Effect of materials character on the design of the 12 slot 8 pole generators on power efficiency

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Abstract. The development of renewable energy as electrical energy needs to be followed by the provision of high-efficiency generators, especially for small-scale alternative energy uses. This study discusses the effect of the character of materials on the design of 12 slots 8 pole generator on power efficiency. The material used for the discussion of this research is copper and aluminum as materials for the coil. Comparison of these two material to find the coil forming materials with the highest efficiency. As a result of the experiments described above, the use of aluminium material as a coil can reduce efficiency by 0.1% from the use of copper material as a coil.

1. Introduction
The use of electricity in Indonesia in 2017 reached 114,347.64 MVA [1]. Electricity can be generated from the power plant, one of which is the Electric Power Bank (EPB). EPB utilizes wind energy and utilizes electrical energy. The EPB component consists of wind turbines, generators, and batteries [2].

The working principle of the generator is mechanical energy into electrical energy. The generator consists of two main parts, namely the rotor and stator. The rotor is a moving part and produces a magnetic field. The stator is the stationary part and receives a flux magnet [3,4]. Faraday’s law explains that a wire or coil of the conductor is in a magnetic field that changes with time so that at the ends of the wire or conductor it will cause induction voltage or electromotive force. Changes in the magnetic field produce electric current or electromotive force [5].

This research will find the highest efficiency from the comparison of the use of windings from copper and aluminum for generators.

2. Research Methods
a. Modeling 12 Slot 8 Pole generators with MagNet Software. In figure 1 and 2 illustrate the generator model with MagNet Software.
Figure 1. the first model of 12 Slot 8 Pole generator using copper wire

Material model Figure 1 of the 12 Slot 8 Pole generator is shown in Table 1:

| No | Name       | Material                               |
|----|------------|----------------------------------------|
| 1. | Stator     | Carpenter: Silicon steel               |
| 2. | Coil       | Copper: 5.77e7 Siemens/meter           |
| 3. | Magnet     | Neodymium Iron Boron: 48/11            |
| 4. | Rotor      | Carpenter: Silicon steel               |
| 5. | Air Gap    | Air                                    |

Material model Figure 2 of the 12 Slot 8 Pole generator is shown in Table 2:

| No | Name       | Material                               |
|----|------------|----------------------------------------|
| 1. | Stator     | Carpenter: Silicon steel               |
| 2. | Coil       | Aluminum: 3.8e7 Siemens/meter          |
| 3. | Magnet     | Neodymium Iron Boron: 48/11            |
| 4. | Rotor      | Carpenter: Silicon steel               |
| 5. | Air Gap    | Air                                    |
b. The next process is making rectifier circuits as shown in Figure 3. To be able to simulate and get results from the simulation.

Figure 3. Rectifier circuit with 14 Ohm load

3. Result
This simulation aims to find the efficiency of a permanent magnet generator with two different materials and in loading 14 ohms at a speed of 1000 RPM. The part of the circuit is composed of 3 parallel, rectifier, and load phases. shown in Figure 3.

After adding a rectifier and load circuit, then the generator is solved / re-simulated so that some data is obtained, namely voltage, current, and average torque. Simulation data are listed in Table 3 below.

| Coil Material | Voltage (V) | Current (A) | Torque (Nm) |
|---------------|-------------|-------------|-------------|
| Copper        | 23.042      | 1.664       | 0.44        |
| Aluminum      | 23.029      | 1.645       | 0.44        |

To determine the efficiency of the generator, can then be calculated the value of the input power, output, and efficiency is by the formula [6, 7]:

\[ P_{in} = \tau \cdot \upsilon \cdot \frac{2\pi}{60} \]  

(1)

Explanation:

\( P_{in} \): Entry Power (W)
\( \tau \): Torque (Nm)
\( \upsilon \): Speed (RPM)

\[ P_{out} = I \times V \]  

(2)

Explanation:

\( P_{out} \): Power Out (W)
\( I \): Current (A)
\( V \): Voltage (V)

\[ \eta = \frac{P_{out}}{P_{in}} \times 100\% \]  

(3)

Explanation:

\( \eta \): Efficiency (%) 
\( P_{out} \): Power Out (W)
\( P_{in} \): Entry Power (W)

Calculation of input and output power in the simulation results is shown in Table 4. From Table 4 we get a graph of the comparison of input and output power in the variation of material used on the coil as in Figure 4.
Calculation of input and output power efficiency in the simulation results is shown in Table 5. From Table 5 we get a graph of efficiency comparison on the variation of material used on the coil as shown in Figure 4.

| Coil Material | Power Input (W) | Power Output (W) |
|---------------|-----------------|------------------|
| Copper        | 48.004          | 38.90            |
| Aluminum      | 48.004          | 38.83            |

![Graph of comparison of input and output power from the simulation results](image1)

**Figure 4.** Graph of comparison of input and output power from the simulation results

| Coil Material | Efficiency |
|---------------|------------|
| Copper        | 81         |
| Aluminum      | 80.9       |

![Graph of the comparison data of efficiency from simulation results between copper and aluminum](image2)

**Figure 5.** The comparison data of efficiency from simulation results between copper and aluminum

### 4. CONCLUSION

This paper has discussed the comparison of copper and aluminum material as a material for a coil with high efficiency from the 12 slots 8 pole generator model using software from infolytica. As a result of the experiments described above, the use of aluminum material as a coil can reduce efficiency by 0.1% from the use of copper material as a coil.
References
[1] Direktorat Jendral Ketenagalistrikan KESDM. 2018. *Statistik Ketenagalistrikan*.
[2] LAN. 2014. Pengenalan Teknologi Pemanfaatan Energi Angin. Tasikmalaya.
[3] Kundur, Prabha. 1994. Power System Stability and Control. *McGraw-Hill, Inc.* New York
[4] Akbar, M. 2012. Rancang Bangun Generator Turbin Angin Axial Tiga Fasa untuk Kecepatan Angin Rendah. *Skripsi. Program Studi Teknik Elektro. Universitas Indonesia*.
[5] Issetyorini, Apik dan Antono, Djodi. 2012. Gaya Gerak Listrik Pada Motor AC. *Jurusan Teknik Elektro. Politeknik Negeri Semarang*.
[6] Lestari, Ayu. 2018. Analisis Efisiensi pada Generator 12 Slot 8 Pole. *Program Studi Teknik Mesin. Universitas Jember*.
[7] Windarto J*, Sudjadi, Karnoto, Sukmadi T, Santoso I and Desmiarti A. 2018. Effect of Geometry Generator Variation Design 12 Slot 8 Pole on Power Efficiency Design. *Electrical Engineering. Diponegoro University*. 