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4/25/25

CWC GEN

Wire Gauge Calculations

ME 476C Sec 001

Introduction

Our senior design project involves the creation of a custom generator for a small-scale wind turbine system. The generator is intended to operate efficiently under low-speed, high-torque conditions typical of wind power applications. My individual contribution has been focused on analyzing the selection of wire gauge for the stator windings, a decision that critically impacts the generator's electrical performance, thermal safety, and manufacturability. Wire gauge affects several important characteristics, including current-carrying capacity, resistive losses, heat dissipation, voltage drop, and the overall size of the winding assembly. The goal of this analysis is to mathematically justify our chosen wire gauge and ensure the final design maintains both electrical and thermal reliability under real-world conditions.

Assumptions and Equations

To evaluate different wire gauges, I used electromagnetic and thermal simulations in ANSYS Maxwell. These simulations allowed me to assess how variations in wire cross-sectional area influence resistive losses, current density, and temperature rise when subjected to our expected operating conditions. The generator is designed for a maximum of 48 volts AC at a current of up to 10 amps, under typical load scenarios. For modeling, I assumed the length of wire per coil to be approximately 12 meters, based on CAD geometry of the stator slots and coil turns. The coils are made of copper due to its high conductivity. The equations used are as follows:

$$J = \frac{I}{A}$$

Where J is the current density, I is the current running through wire, and A is the cross-sectional area of wire. This equation is used to find the cross-sectional area of the wire so that it can be used to find the diameter.

$$d = \sqrt{\frac{4A}{\pi}}$$

Where d is the diameter of wire and A is the cross-sectional area of wire. This equation is used to find the diameter of the wire; it is then cross referenced with the American Wire Gauge cart to find the Gauge number needed.

$$R = \rho \frac{L}{A}$$

Where R is the resistance of wire, ρ is the resistivity of copper, L is total length of wire, and A is the cross-sectional area of wire. This equation is used to find the resistance so that it can be used to calculate power loss of the wire.

$$P_{copper} = I^2 R$$

Where I is the current and R is the resistance of winding. This equation is used to find the power loss of the copper, with the goal of minimizing it as much as possible.

Modeling

Wire gauges tested included AWG 16, 18, 20, 22, and 24. Each configuration was modeled in ANSYS Maxwell using the Segmented Helix tool to accurately represent the coil geometry based on the number of turns that could physically fit into the stator slots. Electromagnetic simulations were used to evaluate how wire gauge affects voltage output, torque generation, and power performance at a constant speed and current. These simulations provided a clear comparison of how coil design choices impact generator behavior under expected operating conditions.

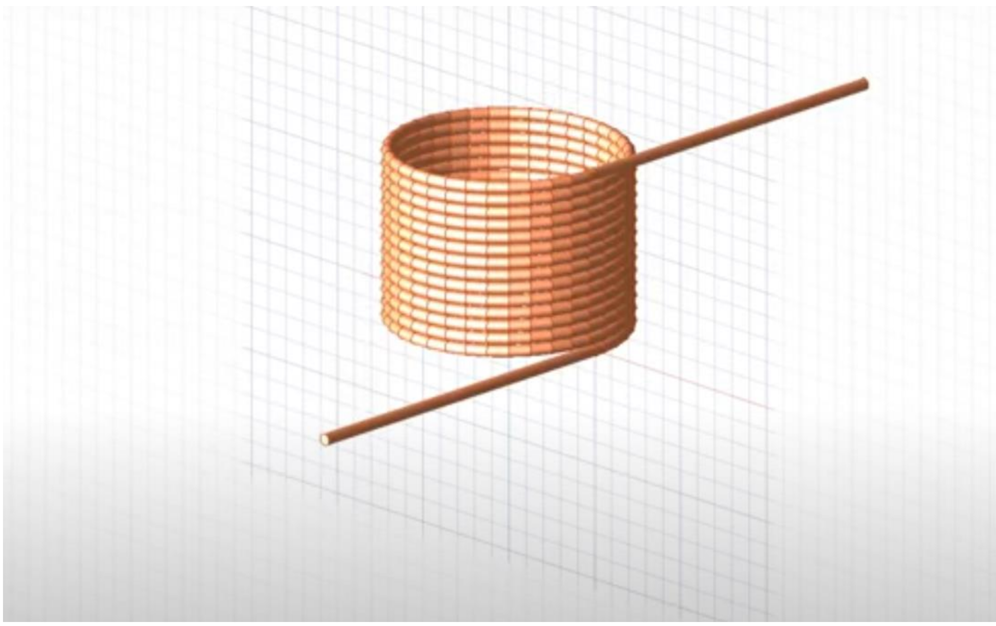

Figure 1: ANSYS Coil Model

Results

The simulation results showed how different wire gauges impacted the generator's electrical performance at 1200 RPM and 10 amps. As wire gauge decreased (thinner wire), we were able to fit more turns in each coil, which increased voltage and power output. However, thinner wires also have higher resistance, which leads to more heat and potential thermal issues.

AWG 16 allowed only 40 turns and produced 20.58 V, with a power output of 285 W and a Kv rating of 61.38 RPM/V. While thermally safe, its voltage and torque (0.091 Nm) were too low for our needs. On the other end, AWG 24 allowed 60 turns and reached a high voltage of 41.88 V and 580.31 W of power. However, it produced only 0.11 Nm of torque and would likely overheat due to its high resistance. AWG 22 and AWG 20 performed better, with voltages of 44.65 V and 35.68 V, and torques of 0.96 Nm and 0.57 Nm, respectively. But their thin size made it harder to wind and increased thermal risk. AWG 18 offered a good balance. With 43 turns, it produced 28.67 V, 397.26 W of power, and 0.18 Nm of torque. Its KV rating of 44.01 RPM/V is ideal for our low-speed generator, and it stays within safe thermal limits.

Table 1: Wire Gauge Results

Wire Gauge	16	18	20	22	24
Voltage	20.58	28.67	35.68	44.65	41.88
Torque	0.091	0.18	0.57	0.96	0.11
Power	285	397.26	494.39	618.69	580.31
KV	61.38	44.01	35.4	28.29	30.16

Based on the goal of having the lowest KV rating, AWG 22 should be chosen for the final design. It provides a strong mix of voltage and torque, while still fitting within the coil space available in our stator model.

References:

[1] F. T. Ulaby and U. Ravaioli, *Fundamentals of Applied Electromagnetics*. Harlow: Pearson, 2023.

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[3] G. Rizzoni and J. Kearns, *Principles and Applications of Electrical Engineering*. New York, NY: McGraw Hill LLC, 2022.