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Steering System of Electric Vehicle using Extreme Learning Machine

disusun oleh:

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Foreword from General Chair EECSI 2020

In the name of Allah, Most Gracious, Most Merciful

Welcome to the 7th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI 2020). The 7th EECSI 2020 provides platform for researchers, academicians, professionals, and students from various engineering fields and with cross-disciplinary working or interested in the field of Electrical Engineering, Computer Science, and Informatics to share and to show their works and findings to the world.

This year, the conference is held virtually, due to the pandemic issue which prevent authors and participants to travel. I would like to express my hearty gratitude to all participants for sharing and presenting your experiences in this virtual conference. Only high-quality selected papers are accepted to be presented in this event, so we are also thankful to all the international reviewers and steering committee for their valuable work. I would like to give a compliment to all partners in publications and sponsorships for their valuable supports.

Organizing such an prestigious conference was incredibly challenging and would have been impossible without our outstanding committee, so I would like to extend my sincere appreciation to all committees and volunteers from Universitas Ahmad Dahlan as a host and all colleagues from Universitas Diponegoro, Universitas Sriwijaya, Universitas Islam Sultan Agung, Universitas Muhammadiyah Malang, Universitas Budi Luhur and IAES Indonesia Section for providing me with much needed support, advice, and assistance on all aspects of the conference. A special thanks for IEEE Indonesia Section for the technical co-sponsorship during the conference. We do hope that this event will encourage the collaboration among us now and in the future.

We wish you all find opportunity to get rewarding technical program, intellectual inspiration and forge innovation. Stay at home, stay safe, and be productive.

Assoc. Prof. Dr. Tole Sutikno
General Chair, EECSI 2020

Foreword from IAES Indonesia Section

Bismillahirrohmannirrahim,
Assalamualaykum warohmatullahi wabarakatuh and Good Day,
Ladies and Gentlemen,

We would like to welcome our colleagues to attend the International Conference on Electrical Engineering, Computer Science and Informatics (EECSI 2020) on 1-2 October 2020.

I hope this event will become a great event for researchers, engineers and professionals to strengthen ties and partnerships and their findings and development to the world in the field of electrical, computer, and informatics. This year, the conference is held virtually using Zoom Conference platform, however, I believe the quality of conference can be maintained in the high level.

Institute Advanced Engineering and Science (IAES) collaborating with Universitas Diponegoro, Universitas Islam Sultan Agung, Universitas Sriwijaya, Universitas Budi Luhur and Universiti Teknologi Malaysia as several tops universities have successfully organized the conference six times since year 2014. This achievement is due to valuable contributions also from our colleagues from Universitas Ahmad Dahlan. I would like to express my sincere gratitude and appreciation for all partners, friends, organizing committee, reviewers, keynote speakers, and participants who have made this event as a key stage to show great development to the world as today.

I would also like to extend my gratitude to Rector of Universitas Ahmad Dahlan, academia and supporting staffs who become a main host and IEEE Indonesia section as a technical co-sponsor for EECSI 2020.

Stay safe, and stay strong.

Thank you.

Assoc.Prof. Mochammad Facta, Ph.D
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Steering System of Electric Vehicle using Extreme Learning Machine

Publisher: IEEE

Sofyan Ahmadi ; Khairul Anam ; Azmi Saleh **All Authors**

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The development of electric vehicle technology is currently increasing and growing very fast. Some efforts have been conducted, one of which is using BLDC (brushless direct current) motors to improve efficiency. This study utilized extreme learning machine (ELM) embedded on the microcontroller as well as the differential method for controlling the rotational speed of the BLDC motor. The experimental results on the acceleration testing by traveling a distance of 200 meters achieved the average current of 1.09 amperes. The average power efficiency test is 104 watts. Furthermore, the results of the efficiency experiment with a track length of 3.3 km (kilometers) in 10 minutes obtained the energy efficiency of 177.34 km / kWh (kilowatt for one hour).

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I. Introduction

In electric vehicles, BLDC (brushless direct current) motors are widely used as prime movers because they are easy to apply because they have massive torque, so they have a more significant field current than DC (direct current) motors. BLDC motor has a disadvantage because it requires a mechanical commutator or brush in the operation of the motor. Therefore, it needs regular commutator (brush) changes [1] [2]. Because DC motors have weaknesses in terms of maintenance, the BLDC motor is used for primary movers in electric cars because there are no mechanical commutators so that it is easier to apply to electric vehicles. For BLDC motor efficiency is higher than DC motors because the rotor is made of permanent magnet [3].

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Steering System of Electric Vehicle using Extreme Learning Machine

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***Abstract*— The development of electric vehicle technology is currently increasing and growing very fast. Some efforts have been conducted, one of which is using BLDC (brushless direct current) motors to improve efficiency. This study utilized extreme learning machine (ELM) embedded on the microcontroller as well as the differential method for controlling the rotational speed of the BLDC motor. The experimental results on the acceleration testing by traveling a distance of 200 meters achieved the average current of 1.09 amperes. The average power efficiency test is 104 watts. Furthermore, the results of the efficiency experiment with a track length of 3.3 km (kilometers) in 10 minutes obtained the energy efficiency of 177.34 km / kWh (kilowatt for one hour).**

Keywords*— BLDC Motor, Differential Electronics, Extreme Learning Machine, Acceleration, Efficiency.

I. INTRODUCTION

In electric vehicles, BLDC (brushless direct current) motors are widely used as prime movers because they are easy to apply because they have massive torque, so they have a more significant field current than DC (direct current) motors. BLDC motor has a disadvantage because it requires a mechanical commutator or brush in the operation of the motor. Therefore, it needs regular commutator (brush) changes [1][2]. Because DC motors have weaknesses in terms of maintenance, the BLDC motor is used for primary movers in electric cars because there are no mechanical commutators so that it is easier to apply to electric vehicles. For BLDC motor efficiency is higher than DC motors because the rotor is made of permanent magnet [3].

In operating a BLDC motor on the rotor, a three-phase voltage source is needed. Because in a BLDC motor, the voltage source is direct current or DC voltage, a three-phase inverter is needed to convert the DC voltage into a non-phase AC Voltage. In using the inverter, there are two methods, namely the six-step sinusoidal PWM method. However, in the application of BLDC motor control, many six-step methods are used because they have a simple algorithm and have high stability. To increase reliability in the six-step method, an appropriate frequency setting is needed. Then to increase the efficiency of the BLDC motor, a closed cycle control system is needed. There are several kinds of algorithmic methods in the design of closed-cycle control, one of which is neural network control [2][4].

To improve energy efficiency in running an electric vehicle, a control in the steering system is needed. The expected steering system is an electronic control, which is commonly called an electronic differential motor control. In the differential control, the speed changes will be made between the right and left motors on electric vehicles so that it is expected to slip or friction with the road when the vehicle is running can be minimized [5].

In the use of differential electronic control on a BLDC motor for electric vehicles, a closed cycle control is needed to get more energy efficiency. In this research, extreme learning machine (ELM) control is used because it has the benefit of analyzing the energy that has been obtained so that after training or data processing, an equation is obtained to be entered into the BLDC motor control algorithm. In the application of ELM, the ELM control used can provide contrast to the current and steering angle to get maximum energy efficiency [6][7].

II. PROPOSED METHOD

A. Differential Electronic Steering Control System

Motor rotation, which is always the same when the vehicle is running, will be prone to slip or slip. Therefore the electronic differential control system BLDC motor will provide different turns between the right motor and the left motor by considering the steering angle and the current rise. In Figure 1, we can see the mechanical system in an electric vehicle based on differential control electronics [8][9].

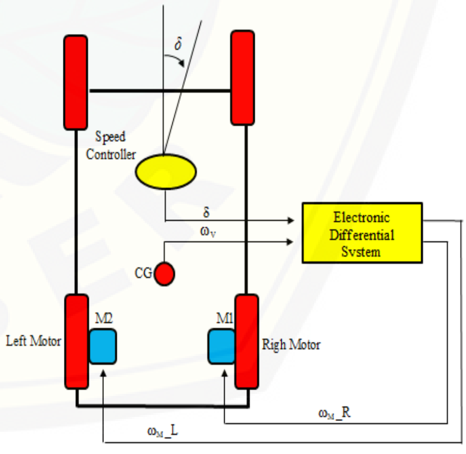

Fig 1. Electric Vehicle based on differential steering system

Vehicles have a total weight of 150 kg with a 50 kg driver weight. Thus, the total workload of the control system is 200 kg. The frame is made of iron with the supine position of the driver with a view to obtaining an aerodynamic function or air resistance. The use of four wheels is to get an easier steering system and lower power on the motor. It minimizes heavy loads on the motor and BLDC motor control in particular. In this steering system, when turning, the speed between the right BLDC motor and the left-hand BLDC motor will change.

Fig 2. Differential Electronic Systems in Electric Vehicles

BLDC motors are installed in-wheal or together with wheels, so they do not need a mechanical transmission system. The use of rear wheels with a diameter of 16 inches while the front wheels with a diameter of 14 inches. In this design, it is expected to provide a small load so that research on BLDC motor control uses the Extreme Learning Machine (ELM) neural network method so that the vehicle can run well with a load that is not too large.

$$WL = (1 + ((\tan^{\delta} (pi / 180) dW) / LW)) (VL /(R)) \quad (1)$$

$$WR = (1 + ((\tan^{\delta} (pi / 180) dW) / LW)) (VR /(R)) \quad (2)$$

In Equation 1 and Equation 2, it can be seen that WL is the energy needed for vehicles to turn left while WR is the energy used by vehicles to turn right. DW is the distance between the right drive motor and the left drive motor. LW is the distance between the front wheels and rear wheels of the vehicle. Then for VL is the speed of the left motor drive, and VR is the speed of the right motor drive, and R is the wheel diameter on the vehicle used [10][11].

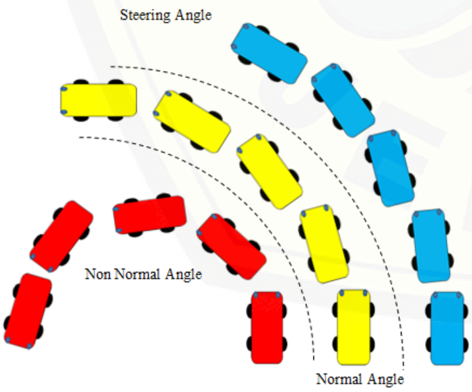

Fig 3. Electric Vehicle Turn System

B. Electronic Vehicle Differential System Design

In designing an electronic system, the differential electric vehicle is a controlling speed of the BLDC motor rotating. The steering system is added by an angle sensor to determine the speed input as ordered by the microcontroller [12].

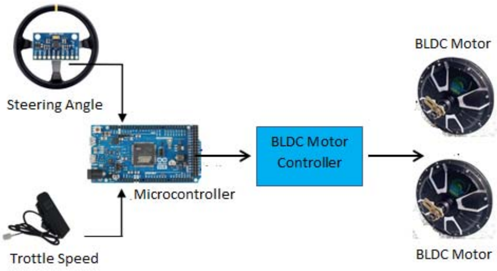

Fig 4. Electronic Differential Block Diagram of Electric Vehicles

In Figure 4, there are two parts of the schematic design, the first part is the design of the MOSFET driver, and the second part is the design of the Arduino ports connecting with the MOSFET driver circuit. In designing the MOSFET of the ELM driver, there are two parts, namely high-side and low-side [13]. Each of these two parts has a function for the switching process to drive the MOSFET to produce a rotating motion on the BLDC motor, which will be controlled by rotating speed. In the MOSFET driver circuit, there are three transistors, the BC 547 type, which is very suitable for switching types with Vcc voltages up to 50 volts on the datasheet. The first transistor has a function as a switch or switching. The second transistor will strengthen the switching process via the PWM input from the Arduino microcontroller. If there is no current strengthening the drive MOSFET, the voltage at the foot of the MOSFET gate will experience a voltage drop.

C. ELM Controller Design

In-plant identification with ELM is used to determine the plant. The plant identification below has one output, PWM. The identification applied here uses an identification model reference. The following is the model of the ELM plant.

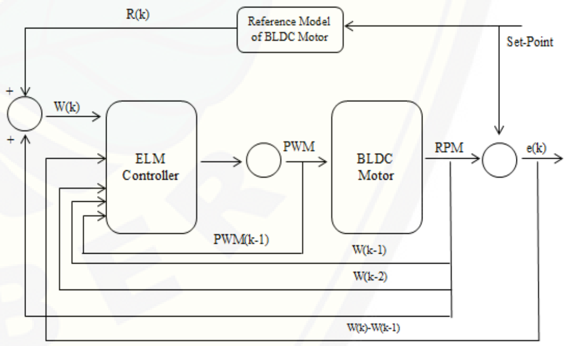

Fig 5. ELM Controller Diagram Block

Figure 5 is a plant model from ELM. This plant model is applied to Matlab software by using the source code that has been created and designed. The ELM plant model above where the input is RPM data and output is setpoint data. From this RPM input, there will be a delay, as shown above, with the Matlab software according to the source code created. This plant model is an initial identification that will be used as a control of ELM.

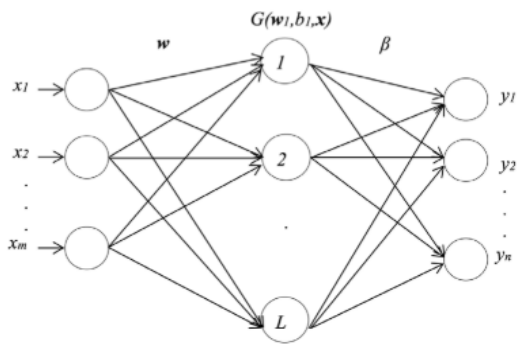

Fig 6. ELM Network [14]

From Figure 6, the design of the motor speed control system with ELM above contains several system blocks. The block from the motor plant is input data in the form of setpoint or PWM and output in the form of RPM. Where the results of this motor plant will be used as an identification of the ELM controller. However, the output of this motor will be used as input on the ELM controller, and the output of the ELM controller is a PWM motor [14]. So the input from the ELM controller is the speed in units of RPM, and the steering angle, and the output is a PWM motor. To get the value of current and speed when testing electric vehicles, a sensor is used as a parameter to be processed in an ELM (artificial Neural Network) system. The speed sensor is used to detect the speed of electric vehicles mounted on the wheels of vehicles that have been calibrated, as for the angle sensor mounted on the steering wheel of the vehicle.

III. Results and Discussion

A. Acceleration Testing

Acceleration Testing is a form of testing for the acceleration of the toughness of an electric vehicle system when used on roads with driving in a straight line. Figure 7 is a graph between the set point value of speed in RPM is a vehicle acceleration testing using ELM control. Acceleration testing is done by running the system at a distance of 200 meters. This acceleration testing emphasis on increasing current. The set point value cannot be balanced with the increase in the desired RPM value because there is an effect of the increase in current on the BLDC motor control.

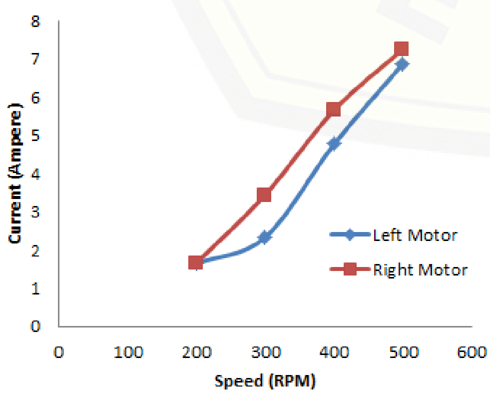

Fig 7. Flow Testing on Electric Vehicle Acceleration using ELM Control

Changes in the setpoint value quickly will give the effect of a drastic change in the value of the speed so that the current will increase rapidly. The experimental results for the system without ELM control obtained an average current of 1.34 amperes, whereas the system that used the ELM controller obtained an average current of 1.05 amperes. The current at the start of the system works slowly because the neural network control suppresses the rapid increase in PWM due to current control on the ELM system.

B. Energy Efficiency Testing of Electric Vehicles

The experiments on energy efficiency in electric vehicles evaluates the energy analysis when electric vehicles are used directly on the track or on the highway. Figure 8 is the experimtal resulst of energy efficiency of electric vehicles using ELM control. We can see graphs of efficiency testing in close-loop mode or using ELM control with an unstable power value. The average power value obtained is 101 watts. Then the measured energy meter for completing the 3.3 km trajectory is 18.4 kWh.

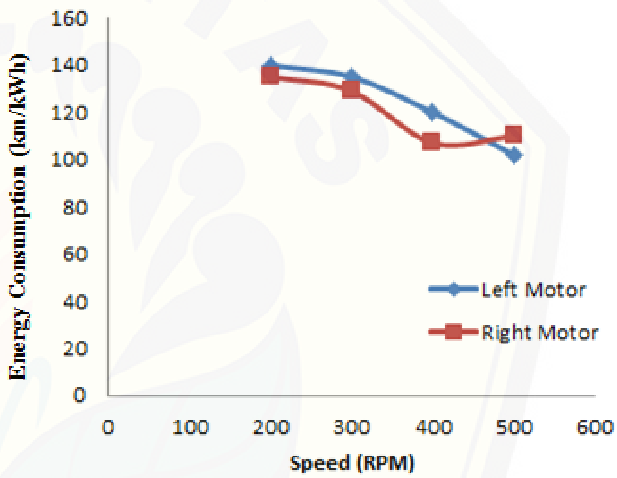

Fig 8. Electric Vehicle Energy Efficiency Testing Chart with ELM

TABLE 1 Comparison of ELM Control Testing

No.	Controll er	Testing		
		Current (Ampere)	Distance	Energi (watt)
1	Without ELM	1,25	1 kWh = 170,48 km	115
2	PID	1,23	1 kWh = 171,76 km	114
3	ELM	1,09	1 kWh = 177,34 km	104

Table 1 show the comparison of the the system with ELM control and without ELM control. In the experiment of energy efficiency without ELM control, the energy transfer is 1 kWh (kilowatt for one hour) on the battery. It can move the vehicle as far as 170.48 km (Kilometers) or 170.48 km (kilometers) / kWh. Meanwhile, the energy efficiency of the system with ELM control obtained energy transfer of 1 kWh energy on the battery. It can move the vehicle as far as 177.34 km or 177.34 km / kWh, as can be seen in Figure 9.

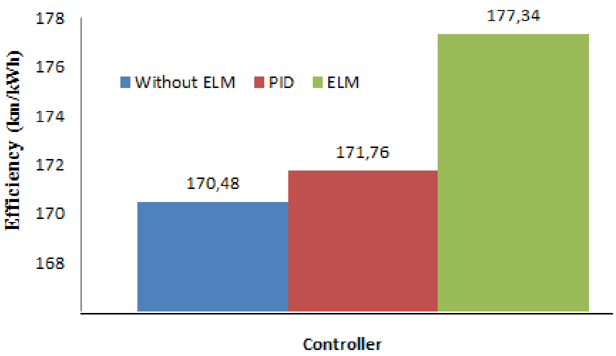

Fig 9. Comparison of Vehicle Energy Usage Results

IV. Conclusion

This paper present the new control system of the electric vehicle using exterme learning machine (ELM). The experimental results on the acceleration testing, by traveling a distance of 200 meters, the system obtained an average current value of 1.09 amperes. As for the testing the efficiency, by traveling a distance of 3.3 km (kilometers) with 10 minutes, the system achieved an average power of 104 watts with energy consumption of 177.34 km / kWh (kilowatt for one hour).

References

[1] H. T. Al-Fiky, M. S. Asfoor, M. I. Yacoub, and A. H. Sharaf, "Speed control modeling for in-wheel permanent magnet brushless DC motors for electric vehicles," *2019 24th Int. Conf. Methods Model. Autom. Robot. MMAR 2019*, pp. 438–443, 2019, doi: 10.1109/MMAR.2019.8864664.

[2] A. C. Lee, S. Wang, and C. J. Fan, "A Current Index Approach to Compensate Commutation Phase Error for Sensorless Brushless DC Motors with Nonideal Back EMF," *IEEE Trans. Power Electron.*, vol. 31, no. 6, pp. 4389–4399, 2016, doi: 10.1109/TPEL.2015.2468081.

[3] H. F. Prasetyo, A. S. Rohman, F. I. Hariadi, and H. Hindersah, "Controls of BLDC motors in electric vehicle testing simulator," *Proc. 2016 6th Int. Conf. Syst. Eng. Technol. ICSET 2016*, pp. 173–178, 2017, doi: 10.1109/FIT.2016.7857560.

[4] Y. He, S. Zheng, and J. Fang, "Start-up current adaptive control for sensorless high-speed brushless DC motors based on inverse system method and internal mode controller," *Chinese J. Aeronaut.*, vol. 30, no. 1, pp. 358–367, 2017, doi: 10.1016/j.cja.2016.12.006.

[5] M. John Prabu, P. Poongodi, and K. Premkumar, "Fuzzy supervised online coactive neuro-fuzzy inference system-based rotor position control of brushless DC motor," *IET Power Electron.*, vol. 9, no. 11, pp. 2229–2239, 2016, doi: 10.1049/iet-pel.2015.0919.

[6] O. C. Kivanc and O. Ustun, "Dynamic control of electronic differential in the field weakening region," *Int. J. Electron.*, vol. 106, no. 10, pp. 1583–1601, 2019, doi: 10.1080/00207217.2019.1600742.

[7] A. Gago-Calderón, L. Clavero-Ordóñez, J. R. Andrés-Díaz, and J. Fernández-Ramos, "Hardware architecture and configuration parameters of a low weight electronic differential for light electric vehicles with two independent wheel drive to minimize slippage," *World Electr. Veh. J.*, vol. 10, no. 2, 2019, doi: 10.3390/wevj10020023.

[8] A. Darba, F. De Belie, P. D'Haese, and J. A. Melkebeek, "Improved Dynamic Behavior in BLDC Drives Using Model Predictive Speed and Current Control," *IEEE Trans. Ind. Electron.*, vol. 63, no. 2, pp. 728–740, 2016, doi: 10.1109/TIE.2015.2477262.

[9] A. G. De Castro, W. C. A. Pereira, T. E. P. De Almeida, C. M. R. De Oliveira, J. Roberto Boffino De Almeida Monteiro, and A. A. De Oliveira, "Improved Finite Control-Set Model-Based Direct Power Control of BLDC Motor with Reduced Torque Ripple," *IEEE Trans. Ind. Appl.*, vol. 54, no. 5, pp. 4476–4484, 2018, doi: 10.1109/TIA.2018.2835394.

[10] A. UYSAL and E. SOYLU, "Embedded System Design and Implementation of an Intelligent Electronic Differential System for Electric Vehicles," *Int. J. Adv. Comput. Sci. Appl.*, vol. 8, no. 9, pp. 129–134, 2017, doi: 0.14569/ijacsa.2017.080918.

[11] F. J. L. Daya, P. Sanjeevikumar, F. Blaabjerg, P. W. Wheeler, J. Olorunfemi Ojo, and A. H. Ertas, "Analysis of Wavelet Controller for Robustness in Electronic Differential of Electric Vehicles: An Investigation and Numerical Developments," *Electr. Power Components Syst.*, vol. 44, no. 7, pp. 763–773, 2016, doi: 10.1080/15325008.2015.1131771.

[12] W. Xie, J. S. Wang, and H. B. Wang, "PI Controller of Speed Regulation of Brushless DC Motor Based on Particle Swarm Optimization Algorithm with Improved Inertia Weights," *Math. Probl. Eng.*, vol. 2019, 2019, doi: 10.1155/2019/2671792.

[13] Y. C. Chang *et al.*, "A new control strategy for an electronic differential system for urban electric vehicles," *Inventions*, vol. 3, no. 1, pp. 1–11, 2018, doi: 10.3390/inventions3010019.

[14] K. Anam and A. Al-Jumaily, "Evaluation of extreme learning machine for classification of individual and combined finger movements using electromyography on amputees and non-amputees," *Neural Networks*, vol. 85, pp. 51–68, 2017, doi: 10.1016/j.neunet.2016.09.004.