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# DEGISN OF A CHARGING SYSTEM USING AN ALTERNATOR TO SUPPORT THE PERFORMANCE OF THE REGENERATIVE BREAK SISTEM IN ELECTRIC VEHICLE

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**Abstract**
*The use of electric vehicles is now supported by a braking system capable of absorbing energy wasted from the braking process, known as regenerative brake. This research aims to optimize the use of the regenerative brake system by adding an alternator as a power generator to achieve more optimal charging. The voltage magnitude in the testing of the electric motorcycle NIU GOVA 03 obtained a generation voltage of 26VDC when traveling downhill for 100 meters at a speed of 45km/h. After designing the alternator for the electric motorcycle, the generation output increased to meet the battery charging voltage specification of 74VDC, suitable for application as a power source for a battery with a capacity of 60V14.7Ah. The braking portion before using the regenerative brake system over a distance of 100 meters took 4.8 seconds, but after implementing the regenerative brake system, the time decreased to 5.1 seconds. This indicates that the regenerative brake system, coupled with the alternator, can provide an effect in the form of decelerating the electric motorcycle by 8.7%.*

## 1.0 INTRODUCTION

The use of electric vehicles is now supported by braking systems that can capture wasted energy from the braking process, known as regenerative braking. Electric motorcycles generally use BLDC (Brushless Direct Current) motors with varying power capacities as their primary drive system. The selection of the BLDC motor for electric motorcycles is done through mathematical calculations. Accurate calculation in selecting the right motor capacity can reduce errors such as choosing a motor with power that is either too large or too small. This becomes one of the challenges in managing the battery consumption of electric motorcycles. All types of vehicles have various potential causes for accidents. Accidents can occur due to several factors, one of which is human factors. Therefore, the design and development of an alternator to support the performance of the regenerative braking system is expected to influence the deceleration of the BLDC motor's rotational speed (rpm), thereby affecting the vehicle's speed reduction. The alternator focuses on creating a battery charging cycle for electric motorcycles while the regenerative braking system is operating. Thus, calculating the capacity of the motor that can efficiently drive the alternator is crucial.

Based on the background provided, the author intends to design an alternator to support the performance of the regenerative braking system. It is hoped that the design and development of the alternator will be implemented in the creation of better electric motorcycles.

## 2.0 THEORETICAL

### 2.1. Theory is related to the object of research

Regenerative braking is an electric braking system that can slow down a vehicle while also capturing kinetic energy during braking, which can be used for other needs on the vehicle (Pradipta 2018). By harnessing mechanical energy from the motor and converting kinetic energy into electrical energy, it is fed back into the battery. Theoretically, regenerative braking systems can convert a small portion of their kinetic energy to charge the battery, using principles similar to those of an alternator. Regenerative braking systems commonly used are mechanical and electrical systems. Regenerative braking has been successfully implemented and can shorten the time required for motor deceleration, with an average time of 0.4654 seconds, while the fastest time is 0.143 seconds and the longest is 0.661 seconds (Prima Nugraha Ardiansyah, 2022). In mechanical regenerative braking systems, the absorbed energy is stored in a flywheel and used to assist the engine in the vehicle's acceleration process. In electrical regenerative braking systems, the absorbed energy is converted into electrical energy through a BLDC motor and stored in the battery.

This research was conducted by Melda Latif et al. (2018). Regenerative braking is a mechanism for recovering energy lost during the braking process. Normally, during braking, the kinetic energy from the moving wheels is converted into heat due to brake friction. In regenerative braking, this kinetic energy is converted into electrical energy with the help of a dynamo. The aim of this study is to determine the current, voltage, and power generated from the regenerative braking of a bicycle using a bicycle dynamo. By adding a prototype consisting of a bicycle dynamo, a rectifier, and a DC-DC converter, regenerative braking can be converted into electrical energy. The research was conducted with three different conditions on the front disc brake of the bicycle: with rough insulation, smooth insulation, and no insulation. The best testing result was achieved with rough insulation. At a speed of 70 km/h, the voltage, current, and power produced were 12.8 volts, 130 mA, and 1664 mW, respectively. The advantage of using rough insulation is that the friction force and slip produced are minimal. The heat generated is less compared to smooth insulation and no insulation, and the noise produced during testing is also lower.

This research was conducted by Prasetyo et al. (2021), which discusses how to determine the capacity of a brushless direct current (BLDC) motor as the drive system for an electric car. This study has several objectives: (1) To identify the appropriate type of motor to use for an electric car with a single-passenger capacity. (2) To determine the capacity of the electric motor used as the drive system for an electric car with a single-passenger capacity. This research employs the Research and Development (R & D) level 1 method, with the research subjects being students and lecturers from the Automotive Engineering Education Department of Universitas Muhammadiyah Purworejo, totaling 8 students and 4 lecturers. The "SALWA" electric car from Universitas Muhammadiyah Purworejo is planned to use a Brushless Direct Current (BLDC) hub motor. The "SALWA" electric car uses a 2000-watt BLDC hub motor operating with a voltage range of 49 volts to 96 volts.

This research was conducted by Melda Latif et al. (2018), which focuses on utilizing mechanisms to recover energy lost during friction in the braking process of motorcycle disc brakes. In regenerative braking, this kinetic energy is converted into electrical energy with the help of a dynamo. The aim of this study is to determine the current, voltage, and power generated from the regenerative braking of a motorcycle using a bicycle dynamo. By adding a prototype consisting of a bicycle dynamo, a rectifier, and a DC-DC converter, regenerative braking can be converted into electrical energy. The research was conducted with three different conditions on the front disc brake of the motorcycle: with rough insulation, smooth insulation, and no insulation. The best testing result was achieved with rough insulation. At a speed of 70 km/h, the voltage, current, and power produced were 12.8 volts, 130 mA, and 1664 mW, respectively. The advantage of using rough insulation is that the friction force and slip produced are minimal. The heat generated is less compared to smooth insulation and no insulation, and the noise produced from the friction during testing is also lower.

electric motor is a type of machine that can convert electrical energy stored in a battery into mechanical/kinetic energy. Typically, electric motors use brushless DC (BLDC) motors. Generally, electric bicycles/motorcycles do not use feedback systems. In electric motorcycles, the vehicle's operational condition can be monitored through speed (km/h) and battery status (in percentage), which is usually displayed on a small monitor screen that serves as an indicator for the rider, allowing them to control and operate the vehicle effectively (Kumara, 2021).

## 3.0 METHODOLOGY

The research was conducted at the Faculty of Engineering, Udayana University, Jimbaran, South Kuta District, Badung Regency, and field research at PT. RODA ELEKTRI GELIMANG, located at Jl. Antasura No.50, Peguyangan Kangin, North Denpasar District, Denpasar City, Bali 80115. Data analysis can be seen in the figure :

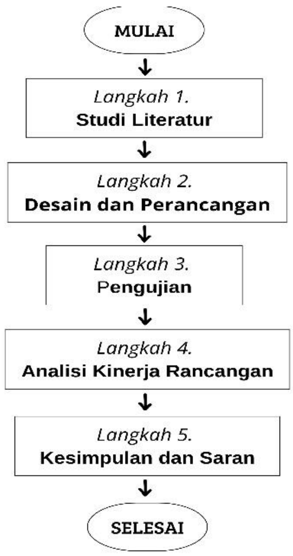


**Figure 1. Research Flowchart**

Step 1. Literature Review
The research begins with a literature review as a guideline for the work, followed by calculations to select the specifications for the BLDC motor and the alternator, and to determine the parameters that will describe the real conditions of the testing.

Step 2. Design
Designing is done after the author obtains the appropriate specifications. For all the component parts in the design, the author purchases them from the domestic market.

Step 3. Testing
In the testing process, the parameters from the calculation stage are used to evaluate the alternator's performance and observe the voltage increase according to the settings on the DC to DC Boost Converter.

Step 4. Performance Analysis of the Tool Design
The analysis stage is conducted to observe whether the regenerative brake operates as planned and to review factors that might hinder the performance of the regenerative braking system in electric motorcycles.

Step 5. Conclusions
Based on the fourth step, conclusions can be drawn.

### 3.1 Realization of Electrical System

In the research on the design and development of an alternator to support the performance of the regenerative braking system in electric motorcycles, the author first creates an electrical schematic to facilitate the design process, as shown in Figure :

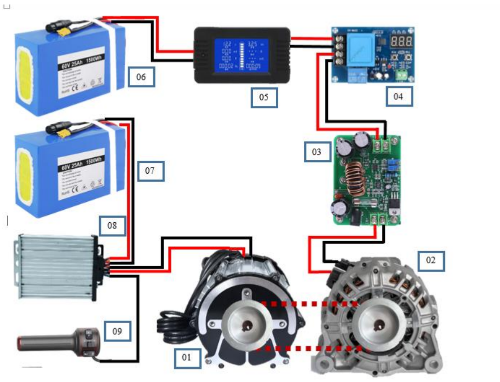


**Figure 2. Realization of Electrical System**

### 3.2 Implementation of the Alternator Design

From the electrical system detailed in section 3.2, the author designed the alternator to be positioned correctly so that the coupling process between the BLDC motor and the alternator using a V-belt aligns with the plan, as shown in Figure 3.

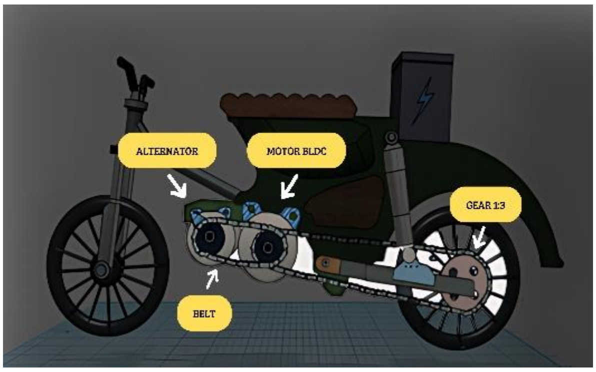


**Figure 3.** Design of the Alternator for the Regenerative Brake System

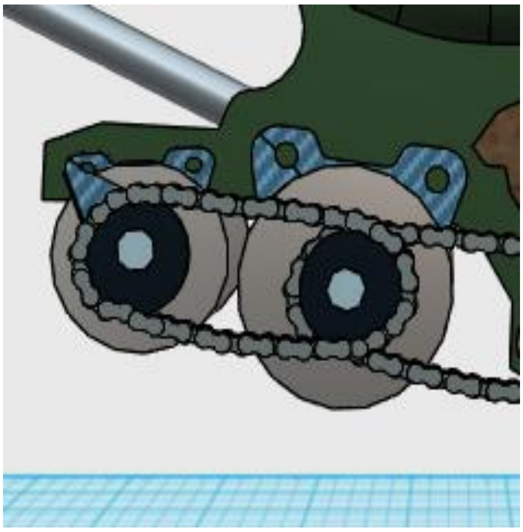

**Figure 4.** Implementation of Alternator Coupling with the BLDC Motor

### 3.3 Alternator Prototype as a Support for the Performance of the Regenerative Brake System in Electric Motorcycles

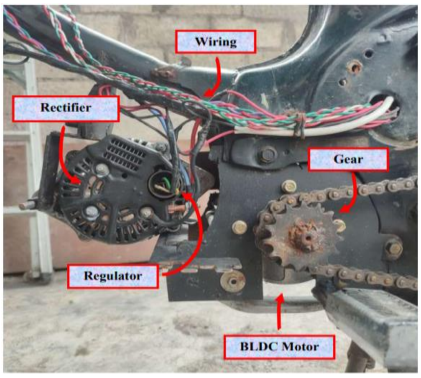


**Figure 5.** Left Side Alternator Coupling

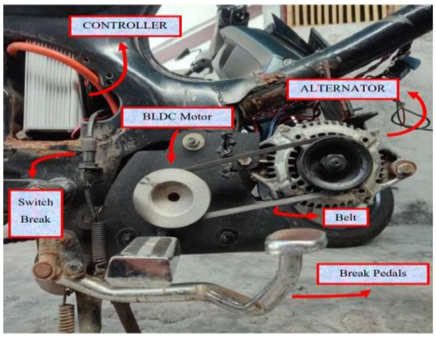


**Figure 6.** Right Side Alternator Coupling

## 4.0 RESULANTS

To obtain results that accurately reflect real conditions, the author conducted the tests under two different road conditions: downhill and flat, as shown in Figure X and detailed in Table 1 below.

### 4.1 Testing in Maydown

**Figure 7.** Testing in Maydown

**Tabel 1.** Data from alternator testing on maydown

| Test | distance | speed | Time |
|---|---|---|---|
| Test. 1 | 100 Meter | 20km/h | 5 |
| Test. 2 | | 18km/h | 5,5 |
| Test. 3 | | 19km/h | 5,1 |
| Test. 4 | | 20km/h | 5,1 |
| Perc. 5 | | 19km/h | 5 |
| Perc. 6 | | 20km/h | 5 |
| Perc. 7 | | 20km/h | 5 |
| Perc. 8 | | 20km/h | 4,7 |
| Perc. 9 | | 21km/h | 4,7 |
| Perc. 10 | | 20km/h | 5 |

The average speed during the regenerative braking system tests on downhill conditions is :

$$Average = \frac{Amount\ of\ Value}{Total\ Value}$$

$$Average = \frac{44{,}8}{10}$$

= 5,1 second

### 4.2 Testing in Flat Road

**Figure 8.** Alternator testing on flat road

**Tabel 2.** Data from alternator testing on flat road

| Test. | Distane | Speed | Time |
|---|---|---|---|
| test. 1 | 71m | 45- 20km/h | 5 |
| Test. 2 | 74m | 45- 18km/h | 5,5 |
| Test. 3 | 72m | 44-20km/h | 5,1 |
| Test. 4 | 70m | 45-20km/h | 5,1 |
| Test. 5 | 70m | 45-20km/h | 5 |
| Test. 6 | 70m | 44-20km/h | 5 |
| Test. 7 | 72m | 44-20km/h | 5 |
| Test. 8 | 70m | 43-20km/h | 4,7 |
| Test. 9 | 70m | 45-20km/h | 4,7 |
| Test. 10 | 70m | 45-20km/h | 5 |

The average speed during the regenerative braking system tests on flat road conditions is :

$$Average = \frac{Amount\ of\ Value}{Total\ Value}$$

$$Average = \frac{69{,}8}{10}$$

= 6,98 second

Thus, in the trials, there was an increase in time due to the coupling load experienced from the coupling with the alternator. Therefore, the author determined the travel time based on the average calculation of 70.9 meters to be 6.98 seconds.

The results of the power generated by the alternator can be seen in Figure 9 below:

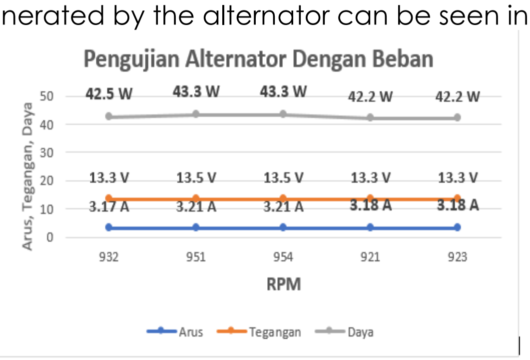


**Figure 9.** Alternator testing with dummyload

The output voltage generated is regulated by a voltage regulator, so varying rotational speeds (rpm) do not affect the output voltage (Vout) of the alternator. Thus, the alternator can produce a stable voltage of 16VDC.

### 4.3 Testing of DC to DC Boost Converter

Testing was carried out by measuring the output voltage (Vout) of the DC to DC boost converter, as shown in Figure 10 below:

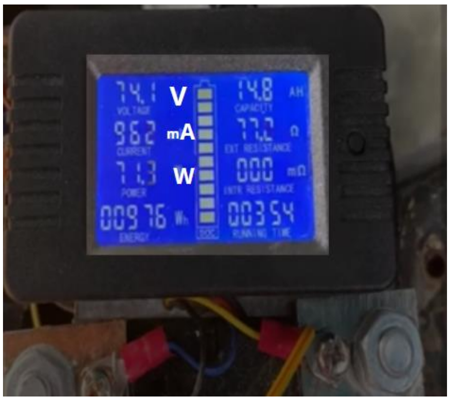

**Figure 10.** *Boosting* voltage running

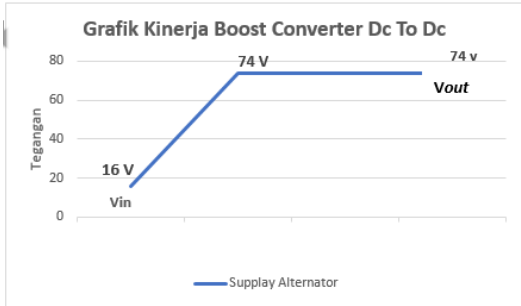


**Figure 11.** *Boost Converter Dc to Dc chart*

The output voltage generated by the alternator will be increased (boosted) using a DC to DC boost converter. As shown in Figure 11, the voltage, initially 16VDC, is successfully boosted to 74.1VDC. This voltage adjustment is made to match the nominal voltage of conventional charging equipment. The 60V 14.7Ah battery has a floating charge of 23% of the battery's nominal voltage.

### 4.5 Auto Cut Off Charging Testing

The testing was conducted by reviewing the performance of the relay in disconnecting and reconnecting the design from the load for charging purposes.

**Table 3**. Data from Auto Cut Off Charging Testing

| No | *Cut Off Voltage* (V) | Re-Connect (V) | QC |
|---|---|---|---|
| **1** | 74,1Vdc | 53Vdc | succes |
| **2** | 74Vdc | 52Vdc | succes |
| **3** | 74,2Vdc | 52vdc | succes |
| **4** | 74Vdc | 53Vdc | succes |
| **5** | 73,8Vdc | 53Vdc | succes |

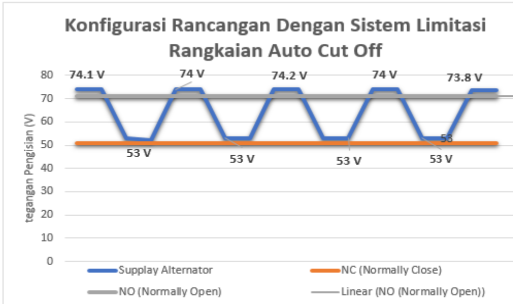


**Figure 12.** *Auto cut off charging chart*

The above condition indicates that the battery can be charged when its capacity decreases, causing the operating voltage for the BLDC motor to weaken until it reaches 53VDC. The sensor reading is adjusted to trigger the relay to switch to the Normally Open (NO) position, allowing the charging supply to flow to the load (battery) until the battery reaches a full charge voltage of 60VDC. The charging voltage is set at 74VDC by reviewing the real specifications of conventional charging equipment generally used for batteries with a specification of 60V 14.7Ah, similar to those used in the author's research on the design and development of an alternator to support the performance of the regenerative braking system in electric motorcycles.

**4.6 System Design Efficiency Analysis**

The design of the alternator to support the performance of the regenerative braking system in electric motorcycles has been successfully designed and tested. From all the types of testing, to determine the real performance of the regenerative braking system using the alternator, the author summarizes and calculates the efficiency of the system.

**Tabel 4.** data from system running on road

| **Alternator** | | ***Boost Converter Dc to Dc*** | | | |
|---|---|---|---|---|---|
| Eksitasi $B = \frac{\mu 0.I}{2\pi r}$ (V,A) | $\varepsilon$max (V) | V In | V Out | I | Watt |
| 12V1A | 16V | 16V | 74V | 0,98A | 72,6W |

The alternator design can generate a constant voltage of 16VDC, which is then boosted by a DC to DC boost converter to 74.1VDC to match the floating charge voltage of a charging device. To produce this voltage, the alternator is coupled with a BLDC motor, where the BLDC motor acts as the primary mover for the alternator when the electric motorcycle is on a downhill road, as shown in Table 5 below:

**Table 5**. Input Power Based on Torque

| **Revolusi per Minute (rpm)** | **Kilometer per hour (km/h)** | **Watt** |
|---|---|---|
| **1100 RPM = 115,2 Rad/s** | 25km/h | 576W |
| **13500 RPM = 157,1 Rad/s** | 35km/h | 785W |
| **1500 RPM = 209,4 Rad/s** | 45km/h | 1047W |

From the data in Table 5, the author found that the average input power is:

$$Average = \frac{Amount\ of\ Value}{Total\ Value}$$

$$Average = \frac{2.408}{3}$$

= 802W

It should be noted that the input power is derived from the primary mover and results from the conversion of rotational speed and the rate of the electric motorcycle when traveling on both flat and downhill roads. Thus, it purely represents the aerodynamic utilization occurring in the braking system of an electric motorcycle under these conditions. To determine the efficiency of the system design during charging, the data in Table 6 is used as a parameter for the calculations:

**Table 6**. Charging Duration Using the Alternator Design in the Regenerative Brake System

| System Design **(V,I,W)** | | | **(Ah)** | $t = \frac{Ah}{A}$ |
|---|---|---|---|---|
| **(V)** | (I) | (W) | | |
| **74,1VDC** | 0,98 A | 72,6 W | 14,7 Ah | 15h |

The research on the design and development of an alternator to support the performance of the regenerative braking system in electric motorcycles has been completed and has yielded quite satisfactory results. The charging process can occur with power generation from the alternator, which is boosted using a DC to DC boost converter.

## 5.0 CONCLUSION

Based on the research conducted in the capstone project on the design of an alternator to support the performance of the regenerative braking system in electric motorcycles, the following conclusions can be drawn, the capacity of the BLDC motor can be determined based on calculations of rolling resistance, aerodynamic drag, torque, and power. The selected BLDC motor is a tricycle BLDC 1000W 60V DC, with a torque of 81 Nm and an efficiency of 85%. The design of the alternator as a generator, configured with a DC to DC boost converter, can produce an output of 16V and achieve a voltage increase up to 72V. The measurement tool used can measure current, power, and voltage of the generation using the DC to DC boost converter by setting the trimpot Current Voltage (CV) until the adjusted voltage is 74.1V DC. The vehicle's deceleration increases due to the load coupling between the BLDC motor and the alternator rotor, resulting in a 8.7% reduction on downhill conditions and a 5.5% reduction on flat road conditions.

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