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DESIGN AND IMPLEMENTATION OF A BLDC SPEED CONTROL SYSTEM WITH PWM SIX-STEP COMUTATION ON DISABILITY ELECTRIC MOTORBIKES

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Abstract. Persons with disabilities are people who have limited activities like people in general due to physical disability or paralysis, especially for mobility although there are many tools specifically for people with disabilities, for example wheelchairs certainly these aids may not fully help for example for to travel quite far. This raises its own concerns for people with disabilities because they have limitations to do activities like other people. This research was conducted with the aim of designing a motor control system BLDC on electric motorbikes with disabilities. The BLDC motor used is type 350 Watt. The method used for motor speed regulation is PWM Six-Step Commutation. Arduino is used to implement the method. With the controller the BLDC motor speed can be easily regulated. For find out the performance of the controller carried out several tests namely measuring the voltage value and electric current at the three-phase input and output drivers and measuring the rotational speed of the rotor to variations in the percentage value of the duty cycle. The duty cycle value is varied every 5% so the data obtained is the value of rpm in the duty cycle range of 5% - 100%. The results obtained from the test show that at the 100% duty cycle the dc current value is 0.59 A and the engine speed is 299 RPM.

Keywords: Disability Electric Motorbikes, BLDC 350 W, PWM Six-Step Commutation, Arduino

I. INTRODUCTION

In an electric vehicle generally uses a Brushless DC motor as a driving motor because when viewed from the construction and how it works the Brushless DC motor has a higher initial efficiency and torque when compared to an induction motor and lower maintenance costs. Inversely related to the reliability of the Brushless DC motor, it is more complicated in its control because the Brushless DC motor does not use a brush for the commutation process. The working system of a BLDC motor is by utilizing the electromagnetic force of a copper coil on an iron core, between the iron core and permanent magnet arranged so as to produce a continuous rotation of the rotor when the coil is flowed by three-phase electric current.

Microcontroller is a device that regulates electronic circuits such as running lights, in a motor control device BLDC microcontroller has a role to regulate the switching process in the inverter circuit. Where the working system of the microcontroller is to process analog input data which is then converted into a digital signal as output or called an Analog-to-Digital Converter (ADC). Arduino Uno R3 is an Atmega328 based microcontroller that will be used to control the switching process in a three phase inverter circuit, the microcontroller receives analog input in the form of signals from the Hall Effect Sensor and Throttle Speed Control then the data will be

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processed into an output in the form of a PWM signal.

In previous studies, the controller is only intended for vehicles in general, with a variety of power specifications and microcontrollers that are used to adjust to the motor that is sold in the market. Open-loop testing is done by varying the duty cycle value from 0% to 95% [4]. BLDC motor speed regulation can be done by changing the frequency [1], besides making a simulation control program using PSIM software [5], PID Method [3].

In this study, we designed an electric vehicle controller for persons with disabilities, of course the weight of the vehicle will be different from the vehicle for normal people, this will affect the controller power specifications. The controller testing process is done by testing the duty cycle percentage from 0% to 100% at a multiple of 5, so that the resulting data is more accurate.

II. Method

A). Six-Step Commutation

Commutation is a three-phase electric current supply system on a BLDC motor coil so that the rotor can rotate at the right time and orientation. The coil which will be electrified depends on the signal from the Hall Effect Sensor that enters the microcontroller input, the Hall Effect Sensor is a device whose role is to send information about the position of the rotor on the microcontroller so that the electric current will flow on the coil according to the position of the rotor. Overall the BLDC motor speed control system as presented in Figure 1, the following is a diagram of the BLDC motor speed control system:

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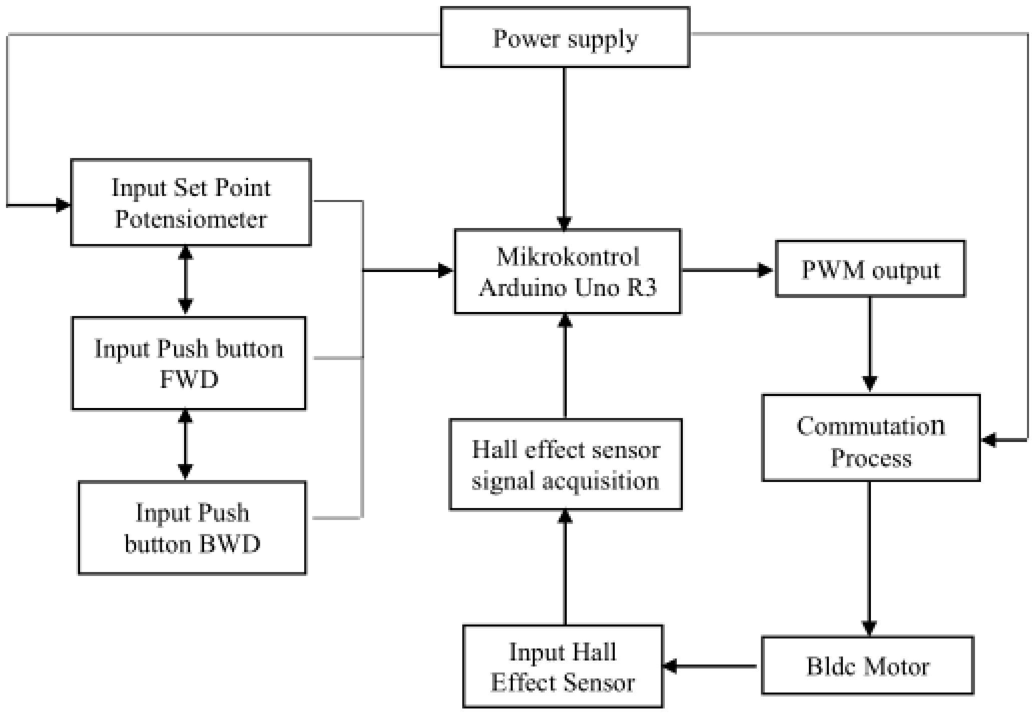

Figure 1. Diagram of a BLDC motor speed control system

Step	Hall Sensor Value			Phase	Switching					
					A High	A Low	B High	B Low	C High	C Low
1	1	0	0	A-C	ON					ON
2	1	1	0	A-B	ON			ON		
3	0	1	0	C-B				ON	ON	
4	0	1	1	C-A		ON			ON	
5	0	0	1	B-A		ON	ON			
6	1	0	1	B-C			ON			ON

Figure 2. Six step commutation

B). Microcontroller

Arduino Uno is a microcontroller board based on Atmega328. This tool has 14 digital input / output pins and 6 of them can be used as PWM outputs, 6 analog inputs, 19MHz ceramic resonators, USB connections, power sockets, ICSP headers, and reset buttons. Figure 2.3 is a physical display of Arduino Uno. With a USB cable this tool is easily connected to a computer and can be activated by a battery or AC to DC adapter.

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Figure 3. Arduino Microcontroller

C). Inverter 3 phase

Three-phase motor driver whose output can regulate the speed of the BLDC motor, there are six transistors installed in pairs. The transistor used is the IRF3205 mosfet transistor. IRF3205 transistor is an N-type transistor on a transistor FET (Field Effect Transistor), this transistor can work up to 110 Amperes and 55 Volts. The IRF3205 transistor is used as a gate driver or drive switch. The switch used in a full-bridge circuit is the IRF3205 mosfet. In controlling mosfets on the lower side it is easier to do because the gate voltage has a ground reference. As for the upper side of the gate voltage reference is the source pin on the mosfet that is not connected to the ground.

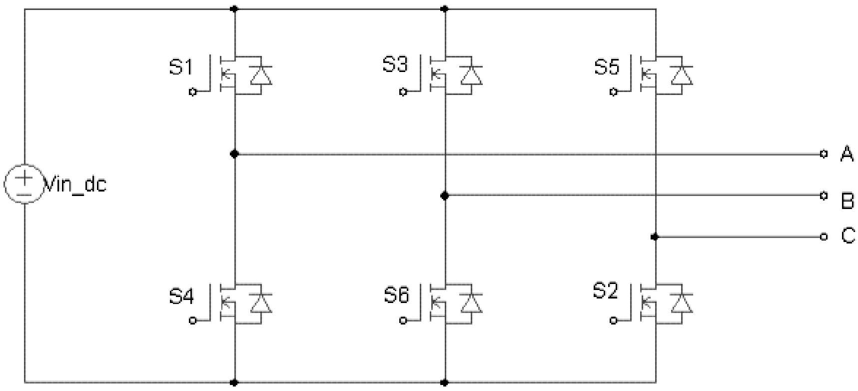

Figure 4. 3-phase inverter circuit

D). Pulse Width Modulation (PWM)

PWM is a series of engineering tools in regulating or controlling the work of an equipment that requires a large pull-in current and to avoid excessive power dissipation from the equipment to be controlled. Duty cycle is a comparison of the length of time a signal is in high condition with the length of time a signal is in condition (high + low), duty cycle is very useful in designing tools that use the PWM concept.

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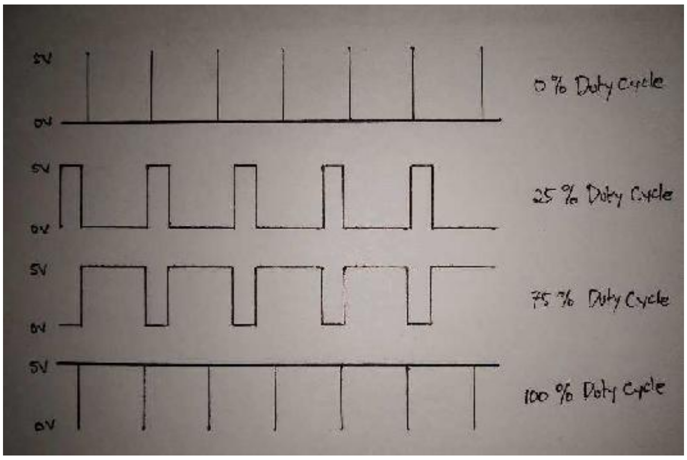

Figure 5. Duty Cycle PWM

III. TESTING AND ANALYSIS

The following is a picture of the whole controller after assembly:

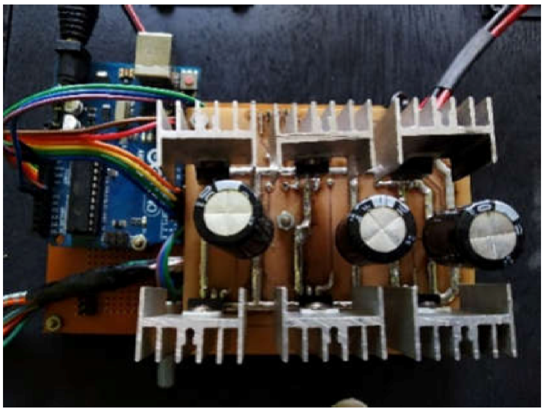

Figure 6. The controller circuit

The test is intended to determine the performance of the controller that has been previously designed, the test includes visualization of the shape of the PWM signal and the output of the motor in the form of voltage, current and rotation per minute (RPM).

1). Testing Visualization of PWM Signal Forms

The PWM signal generated by Arduino Uno microcontroller is performed in three duty cycle ranges, namely 25%, 50% and 85%. PWM signals are visualized using an oscilloscope.

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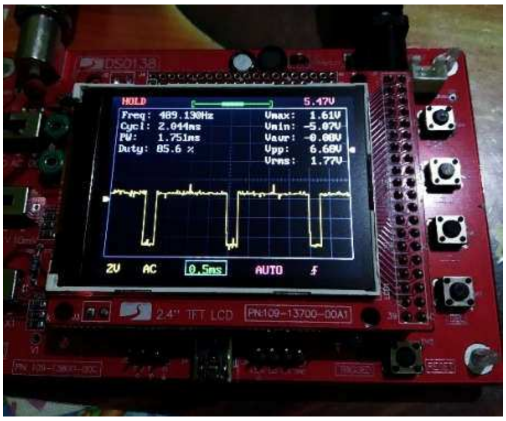

Figure 7. Testing PWM signals

2). Testing Motor Output For Voltage

Testing for voltage on a BLDC motor is done by measuring the phase to phase voltage using a digital multimeter.

Figure 8. Motor voltage testing

3). Testing Motor Output For Currents

Testing the current on the BLDC motor is done by measuring the current flowing in the phase A motor.

Figure 9. Testing motor currents

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4). Testing Motor Output For RPM

BLDC motor RPM testing is done when the motor is running using an infrared tachometer by directing the infrared beam on a sticker affixed to the motor.

Figure 10. Testing of motor RPM

IV. RESULTS

The test is carried out without loading on the BLDC motor, the following is a table for hall sensor signals for mosfet switching times in the 3-phase driver:

Table 1. Hall sensor values for mosfet switching

Hall Sensor Value	Phase	Switches
100	A-B	S3, S6
110	A-C	S3, S2
010	B-C	S5, S2
011	B-A	S5, S4
001	C-A	S1, S4
101	C-B	S1, S6

The following is the test result data presented in the table below:

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Table 2. Duty cycle of voltage, current and RPM

Duty cycle (%)	VAC (volt)	IAC (Ampere)	VDC (volt)	IDC(Ampere)	RPM
5	2	0,07	50,8	0,02	13,5
10	3,7	0,15	50,8	0,04	30,6
15	5,3	0,2	50,8	0,07	48
20	7,2	0,22	50,8	0,1	69
25	9,3	0,26	50,8	0,13	90
30	11,2	0,28	50,8	0,17	113
35	13	0,31	50,8	0,2	133,5
40	15,5	0,36	50,7	0,23	158
45	17,3	0,37	50,7	0,27	179
50	19,2	0,4	50,7	0,3	200
55	21,2	0,42	50,7	0,35	222
60	23	0,43	50,7	0,4	245
65	24,9	0,44	50,7	0,44	264
70	26,3	0,45	50,7	0,46	281
75	27,6	0,46	50,6	0,49	296
80	29,3	0,47	50,6	0,53	314
85	30,7	0,47	50,6	0,53	331
90	32	0,48	50,6	0,6	346
95	33,4	0,49	50,6	0,63	362
100	33,9	0,49	50,6	0,65	369

From the data in table 2 then presented in the form of a graph as follows: The following graph is a duty cycle graph of AC voltage.

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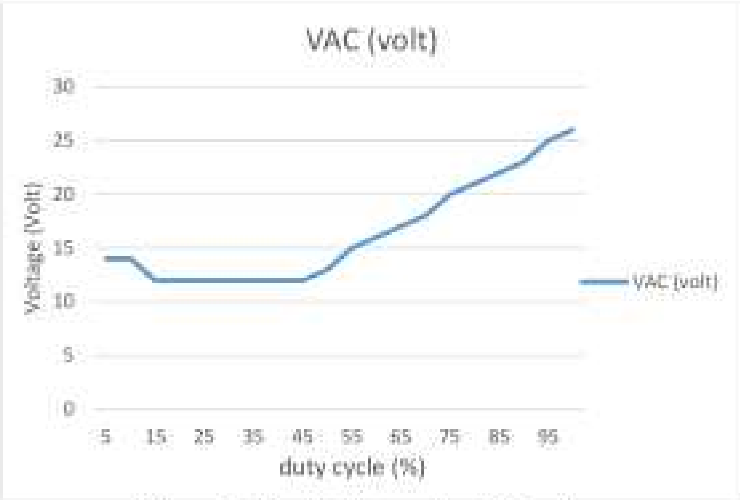

Figure 11. Graphic duty cycle of AC voltage

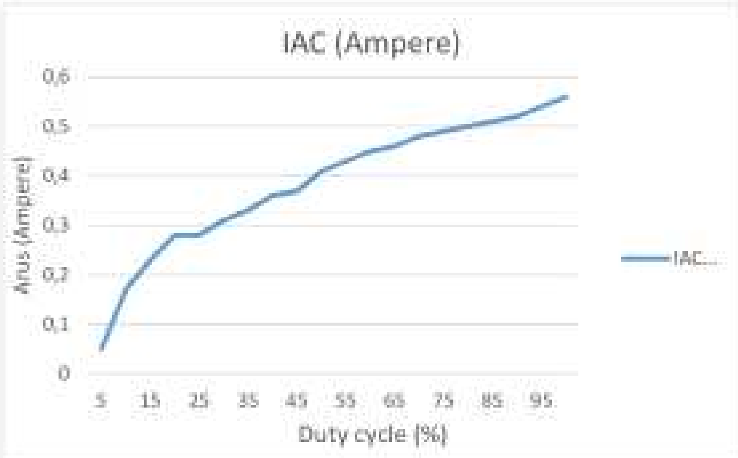

Figure 12. Graphic duty cycle of current

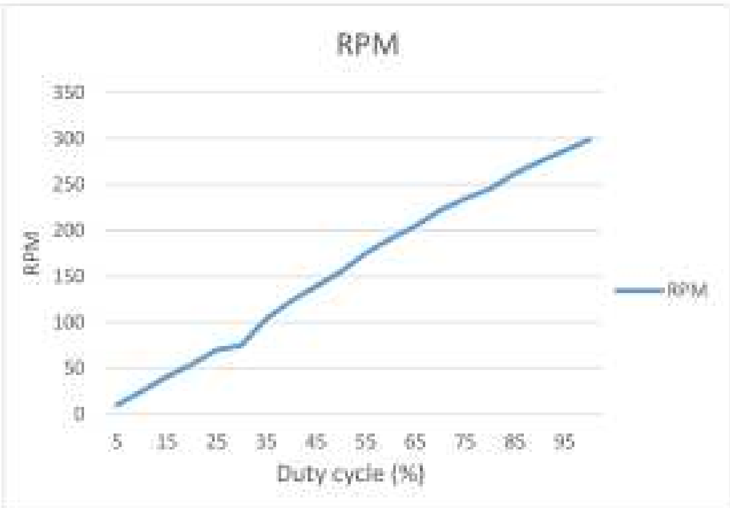

Figure 13. Graph of duty cycle to RPM

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From the figure 11,12 and 13, it can be seen that the three comparison parameters to the percentage value of the duty cycle have increased along with the increase in the value of the duty cycle, this is an indication that the performance of the controller can be said to be good.

From the above data to get power of 350 watts can be determined by the formula of electric power in equation, where the variable value that changes is the current. Of course the current will change when the motor gets a bigger twisting load, the following is the calculation of the current for 350 watts of electrical power:

1). 3-phase electric power formula :

$$P = V \,.\, I \,.\, cos\varphi \,.\, \sqrt{3}$$

Ex :

P	= Power (watt)
V	= Voltage (volt)
I	= Current (ampere)
Cosφ	= Power Factor (0,85)

2). Formula for calculating current if power is known

$$I = \frac{P}{V \,.\, \cos\varphi \,.\, \sqrt{3}}$$

$$= \frac{350}{48 \,.\, 0{,}85 \,.\, 1{,}73}$$

$$= 4{,}95\ A$$

From the above calculations it can be seen that to get the motor power of 350 watts a current of 4.95 amperes per phase is needed, the nominal current is the minimum value needed by the motor so that the motor can run normally when it gets charged.

V. CONCLUSIONS

From the discussion above, it can be concluded that to be able to control the speed of the BLDC motor, it is necessary to vary the input voltage at the gate foot of the MOSFET by adjusting the percentage duty cycle of the PWM signal generated by the Arduino microcontroller.

When the voltage value at the gate foot of the mosfet increases, the current and voltage passing through the drain and source foot will also increase, therefore a mosfet with characteristics that can deliver current according to the motor's power requirements.

To be able to do the switching process on the 3-phase Arduino microcontroller mosfet driver circuit requires signal input in the form of rotor position information using a magnetic field sensor component in the form of hall effect sensor.

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