

Electrical Engineering Preparation Summary

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1 Introduction

This document provides a concise summary of key electrical engineering concepts focused on electrical machines, including electromotive force (EMF), radial speed, current flow, and electromagnetic torque, to aid in preparation.

2 Electrical Machines

2.1 Electromotive Force (EMF)

Electromotive Force (EMF) is the voltage generated in a conductor moving through a magnetic field, such as in a generator or motor.

$$\text{Formula: } E = \frac{pN\Phi n}{a}$$

- **Parameters:**

- E : Induced EMF (V).
- p : Number of poles in the machine.
- N : Number of conductors.
- Φ : Magnetic flux per pole (Wb).
- n : Rotational speed (rad s^{-1}).
- a : Number of parallel paths in the winding.

- **Explanation:** The EMF is proportional to the number of poles, conductors, magnetic flux, and rotational speed, divided by the parallel paths. This is critical for understanding voltage generation in machines like generators.
- **Example:** A 4-pole generator with 100 conductors, a flux of 0.02 Wb, speed of 1200 rpm, and 2 parallel paths generates an EMF calculated by converting speed to radians per second (see below) and applying the formula.

2.2 Radial Speed

Radial Speed (or angular speed, ω) represents how fast a rotor spins in a rotating machine, measured in rad s^{-1} .

$$\text{Formula: } \omega = \frac{2\pi n}{60}$$

- **Parameters:**

- ω : Angular speed (rad s^{-1}).
- n : Rotational speed in revolutions per minute (RPM).

- **Simple Explanation:** This formula converts rotational speed from RPM to radians per second. One revolution equals 2π radians, and dividing by 60 adjusts for seconds in a minute. For example, at 1200 RPM:

$$\omega = \frac{2\pi \cdot 1200}{60} = 40\pi \approx 125.66 \text{ rad s}^{-1}.$$

- **Why It Matters:** Angular speed is used in EMF and torque calculations to determine how fast the magnetic field changes, affecting voltage and mechanical output.

2.3 Current Flow in the Circuit

Current Flow in a circuit (armature) of an electrical machine is determined by the difference between the EMF and the voltage across the circuit, accounting for the internal resistance.

$$\text{Formula: } I = \frac{E - V}{R}$$

- **Parameters:**

- I : Current flowing through the circuit (A).
- E : Electromotive force (EMF, V).
- V : Voltage across the circuit (V).
- R : Internal resistance of the circuit (Ω).

- **Explanation:** The current is driven by the difference between the generated EMF and the circuit's terminal voltage, divided by the internal resistance. The power consumed by the internal resistor is $P = I^2 R$, where I results from the voltage drop across the resistor, controlling current flow.

- **Example:** For an EMF of 100 V, a circuit voltage of 90 V, and an internal resistance of 2 Ω , the current is:

$$I = \frac{100 - 90}{2} = 5 \text{ A}.$$

The power consumed by the internal resistor is $P = 5^2 \cdot 2 = 50 \text{ W}$.

2.4 Electromagnetic Torque

Electromagnetic Torque (C) is the rotational force produced in an electrical machine, such as a motor, due to the interaction of current and magnetic flux.

$$\text{Formula: } C = \frac{E \cdot I}{\omega}$$

- **Parameters:**

- C : Torque (N m).
- E : Induced EMF (V).

- I : Current in the circuit (A).
- ω : Angular speed (rad s^{-1}).

• **Alternative Formula:**

$$\text{Formula: } C = \frac{p}{a} \cdot \frac{N \cdot \Phi \cdot I}{2\pi}$$

- p : Number of poles.
- a : Number of parallel paths.
- N : Number of conductors.
- Φ : Magnetic flux per pole (Wb).
- I : Current (A).

- **Explanation:** Torque is the mechanical output of an electrical machine, resulting from the interaction of the EMF and current, divided by angular speed in the first formula. The alternative formula expresses torque in terms of the machine's physical parameters, showing how the number of poles, conductors, flux, and current contribute to the rotational force. Both yield torque in N m.

- **Example:** For a machine with $E = 100 \text{ V}$, $I = 5 \text{ A}$, and $\omega = 125.66 \text{ rad s}^{-1}$ (from 1200 RPM), the torque is:

$$C = \frac{100 \cdot 5}{125.66} \approx 3.98 \text{ N m.}$$

Using the alternative formula, for $p = 4$, $a = 2$, $N = 100$, $\Phi = 0.02 \text{ Wb}$, and $I = 5 \text{ A}$:

$$C = \frac{4}{2} \cdot \frac{100 \cdot 0.02 \cdot 5}{2\pi} \approx 3.18 \text{ N m.}$$

(Note: Discrepancies may arise due to simplifying assumptions; verify with specific machine constants.)