of the motors the microcontroller compares it with the desired speed signal given to it. The desired signal is theoretically calculated by using steering angle, vehicle chassis dimensions and wheel speed. The difference between the actual speed and the desired speed is called as error. Microcontroller fed the error output to the digital to analog (D/A) converter. Therefore the analog voltage from the D/A converter is directly proportional to the error output. The output of the D/A converter is then given to the DC motor through driver circuit. The output of the D/A converter is continuously changed until the speed of the DC motor reaches the desired value.

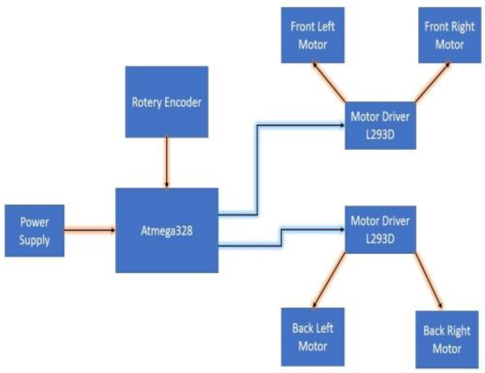

Fig. 3. Block diagram for hardware

D. *Algorithm of Proposed System*

In a flow chart the input is fed to the system manually in the form of steering angle. The motor controller drive, process input signal and calculate the linear motion, speed of each wheel also the speed of each motor according to the steering angle. Then the calculated values are compared with The reference values. And perform the suitable tasks according to the conditions specified in algorithm.

E. *Modeling and Control Strategy*

Here the main basic unit is vehicle controller which is mounted in center of electric vehicle.Each wheel of vehicle is followed by speed following controller to give the real time values of speed and velocity of vehicle. simultane-ously,steering angle is also fed-up to the vehicle controller via., speed command, and every motor of each wheel is controlled through these strategy as shown in fig.

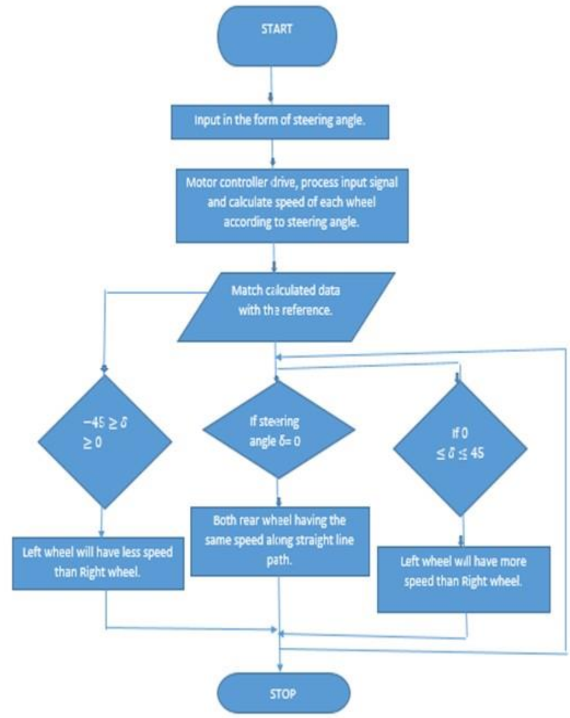

Fig. 4. Flowchart of ED system

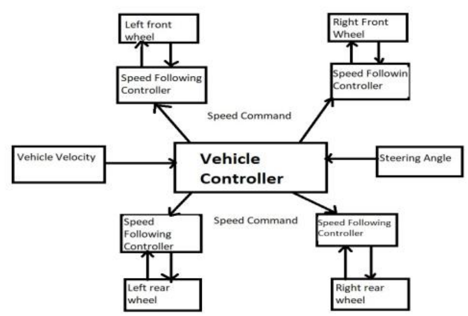

Fig. 5. Topology of Control Strategy

HARDWARE DESIGN

Consider Ackerman and Jeantand model to determine vehicle driving trajectory.

Consider, V_r = Velocity of rear axle at center,

V_3 = Velocity of left rear driven wheel,

V_4 = Velocity of right rear driven wheel,

R_3 = Distance of left rear wheel to turning center, R_4 = Distance of right rear wheel to turning center, R_r = Turning radius of rear axle center,

Let Velocity is directly proportional to radius,

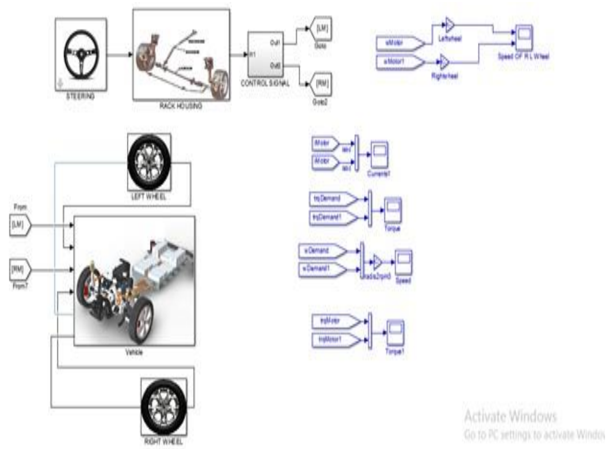

Fig. 6. Proposed diagram of system architecture

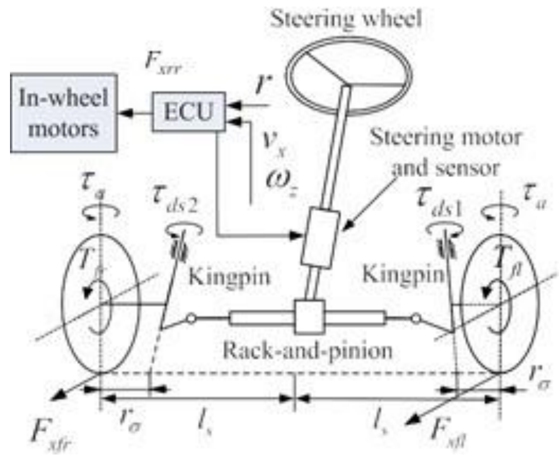

Fig. 7. Steering System Model

$\frac{V_3}{} = \frac{V_4}{} R_3 \qquad \frac{R_4}{} = \frac{V_r}{} R_r$ (1)

If it not compiled it may cause running of Electric Vehicle instable.Where, It cause difficult problem in various turnings.Ackerman and Jeantand model used to determine vehicles driving trajectory, But it ignoring the influence of centrifugal force and centripetal force when drive on curved road.

a) : Two separate motors drive two rear wheels directly speed of each wheel controlled directly.Here, we use micro-controller or PID controller which receives speed signal from wheel drive and steering angle, after calculating speed difference of two wheel electronic controller send signal back to two motor controllers to adjust speed of wheel independently.Position encoder used to sense angular position of steering wheel.We are sensing the linear displacement of the pinion ring connected to steering wheel.

Conditions of turning on basis of steering angle and linear displacement. where,$\delta$is steering angle,

Consider,

$\delta > 0$=Turn left with positive value, $\delta = 0$= Straight ahead with null value, $\delta < 0$= Turn right with negative value,

Common reference speed W_{ref} is set by accelerator redial command

Let,

W_{ref3} - Actual reference speed for left drive

W_{ref4} - Actual reference speed for right drive

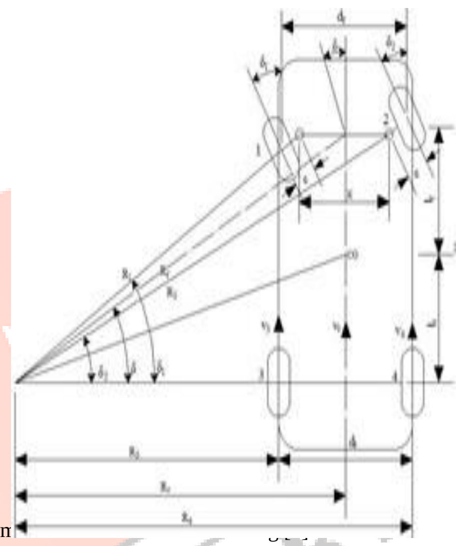

Fig. 8. Ackerm

When vehicle is turning at right side, speed of left side wheel $W_{ref\,3}$ is increased and speed of right side wheel $W_{ref\,4}$ is decreased.

When vehicle is turning at left side, speed of left side wheel $W_{ref\,3}$ is decreased and speed of right side wheel $W_{ref\,4}$ is increased.i.e., which speed is less is nothing but equal to the reference speed i.e.,$W_{ref\,4}$.

Where,

d_r - Distance between rear wheels

l_f - Distance between centre of car and front wheel

l_r - Distance between centre of car and rear wheel

$$l = l_f + l_r \tag{2}$$

From geometrical relationship the turing radius of rear wheel can expressed by following equation -

$$R_3 = \frac{l_f + l_r}{\tan\delta} - \frac{d_r}{2} \quad (3)$$

$$R_4 = \frac{l_f + l_r}{\tan\delta} + \frac{d_r}{2} \quad (4)$$

The angular velocities of each rear wheel (W_{3w} , W_{4w}) can calculated by-

$$W_{3w} = \frac{V R_3}{R_{cgv}} = W_{3m} \quad (5)$$

$$W_{4w} = \frac{V R_4}{R_{cgv}} = W_{4m} \quad (6)$$

Where,
W_{3m} & W_{4m} - Are angular velocities of rear motors
R_{cgr} - Radius of EV's gravity centre of rear wheels
v - Velocity of car

RESULTS

F. Simulation Result

The simulation results of performance of electrical differential shows in the form of wheel speeds, wheel torque and motor torque. On the basis of steering angle, the system recognizes the desired direction of travel. Speed sensors on each wheel measure the wheel speed. At the same time, yaw rate sensors measure vehicle rotation around its vertical axis, as well as lateral acceleration. From these data, the control unit calculate the actual movement of the vehicle comparing it 25 times per second with the desired direction to travel. If the values do not correspond, the system react in an instant, without any action a part of driver. It reduces engine power in order to restore vehicle stability.

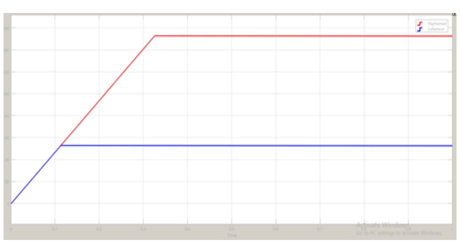

Fig. 9. Wheel speed while turning to left side.

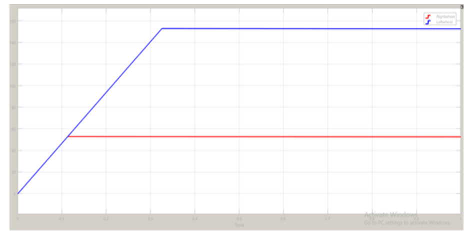

Fig. 10. Wheel speed while turning to right side.

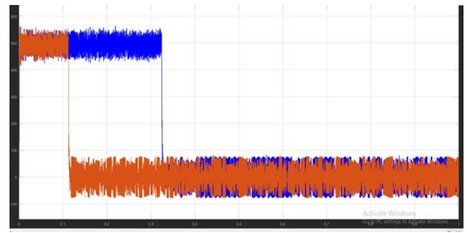

Fig. 11. Wheel Torque while turning to left side

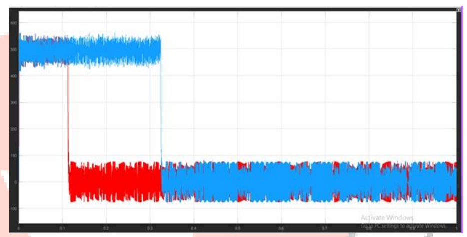

Fig. 12. Wheel Torque while turning to right side

G. Hardware Results

In-wheel motor drive EV is a promising configuration of EVs, which makes it possible to eliminate the heavy and complex mechanical differential by using the control method to ensure the vehicle stability on curved road driving or lanes changing conditions. A novel electronic differential control system for a independent-wheel drive electric vehicle was proposed in this project. The hardware was designed after the modeling. The results indicated that the electronic differential system operated satisfactorily and the two-wheel-individual drive electric vehicle can operate smoothly both on the straight line and during the curve comer. The electronic differential can realize all the functions of the mechanical differential while reducing the weight and it will have a potential future.

Steering Angle(Degree)	Front Left (RPM)	Back Left (RPM)
75	140	120
60	180	150
45	250	200

TABLE I
VALUES OF WHEEL SPEED WHEN EV TURNING AT RIGHT.

Steering Angle (Degree)	Front Right (RPM)	Back Right (RPM)
105	140	120
120	180	150
135	250	200

TABLE II
VALUES OF WHEEL SPEED WHEN EV TURNING AT LEFT.

CONCLUSION

This project has dealt with an ED-based EV. The design of ED drive a pair of wheels and allowing them to rotate at different speeds. ED provides the required torque for each driving wheel and allow different wheel speeds. While cornering, the inner and outer wheels rotate at different speeds, because the inner wheel describes a smaller turning radius and outer wheel describes the larger turning radius. The electronic differential use steering angle command signal and the motor speed signals to control the power to each wheel so that all wheels are supplied with the torque they need. And all these conditions are satisfied within the matlab Simulink software. Also the simulation results show these conditions satisfactorily. The results indicated that the electrical differential system operated satisfactorily and electric vehicle can operate smoothly both on the straight line and during curve corner.The electrical differential can realize all functions of mechanical differential while reducing weight and it will have potential future.

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