Available onlinewww.ejaet.com

European Journal of Advances in Engineering and Technology, 2022, 9(4s):598-604
International Conference on Tech Trends in Science & Engineering (ICTTSE) 2022
Suryodaya College of Engineering & Technology, Suryodaya Polytechnic, Nagpur, Maharashtra, India

Research Article ISSN: 2394 - 658X

Electronic Differential System for an Electric Vehicle with In-Wheel Motor

P.A. Pothi[1], A.P. Polke[2], G.M. Dekate[3], A.S. Giripunje[4]

[1,2] Asst. Prof., SCET
[3,4] Student, SCET

ABSTRACT

This paper discusses design, implementation and testing of a separate electrical system intended for simple electricity cars. Its performance is based on the distribution of torque evenly two independent brushless DC motors mounted on the same axis of the car and connected directly to the wheels. This configuration allows engines to rotate at different speeds there the car follows the curve. The system also detects and fixes smoothness of any tire engine. The main feature of the proposed system is that it does not they require any sensors to measure the directional angle as well as wheel speed. Another factor is that using standard electric bicycle controls and a general-purpose field. These parts are too many low cost and readily available in any were.

Key words: Electric Vehicle, In-wheel Motor, Electronic Differential System.

INTRODUCTION

Expansion of the transport sector is causing more and more pollution problems and a decrease in fossil fuels. Therefore, EVs are used to eliminate greenhouse gas emissions, reduce dependence on oil-exporting countries by providing fuel savings, and preventing air pollution. In recent years, the use of EVs has increased due to advances in driver and battery technology, the use of efficient electric motors, and safe driving [1, 2]. The weight of the EV with a single traction-motor pulling two wheels using a different gear increases due to the batteries. To reduce the weight of the EV and to use the steam locomotives, get a quick response to the motors, and provide independent torque control for each wheel, motor-mounted wheels. Different motor systems are used on slippery and slippery roads to distribute power and torque evenly to the tow wheels. Cars with a combustion engine have different mechanical properties using a different gear. When the tire accelerates when it is not using different gears, the wheels slip because of the brakes to slow down. This also results in unsafe driving, increased fuel consumption and tire wear. Therefore, the speed of the inner wheel should be different from the speed of the outer wheel of a car driving in a curved area. road [5]. On the other hand, for EVs, EDS is used due to having self-propelled wheels instead of a traditional dividing gear. Therefore, other barriers such as equipment loss, maintenance, and gear costs caused by powertrains are also eliminated. As the literature of EDS studies is examined, the modeling and EDS simulation of EV with motor-wheel drive is characterized by a non-trivial control mechanism used to measure the slope of each wheel in. The built-in EDS is verified by Mat lab / Simulink results. Aedile Daron makes a separate electronic speed controller for two-wheeled vehicles at [6]. This method incorporates the precise torque control of each wheel engine which is the Permanent Magnet Synchronous Motor (PMSM). The system is designed to adapt to different road conditions namely straight and curved roads. It is noteworthy that the stability of the vehicle is well provided on the curved road. In, a separate two-wheel drive separate EV rear is introduced and the speed and torque viewer of the DC vehicle are analyzed. The rear wheel torque torque algorithm based on the Ackermann Jean and model is designed for dual motor electric drive system in [8]. System simulations are performed in Excel to show different folding cases. The authors in [9] propose a different steering wheel for a four-wheel-drive independent EV. The figures are given by the Ackermann Jean and model based on the speed of the car. The accuracy of the system designed is proven in both simulation and test results. [5] incorporates a neural network model used for vehicle-based analysis and EV EDS directional angle. It is evident that the designed EDS is useful for EV. In another paper [10], an EV EDS with two independent rear wheels is designed to control the neural network used to measure vehicle speed. With the change of speed of the car, the speed of the rear wheels is achieved in this way. Imitation results are confirmed by testing two 37-kW input engines. A separate electronic controller for speed control of four-wheel drive EV is controlled by the Neural Networks PID power difference in. It is evident that the simulation results based on the speed of the vehicle and the angle of directing are satisfactory. introduces a new EDS control system for drag-and-drop electric hybrid electric vehicles (HEVs). In this study there are Kinematic models and automotive models. The simulation results were successfully tested by taking the results of the HEV test on low scale (HELVIS) -Sim simulation. As a result, it is noted that EDS studies of abnormal EV wheels have been frequently seen in literature. In contrast to this paper, the EDS for front-wheel drive EV is modeled. According to the change of the steering angle and speed of EV, the speeds of the front in-wheel motors have been estimated by Codey's Software Package using mathematical equations obtained from Ackermann-Jean and model This paper is organized that Section II describes EDS for EV. Besides, Ackermann-Jean and model of driving trajectory at low speeds is comprehensively explained in this section. In Section III, Mat lab/Simulink modelling of EDS is carried out. Codey's results are compared with Simulink results. Conclusions are given at the end.

ELECTRONIC DIFFERENTIAL SYSTEM FOR EV

EDS plays a significant role for EVs. According to the road curve, the speed of the inner wheel must be less than the speed of the outer wheel. In this study, Ackermann-Jonatan model is preferred in the EDS design. This model was discovered by Rudolf Ackermann in the 19th century and it gives the relationship between the inner and outer wheels on a curved road. It is commonly used at low speeds due to the effect of centrifugal force and centripetal forces when driving on a curved road. The tires are not considered in this model. Some parameters such as the road curvature radius, speed of the vehicle, distance between the front and rear wheel, steering angle, distance between rare wheels are included in the model. Ackermann-Jean and model of EDS for the dual-front-wheel independently driven electric vehicle (EV) is shown

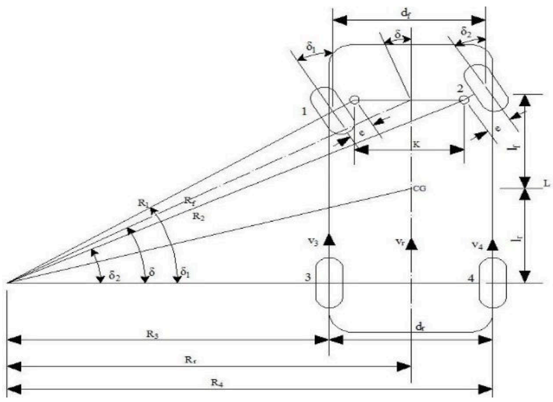

Fig. 1 Ackermann-Jean and model of driving trajectory at low speeds

A position encoder is used for the steering angle. When the steering angle is zero, it means that EV drives on a straight road. Once the steering angle is different from zero, it means that the wheels of EV turn left or right and the speed of the inner wheel has to be less than the speed of the outer wheel according to the turning direction [15]. In this situation, the EDS is activated. If the steering angle (δ)>0 is, the EV drives left and if the

EV drives right. If δ=0 is, the EV drives straight ahead [14, 3]. The equations derived from this model are as follows: The inner steering angle of the front wheel is given by

$$\delta_1 = \arctan\left[\frac{L \cdot \tan(\delta)}{L - ((K/2) \cdot \tan(\delta))}\right] \qquad (1)$$

The outer steering angle of the front wheel is given by

$$\delta_2 = \arctan\left[\frac{L \cdot \tan(\delta)}{L + ((K/2) \cdot \tan(\delta))}\right] \qquad (2)$$

where K is the distance between the left and right kingpin, L is the distance between the front and rear wheel, is the steering angle. To estimate the speeds, the turning radii of the front inner and outer wheels, rear inner and outer wheels can be respectively expressed by

$$R_1 = \frac{L}{\sin(\delta)} \quad (3)$$

$$R_2 = \frac{L}{\sin(\delta)} \quad (4)$$

$$R_3 = \frac{L}{\tan(\delta)} - \frac{d_r}{2} \quad (5)$$

$$R_4 = \frac{L}{\tan(\delta)} + \frac{d_r}{2} \quad (6)$$

where dr is the distance between rear wheels. The radius of the gravity center of EV is

$$R_{cg} = \sqrt{(R_3 + (d_r / 2))^2 + (l_r)^2} \quad (7)$$

where lr is the distance between the rear wheel and gravity center. The angular speeds of the front inner and outer wheels, and rear inner and outer wheels can be respectively expressed by

$$w_1 = \frac{V \cdot R_1}{(R_{cg}) \cdot r} \quad (8)$$

$$w_2 = \frac{V \cdot R_2}{(R_{cg}) \cdot r} \quad (9)$$

$$w_3 = \frac{V \cdot R_3}{(R_{cg}) \cdot r} \quad (10)$$

$$w_4 = \frac{V \cdot R_4}{(R_{cg}) \cdot r} \quad (11)$$

where r is the radius of the wheel and V is the speed of EV.
The equations which are derived from Ackermann-jean and geometry are given into the Codey's Software Package. L, lr, dr, r, and K parameters whose values are taken from a vehicle are used as the constant values in the programmer. These parameter values are shown in Table 1. The steering wheel position is taken by using an encoder over CAN-Bus. This position value is converted to the angle in Codey's Software. While the speed of an EV having 21-inch wheel size is 50 km/h, the vehicle speed corresponding this value is 505.538 rpm. Therefore, this speed value is used in the software. According to the different steering angles and speed of the EV, the speeds of the front wheels are estimated by Codey's Software. The simulation of EDS realized by Codey's is illustrated in Fig. 2.

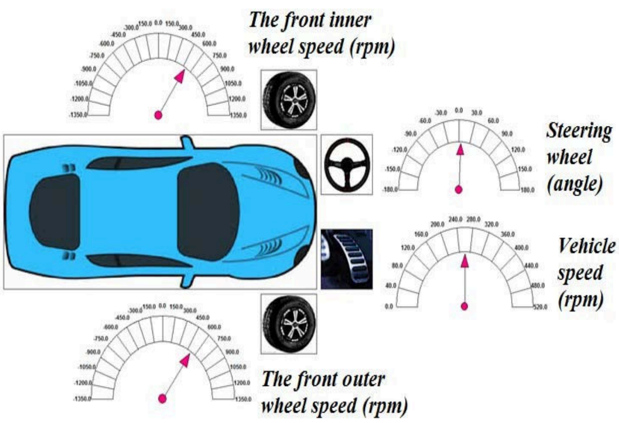

Fig. 2 Codey's simulation of EDS

MAT LAB/SIMULINK SIMULATION MODEL AND RESULTS

The simulation of EDS is also realized by Mat lab/Simulink to validate the front wheel speeds of EV estimated by Codey's. The simulation model is shown in Fig. 3. Once the steering angle and the speed of the EV are respectively taken as 1□ and 505.538 rpm that is the speed corresponding 50 km/h, the wheel speeds estimated by Simulink are shown in Fig. 4. In case of changing the steering angle from 1□ to 15□ with a degree range, Codey's results of front wheel speeds (n1, n2) are compared with Simulink results in Table 2 and Table 3 based on the direction of the steering wheel

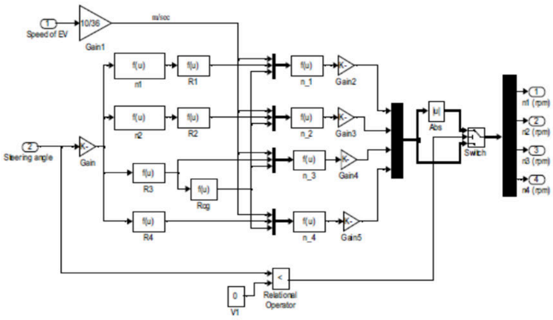

Fig. 3 Matlab/Simulink model of EDS

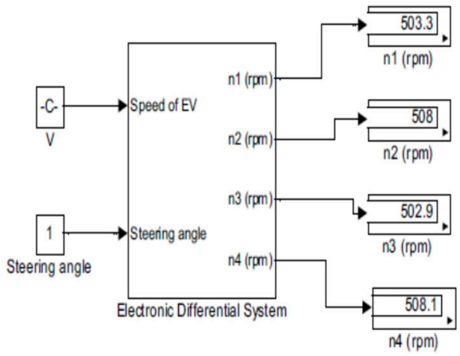

Fig. 4 Mat lab/Simulink results of EDS

Table-1 Comparison of Simulink and Codey's

Steering Angle (Degree)	Codey's Results (rpm)		Simulink Results (rpm)		Error (%)	
	n_1	n_2	n_1	n_2	n_1	n_2
0	502.538	502.538	505.5	505.5	0.007	0.008
1	503.251	504.958	503.3	508	0.009	0.008
2	501.099	510.510	501.1	510.5	0.0002	0.002
3	499.083	513.195	499.1	513.2	0.0034	0.001
4	497.204	516.01	497.2	516	0.0008	0.002
5	495.464	518.957	495.5	519	0.0073	0.008
6	493.865	522.035	493.9	522	0.0071	0.007
7	492.409	525.243	492.4	525.2	0.0018	0.008
8	491.098	528.583	491.1	528.6	0.0004	0.003
9	489.936	532.054	489.9	532.1	0.0073	0.008
10	488.924	535.657	488.9	535.7	0.0049	0.008
11	488.065	539.394	488.1	530.4	0.0072	0.001
12	487.364	543.264	487.4	543.3	0.0074	0.006
13	486.822	547.270	486.8	547.3	0.0045	0.005
14	486.444	551.412	486.4	551.4	0.009	0.002
15	484.234	555.693	484.2	553.7	0.007	0.001

Table-2 Comparison of Simulink and Codey's results for the steering wheel in the opposite direction

Steering Angle (Degree)	Codey's Results (rpm)		Simulink Results (rpm)		Error (%)	
	n_1	n_2	n_1	n_2	n_1	n_2
0	505.538	505.538	505.5	505.5	0.008	0.007
1	507.958	503.251	508	503.3	0.008	0.009
2	510.510	501.099	510.5	501.1	0.002	0.0002
3	513.195	499.083	513.2	499.1	0.001	0.0034
4	516.01	497.204	516	497.2	0.002	0.0008
5	518.957	495.464	519	495.5	0.008	0.0073
6	522.035	493.865	522	493.9	0.007	0.0071
7	525.243	492.409	525.2	492.4	0.008	0.0018
8	528.583	491.098	528.6	491.1	0.003	0.0004
9	532.054	489.936	532.1	489.9	0.009	0.0073
10	535.657	488.924	535.7	488.9	0.008	0.0049
11	539.394	488.065	539.4	488.1	0.001	0.0072
12	543.264	487.364	543.3	487.4	0.007	0.0074
13	547.270	486.822	547.3	486.8	0.005	0.0045
14	551.412	486.444	551.4	486.4	0.002	0.009
15	555.693	486.234	555.7	486.2	0.001	0.007

According to the direction of the steering wheel, the speed values of front in-wheel motors obtained by Codey's and Simulink have been plotted in Fig. 5, 6, 7, and 8, respectively. As seen in the graphics, Codey's results are verified by Simulink results.

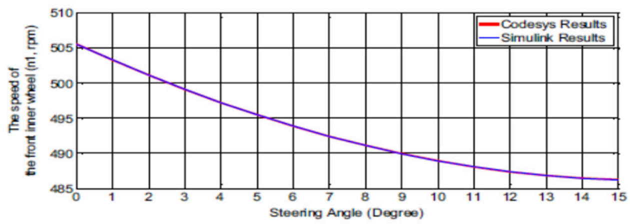

Fig. 5 Simulink and Codey's results of n1

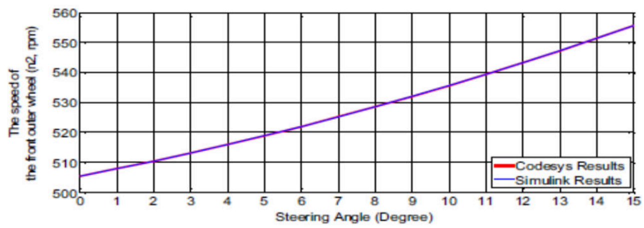

Fig. 6 Simulink and Codey's results of n2

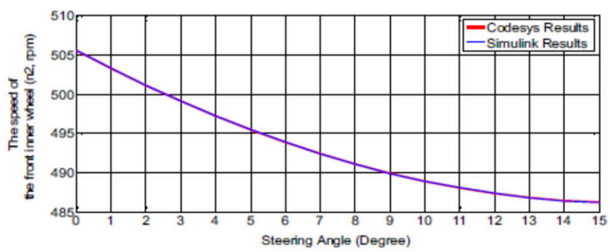

Fig. 7 Simulink and Codey's results of n2 for steering wheel in the opposite direction

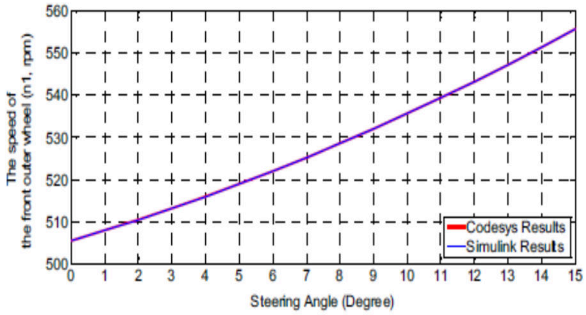

Fig. 8 Simulink and Codey's results of n1 for steering wheel in the opposite direction

CONCLUSION

In this paper, an EDS for EVs with in-wheel motors has been modelled and simulated. While the EDS for rare wheels of the EV has been studied generally in the literature, an EDS for front wheels has been presented in this study. According to the steering angle and speed of the EV, the speeds of front in-wheel motors have been estimated by mathematical equations derived from Ackermann-Jean and model using Codey's Software Package. Then, Mat lab/Simulink modelling has been carried out using these equations. The speed values of the front wheels have been obtained by both Codey's and Simulink simulations for changing of the steering angle from 1 to 15 with a degree range. It has been observed that while the inner wheel speed of the EV decreases, the outer wheel speed increases by rising the steering angle value. The speeds of the front wheels estimated by Codey's Software Package have been also verified by comparing with Simulink results. Consequently, the simulation results are satisfactory.

REFERENCES

[1]. M. Yildirim, M. Polar, H. Kurume, "A survey on comparison of electric motor types and drives used for electric vehicles", in IEEE 16th International Power Electronics and Motion Control Conference and Exposition (PEMC), 2016, pp. 218-223.

[2]. R. N. Tuna, O. Aston, M. Yilmaz, C. Gucci, U. Kara kaya, "Design and implementation of an electric drive system for in-wheel motor electric vehicle applications", in IEEE Vehicle Power and Propulsion Conference (VPPC), 2011, pp. 1-6.

[3]. Y. E. Zhao, J. W. Zag, and X. Q. Gun, "Modelling and simulation of the electronic differential system for an electric vehicle with two-motor-wheel drive", International Journal of Vehicle Systems Modelling and Testing, vol. 4, no. 1-2, pp. 1209-1214

[4]. M. Jain and S. S. Williamson, "Suitability analysis of in-wheel motor direct drives for electric and hybrid electric vehicles", in IEEE Electrical Power & Energy Conference (EPEC), 2009, pp.1-5.

[5]. J. S. Lee, Y. J. Roy, Y. C. Lim, P. Frere, T. G. Kim, S. J. Son, and E. S. Kim, "A neural network model of electric differential system for electric vehicle", in IEEE 26th Annual Conference of the Industrial Electronics Society (IECON), vol. 12000, pp83-88.

[6]. A. Daron, "Electronic differential speed control for two in-wheels motors drive vehicle", in IEEE Fourth International Conference on Power Engineering, Energy, and Electrical Drives (POWERENG), 2013, pp. 764-769.

[7]. Frito, G. Manuel, and V. F. Piers, "Road motion control electric vehicle with speed and torque observer", in IEEE International Conference on New Concepts in Smart Cities: Fostering Public and Private Alliances (Smart MILE), 2013, pp. 1-6.

[8]. B. R. Monosomy, R. Balasharmila, and J. D. Weigh, "Design of rear wheel torque vectoring for dual motor electric drive system", in IEEE Ninth International Conference on Ecological Vehicles and Renewable Energies (EVER), 2014, pp. 1-20.

[9]. X. Wu, Y. Li, and X. Min, "Speed following control for differential steering of 4WID electric vehicle", in IEEE 2014-40th Annual Conference of the Industrial Electronics Society (IECON), 2014, pp. 3054-3059.

[10]. A. Haddon, M. E. H. Benbouzid, D. Diallo, R. Abdisamad, J. Ghoulies, and K. Shari, "Modeling, analysis, and neural network control of an EV electrical differential", IEEE Transactions on Industrial Electronics, vol. 55, no. 6, pp. 2286-2294, 2008.

[11]. L. Zhao and S. Dong, "Electronic differential speed steering control for four in-wheel motors independent drive vehicle", in IEEE 9th World Congress on Intelligent Control and Automation (WCICA), 2011, pp. 780-783.

[12]. R. C. B. Sampi, A. C. Hernandez, V. D. V. M. Fernandez. Becker, and A. A. G. Sequoia, "A new control architecture for robust controllers in rear electric traction passenger HEVs", IEEE Transactions on Vehicular

Technology, vol. 61, no. 8, pp. 3441-3453, 2012.
[13]. M. W. Choi, J. S. Park, B. S. Lee, and M. H. Lee, "The performance of independent wheels steering vehicle (4WS) applied Ackerman geometry", in IEEE International Conference on Control, Automation and Systems (ICCAS), 2008, pp. 197-202.
[14]. H. Kahveci, H. İ. Oculus, and M. Elicit, "An electronic differential system using fuzzy logic speed controlled in-wheel brushless DC motors", in IEEE Fourth International Conference on Power Engineering, Energy and Electrical Drives (POWERENG), 2013, pp. 881-885.
[15]. Y. Zhou, S. Li, X. Zhou, and Z. Fang, "The control strategy of electronic differential for EV with four in-wheel motors" in IEEE Control and Decision Conference (CCDC), 2010, pp. 4190-4195.