International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 12 | Dec - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Electronic Differential with Direct Torque Field Oriented Control for Vehicle Propulsion System

Sagar Kale[1], Kiran Kimmatkar[2], Manjeet Sakhare[3]

[1]Student Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur, India.
[2]Assistant Professor Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur, India.
[3]Assistant Professor Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur, India.

---***---

Abstract –

This paper deals with the design, implementation and evaluation of an electronic differential system intended for light electric vehicles This system utilizes a dual-motor configuration that consists of a pair of DC motors installed on the same axis of a vehicle and connected to the wheels. When the vehicle moves around a curve, the motors' rotation can vary.The system also detects and corrects the slipping of any traction wheel. The main feature of the proposed system is that it does not require specific sensors to measure the steering angle and the speed of the drive wheels. Another important feature is that it is implemented using field-oriented controllers and a general-purpose Arduino nano platform. These components are very inexpensive and are available almost anywhere in the world.

***Key Words*:** BLDC motors, Steering, Arduino nano, Field Oriented Control

1.INTRODUCTION

Light Electric Vehicles (LEVs) are currently one of the most important alternatives to get the objective of sustainable urban mobility.Even if the term "LEV" is not entirely clear, we can a ssume that it can be used to describe cars whose weight is co mparable to the total weight of the passengers for which they aredesigned.(For example, 75 kg for a single passenger vehicl e and 150 kg for two). So, its main characteristic is the low weight, which results in a very low energy consumption and, therefore, a mobility efficiency superior to those conventional electric vehicles. The most common LEVs nowadays are two-wheeled types, such as electric bicycles, mopeds, and motorbi kes. In addition to their reduced weight, another advantage of LEVs is that they have a single drive wheel. So, the control system and the motor (normally a hub motor) have low complexity and cost.
However, these vehicles have three primary disadvantages: a high aerodynamic coefficient (which reduces energy efficienc y), the driver's exposure to the elements, and poor stability at l ow speeds. Three-wheeled and closed body LEVs look to be a better alternative than twowheeled vehicles since they address these disadvanta ges. They also have a single drive wheel, so both the control system and the motor are as simple and inexpensive as those of two-wheeled vehicles. However, three-wheeled LEVs also have drawbacks. One of them is the low cornering stability, that limits the maximum speed under these conditions. Although there are sophisticated solutions to improve the stability of tricycles such as tilt-wheeled designs, the most accepted solution to improve stability is the use of four-wheeled vehicles. The power train of four-wheel vehicles is more complex than the power train of tricycles since it must allow that the two drive wheels rotate at different speeds when cornering. The mechanical system that allows this mode of operation is known as differential. The use of mechanical differential is widespread in most conventional VEs and even in some LEVs, however, it has the drawback of being very heavy. The mechanical differential is not suitable to be used in the LEVS due to its high weight. For these vehicles it is advantageous to implement an electrical or electronic differential (ED) system

The main characteristics of the ED are: -

There is no mechanical link connecting the two drive wheels. Each of them is coupled to an electric motor that is independently controlled.

- The controller applies traction power separately to each

wheel

- When cornering, the controller will apply less power to the inner wheel.

The ED simulates differential lock while the front wheels driv e straight.
The addition of an ED also enhances the stability of tricycles with two drive wheels. There are different ways to implement an ED.
Some are sophisticated, such as "side slip control," which invo lves regulating the torque in each motor to optimize the vehicl e's yaw rate. However, the simplest way to implement an ED is to apply the same torque to each of the driving wheels. Even in this simplest form of implementation, a controller of these characteristics presents a level of complexity quite superior to

the standard controllers of electric bicycles, which are designed to regulate the power of a single motor. Therefore, the use of this type of low cost and widespread controllers should be discarded, with the consequent increase in the overall cost of the system. Most of ED controllers require at least sensors to measure the speed of the driving wheels, the current of each motor and the steering angle. However, some controller designs omit some of these sensors in order to improve simplicity at the risk of losing some of its features. In this line, a controller without wheel speed sensors is proposed in and another controller without steering angle sensor nor speed sensors is proposed in. Both concepts are used to VEs powered by induction motors.
In standard industrial frequency converters are used instead of the design of a new type of controller. This enables for the benefits of increased dependability, lower prices, and a wider selection of products and providers. In this paper a design similar to the previous one is proposed, but applied to a LEV equipped with BLDC motors and standard electric bicycle controllers. The control system has been completed with the well-known Arduino platform, which allows the addition of special functions such as traction control and anti-lock wheel system.

2.. Work Methodology

A. Fundamentals Theory.

The principle of operation of the proposed ED is to ensure that the two motors of the power train deliver the same torque and can rotate at different speeds. Figure 1a depicts the torque-speed curves of a BLDC motor for various applied voltage val ues (corresponding to the control signal's duty cycle) The operating point of the two motors when the vehicle is travelling in a straight line at medium speed is also represented (We assume that the two engines have equal characteristics an d that the accelerator determines the torque set point, TC).
When the steering system forces the vehicle to trace a curve, the torque of each motor (TL and TR) will be modified to allow each wheel to turn at a different speed (before the response of the control system occurs). Given this variation of the torque delivered to each wheel, the control system acts to reduce the duty cycle of the control signal of the inner wheel motor (left) and increase that of the outer wheel until the torque delivered by both motors returns to be equal to the set point set by the accelerator.In this new stage, the motors' speed is sufficient to trace the curve accurately.

B. Hardware

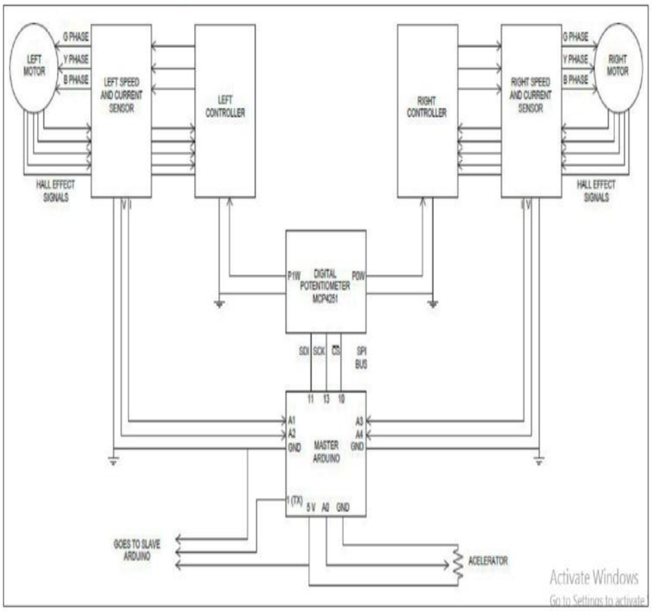

Figure 1 Block Diagram

Two versions of hardware have been developed to implement the ED proposed in this paper. In the first version, only two sensors were used to measure the current applied to each motor. The torque delivered by a BLDC motor is proportional to its current, so it can be estimated by measuring that current. In this version there is no speed sensor available to measure the speed of the driven wheels.

This has the disadvantage of not detecting odd situations like wheel blockage or slippage. To overcome this problem a second hardware version has been made. In this version the signals of the Hall effect sensors of the BLDC motors have been used to estimate the rotation speed of the wheels. In this way, it has not been necessary to add any new speed sensor to the system.

Figure 1 depicts the block diagram for the second iteration of the hardware. The main components of the hardware are the following:

1) BLDC motors

Two BLDC motors have been used for implementing the ED. The type of motor was the Nine Continent RH205B.

2) BLDC controllers. Two Infineon 17A standard bicycle controllers were used.

3) Speed and current sensors

Speed and current sensors have been joined in a unique device for each wheel. We have used unidirectional “shunt” sensors to measure the current, while speed sensors utilize the Hall effect sensors which are already integrated in BLDC motors.

4) Arduino platform

The microcontroller used to implement the control algorithm is the Arduino Nano platform.

5) Digital potentiometer

Electric bicycle standard controllers use a potentiometer to set the duty cycle of the output transistors control signal In this method, the power given to the motor is controlled.
This potentiometer establishes a voltage at the input of the controller that varies from 1V to approximately 4V. The potentiometer can be eliminated by applying directly to the input of the controller the output of a digital to analog converter (DAC). The Arduino Zero and Arduino DUE platforms have this type of outputs, so they could be used by connecting them directly to the controller input. This allows the automatic regulation of the voltage at the input of the controller at a level established by the control algorithm executed by the Arduino platform.
However, in our Hardware version, we have chosen an Arduin o Nano platform, which has no DAC outputs. Therefore, the solution implemented has been the replacement of the potentiometers of the controller by digital potentiometers regulated by Arduino. We have used a chip MCP4251, which includes two digital potentiometers, one for each motor.

C. Software

1) Main program

The operation process is the following: The accelerator sets the torque set point that both motors must deliver. This is received by the Arduino, which also reads the feedback of the current flowing through the motors, which is measured by the current sensors. Attending to the set point and the feedback, the program executes a Proportional-Integral control to obtain the optimal values of the control signals. These values are send to the digital potentiometers that regulates the output level of the motors controllers.

2) Traction control

Using the vehicle's minimal turning radius (rmin) (the radius o f the perimeter that traces the outer wheel), the ratio of the spe eds of the drive wheels must be within the range. shown in the following equation:

$$\frac{r_{\min}-d}{r_{\min}} \leq \frac{v_{wheelR}}{v_{wheelL}} \leq \frac{r_{\min}}{r_{\min}-d}$$

Where d is the distance between the drive wheels. The slip of any of the drive wheels is detected when the ratio of the speeds of both wheels is outside the range shown in equation. In this situation, the traction control algorithm decreases the s et point of the wheel that rotates at a faster speed until the rati o of the speeds of both wheels is again within that range. This algorithm works well whenever only one of the drive wheels slips, but it is not useful when the two wheels do.

This limitation can be overcome if the vehicle has a speed sensor coupled to any of the non-driven wheels, usually the front steering wheels. Assuming a tricycle with a single front non-drive wheel and that this wheel does not slip, the equation that gives the limits of the ratio between the speed of any of the traction wheels and the front wheel are the following:

$$\frac{2\cdot r_{\min}-2\cdot d}{2\cdot r_{\min}-d} \leq \frac{v_R}{v_F} \leq \frac{2\cdot r_{\min}}{2\cdot r_{\min}-d}$$

Where vF is the speed of the front wheel and vR the speed of any of the traction wheels. The slip of any of the drive wheels is detected when the value of this ratio is outside those limits

3. System testing and results

Figure 2: Modal Prototype

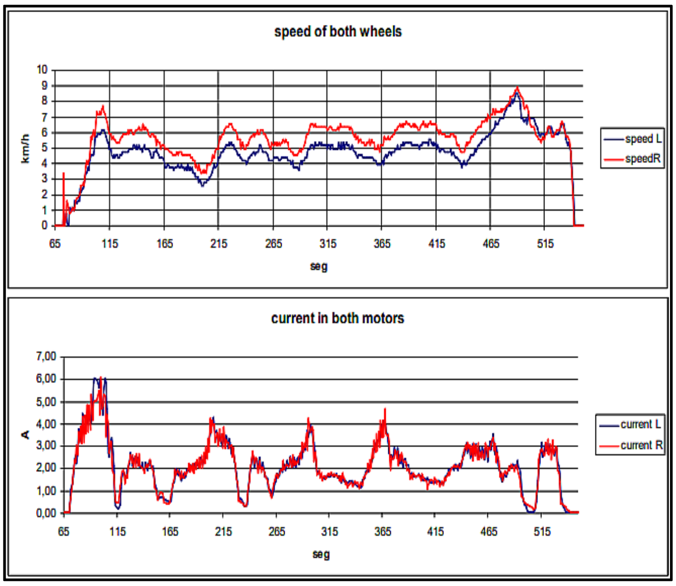

Figure 3: Result of the Test

The system has been installed on a prototype (Figure 2) and then tested in order to check its performance. The prototype is a threewheeled vehicle derived from a bicycl e, with a bar support that holds the two back wheels. BLDC motors are directly coupled to these wheels. To check the

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 12 | Dec - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

performance of the ED, the vehicle has been subjected to the worst-case test: a circular path with the minimum radius. The vehicle has been driven on a circumference with a radius of 4 meters and the current and speed data from the motors has been collected and analyzed. The results of the test are shown in figure 3

4. Discussion

The first and the last stretch, in which both wheels carry the same speed, correspond to the initial and final straight trajectory. It is observable that when the trajectory becomes curve, the inner wheel speed (the left wheel in this case) is lower than the outer one (right one). On the other hand, the current signal remains practically identical for both motors, which means that the torque is the same. The theoretical speed ratio of both wheels was also compared to the experimental value, yielding a 2.03 percent inaccuracy. This error is within the expected range, due to the difficulty of maintaining an exact radius of 4meters during the entire path. From the analysis of these data, we can establish that the ED works correctly at low speed in sharp curves when there is no slip on any of the wheels.

5. Conclusions

It has been demonstrated that it is attainable to do an electronic differential gadget without direction point sensors nor dedicated speed sensors. The equipment of the gadget depends absolutely on in vogue BLDC vehicles and regulators and the overall rationale Arduino stage. Its principle attributes are exceptionally little weight and minimal expense. This makes it exceptionally proper to be utilized in gentle electric vehicles with numerous power wheel. In order to play out an extra thorough evaluation of the proposed machine, new looks at should be conveyed at a higher velocity and in circumstances of slippage of force instruct wheels.

6. Future Scope

The project has covered testing of the Hall sensors of the BLDC motor. This has been followed by the fabrication of the inverter and driver circuit of the inverter for the BLDC motor to operate. This has been covered along with the real time simulation and pulse generation for the inverter driver circuit from the Opal RT digital outputs.

7. References

1. Van den Bossche, Alex, Peter Sergeant, and Isabelle Hofman, “Towards Low Energy Mobility Using Light and Ultralight Electric Vehicles.”, First International Conference On Electromechanical Engineering, Proceedings. Ed. Abderrezak Metatla. University of Skikda Algeria, 2012.

2. Hofman, P. Sergeant and A. Van den Bossche, "Drivetrain design for an ultra light electric vehicle with high efficiency,“ 2013 World Electric Vehicle Symposium and Exhibition (EVS27), Barcelona, 2013, pp. 1-6. doi: 10.1109/EVS.2013.6914766

3. Gil-Sánchez, Marina; Fernández-Ramos, José. “A specific photovoltaic panel for an ultra-light electric vehicle focused on urban mobility”, The first World Light Electric Vehicle Summit (LEVS16), Barcelona, 2016 http://hdl.handle.net/10630/12435

4. Muetze and Y. C. Tan, "Performance evaluation of electric bicycles," Fourtieth IAS Annual Meeting. Conference Record of the 2005 Industry Applications Conference, 2005.,2005, pp. 2865-2872 Vol. 4. doi: 10.1109/IAS.2005.1518866

5. L. Solero, O. Honorati, F. Caricchi and F. Crescimbini, "Nonconventional threewheel electric vehicle for urban mobility," in IEEE Transactions on Vehicular Technology, vol. 50, no. 4, pp. 1085-1091, Jul 2001. doi: 10.1109/25.938582

6. J. Sindha, B. Chakraborty and D. Chakravarty, "Rigid body modeling of three wheel vehicle to determine the dynamic stability — A practical approach," 2015 IEEE International Transportation Electrification Conference (ITEC), Chennai, 2015, pp. 1-8. doi: 10.1109/ITEC-India.2015.7386889