Implementation of 2 Phase Winding and 3 Phase Winding Connected Commutation to Voltage and Load On External Rotor Brushless Direct Current (BLDC) Motor

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Abstract
Driver is a major part of a vehicle. One part of the driver is a Brushless Direct Current Motor (BLDC). BLDC has many advantages than the ordinary DC motor, in example is a commutation which can be separated, such that 2-phase winding connected commutation and 3-phase winding connected commutation. 2-phase winding connected commutation process begins from 30° initial movement point, while for 3-phase winding connected commutation process begin from 0° initial movement point for each electrical displacement. Then, for medium power occurs in 2-phase winding connected commutation and for maximum power occurs in 3-phase winding connected commutation. In this research, the response we want to observe is the number of RPM for each increment of duty-cycle given in BLDC motors, with varying values of voltage and load. This research has been successfully implemented on BLDC motor speed control system with duty-cycle regulation viewed from each of the switching commutation, which is for 2-phase windings connected commutation obtained amount of RPM lower than the 3-phase windings connected commutation, both for state voltage of 12V or 24V and for condition with load or without load.

Keywords: BLDC; RPM; load; brushless

INTRODUCTION
The part of a motor is a main part from a vehicle. One of the main part of the motor is Brushless Direct Current Motor (BLDC). BLDC is used because it has many advantages such as it didn’t consume electricity power by excitation magnetic system, has torsi and more power-full than induction motor, has a simple construction that can increasing the fee of a production for used in some machine.

This BLDC’s one-way without a brush has commutation that can be separate, that is commutation of 2 connected fasas’ coil and commutation of 3 connected fasa’s coil. The commutation of 2 connected fasa’s coil first movement is started from 30° and the commutation of 3 connected fasa’s coil’s first movement is started from 0° for each electricity movement. So the average power can be exist in commutation of 2 fasa’s coil and maximum power can be exist in commutation of 3 fasa’s coil. Because of that different, author wants to see the impact for each commutation by doing some experiment in BLDC’s motor, by given a variation of value of a tension and a burden of mechanic to BLDC. Whilst RPM is a respond to observe for each amount of PMW that given to. And anova is used for he processing and the conclusion in the end. The result from this observation is to know about the different torsion that happen between combination system of 2 connected fasa’s coil and combination of commutation of 3
connected fasa’s coil by observe the amount of the rotation per minute (RPM) to every duty cycle that has given.

Motor BLDC is used in motor application because it has many advantages. Motor BLDC didn’t have many brush so it didn’t spend a time be waste to care. It didn’t effect a noisy than a conventional motor. Motor BLDC is composed by rotor and stator. Rotor is a spin part and stator is a part that ism by an electricity flow in sequence. And sensor hall that has integration with BLDC that can be used as detection of magnetic rotor.

The principle of motor BLDC is started from rotor can be spin because of the coil on the stator drained by electricity in consecutive and spin so it caused a magnetic field and spin followed by magnetic field on the rotor side. The different lie on switching regulation system which doing by electronic switching. BLDC switching motor always adjust as always, so the stator coil which produce the magnetic field direction form a corner by the magnetic field direction rotor. So the magnetic on the rotor always trying to activate rotor, so the magnetic field direction and magnetic field that be produced by stator coil can be in the same direction.

In order to this rotor movement be a continue spinner movement, so stator coil which is drained by electricity constantly changed before the magnetic field direction of rotor turns to parallel with the direction of magnetic field by stator coil. This matter required a switching timing in the right time. For decided the right commutation timing on the motor so it can produce the constant torsi and the constant speed, it needs 3 sensor hall and/or encoder. Switching timing (commutation) is decided by detection of magnetic field rotor which used 3 sensor hall to gain 6 different combination timing. Driver 3 fasa motor BLDC is used as a switching system which determined switching (commutation) as a part of a process for twist BLDC motor.

![Fig 1. Simple Series of Switching Motor BLDC 3 Phase System](image)

Because of Motor BLDC 3 phase has 3 terminals on its stator’s coil, so it can do switching, that is the combination of switching with combination of 2 connected switching (commutation) even for switching 3 connected terminal system and switching 2 connected terminal system connected in a good condition for the same direction of clockwise and opposite of the clockwise

| Table 1: The Switching of 3 Connected Fasa Coil |

<table>
<thead>
<tr>
<th>Terminal (€)</th>
<th>Polarity terminal (GND, blue, yellow)</th>
<th>Fasa Terminal</th>
<th>Motor state (1=1, 0=0)</th>
<th>Exchange terminal (Kuning)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0=360° GND, blue, yellow</td>
<td>+Vs</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0=360° GND, blue, yellow</td>
<td>+Vs</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1=180° GND, blue, yellow</td>
<td>+Vs</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>2=180° GND, blue, yellow</td>
<td>+Vs</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>3=360° GND, blue, yellow</td>
<td>+Vs</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>4=360° GND, blue, yellow</td>
<td>+Vs</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Motor BLDC works when stator that made from bobbin given by the flow of 3 fasa. Because of that bobbin on the stator magnetic field (B) is arise:

\[ B = \frac{\mu N I}{2i} \]
When
\[ N = \text{Amount of the coil} \]
\[ I = \text{Flows} \]
\[ l = \text{length of the coil} \]
\[ \mu = \text{permeability of the material} \]

**Table 2:** The Switching of 2 Connected phase Coil

<table>
<thead>
<tr>
<th>Order</th>
<th>Phase</th>
<th>Terminal</th>
<th>Polarization</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>30°</td>
<td>+Vs</td>
<td>QND</td>
</tr>
<tr>
<td>1</td>
<td>90°</td>
<td>-Vs</td>
<td>QND</td>
</tr>
<tr>
<td>2</td>
<td>150°</td>
<td>+Vs</td>
<td>QND</td>
</tr>
<tr>
<td>3</td>
<td>210°</td>
<td>-Vs</td>
<td>QND</td>
</tr>
<tr>
<td>4</td>
<td>270°</td>
<td>+Vs</td>
<td>QND</td>
</tr>
<tr>
<td>5</td>
<td>330°</td>
<td>-Vs</td>
<td>QND</td>
</tr>
</tbody>
</table>

Because of the flow is given a flow AC phase, the amount of the magnetic field and polarization of each bobbin will be changeable everytime. The impact that can be showed because of that polarization and the amount of the magnetic field for each bobbin are occurrence the spin of magnetic field by the speed of \( N_s \):

\[ N_s = \frac{120f}{P} \]

When:
- \( F = \text{the frequency of input tension by Hz per second} \)
- \( P = \text{the amount of pole on the rotor} \)
- \( 120 = \text{on rotation (360) per 3 fasa motor} \)

When RPM (Revolutions per minute) and KV state for constant motor speed measured by RPM per volt. Here is the Picture 2.3 showed the form of wiring diagram BLDC.

![Wiring Diagram BLDC](image1)

**Fig. 2:** Wiring Diagram BLDC

Pulse Widely Modulus (PWM) be attained by a support of wave box, which is duty cycle of that wave is changeable. To get the variation of outer tension in which an average from that wave. Just like the Fig 2.13 below:

![Pulse Widely Modulus](image2)

**Fig. 3:** Pulse Widely Modulus
$T_{on}$ is a time when outer tension occure on the high position (red: high or 1) and $T_{off}$ is a time when outer tension lie on the low position (red: low or 0). Consider that $T_{total}$ is a time for one siklus or the amount between $T_{on}$ and $T_{off}$, known by named “one wave periode”

$$T_{total} = T_{on} + T_{off}$$

A dutycycle of the wave is definition by:

$$D = \frac{T_{on}}{(T_{on} + T_{off})} = \frac{T_{on}}{T_{total}}$$

The outer tension can be variation with dutycycle and can be assumed as:

$$V_{out} = DxV_{in}$$

So,

$$V_{out} = \frac{T_{on}}{T_{total}} xV_{in}$$

From the formula above can be resume that the outer tension is changeable directly by changing the amount of $T_{on}$

when $T_{on}$ is 0, $V_{out}$ will be 0. When $T_{on}$ is $T_{total}$ so $V_{out}$ is $V_{in}$ or maximum amount.

**DESIGN AND THE IMPLEMENTATION**

This research will implementation the system of Motor BLDC speed 3 fasa for application vehicle electric to see the amount of tortion from each commutation from an amount of the coil’s motor in one minute (RPM), wich is this system has diagram blok, as shown as:

![Diagram Scheme of Control System’ Flow BLDC](image)

**Fig. 4:** Diagram Scheme of Control System’ Flow BLDC

From the picture above has shown that in this research, author used 2 microcontrollers Arduino Uno, first Arduino Uno is used for commutation process, and the second Arduino Uno is used for reading the amount of spin for each minute (RPM) and for display to LCD. Driver is a tool that has a function to connect the motor to the system that author’s plan. Potensio’s function is adjust the size of duty cycle from PMW. The added exor series that used for connect 3 sensor hall, so the outer from sensor hall’s amount only 1 or just 0, this used because the author used program counter to counting its RPM.

![Scheme Diagram of Commutation of Control System’s Flow BLDC](image)

**Fig. 5:** Scheme Diagram of Commutation of Control System’s Flow BLDC
EXPERIMENTAL RESULT

Driver Motor BLDC 3 Phase
The detail of switching series that used in this research can be shown in Picture 3. The series of the switching is the series that design and built by complete the series on the research before, which is adding or making less the component that is used. On the picture of switching series, terminal R, S and T are the terminal that connected with terminal stator motor coil. Terminal (+) and (-) are terminal that used to connect between power tension supply with switching series. 6 terminals that used as pin connector between microcontroller by AND logic. And the last is terminal ground that connected by terminal ground from power supply microcontroller even master or slave. On this switching series is used MOSFET IRF540 that has function as electronic switch. The amount of the MOSFET that used is 6 MOSFET, which is 3 MOSFET used to switch connector 3 terminal coil stator for each positive terminal power supply and 3 MOSFET is used as connector of 3 terminal stator with negative terminal power supply.

Except MOSFET, this switching series also used optoisolator TLP250, which is the amount of its are 6 too, each of outer optoisolator connect to MOSFET and the input connect with a pin from microcontroller. Because of that this series is isolator series in which optoisolator TLP250 being the reference from between controller series by inverter series. Apart of that on this series given 2 diode 3A which is be assembled as parallel so it can held their alternating current about 6A.

![Driver Series Motor BLDC 3 Fasa](image)

**Fig. 6: Driver Series Motor BLDC 3 Fasa**

Implementation switching system (Driver) Motor BLDC 3 Phase
On the table 5 shown table for implementation on microcontroller for motor spin BLDC clockwise with 2 connected Phase. While table 6 shown implementation on microcontroller for motor spin BLDC clockwise with 3 connected Phase.

**Table 5: Implementation Switching System 2 Connected Terminal Phase**

![Table 5](image)

**Table 6: Implementation Switching System 3 Terminal Phase**

![Table 6](image)
Fig. 7: Diagram of Implementation of Recitation Motor Speed BLDC

The examination of error scale (duty cycle 0%-100% and duty cycle 100%-0%) from system to the amount of RPM for Combination of 2 and 3 connected Phase coil.

Fig 8. Combination Switching 2 connected Phase coil
Fig 9. Combination of Switching 3 Connected Phasa Coil

CONCLUSION
1. The measurement error test that designed for 2 connected Phase coil and combination of 3 connected Phase coil with a variation of input tension and variation load produce a respond to increase a value of PMW to an amount of RPM shown a value measurement linear.
2. For the system that had designed works well on dutycycle on 10% - 80%
3. Test of the impact tension to an amount of RPM for combination of 2 connected fasa coil and combination of 3 connected Phase coil. The result is there had a different of amount of RPM between input tension of 12V with input tension of 24V.
4. The test of error measurement on the system that had designed for combination 2 connected Phase coil and combination of 3 connected Phase coil by a variation input tension and variation of load had result can raising respond of PMW to an amount of RPM shown a linear value.
5. For the system that had designed it works well on dutycycle between 10%-80%.
6. The test of the impact tension to an amount of RPM for combination of 2 connected Phase coil and combination of 3 connected Phase coil. The result is there a different of an amount of RPM between input tension 12V by input tension 24V.

REFERENCES