Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 7, S. 415-419, 4, 2023

Araştırma Makalesi

IJANSER

https://as-proceeding.com/index.php/ijanser
ISSN: 2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 7, pp. 415-419, 4, 2023

Research Article

BLDC Motor Controller Design For Light Cars Aiming Safety Driving

Göktürk Koçaş*, Bayram Akdemir [2]

[1,2] *Electrical and Electronics Dep. /Engineering and Nature Science Faculty, Konya Technical University, Konya, TURKEY*

[*1] *gokturk.kocas@gmail.com* , [2] *bakdemir@ktun.edu.tr*

(Received: 10 May 2023, Accepted: 26 May 2023)

(DOI: 10.59287/ijanser.756)

ATIF/REFERENCE: Koçaş, G. & Akdemir, B. (2023). BLDC Motor Controller Design For Light Cars Aiming Safety Driving. *International Journal of Advanced Natural Sciences and Engineering Researches,* 7(4), 415- 419.

Abstract – This study investigates the Pulse Width Modulation (PWM) signal management techniques used in electric vehicles and how battery heat control is performed. It discusses how the application of the gas pedal, gear changes, and simultaneous pressing of gas-brake pedals prevent accidental movement of the vehicle in certain scenarios. Additionally, it evaluates the impact of battery management and heat control on the safety of the vehicle. The reviews and conclusions carried out have the potential to improve vehicle safety and battery life.

Keywords – EV Safety Measures, BLDC, PWM Control in EVS, Powertrain Optimization, Motor Driver for EVs

I. Introduction

Electric vehicles (EVs) are rapidly gaining acceptance and becoming widespread as an environmentally friendly transportation solution. However, a range of technical and management strategies are required to ensure the safe and efficient operation of such vehicles [1-3].

This study focuses particularly on PWM (Pulse Width Modulation) signal management and battery heat control techniques. PWM plays a crucial role in the control of electric motors, and hence, understanding how it responds to different driving scenarios is important. PWM is a simple way to control energy flowing [4,5]. These scenarios include the application of gas pedals, gear changes, and simultaneous pressing of gas and brake pedals. Battery management and heat control, on the other hand, have a significant impact on the overall performance and safety of EVs [6-8]. Shedding light on these issues can assist us in developing safer and more efficient EVs.

II. Materials and Method

The vehicle is equipped with a BLDC Hub motor directly connected to the wheel, obviating the need for a transmission system. Carbon fiber is utilized for the external bodywork, while the chassis is manufactured from aluminum. An emergency stop feature capable of mechanically cutting the motor's energy is included for safety. Seats are designed as double-belted racing seats, produced from non-combustible materials. All moving parts and control elements within the vehicle are secured to prevent dispersion in the event of an accident.

In addition to these safety measures, safety software central to this study has been integrated into the software of the BLDC motor controller. This software ensures the safe operation of the motor and prevents the motor from being damaged in case of mishaps.

Fig. 1 Exterior view of the manufactured vehicle.

The produced electric vehicle has specific dimensions and equipment features. The lateral axle distance is 162 cm, the longitudinal axle distance is 311 cm, and the total vehicle length is 365 cm. The core of the energy conversion mechanism in the vehicle is a nominal 2kW power BLDC (Brushless Direct Current) Hub motor. The low power of this motor has been determined with the objective of maximizing energy efficiency. As illustrated in (Fig. 1).

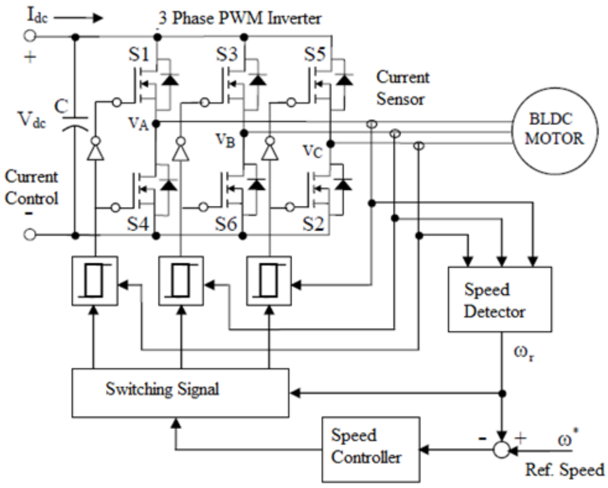

Fig. 2 3 phase PWM inverter schematic.

The motor control mechanism is implemented with a specially designed BLDC motor driver. This driver is designed using an STM32 series 32bit ARM-based microcontroller. The STM32 evaluates the input signals and generates a PWM (Pulse Width Modulation) signal. Examples of PWM signal graphs can be observed in (Fig. 4). A switching frequency outside the audible frequency range is employed to minimize acoustic disturbances. This design choice aims to prevent the distraction of the driver and allow a clearer perception of environmental sounds. The generated PWM signal is transmitted to the IGBT switching element using isolated gate drivers for safety [9,10]. This control system constantly monitors the motor temperature, IGBT temperature, and current values. (Fig. 2) presents a schematic view of the experimental setup.

The fundamental structure of BLDC (Brushless Direct Current) motor controllers comprises a microcontroller, a gate driver, and a switching component that can be an IGBT (Insulated-Gate Bipolar Transistor) or a MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor). In this research, a microcontroller from the STM32F103 series, gate drivers from the TLP250 series, and an MWI 75-06 A7 IGBT block have been utilized. The IGBT blocks fundamentally incorporate a three-phase Pulse Width Modulation (PWM) inverter circuit. The designed driver image is given in the (Fig 3.).

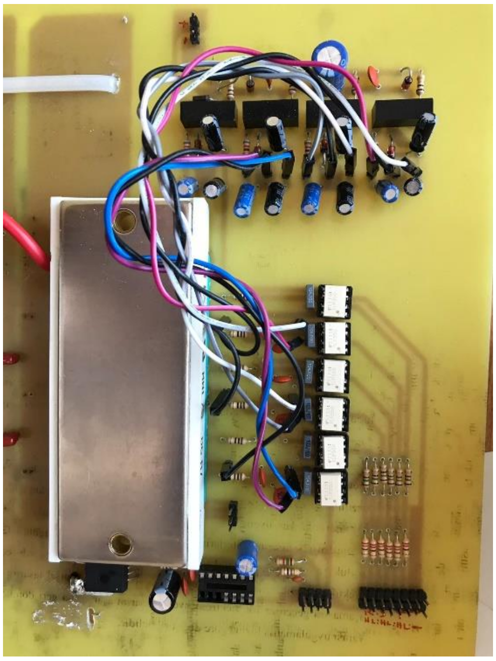

Fig. 3 Photograph of the BLDC motor driver designed for the EV produced in the study.

Control of a BLDC motor necessitates an understanding of the motor's position state. In this study, a switching method based on data received from Hall sensors has been adopted. Compared to a sensorless method, this technique enables approximately 5% additional torque production [11,12].

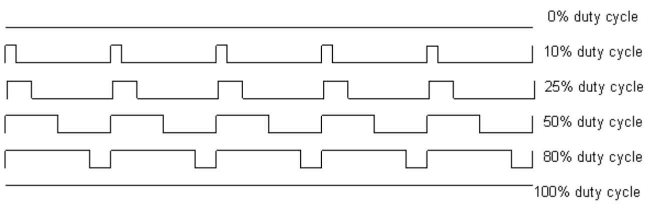

Fig. 4 PWM signal with different duty cycles.

The duty cycle of the PWM signal can vary between 0% and 100%, determined by the signal received from the vehicle's throttle. In situations requiring caution, the PWM signal can be limited to a lower maximum value. This restricts the maximum power output of the vehicle, simultaneously limiting its speed. In challenging weather conditions (rain, snow, etc.), the signal from the throttle is converted into a PWM signal using a ramp function for a softer throttle response. However, in this study, this function is disabled when the racetrack conditions are suitable.

In this project, materials with low specific gravity were preferred to ensure the lightness of the vehicle. For instance, a carbon fiber body, aluminum chassis, and lightweight wheels have been used to reduce friction. Considering safety and lightness, plexiglass was chosen over glass. The energy storage system used in the vehicle is a 72-volt battery pack created by connecting 18650-coded Li-ion batteries in series and parallel. 18650-coded batteries are widely used in electric vehicles to energize [13,14]. To minimize the risk of combustion and explosion, the battery is placed in a special protective box.

Within the scope of high-security protocols, the high-current carrying cables and signal cables of the motor have been placed as far apart as possible. These arrangements have been implemented to prevent potential confusion that electromagnetic noise and parasitic signals can cause. Additionally, the Faraday cage principle has been used for the electromagnetic protection of the cables.

The algorithm operates in real-time on an STM32 microcontroller, continuously monitoring and adjusting the state of the vehicle from the initiation process to the parking process. Please refer to (Fig. 5) for a detailed illustration of the algorithm.

At the start, if the ignition is on and the accelerator pedal is activated, the algorithm prevents the vehicle from starting. The system will not start until the accelerator pedal is released. Furthermore, to ensure that the vehicle is stationary during ignition, the algorithm requires that the brake pedal be kept depressed. When these two safety conditions are met, the vehicle becomes ready for operation. The speed control signal, Pulse Width Modulation (PWM), is initially set to zero.

The vehicle's transmission system is configured to support only forward and reverse movements. There are three available gear positions: Drive (D), Neutral (N), and Reverse (R). In the N gear position, the PWM signal maintains a zero level, preventing the vehicle from moving. The D gear enables forward movement, while R indicates reverse movement. To initiate movement, the vehicle must be set to a gear position other than N.

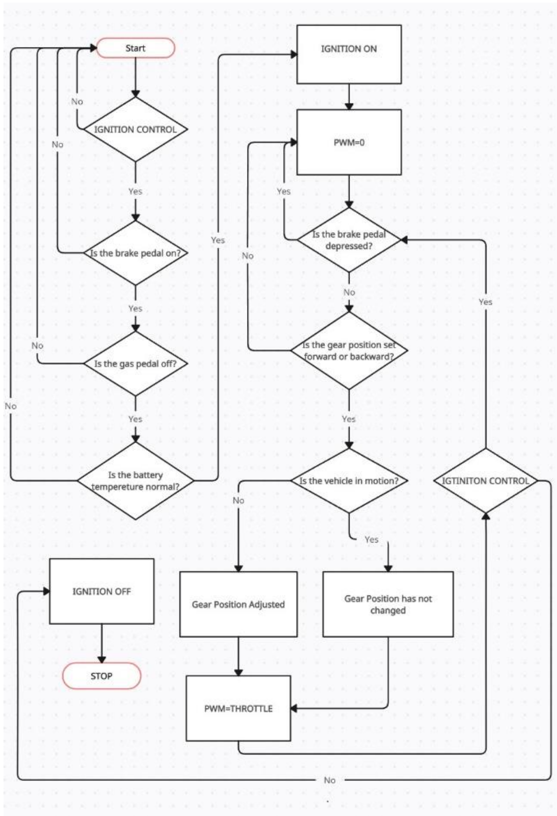

Fig. 5 The security algorithm diagram produced in the study.

Gear changes cannot be made while the vehicle is in motion. Once the vehicle is confirmed to be completely stationary, the desired gear position can be selected, and the PWM signal can be released, allowing movement. When the brake pedal is pressed, the PWM value is swiftly reset to zero, allowing the vehicle to continue its movement by inertia, thereby preventing power loss, maintaining safety, and preempting potential problems.

The PWM signal is typically activated in conjunction with the accelerator pedal, assuming that the necessary safety systems are functioning correctly. When the ignition is off, the process is halted and requires a restart. The aforementioned algorithm can be seen above.

III. Results

This study encompasses the design and development of a safe motor driver and an electric vehicle explicitly tailored for a competition involving student participation. We present a series of algorithms and procedures in our study, specifically devised to ensure the safety of the vehicle's operation. The vehicle and driver have been designed to optimize safety during operation by controlling the PWM signal according to safety conditions and managing battery temperature.

The research assessed the vehicle's performance and safety under various operational scenarios. These scenarios include situations such as gear changes, simultaneous application of the gas and brake pedals, and instances of battery overheating. In each case, the performance and safety of the vehicle and motor driver were upheld at satisfactory levels due to the applied algorithms and control mechanisms

In conclusion, this study introduces a novel approach to prioritizing safety in the design and development of electric vehicles. The design of the vehicle and motor driver, along with the utilized algorithms, provides a valuable reference for future work.

IV. DISCUSSION

The development and evaluation of a safe motor driver for an electric vehicle underscored the importance of integrating safety considerations into the design and development phase of electric vehicles. Critical operational situations such as responses to gas and brake pedals, gear changes, and battery management were taken into account. These scenarios simulate situations that can be encountered in real-world driving scenarios.

The developed algorithms and control mechanisms successfully operated to prevent potential safety risks. However, considering more complex and unpredictable scenarios, future work needs to further enhance these algorithms and mechanisms.

In conclusion, this study highlights the importance of integrating safety as a primary factor in the design and development processes of electric vehicles and motor drivers. This approach is of critical importance, especially in situations such as competition vehicles to be used by students and young engineers.

V. CONCLUSION

This study involved the design and implementation of a safety-prioritized motor driver for electric vehicles. We developed algorithms and mechanisms focused on the control of gas and brake pedals as well as gear changes and battery management. These mechanisms have effectively worked to secure various aspects of vehicle operation.

The results indicate the importance of integrating safety into the design and development stage of electric vehicles, especially for young engineers and students. This study reveals that safety-focused vehicle design and development serves as a guide to overcoming challenges encountered in real-world driving scenarios.

Further investigations are suggested to focus on more complex and unpredictable driving scenarios and to further develop safety mechanisms accordingly.

ACKNOWLEDGMENT

We would like to thank MOSAŞ Group Corp. for giving us the opportunity and resources.

This designed car and system protection was tested in the TUBITAK Efficiency Challenge car race and exposed in the 2023 TEKNOFEST fair.

REFERENCES

[1] Q. Cheng, Qi, Lydie Nouveliere, and Olivier Orfila. "A new eco-driving assistance system for a light vehicle: Energy management and speed optimization." 2013 IEEE Intelligent Vehicles Symposium (IV). IEEE, 2013.

[2] Keall, Michael D., and Stuart Newstead. "Passenger vehicle safety in Australasia for different driver groups." Accident Analysis & Prevention 43.3 (2011): 684-689.

[3] Metzger, K. B., Sartin, E., Foss, R. D., Joyce, N., & Curry, A. E. (2020). Vehicle safety characteristics in vulnerable driver populations. Traffic injury prevention, 21(sup1), S54-S59.

[4] Verma, Vijay Kumar, and Rajeev Kumar Ranjan. "Design of active PWM control driver circuit for torque system using ccii." IEEE Access 9 (2021): 75426-75434.

[5] de Araujo Ribeiro, Ricardo Lúcio, et al. "Fault-tolerant voltage-fed PWM inverter AC motor drive systems." IEEE Transactions on Industrial Electronics 51.2 (2004): 439-446.

[6] Gabbar, Hossam A., Ahmed M. Othman, and Muhammad R. Abdussami. "Review of battery management systems (BMS) development and industrial standards." Technologies 9.2 (2021): 28.

[7] Karlsen, Haakon, et al. "Temperature-dependence in battery management systems for electric vehicles: Challenges, criteria, and solutions." IEEE Access 7 (2019): 142203-142213.

[8] Pesaran, Ahmad A. "Battery thermal management in EV and HEVs: issues and solutions." Battery Man 43.5 (2001): 34-49.

[9] Chen, Baoxing. "Isolated half-bridge gate driver with integrated high-side supply." 2008 IEEE Power Electronics Specialists Conference. IEEE, 2008.

[10] Kennedy, Brian. "Implementing an isolated half-bridge gate driver." Analog Dialogue 46.4 (2012): 10-12.

[11] Alaeinovin, Pooya, and Juri Jatskevich. "Hall-sensor signals filtering for improved operation of brushless DC motors." 2011 IEEE International Symposium on Industrial Electronics. IEEE, 2011.

[12] Park, Sung-In, et al. "An improved current control method for torque improvement of high-speed BLDC motor." Eighteenth Annual IEEE Applied Power Electronics Conference and Exposition, 2003. APEC'03.. Vol. 1. IEEE, 2003.

[13] Szürke, Szabolcs Kocsis, et al. "Statistical approach for designing generic 18650 battery model." 2021 17th Conference on Electrical Machines, Drives and Power Systems (ELMA). IEEE, 2021.

[14] Liu, Binghe, et al. "Mechanical integrity of 18650 lithium-ion battery module: Packing density and packing mode." Engineering Failure Analysis 91 (2018): 315-326.