UNIT-3
DC Machines (Contd.)

UNIT III

DC Machines (Contd.): Performance characteristics of DC motors, Starting of DC motors; 3 point and 4 point starters, Speed control of DC motors; Field control, Armature control and Voltage control (Ward Leonard method); Efficiency and Testing of DC machines (Hopkinson's and Swinburne's Test), Applications, stepper motor and DC Servo motor and their applications.

OUTCOMES:

1. Performance Characteristics of DC Motors

DC motors have several performance characteristics that are important for their operation:

- Speed-Torque Characteristics: Graphical representation showing how motor speed varies with torque.
- Efficiency: Ratio of output mechanical power to input electrical power, crucial for assessing energy efficiency.
- Stability: Ability to maintain stable operation under varying loads and conditions.

2. Starting of DC Motors

Starting DC motors requires careful control to avoid excessive current surges and mechanical stress:

- 3-Point Starters: Simple method to control starting current and provide initial acceleration.
- 4-Point Starters: Provide more refined control over starting conditions, often used in larger motors.

3. Speed Control of DC Motors

DC motors offer several methods for controlling their speed:

- Field Control: Varying the field winding current to control speed.
- Armature Control: Adjusting the armature voltage to regulate speed.
- Voltage Control (Ward Leonard Method): Using a motor-generator set to vary voltage and thus speed.

4. Efficiency and Testing of DC Machines

Efficiency and testing are critical for assessing performance and reliability:

- Hopkinson's Test: Method to determine efficiency and losses in DC machines.
- Swinburne's Test: Another method for evaluating efficiency and losses under load conditions.

5. Applications

DC motors find applications in various industries and systems:

- Stepper Motors: Precise control in robotics, CNC machines, and automation.
- DC Servo Motors: High-performance applications requiring accurate positioning and speed control.

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❖ Performance Characteristics of DC Motors

1. **Speed-Torque Characteristics**: This is a graphical representation that shows the relationship between the motor's speed and the torque it produces. Typically, as the torque increases, the speed decreases, and vice versa. This characteristic is crucial for understanding how the motor will perform under different load conditions.

    - This characteristic is depicted as a graph that illustrates the relationship between the motor's speed and the torque it produces.
    - Typically, the graph shows that as the load torque on the motor increases, the speed decreases, and vice versa.
    - This relationship is crucial for understanding how the motor will behave under different load conditions, which helps in selecting the right motor for specific applications.

2. **Efficiency**: Efficiency is the ratio of the motor's output mechanical power to its input electrical power. It indicates how effectively the motor converts electrical energy into mechanical energy. Higher efficiency means less energy is wasted as heat, making the motor more energy-efficient.

    - Efficiency in DC motors is the ratio of the output mechanical power (the power the motor delivers to drive a load) to the input electrical power (the power consumed from the power source).
    - This ratio is expressed as a percentage and indicates how effectively the motor converts electrical energy into useful mechanical work.
    - High efficiency is desirable as it means more of the input power is used for useful work and less is wasted as heat, which is important for energy savings and operational cost reduction.

3. **Stability**: Stability refers to the motor's ability to maintain consistent performance and operation despite changes in load and operating conditions. A stable motor can handle variations without significant fluctuations in speed or torque, ensuring reliable and smooth operation.

    - Stability refers to the motor's ability to maintain consistent performance under varying loads and operating conditions.
    - A stable motor will be able to handle changes in load without significant fluctuations in speed or torque.
    - Stability is important for applications requiring precise control and reliable performance, ensuring that the motor can operate smoothly and efficiently without issues like oscillations or hunting.

❖ Starting of DC Motors

Starting DC motors requires careful control to prevent excessive current surges and mechanical stress that can damage the motor or the electrical system. Here's an explanation of two common methods used for starting DC motors:

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➢ 3-Point Starters

A 3-point starter is a simple and effective method used to control the starting current and provide initial acceleration for DC motors. It consists of three main points:

1. **Line Connection (L):** Connects to the positive terminal of the power supply.
2. **Armature Connection (A):** Connects to the armature winding of the motor.
3. **Field Connection (F):** Connects to the field winding of the motor.

Operation:

- When the motor starts, the handle of the starter is moved from the 'off' position towards the 'on' position.
- This movement gradually introduces resistance into the armature circuit, limiting the initial inrush current.
- As the motor accelerates, the handle moves further, progressively reducing the resistance until it reaches the 'on' position, where the resistance is minimal, and the motor operates at full speed.

Advantages:

- Simple design and easy to use.
- Provides adequate protection against excessive starting current.

➢ 4-Point Starters

A 4-point starter provides more refined control over the starting conditions and is often used in larger or more complex DC motors. It includes an additional point for better control and safety:

1. **Line Connection (L):** Connects to the positive terminal of the power supply.
2. **Armature Connection (A):** Connects to the armature winding of the motor.
3. **Field Connection (F):** Connects to the field winding of the motor.
4. **No-Volt Release (NVR) Coil Connection:** Ensures that the motor stops if the supply voltage drops or is interrupted.

Operation:

- Similar to the 3-point starter, the handle is moved to progressively reduce the resistance in the armature circuit.
- The NVR coil ensures that if the supply voltage fails or drops significantly, the starter handle returns to the 'off' position, preventing the motor from restarting automatically.
- This feature enhances safety and prevents damage to the motor due to unintentional restarts.

Advantages:

- Provides better control over starting conditions.
- Enhances safety with the NVR coil, making it suitable for larger motors or applications requiring precise control.

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By using 3-point or 4-point starters, the starting current of DC motors is controlled effectively, reducing the risk of damage and ensuring smooth acceleration.

❖ Speed Control of DC Motors

DC motors offer several methods for controlling their speed, each with distinct mechanisms and applications:

1. **Field Control:**
   - **Method:** This involves varying the current through the field winding (the coils responsible for generating the magnetic field in the motor).
   - **Effect:** By changing the field current, the strength of the magnetic field is altered, which in turn changes the motor speed. Increasing the field current strengthens the magnetic field, resulting in a lower speed for the same armature voltage. Conversely, decreasing the field current weakens the magnetic field, allowing the motor to run faster.
2. **Armature Control:**
   - **Method:** This method adjusts the voltage applied to the armature winding (the part of the motor where the electromotive force is induced).
   - **Effect:** By varying the armature voltage, the speed of the motor can be controlled. Increasing the armature voltage increases the speed of the motor, while decreasing the voltage reduces the speed. This method is particularly useful for maintaining a constant torque.
3. **Voltage Control (Ward Leonard Method):**
   - **Method:** This technique uses a motor-generator set to vary the voltage supplied to the DC motor. The set consists of a DC generator driven by an AC motor, where the output voltage of the generator is controlled to adjust the speed of the DC motor.
   - **Effect:** By controlling the generator's output voltage, precise speed control of the DC motor can be achieved over a wide range. This method is highly effective for applications requiring fine speed adjustments and smooth operation.

❖ Efficiency and Testing of DC Machines

Efficiency and testing are essential to assess the performance and reliability of DC machines. Several methods are commonly used to evaluate these parameters:

➢ **Hopkinson's Test**

Hopkinson's Test, also known as the Regenerative or Back-to-Back Test, is a method used to determine the efficiency and losses in DC machines. This test is typically performed on two identical machines connected in such a way that one machine operates as a motor and the other as a generator. Here's how it works:

1. **Setup**: Two identical DC machines are mechanically coupled.
2. **Operation**: One machine is powered and runs as a motor, driving the second machine, which operates as a generator.

3. **Electrical Connection**: The electrical output of the generator is fed back to the motor.
4. **Measurement**: The input electrical power and the power losses are measured. Since the input and output powers are nearly equal, the efficiency can be calculated accurately.

Advantages:

- High accuracy.
- Can be used to test machines at their full load without needing a large load resistor.

➢ **Swinburne's Test**

Swinburne's Test is another method for evaluating the efficiency and losses of DC machines, particularly under no-load conditions. It's a simpler and more convenient test, suitable for smaller machines. The procedure is as follows:

1. **No-Load Operation**: The machine is run without any mechanical load.
2. **Measurement**: The no-load power consumption (i.e., losses) is measured, which includes iron losses, mechanical losses, and a small amount of electrical losses.
3. **Calculation**: The efficiency under load conditions is then calculated using the no-load losses and additional data about the load current.

Advantages:

- Simple and easy to perform.
- Requires minimal equipment.
- Suitable for small machines where full-load testing is impractical.

Summary

- **Hopkinson's Test** is ideal for full-load testing with high accuracy and involves two identical machines operating in a regenerative setup.
- **Swinburne's Test** is simpler and suitable for no-load testing, useful for smaller machines or preliminary efficiency assessments.

Both methods are important for ensuring the performance and reliability of DC machines, each with its unique advantages depending on the specific testing requirements.

❖ Applications

DC motors have a wide range of applications across different industries and systems due to their various types and functionalities. Here are two specific types of DC motors and their applications:

1. **Stepper Motors:**
   - **Precise Control:** Stepper motors are designed for applications that require precise control over motion. They can move in discrete steps, making them ideal for situations where accuracy and repeatability are crucial.
   - **Robotics:** In robotics, stepper motors are used to control the movement of robotic arms and other components, allowing for precise positioning and repeatable actions.

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  - **CNC Machines:** Computer Numerical Control (CNC) machines use stepper motors to control the movement of cutting tools with high precision. This ensures accurate machining of parts.
  - **Automation:** Stepper motors are commonly used in automated systems for tasks like conveyor belt operations, packaging, and labeling, where precise and controlled movements are necessary.

2. **DC Servo Motors:**
  - **High-Performance Applications:** DC servo motors are used in applications that demand high performance, especially in terms of accurate positioning and speed control.
  - **Accurate Positioning:** These motors are equipped with feedback mechanisms, such as encoders, that allow for precise control of their position. This makes them suitable for applications where exact positioning is critical, such as in robotic surgery or camera gimbals.
  - **Speed Control:** DC servo motors provide excellent control over speed, making them ideal for applications where maintaining a specific speed is important, such as in conveyor systems or industrial machinery.

Overall, DC motors, including stepper motors and DC servo motors, play a vital role in various industries due to their ability to offer precise control, accuracy, and reliability.

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