Vehicle with Electronic Differential Speed Control for Two In-Wheel Motors

[1] **Gaurav M. Dekhate,** UG Student
[2]**Prasanna Pothi,** Asst. Prof
[3]**Prasanna P.Titermare,** .Asst. Prof.
[4]**Ashish R. Polke,** Asst. Prof.

[5] **Pradip N. Dibbey,** UG Student
[6]**Anil S. Girhepunje,** UG Student
[7]**Mahendra S.Ambole,** UG Student
[8]**Aakash P. Gajbhiye,** UG Student

1,2,3,4,5,6,7,8 - Department of Electrical Engineering, Suryodaya College of Engineering & Technology,
Nagpur, Maharashtra, India

Abstract

We model an electronic differential in this work that will provide the best vehicle stability on a curved route. The usage of an electronic differential is a step forward in vehicle design in the direction of more electric automobiles. Electronic differentials have the advantage of replacing inefficient mechanical transmissions and differentials with more efficient, light, and tiny electric motors directly linked to the wheels through a single gear or an in-wheel motor. Electronic differentials for two and four wheeled vehicles have been proposed thus far. Two permanent magnet synchronous (PMS) machines are used in the proposed traction system to drive two back-driving wheels.For each wheel-motor, the suggested control mechanism is based on direct torque control. A vehicle was driven on a straight road, a straight road with a slope, and a vehicle was driven on a road that curved left and right, among other simulations. On a curving road, the simulation results show good vehicle stability.

Keywords: Permanent Magnet Synchronous (PMS), Speed Control, Driving Wheel

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Introduction

An electric car is a vehicle that runs on electricity. The heart of the new generation of electric vehicles is the electric propulsion system [1]. The motor drive, transmission device, and wheels are all part of it. The electric motor, power converter, and electronic controller make up the motor drive, which is the heart of the EV propulsion system. DC motors have long been used in electric propulsion because of their torque-speed characteristics, which are ideally suited to traction requirements, and their ease of speed control.Recent technology advancements have catapulted commutatorless motors into a new era, with advantages over DC motors such as high efficiency, high power density, low operating cost, increased dependability, and low maintenance.Because they are sturdy and highly reliable, permanent magnet synchronous motors (PMSM) are a widely recognizedcommutatorless motor for EV propulsion.

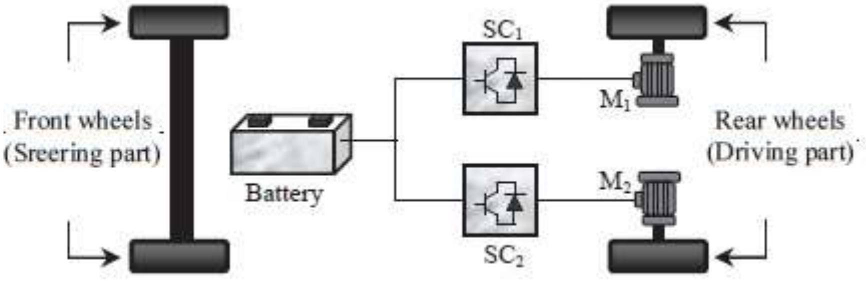

Fig. Two separate rear wheels make up the vehicle construction.

Vector control is often preferred for increasing the dynamic performance of PSM motor drives for electric vehicle propulsion. To enable quick torque control of a permanent magnet synchronous motor, however, vector control necessitates very sophisticated coordinate transformations on line to separate the interaction between flux control and torque control. As a result, the computation is time-consuming, and its implementation often necessitates the use of a high-performance DSP processor.

In recent years (DTC), a new control method known as direct torque control has gained popularity for electric propulsion systems [2-4]; this is because, unlike vector control, it can produce fast torque control of the induction motor and does not require substantial calculation on-line. Different simulations were carried out in order to characterize the electronic differential system for an electric vehicle driven by two permanent synchronous motors attached to the rear wheel using direct torque control (Fig. 1), including driving on a straight road, a straight road with slope, and driving over a road curved right and left.

The mechanical differential delivers the propelling power from the internal combustion engine to the wheels in typical traction systems. This mechanism is made up of a series of gearings that apply the same torque to both traction wheels while allowing for varying speeds. This traction system suffers from friction losses and is unable to adjust torque in each wheel separately. On the other hand, an electronic differential prevents such losses while increasing device profitability. It also provides for better vehicle traction control. The accepted scheme is shown in Fig. 2, which allows the mechanical differential to be replaced while still meeting the EV criteria.

In this scheme, the traction motors, which are controlled by DTC[5]-[6] through two independent inverters and each attached to one of the rear wheels, can be observed. Three-phase PMS motors were employed in this project. Table A1 lists the exact specifications of these motors. When cornering, the electronic differential must account for the speed difference between the two wheels. The system calculates the needed inner and outer wheel speeds using the vehicle speed and steering angle as input data, with the two wheels operated individually by two PMS motors.

METHOD OF ELECTRONIC DIFFERENTIAL SPEED CONTROL

A. Electronic Differential Speed Control System Structure

To determine the speed difference and manage the torque distribution for the four in-wheel motors, an electronic differential speed control system is set up as illustrated in Fig.3. The energy convertor would be supplied in parallel by the power battery pack and the engine generator set, which would then power the DC power bus through the energy convertor. When the voltage on the bus exceeds the set limit, the energy absorber kicks in and absorbs the excess energy.

According to the signal from the steering wheel and pedal, a comprehensive electronic differential speed controller would determine vehicular velocity v, steering angle, four wheels steering angle rrrlfrfl,,, and four wheels velocity rrrlfrfl,,, vvvvThe speed-torque coordinate management of electric differential is performed using a comprehensive controlling approach based on neural networks PID. To actualize the vehicular electronic differential speed control continuous steering, torque signals on the CAN bus would be delivered to the four motors controller to regulate the torque of the four driving wheels.

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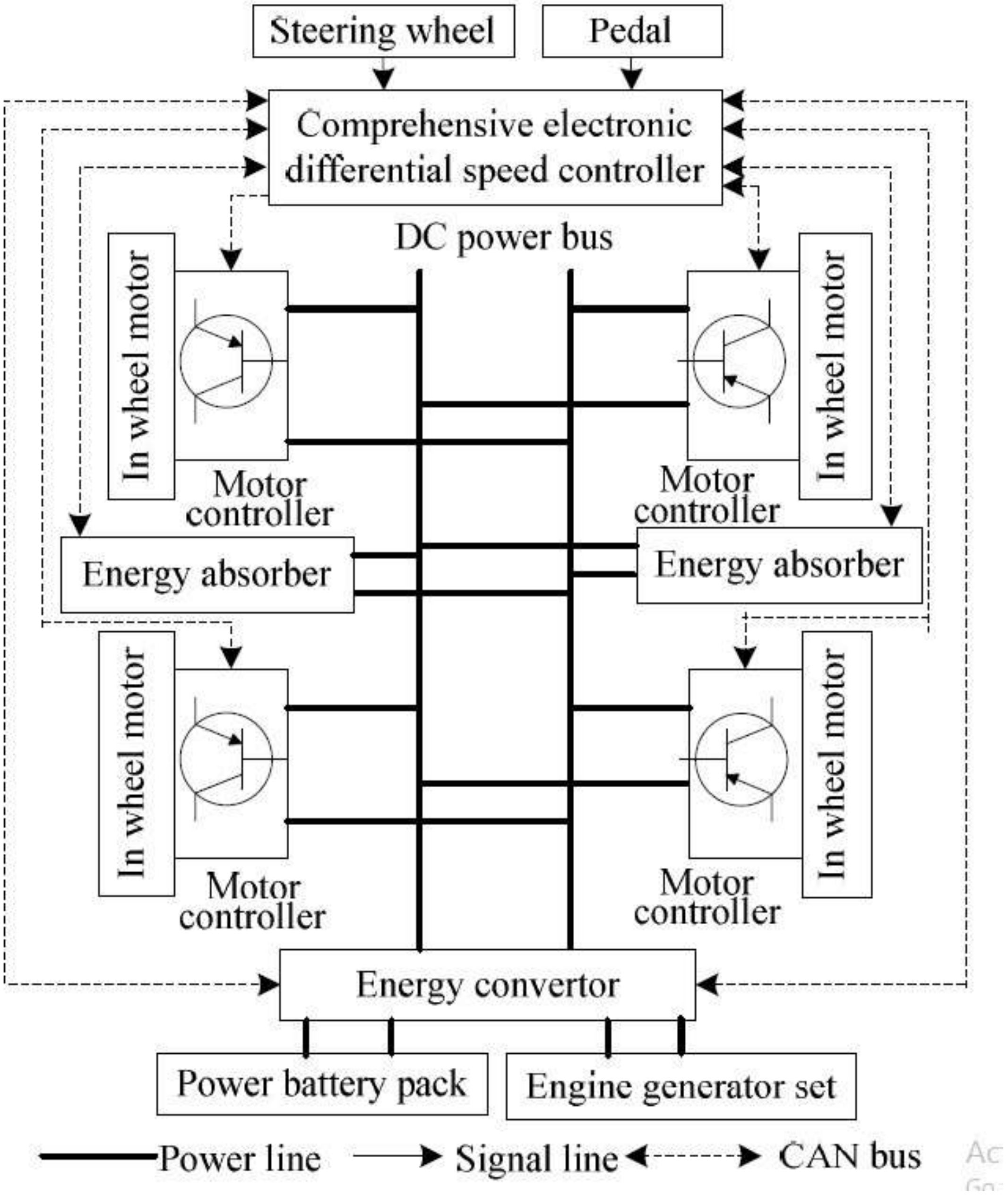


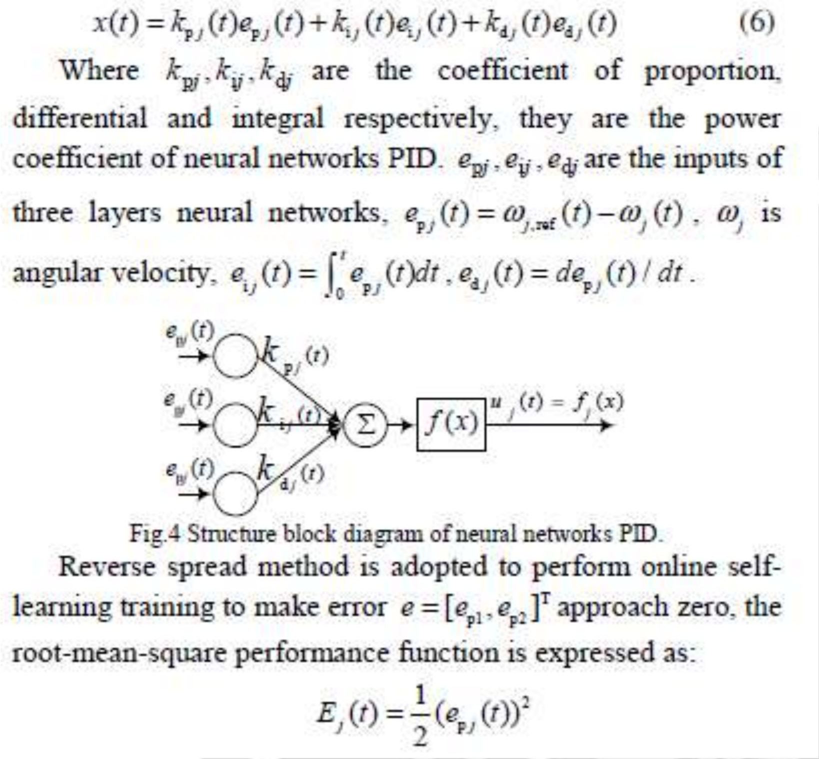
Fig.System for electronic differential speed control.

Neural Networks' Strategy Differential Speed Control using PID

1) Neural Networks PID: Neural networks are a type of neural network. The sigmoid function using the controller out layer's output can be written as: PID controller adopt three layers nerve cell structure network illustrated in Fig.4, sigmoid function using the controller out layer's output can be expressed as:

$$T_{j,\mathrm{ref}} = u_j = f_j(x) = \frac{1}{a(1+e^{-ax})} \quad j = 1,2$$

Input of the output layer is:



$$x(t) = k_{\mathrm{p}_j}(t)e_{\mathrm{p}_j}(t) + k_{\mathrm{i}_j}(t)e_{\mathrm{i}_j}(t) + k_{\mathrm{d}_j}(t)e_{\mathrm{d}_j}(t) \qquad (6)$$

Where $k_{\mathrm{p}j}, k_{\mathrm{i}j}, k_{\mathrm{d}j}$ are the coefficient of proportion, differential and integral respectively, they are the power coefficient of neural networks PID. $e_{\mathrm{p}j}, e_{\mathrm{i}j}, e_{\mathrm{d}j}$ are the inputs of three layers neural networks, $e_{\mathrm{p}_j}(t) = \omega_{j,\mathrm{ref}}(t) - \omega_j(t)$, ω_j is angular velocity, $e_{\mathrm{i}_j}(t) = \int_0^t e_{\mathrm{p}_j}(t)dt$, $e_{\mathrm{d}_j}(t) = de_{\mathrm{p}_j}(t)/dt$.

Fig.4 Structure block diagram of neural networks PID.

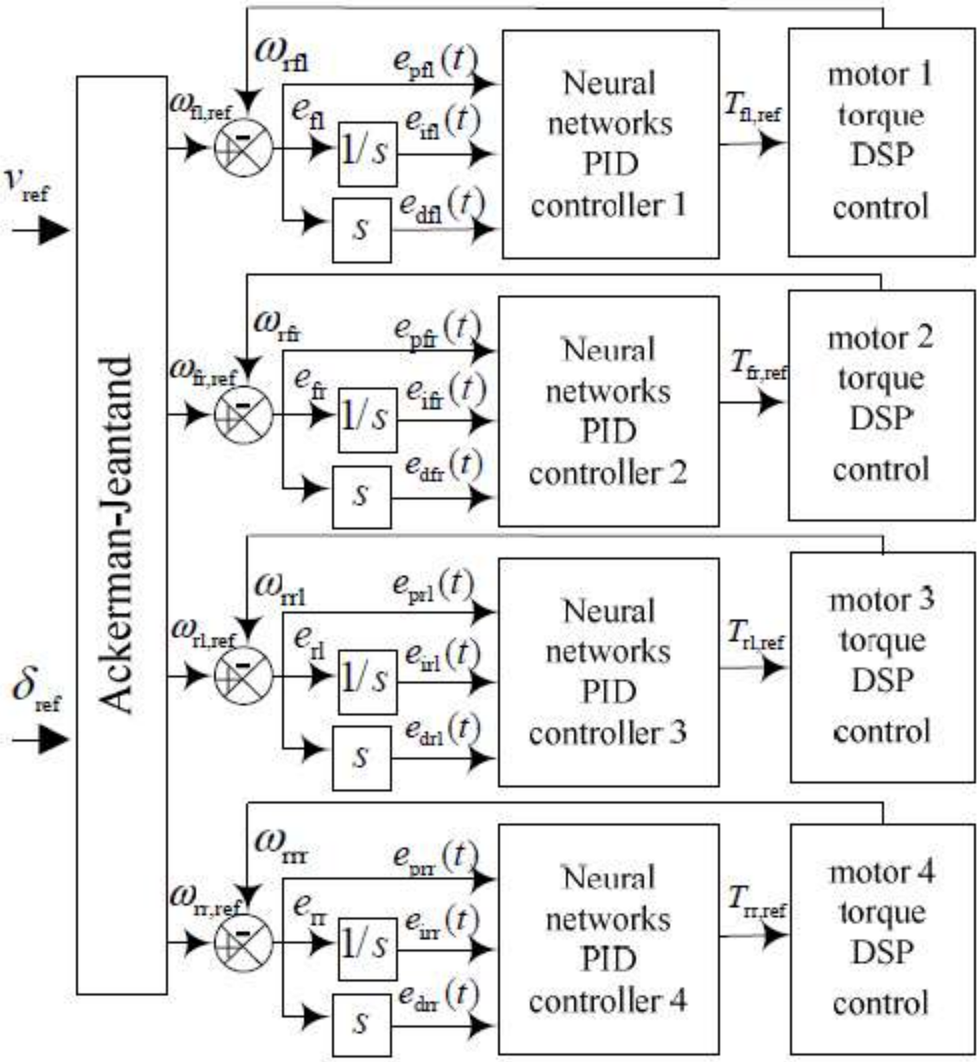
Reverse spread method is adopted to perform online self-learning training to make error $e = [e_{\mathrm{p1}}, e_{\mathrm{p2}}]^{\mathrm{T}}$ approach zero, the root-mean-square performance function is expressed as:

$$E_j(t) = \frac{1}{2}(e_{\mathrm{p}_j}(t))^2$$

2) Electronic Differential Speed and Torque Comprehensive Control: The steering wheel's angle is proportional to the steering angle, the steering wheel's angle displacement signal corresponds to the steering angle ref expected by the driver, and the steering wheel's angle range is [-60°, +60°].

The accelerating pedal displacement signal corresponds to the expected vehicle velocity ref v, and the pedal angle displacement range is [0, +45°].

This work has presented the application of an electricvehicle controlled by an electronic differential with twopermanent magnet in-wheel synchronous motor drives. Theresults obtained by simulation show that this structure permitsthe realization of an electronic differential and ensure gooddynamic and static performances. The electronic differentialcontrols the driving wheels speeds with high accuracy either inflat roads or curved ones.



For four in-wheel motors independent driving vehicular steering, a comprehensive coordinately control strategy of speed and torque is used, as shown in Fig.5. A full electronic differential is used to carry out the approach. Based on ref v and ref, the complete electronic differential calculates the steering angular speed of the four in-wheel motors fr,ref,fl,ref,rr,ref,rl,ref, then compares them in real time with simulation fr, fl, rr, rl collected by the four motors' rotor position sensor. Four NNPID controllers were used to reduce the speed error T e = [epfr,epfl,eprr,eprl] and generate the four motors' reference torque Tfr,ref,Tfl,ref,Trr,ref,Trl,ref. Which are delivered in real time to the four motor controllers through the CAN bus.

To accomplish the entire control strategy of electronic differential speed and torque depicted in Fig.5, the digital signal processor DSPTMS320LF2812 is used in the comprehensive electronic differential. Simulink, a Matlabprogramme, is used for modelling and simulation. As an in-wheel motor, a 2kW external rotor brushless motor with a rated speed of 1000r/min and a rated torque of 20N m is used.

The DSPTMS320LF2812 is used to implement direct torque control algorithms, allowing for motor torque control.

Assume that the supplied vehicular speeds are 10 km/h and 15 km/h, respectively, and that the steering wheel angle changes from -60° to +60°. The changing curves of the four in-wheel motors' simulation speed and given speed are illustrated in Fig.6 and 782 Fig.7, respectively. Figures 8 and 9 show the curves of the speed differential between the front and rear wheels.

CONCLUSION

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The three DOF steering dynamics model of the four inwheel motors independent driving vehicle is a nonlinearsystem with multiple inputs and multiple outputs. Thecomprehensive control strategy which based on neuralnetworks PID control electronic differential speed torque is adopted to distribute torque to the four in-wheelmotors coordinately. The results of simulation indicate that thecontrol strategy is feasible and reasonable.Motor’s control properties can affect vehicular steeringproperties directly; therefore the four in-wheel motorsindependent driving vehicle should adopt motors and motorcontrollers with high control properties. Electronic differentialspeed control strategy should combine with motor controlstrategy to make optimization and perfection in order to meetthe requirement of vehicular steering properties.

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