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Identification parameter system for mathematical modeling BLDC motor using transfer function models

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Abstract. The parameter system identification of Brushless Direct Current (BLDC) motorbike on electric bicycles is one of the important factors that support success in improving a stable and reliable control system. The purpose of this paper is to explain the mathematical modeling of BLDC motors by system identification parameters. The method of system identification parameters used in this study is experimentation, namely the pulse width modulation (PWM) signal generation process and the collection of input data in the form of current, voltage, and output data such as speed is carried out using sensors connected to the microcontroller. The input and output data are then simulated using the transfer function model found in the system identification toolbox in the MATLAB program. From the results of testing and simulations carried out on the BLDC motor system, a mathematical model was obtained in the form of a transfer function with third-order transfer function is the best fit value than the others. The sequential values of the transfer function 1, 2 and 3 are 69.81, -1945, and 83.34.

2 Introduction

Brushless Direct Current (BLDC) electric motor is one type of Permanent Magnet Synchronous Motor (PMSM) that has many advantages compared to direct current (DC) motors and induction motors such as smooth sound, compact size, large torque, high efficiency [1], long service life, and the most important thing about the advantages of a BLDC motor is the need for setting speed and position, the ability to control speed with changes in voltage [2].



The most important part of analyzing and designing a speed and position control system is knowing the plant model to be controlled [3]. The BLDC motor bike, as one of the most widely used electric motors in the industrial world, required a control system that can work well and produce the desired torque or speed [4]. One effort to improve the efficiency of the BLDC motor is by engineering and optimizing the BLDC motor speed control system [5]. The optimization of the BLDC motor system requires a mathematical model to design the controller, detect failure, and diagnose transient responses [6].

The mathematical model of the BLDC motor system was obtained through the process of input and output signals. The advantage of using this experiment is that it does not require specific knowledge of the system under study, and simple mathematical models that describe the system can be given as a result. The disadvantage of this analysis is that the previous research system must have the fact that the results of the application are limited to the same system. To get the value of the appropriate control parameters, a simulation performance. The value of the control parameter of the simulation results used as a reference for the implementation of the BLDC motor speed control system hardware [7].

The first step of the parameter identification system is hardware design using several main components such as the Arduino Uno, current sensor, voltage sensor, and speed sensor. The Arduino programmed to produce pulse width modulation (PWM) signals [8]. With changes in the PWM value, the motor rotation speed can be monitored and measured to obtain current, voltage and rotation speed. Motor rotation speed, current and voltage data are used as the basis for modeling BLDC motors mathematically using the system identification toolbox contained in the MATLAB program. These parameters are simulated based on input data such as measured voltage and current and output data which are speed and position.

The motor that identified the input and output data in this study is a BLDC motor which is used as a driver on an electric bicycle with 350 watts of power. After the input and output data are obtained, all data transferred from Excel to the Matlab workspace is simulated using the Identification Toolbox System (SIT) which is one of the tools in the MATLAB program so that the transfer function is obtained. This procedure is faster and simpler than using conventional methods.

2. Method

2.1. System identification

The stages for system identification parameters include taking input, output data pairs [9] and the process of determining parameters and validation [10]. The process of retrieving pairs of input and output data is carried out by the microcontroller while the determination of parameters and validation is done on a PC using the MATLAB program. System Identification (SID) is an additional tool from the Matlab software. SID can be used as a means of identification described in Figure 1, simulation and analysis of dynamic systems using graphical user interface (GUI) [11].

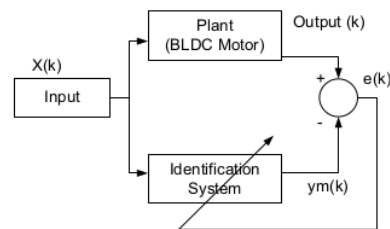


Figure 1. Block system identification parameter of BLDC motor

In this study the process of identifying BLDC motors was carried out through four stages, namely [4]:
 a). Availability of input-output plant data to be identified. b). Model structure selection. c). Estimated model. d). Parameters. Validate the identified model (structure and value of the parameters).

2.2. *Mathematical modeling of BLDC motor*

The design of system identification parameters to obtain a mathematical model in the form of a transfer function [9], the step is to design a BLDC motor speed control system to measure input and output data, through the placement of several sensors connected to the Arduino as shown in Figure 2.

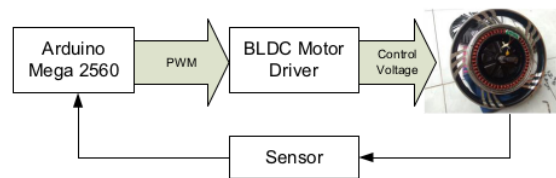


Figure 2. Block design for system identification

The BLDC motor driver circuit is composed of 3 pairs of PNP and NPN transistors. In order to produce a voltage like in Figure 2, each transistor must be given a control signal. The control signal given is a periodic control signal which is divided into 6 conditions. There are two methods for controlling a BLDC motor namely the conventional method or the six step method and the sinusoidal method [12]. The six step method is the method of giving PWM pulses in the form of trapezoidal waves while the second method is sinusoidal method, which is giving PWM pulses in the form of pure sinusoidal waves [13]. This difference is made on the basis of the interconnection of the coil inside the stator winding to provide various types of back emf [14].

In Figure 3. shows a 3 phase inverter circuit that can be arranged by six transistors that can be controlled with the type of MOSFET, Insulated Gate Bipolar Transistor (IGBT). IGBT has work properties that combine the advantages of MOSFET transistors and Bipolar Junction Transistors. Each phase is composed of two switches. Thus the current flowed at each phase can be adjusted. There are two types of inverters commonly used based on the type of conduction, which is 180 degrees and 120 degrees.

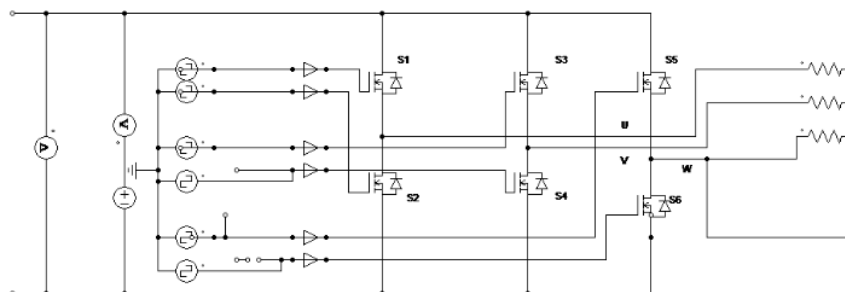


Figure 3. Three phase Inverter circuit

3. Result and analysis

Design testing of BLDC motor system parameter identification is done in several stages, namely taking BLDC motor input and output data, then input and output data simulated and analyzed using the toolbox identification system in the Matlab program.

3.1. Retrieval of input and output data

Collecting 208 data from the input and output of the BLDC motor using the Arduino microcontroller is pulse width modulation, and speed sensors. From input and output data, it is simulated by using the program ident found in MATLAB to get the transfer function. The simulation results are shown in Figure 4.

In Figure 5, we can explain the use of the system identification toolbox found in the MATLAB program by selecting the structure of the transfer function model. With three experiment for first order, second order, and third order. In this study, it has succeeded in realizing an Arduino based BLDC motorbike identification and control module.

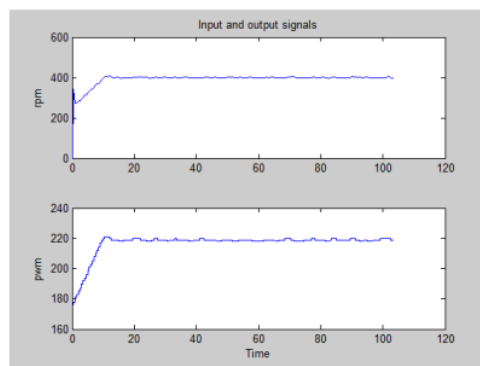


Figure 4. Signal input dan output

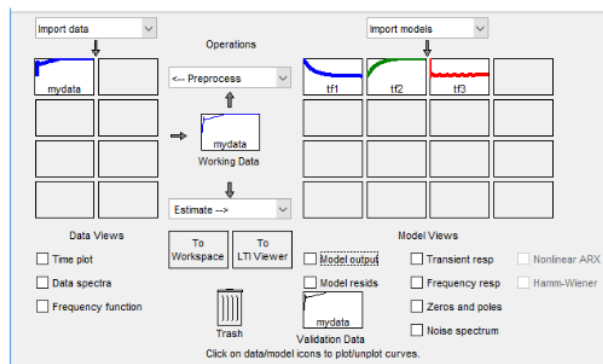


Figure 5. System identification toolbox with transfer function models.

The following Table 1 results in identification with a two type approach.

Table 1. Results of the BLDC motor model approach

1 st order approach	$\frac{1589}{s + 875.4}$
2 nd order approach	$\frac{-32.53s - 10.51}{s^2 + 26.95s + 6.221}$
3 rd order approach	$\frac{12.32s^2 - 7.729s + 4.569}{s^3 + 9.131s^2 + 0.889s + 2.507}$

From Table 1, it was then simulated to find out the output model of first order, second order, and third order. By pressing "Output Model", a comparison between the calculated and measured data will be displayed, and in the right corner of the model accuracy window is calculated because the measured data will appear. When observing the simulation results from experimental data it shows that the calculation for the third order transfer function is the best fit value than the others. The sequential values of the transfer functions 1, 2 and 3 are 69.81, -1945, and 83.34 (Figure 6).

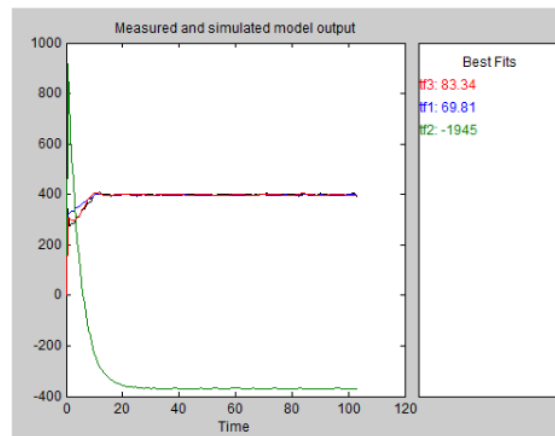


Figure 6. Comparison between the input data and the calculated model

The transfer function of a system is a mathematical model that expresses differential equations that connect output variables to input variables. If the system's transfer function is known, the output or response can be learned from a variety of given inputs. The transfer function provides a comprehensive description of the dynamic characteristics of a system. One-system response analysis uses transfer functions that contain elements termed pole and zero. Pole is a Laplace s variable value which causes the value of the transfer function to become infinite. While zero is the value of the Laplace s variable which causes the value of the transfer function to be zero such as Figure 7. Transfer function is used to determine the stability of the system. Figure 7 shows that the system is stable because the pole is to the left of the

plane s. Beside that, this system has two real zeros, marked by o on the plot, and this system also has a complex pair of poles, with an x.

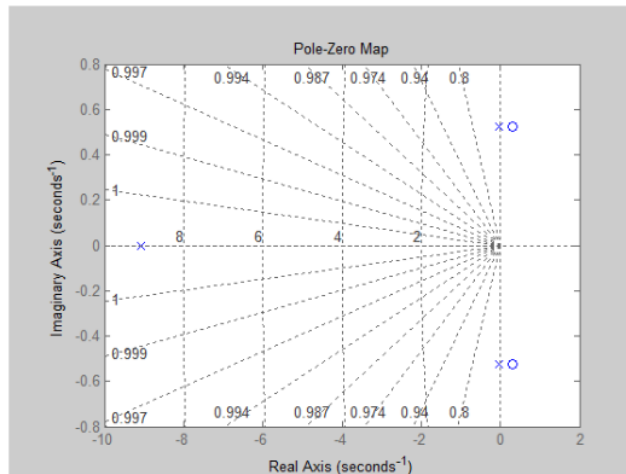


Figure 7. Comparison between the input data and the calculated model

4. Conclusion

This paper explains the approach to identify system parameters with input and one output on ³the BLDC motor speed control system using the System Identification Toolbox which contains Matlab software. In order to identify the model correctly, it is necessary to record the results of input and output data that use the Arduino microcontroller and some sensors to record results in the form of digital data accurately and precisely. ³After conducting experiments and simulations by loading data into the Matlab program, the results of mathematical models in the form of transfer functions with third order. The sequential values of the transfer functions 1, 2, and 3 are 69.81, -1945, and 83.34.

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