

Switching Scheme for Regenerative Braking Mode for BLDC Motor Driver

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Abstract: At present, the BLDC motor is commonly used for an electrical vehicle due to its high efficiency, high frequency and able to regenerate energy. Research that uses MATLAB/Simulink and Arduino IDE software to construct the simulation and hardware to prove the BLDC motor with switching scheme is able to generate energy when the braking process is held on. The MATLAB/Simulink software is used for simulating the BLDC motor virtually. Before constructing the hardware needs to ensure the concept is true as well as able to get the expected result. The Arduino IDE software is used because the Arduino Uno will be used as a microcontroller in this project for controlling the switching scheme, braking system and speed sensor. The results show that the switching scheme is able to operate in regenerative braking mode. Therefore, it is important to study both simulation and hardware to ensure the study will be more accurate.

Keywords: BLDC Motor, Regenerative Braking, Charging Battery, MATLAB, Arduino

1. Introduction

With the increasing use of petrol vehicles and the increase of carbon dioxide to the environment has become more and more serious. The increasing of atmospheric pollution and haze problems have aroused the government's emphasis on energy conservation and new energy applications. An electric vehicle has diversified sources of energy, zero emissions or ultra-low emissions, energy conversion efficiency, and other technical advantages, with a high degree of attention [1]. The EV will be more environmentally friendly because conventional energy like diesel, petrol, and gases that pose problems related to environmental pollution will not be used by EVs.

Brushless dc (BLDC) motors have many advantages over brushed dc motors and induction motors, such as simple structure, high efficiency, high dynamic response, higher speed range, large starting torque, noiseless operation, etc. [2]. Using three or more hall sensors, a sensor-ed BLDC motor determines the rotor position and speed. The BLDC motor is driven by a trapezoidal or rectangular

voltage linked with hall sensors [3]. Regenerative braking is the process of feeding energy from the motor drive back into the battery during the braking process. The back-EMF must be boosted using a dc-dc converter during this regenerative mode of operation so that the electrical energy can be pumped back to the battery at the appropriate voltage level. [4].

2. Materials and Methods

This section explains the implementation of the regenerative braking of a BLDC motor with a maximum energy switching scheme and how the battery charging process when the system brakes. This simulation will not include the forward motoring operation and also the regenerative braking process. MATLAB R2021b software is used to simulate the system. The purpose of the simulation is to confirm the design parameters to function before doing the hardware. The hardware required lots of components and electronic applications and the MATLAB/SIMULINK was able to ensure the design is fully functioning. In addition, the Arduino IDE software is used for programming the system because the Arduino Uno is used as a microcontroller for this project. Program the coding and insert it into the Arduino Uno to operate the BLDC motor and the regenerative braking system.

2.1 Development Process Flowchart

Figure 1 shows the flow chart of the research for the BLDC motor. At the first, the research project is to study deeply about the project. Then, confirm the concept with the supervisor to process the next stage which is to develop the simulation. MATLAB/SIMULINK is the software used in this project.

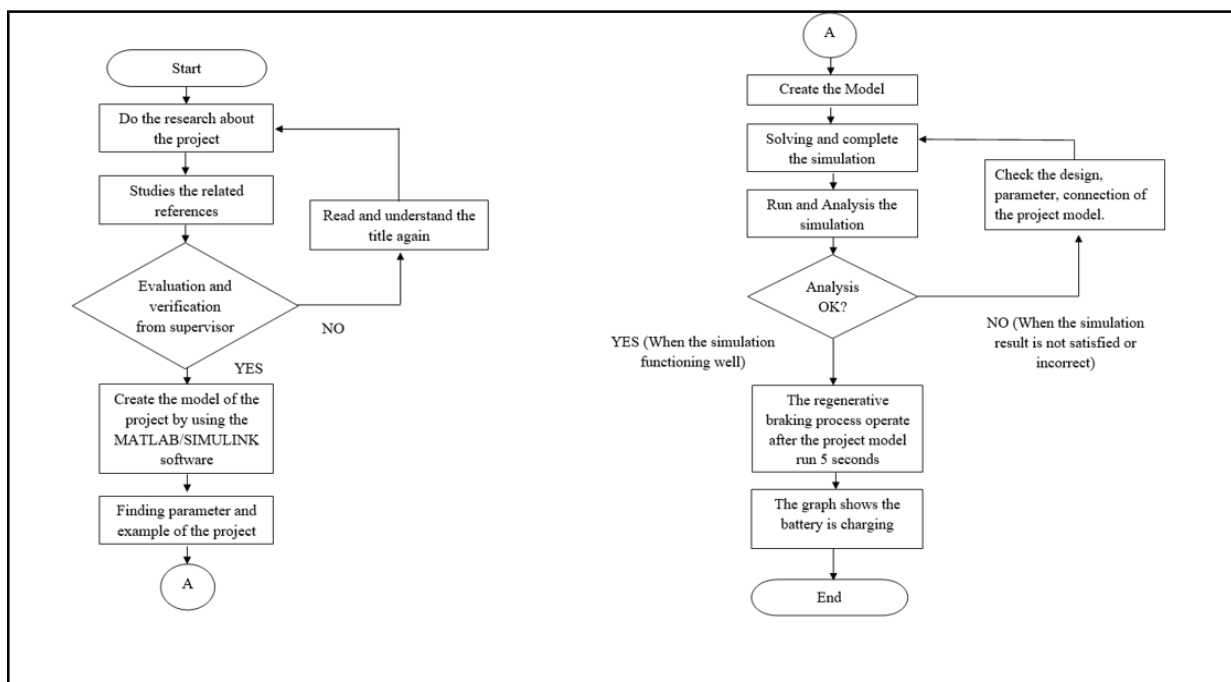


Figure 1: Flowchart of the simulation.

Figure 2 shows the process of developing the hardware model. Firstly, the suitable components and its quantity have to be confirmed to build the hardware. Construct the hardware and then program the hardware using Arduino IDE software. If the hardware not functioning well had to check the algorithm, connection, and coding again. If the hardware is functioning, the result on the graph and sensor will be recorded.

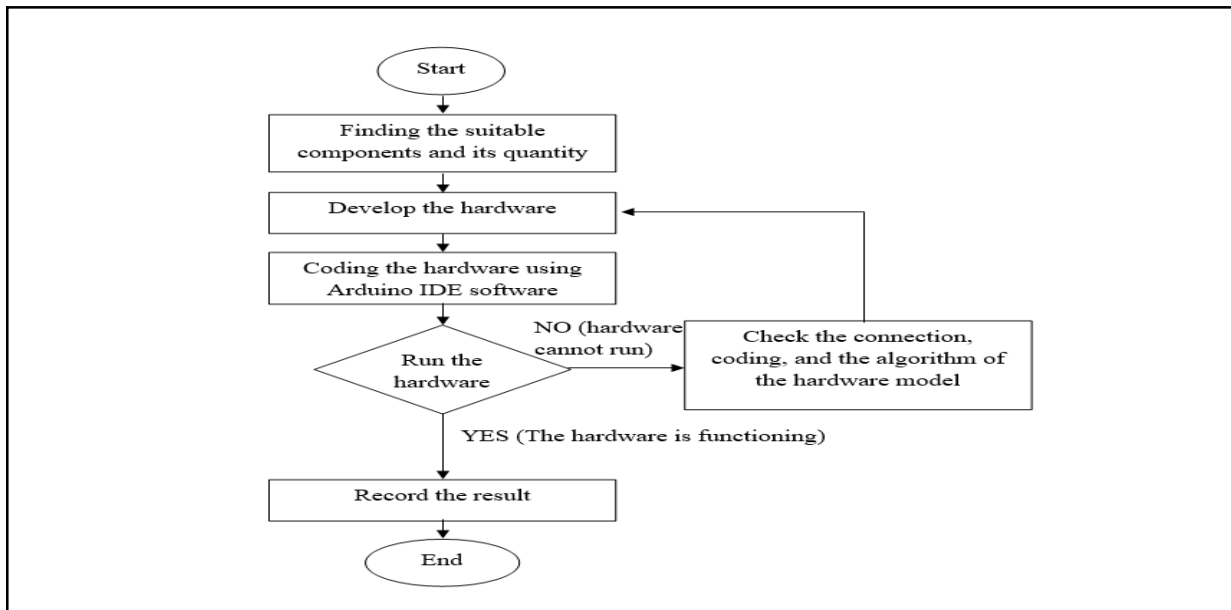


Figure 2: Flowchart of the hardware setup.

2.2 Setup of BLDC motor simulation

Figure 3 is the simulation model of the BLDC model to verify the regenerative braking system is able to charge the battery. The working principle is the 6 switches inverter control the BLDC motor to operate. The logic gates will detect the hall sensor in the BLDC motor and transfer the signals to the 6 switches inverter as well as transmit the braking command. Figure 4 shows the logic gates of this BLDC motor model.

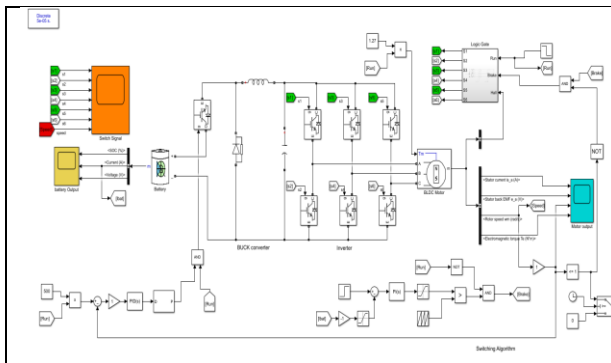


Figure 3: BLDC simulation model

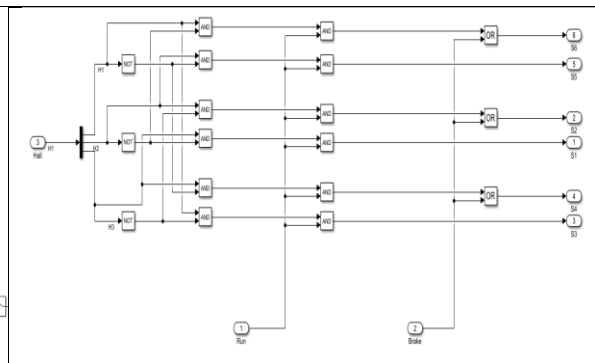


Figure 4: Logic gates

2.3 Setup of BLDC motor hardware

After completing the simulation, the development of the hardware is started in order to prove the simulation for the BLDC motor with regenerative braking can function in a real setup. Table 1 is the components and their quantity that need to use in this hardware setup. Figure 5 is the completed BLDC motor hardware setup. 6 MOSFET is the switching scheme for the BLDC motor to control the rotation of the BLDC motor. The Arduino Uno is the microcontroller in this system same as the logic gates in the simulation. The pushbutton is the brake to stop the system and the rotary encoder is the speed sensor to measure the speed of the BLDC motor.

Table 1: Components for the BLDC motor hardware development.

Components	Quantity
Brushless DC motor	1
IRFZ44N MOSFET	6
10k Resistor	6
1k Resistor	1
Pushbutton	1
Rotary Encoder	1
Breadboard	1

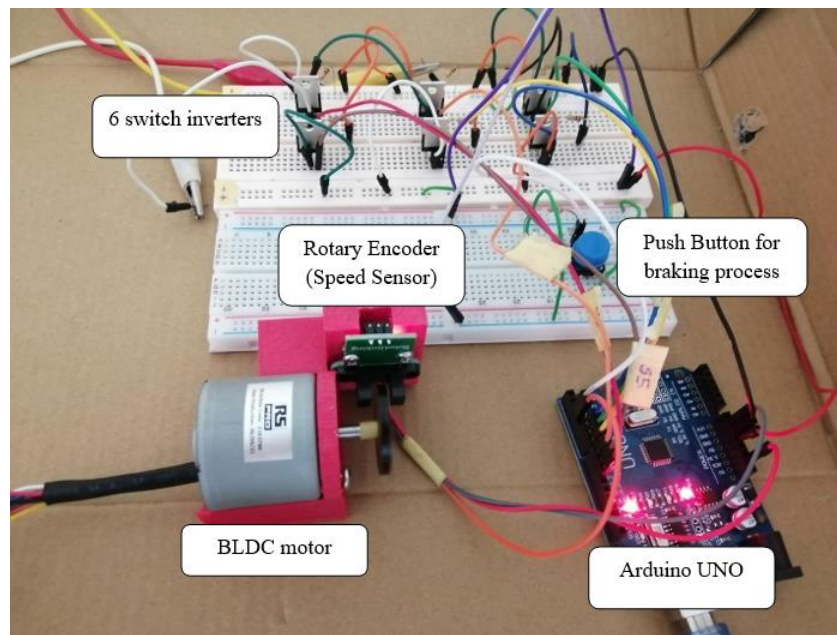


Figure 5: The hardware setup of the BLDC motor.

3. Result and Discussion

The result will show the regenerative braking process on the system and the battery charging after the system is stopped. Also, the result of the BLDC motor and switches in the inverter after the system is stopped and the speed of the rotor.

3.1 Simulation Result

The simulation result for the BLDC motor is to show the motor current, speed, back-emf, and torque for the system. Figure 6 shows the system stopped at 5s and the regenerative braking occur at 6s. Regenerative braking occurs due to the s2 and s6 switches being closed at 6s. Figure 7 shows the switching signal of the 6 switches inverter compared to the speed. In addition, the battery output result in Figure 8 shows the voltage, current and source of charge (SOC) and proves the battery charging after the BLDC stopped.

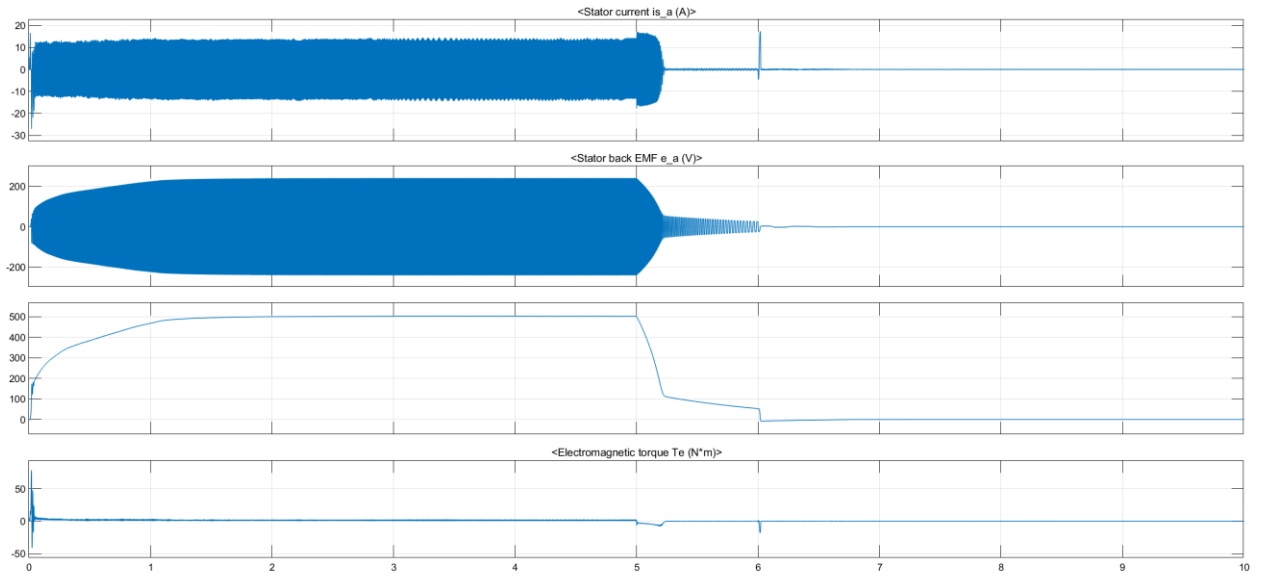


Figure 6: The BLDC motor results.

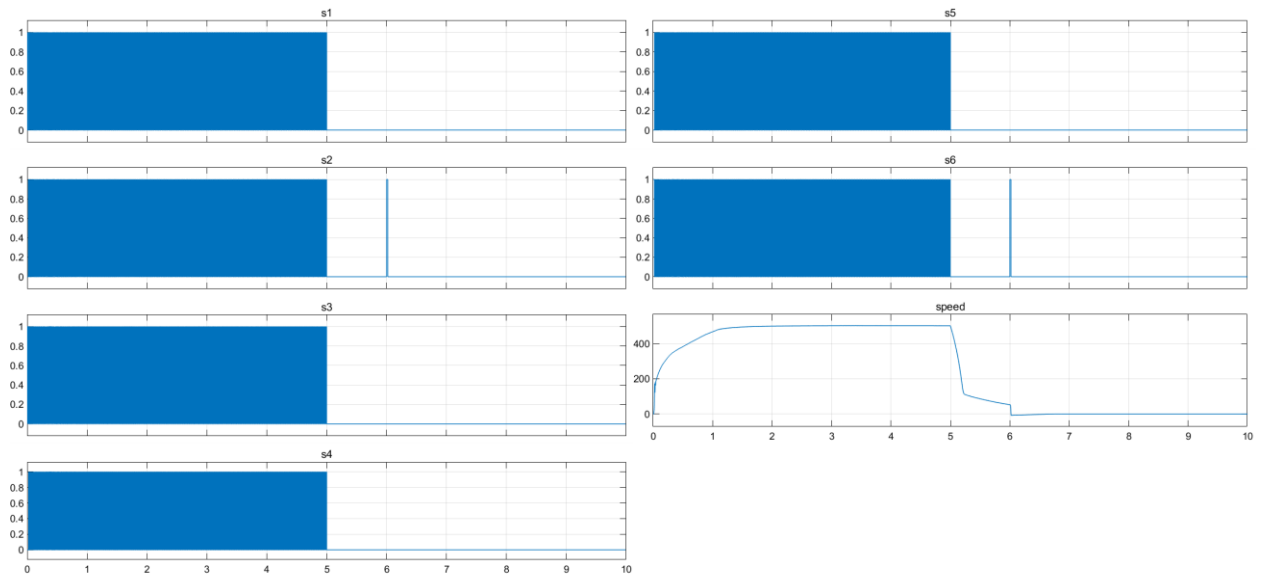


Figure 7: The switching signal and the motor speed.

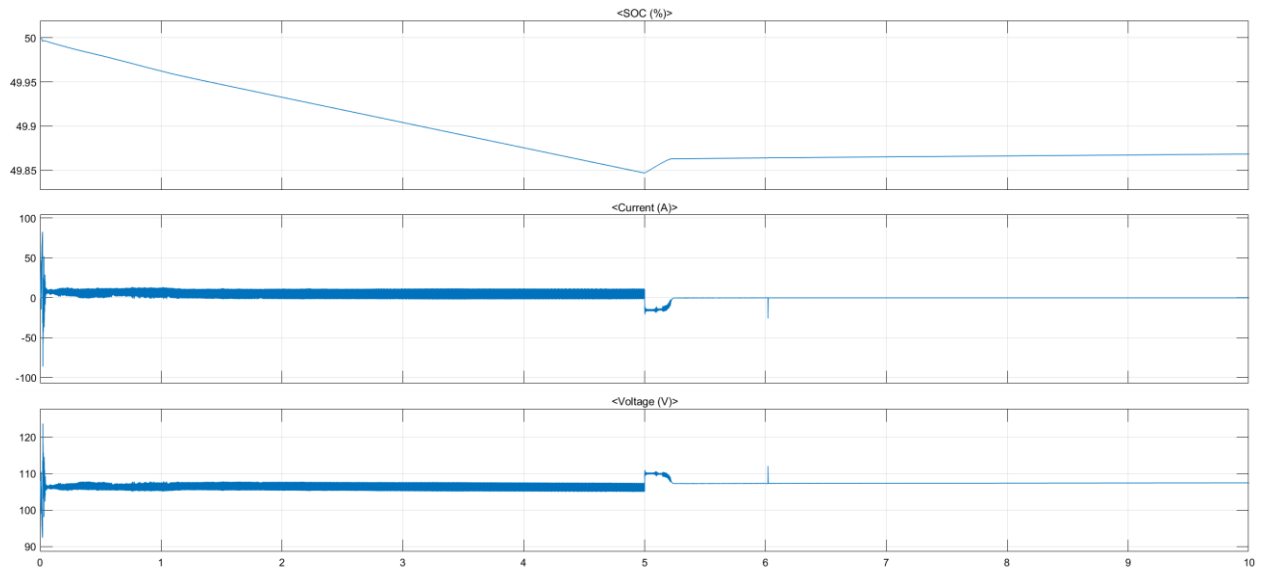


Figure 8: The battery output.

3.2 Hardware Result

The rotary encoder measures the speed of the motor and transfers the result into the Arduino IDE software. When the pushbutton holding on, the system is stopped immediately and the resulting form of Arduino IDE is shown in Figure 9. However, the battery was not used in this hardware setup due to time constraints. The oscillation scope was the replacement for the battery, it able to measure the voltage input of the hardware setup. Figure 10 shows the scope of oscillation and proves the voltage have rising when the system braking.

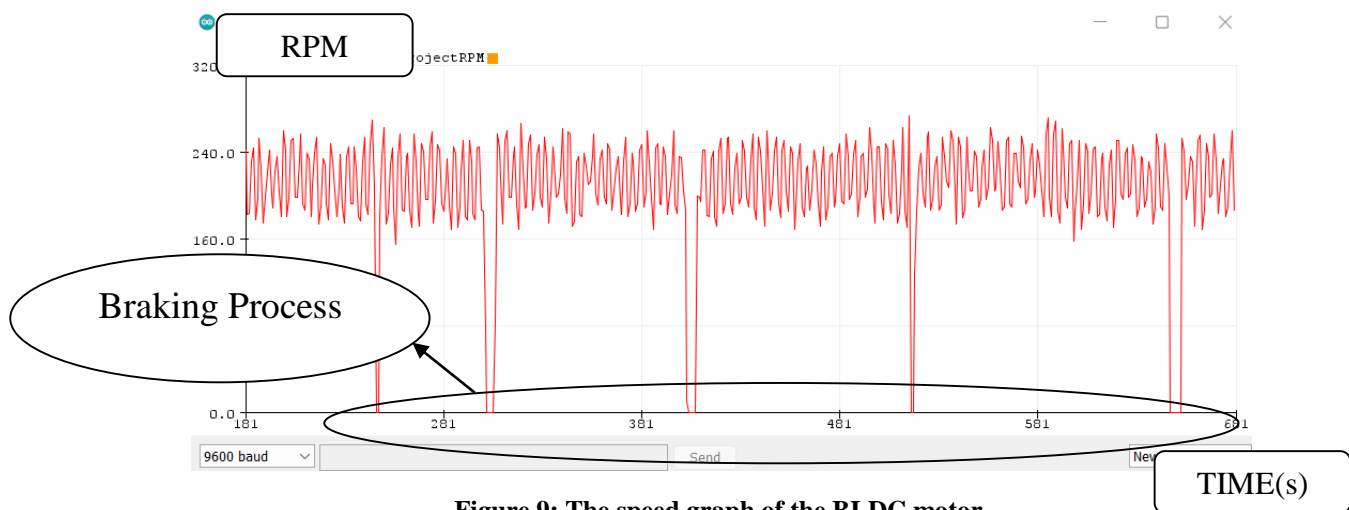


Figure 9: The speed graph of the BLDC motor.

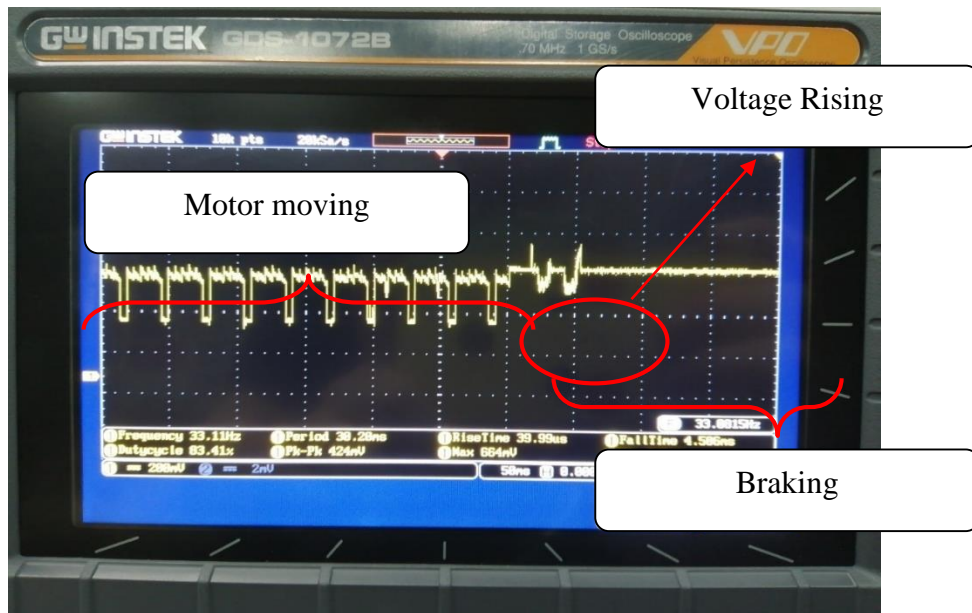


Figure 10: Scope Result for the BLDC motor's voltage.

4. Conclusion

The main goal of the project was to study and design regenerative braking and battery charging for a BLDC motor with a switching scheme. The simulation for the design the BLDC motor is very important to evaluate the speed of the motor, the source of charge for the battery, and the switching sequences for the switches in the inverter. The results of the simulation will be able to show us the regenerative braking process which is able to charge the battery after the system is stopped. Development of hardware model by using Arduino UNO as the microcontroller to measure the speed of the BLDC motor as well as the voltage input. The result of the hardware proved the simulation result of this project correct. In the voltage graph, the graph rises up a bit and then stays constant when the system is braking.

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