"In the name of Allah, The Most Beneficent, The Most Merciful"

Induction Machine Modules

Lab 02 Performance Characteristics and Load Testing

Prepared By: Dr. Mohd Azri Hizami Bin Rasid

Lab Location
Electrical Drive System Lab, FTKPM

Lab Objectives

By the end of this lab, students should be able to:

1. **Analyze** the no-load characteristics of a three-phase induction motor
2. **Evaluate** the relationship between voltage, current, speed, and slip in induction machines
3. **Measure and calculate** power factor variations under different operating conditions
4. **Investigate** the performance characteristics of loaded induction machines
5. **Apply** proper laboratory safety procedures and measurement techniques
6. **Interpret** experimental data and compare with theoretical predictions

Student names	Student ID	Section

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Required Knowledge

Theory Review

- Three-phase induction motor equivalent circuit
- Slip calculation: s = (ns - nr)/ns
- Power factor calculation using two-wattmeter method
- Relationship between torque, slip, and rotor resistance
- Motor efficiency calculations

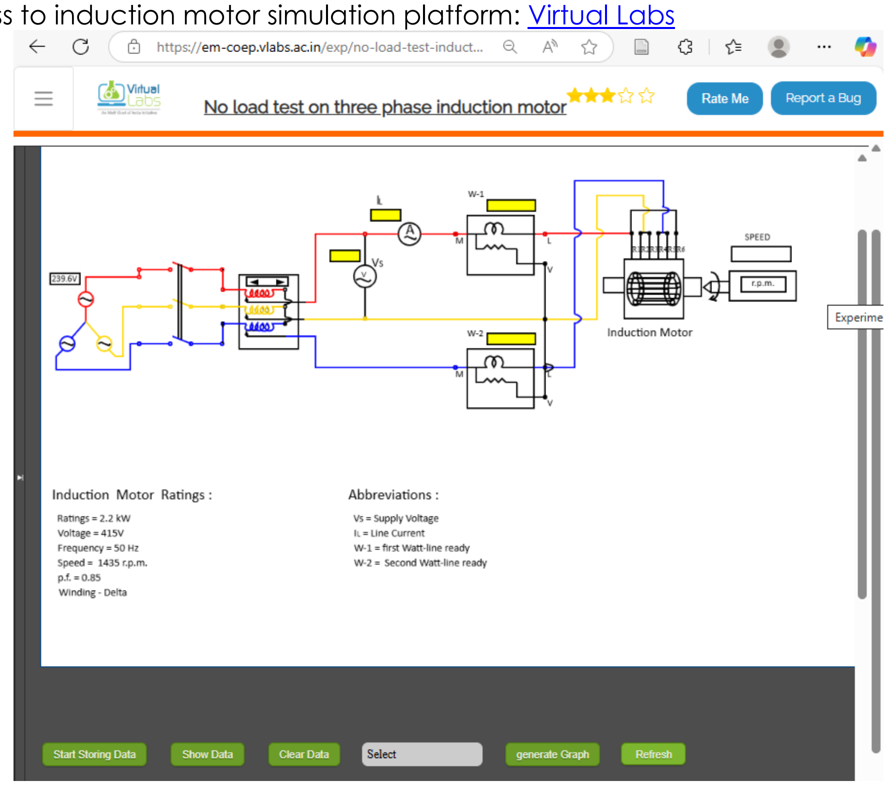
Key Formulas

- Synchronous Speed: ns = 120f/P (rpm)
- Slip: s = (ns - nr)/ns × 100%
- Power Factor: $\cos\varphi = \cos[\tan^{-1}(\sqrt{3}|W_1 - W_2|/(W_1 + W_2))]$
- Efficiency: η = Pout/Pin × 100%

Equipment and Instruments

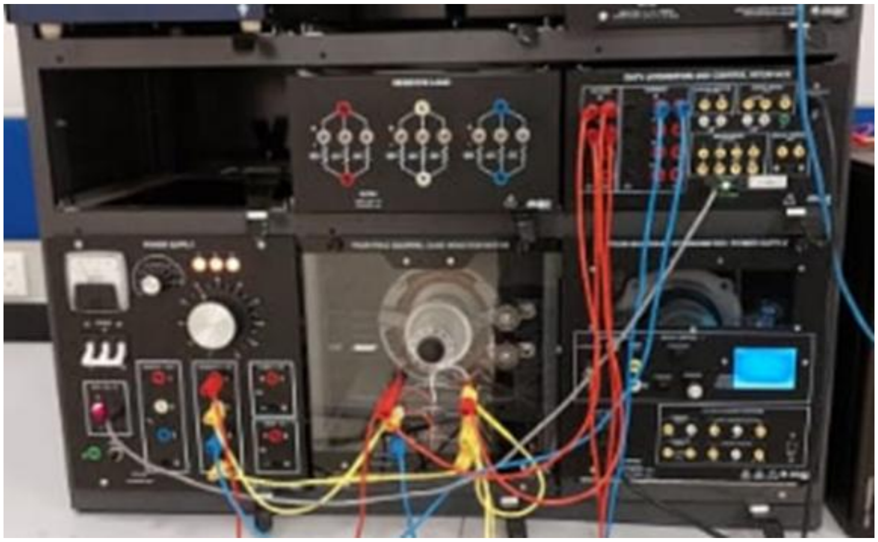
Part 1: Virtual Simulation

- Computer with internet access
- Access to induction motor simulation platform: [Virtual Labs]



Part 2: Physical Laboratory

- 3-phase squirrel cage induction motor (2.2 kW, 415V, 50 Hz, 1435 rpm)
- DC generator (load machine)
- Three-phase variable autotransformer (Variacs)
- Digital multimeters
- Power analyzer/Two wattmeters
- Tachometer
- Data acquisition system (DAQ)
- Oscilloscope
- Connecting cables and safety equipment



Safety Precautions

CRITICAL SAFETY REQUIREMENTS

1. Personal Protective Equipment (PPE):
    - Closed-toe shoes required
    - No loose clothing or jewelry
2. Electrical Safety:
    - Ensure all connections are secure before energizing
    - Never make connections while equipment is energized
    - Use proper lockout/tagout procedures
    - Keep workspace clean and dry
3. Mechanical Safety:
    - Ensure proper belt guard installation
    - Keep hands away from rotating machinery
    - Emergency stop buttons must be functional
4. Emergency Procedures:
    - Know location of emergency stop buttons
    - Report any unusual sounds, smells, or behavior immediately
    - In case of emergency, de-energize equipment immediately

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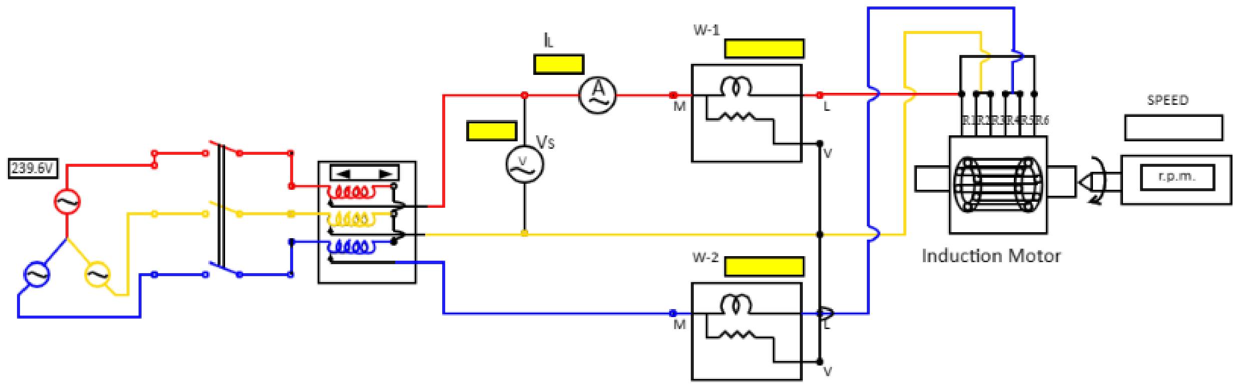
Part 1: Virtual Simulation - No-Load Characteristics

Experimental Setup

The virtual laboratory simulates a three-phase induction motor connected through variable autotransformers. The setup includes voltage, current, power, and speed measurements.



Procedure

1. System Initialization
   - Access the virtual laboratory platform
   - Familiarize yourself with the control interface
   - Verify all measurement instruments are properly connected in the simulation
2. Motor Starting
   - Close the three-phase supply switch
   - Start the motor using reduced voltage (approximately 30% of rated voltage)
   - Gradually increase voltage to avoid excessive starting current
3. Data Collection
   - Create a data table with the following columns:
     - Line Voltage (V)
     - Line Current (A)
     - Power W_1 (W)
     - Power W_2 (W)
     - Speed (rpm)
     - Total Power (W)
     - Power Factor
     - Slip (%)
4. Voltage Variation Test
   - Record measurements at voltage intervals: 0V, 50V, 100V, 150V, 200V, 250V, 300V, 350V, 400V
   - For each voltage setting:
     - Allow motor to reach steady state (approximately 30 seconds)
     - Record all measured parameters
     - Calculate derived parameters (power factor, slip, total power)

Data Analysis and Questions

1. Voltage-Current Relationship
    - Plot line voltage vs. line current
    - Explain the relationship observed
    - For maximum phase voltage of 239.6V, calculate the maximum line voltage
2. Speed Characteristics
    - Plot voltage vs. speed
    - Explain why speed varies with voltage
    - Determine the no-load speed at rated voltage
3. Slip Analysis
    - Calculate slip for each voltage point
    - Plot slip vs. speed
    - Determine if the machine operates in the linear region
    - Explain the physical significance of slip variation
4. Power Factor Analysis
    - Calculate power factor using the two-wattmeter method
    - Plot power factor vs. voltage
    - Explain the variation in power factor with voltage

Part 2: Physical Laboratory - Load Characteristics

Experimental Setup

The laboratory setup consists of:

- Three-phase induction motor (test machine)
- DC generator (loading device)
- Variable autotransformers for voltage control
- Measurement and data acquisition systems installed in PC

Connection Diagram

Refer to manual on the lab bench

Pre-Laboratory Checklist

- Verify all electrical connections
- Check belt coupling between motor and generator
- Ensure all measurement instruments are calibrated
- Confirm emergency stop functionality
- Review safety procedures with instructor

Detailed Procedure

Step 1: Initial Setup and Wiring

1. Motor Connection:
    - Connect the induction motor in wye (star) configuration
    - Each phase should receive line voltage (maximum 240V per phase)
    - Verify proper phase sequence (R-Y-B)
2. Measurement Setup:

- Connect voltage measurement across one line-to-line pair
    - Install current transformer or direct current measurement
    - Setup two-wattmeter configuration for power measurement
    - Connect tachometer for speed measurement
    - Configure DAQ system for real-time monitoring
3. Load Machine Setup:
    - Ensure DC generator is properly connected
    - Set load control to minimum (0 N·m)
    - Verify load measurement instruments

Step 2: No-Load Testing

1. Motor Starting:
    - Start with variacs at 0%
    - Gradually increase to 100% (rated voltage)
    - Allow motor to reach steady-state operation
2. Initial Measurements (No Load):
    - Record: Voltage, Current, Power (W_1, W_2), Speed
    - Calculate: Power factor, Slip, Efficiency
    - Observe voltage and current waveforms on oscilloscope

Step 3: Load Testing

1. Load Application:
    - Apply load in increments of 0.5 N·m
    - For each load point, allow system to stabilize (minimum 2 minutes)
    - Record all parameters as listed in the data table
2. Data Collection Table:

Load (N·m)	Speed (rpm)	Voltage (V)	Current (A)	W_1 (W)	W_2 (W)	P_out (W)	Slip (%)	Power Factor	Efficiency (%)
0.0									
0.5									
1.0									
1.5									
...									

3. Continue until motor approaches stall condition

Step 4: System Shutdown

1. Reduce load to zero
2. Gradually reduce variacs to 0%
3. Open main supply switch
4. Disconnect all measurement leads
5. Secure equipment

Calculations and Analysis

Required Calculations for Each Data Point:

1. Total Input Power: $P\_in = W_1 + W_2$
2. Power Factor: $\cos \varphi = \cos[\tan^{-1}(\sqrt{3}|W_1 - W_2|/(W_1 + W_2))]$
3. Slip: $s = (n\_s - n\_r)/n\_s \times 100\%$ where $n\_s = 1500$ rpm (for 4-pole, 50 Hz motor)
4. Efficiency: $\eta = P\_out/P\_in \times 100\%$
5. Output Power: $P\_out = T \times \omega = T \times 2\pi n/60$ (where T is in N·m, n in rpm)

Analysis Questions

1. Speed-Load Characteristics
   - Plot speed vs. load torque
   - Explain the speed regulation of the motor
   - Determine the rated operating point
2. Slip-Load Relationship
   - Plot slip vs. load torque
   - Compare with theoretical slip-torque characteristics
   - Identify the stable operating region
3. Power Factor Variation
   - Plot power factor vs. load
   - Explain why power factor improves with load
   - Determine the load for maximum power factor
4. Efficiency Analysis
   - Plot efficiency vs. load
   - Determine maximum efficiency point
   - Calculate losses at different load points
5. Performance Comparison
   - Compare experimental results with nameplate data
   - Identify sources of discrepancies
   - Discuss practical implications

Laboratory Report Requirements

Report Structure:

1. Title Page - Include lab title, student information, date
2. Introduction - Theory background and objectives
3. Methodology - Description of experimental procedures
4. Results and Data - All measurements, calculations, and graphs
5. Analysis and Discussion - Answer to all questions with technical explanations
6. Conclusion - Summary of key learnings and practical implications

Required Graphs:

- Voltage vs. Speed (No-load test)
- Slip vs. Speed (No-load test)
- Speed vs. Load Torque
- Slip vs. Load Torque
- Power Factor vs. Load
- Efficiency vs. Load
- Input Power and Output Power vs. Load (on same graph)

Evaluation Criteria:

- Data Accuracy (25%) - Completeness and accuracy of measurements
- Calculations (20%) - Correct application of formulas
- Analysis (25%) - Quality of technical discussion and interpretation
- Graphs (15%) - Professional presentation of data
- Report Quality (15%) - Organization, grammar, and technical writing

Troubleshooting Guide

Common Issues and Solutions:

Problem	Possible Cause	Solution
Motor won't start	No voltage supply	Check connections and fuses
Excessive vibration	Mechanical misalignment	Check coupling and mounting
Incorrect power readings	Wrong wattmeter connections	Verify two-wattmeter method setup
Speed readings unstable	Tachometer issues	Check sensor alignment and connections
Motor overheats	Excessive load or poor ventilation	Reduce load, check cooling

Pre-Lab Preparation Checklist:

- Review induction motor theory
- Understand measurement techniques
- Prepare data tables
- Review safety procedures
- Bring calculator and graph paper