



T-shore
Education

Learning Scenario Manual



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Module:

Yaw Motor Systems

Learning scenario:

Yaw Motor Fault

Diagnosis



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Note This is a fictive generic equipment checklist intended for training purposes and therefore may vary from the equipment checklist provided by a company. It is important that a technician always read and fill checklist carefully prior to any task.

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1 List of tools

Table 1. List of tools

Tool name	Model / Version	Quantity
Maintenance report	V01	1 per participant
Multimeter	RS PRO RS14 Handheld Digital Multimeter	1
Multifunction meter	Fluke 1662 Multifunction Tester	1
Voltage tester	Fluke T150, LCD Voltage tester	1
Torque wrench	DeWalt Torque Wrench 1/2" x 30"	1
Screwdriver set	Wiha Mixed VDE Electricians Tools 6 Piece Set	1
Socket set	May not be needed	1

2 Instruction

2.1 Inspection preparation

Step 1: Documentation

- Fill out Table 1. Documentation overview and Table 2. Report overview in **Yaw motor fault diagnosis report**

Step 2: Safety procedures

- Carry out the correct lockout/tagout procedure to isolate the yaw motor for inspection.
- Fill out *Table 3. Safety procedures* in **Yaw motor fault diagnosis report**

2.2 Exercise 1 – Yaw motor operation safety

Lockout/Tagout Procedure for Yaw Motor and Control Cabinet

This procedure outlines the steps for safely disconnecting power to the yaw motor and control cabinet using proper lockout/tagout (LOTO) procedures. Accurate reporting and objective assessment are crucial for maintaining safety and equipment integrity.

Step 1: Preparation and Risk Assessment

- **Identify Energy Sources:** Before commencing any work, clearly identify all potential energy sources affecting the yaw system. This includes electrical power, stored mechanical energy (e.g., from the yaw brake), and any other relevant sources. Consult the turbine's schematics and documentation.
- **Job Safety Analysis (JSA):** Conduct a thorough JSA with involved personnel. Discuss potential hazards associated with the task, including electrical shock, falls, and pinch points. Document the JSA and ensure all team members understand the risks and mitigation strategies.
- **Gather Necessary Equipment:** Collect all required LOTO devices (locks, tags, hasps), personal protective equipment (PPE) (arc flash suit if required, insulated gloves, safety glasses, etc.), voltage tester, and documentation (LOTO log, turbine schematics, this procedure).
- **Inform Relevant Parties:** Notify the control center and any other relevant personnel about the planned LOTO procedure. Clearly communicate the turbine's identification, the affected systems (yaw motor and control cabinet), and the estimated duration of the work.

Step 2: Yaw System Isolation

- Yaw Brake Engagement (If Applicable): If the turbine is equipped with a yaw brake, ensure it is fully engaged and verified. Document the brake's status in table 4 of the inspection report.
- Electrical Isolation (Control Cabinet):
 - a) Locate the main disconnect switch for the yaw system within the control cabinet. Consult the turbine's electrical schematics to confirm the correct switch.
 - b) Using the voltage tester, verify that the power supply to the yaw system is still energised before operating the disconnect switch. Document the voltage reading in table 4 of the inspection report.
 - c) Open the disconnect switch to the "OFF" position.
 - d) Immediately re-test for voltage on both sides of the now open disconnect switch. Document the voltage readings in table 4 of the inspection report. **Zero voltage must be confirmed.**
- Lockout/Tagout Application (Control Cabinet):
 - e) Apply the appropriate lockout device (lock and hasp if needed) to the disconnect switch, preventing it from being accidentally closed.
 - f) Attach a tag to the lockout device. The tag must clearly identify the technician applying the lock, the date and time of lockout, the reason for the lockout, and the turbine identification.
 - g) Try out: Test the switch to ensure that it cannot be accidentally closed while locked out.

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Step 3: Yaw Motor Isolation (If Separate Disconnect)

- Locate Yaw Motor Disconnect (If Applicable): If the yaw motor has a separate disconnect, repeat the electrical isolation and LOTO procedure described in Step 2. If the yaw motor is hardwired and does not have a separate disconnect, this should be noted.
- Mechanical Block (If Applicable): If deemed necessary by the JSA, and in addition to electrical isolation, implement a mechanical block to prevent yaw movement. This might involve physically securing the yaw system using chains, slings, or other appropriate methods. Document the method of mechanical blocking used in the LOTO log.

Step 4: Verification and Documentation

- Verification of Isolation: After applying LOTO, attempt to operate the yaw system controls (from the control panel or remotely) to confirm that the power is completely disconnected. **Do not attempt to force any movement if the system remains energised.** Document the results of this verification attempt in tables 3 and 4 of the inspection report.
- LOTO Log Completion: Ensure table 3 of the inspection report is fully completed. This includes:
 - a) Turbine identification.
 - a) Location of LOTO points.
 - b) Names and signatures of all personnel involved in the LOTO.
 - c) Date and time of lockout.
 - d) Reason for lockout.
 - e) Results of voltage testing and verification attempts.
 - f) Details of any mechanical blocks used.
- Notification: Inform the control center and any other relevant personnel that the LOTO is in place.

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Step 5: Work Commencement

- Only after all the above steps have been completed and verified can work on the yaw motor and control cabinet commence.

Objective Assessment and Reporting:

Throughout this process, maintain an objective and detailed record of all observations. Note any unusual conditions encountered, such as damaged equipment, previous repairs, or any deviations from standard procedures. Report these findings to the supervisor and include them in the work report. Photographs can be a very effective way to document the state of the equipment, and any issues encountered. Accurate and thorough documentation is essential for ensuring safety, facilitating future maintenance, and improving the overall reliability of the wind turbine.

2.3 Exercise 2 - Yaw motor windings assessment

Yaw Motor Windings Inspection Procedure



This procedure outlines the steps for inspecting the yaw motor windings, including continuity, insulation resistance, and balance tests. Accurate assessment of the motor's condition is crucial for preventing failures and ensuring reliable operation.

Step 1: Visual Inspection

- g) **Control Cabinet:** Inspect the wiring and connections within the yaw control cabinet. Look for signs of damage, such as frayed wires, loose connections, corrosion, or overheating. Note the condition of the terminals and ensure they are securely fastened. Complete table 5 in inspection report.
- h) **Yaw Motor:** Visually inspect the yaw motor itself. Check for physical damage to the housing, fan, and terminal box. Look for signs of oil leaks, corrosion, or other indications of wear. Note the condition of the motor mounting and ensure it is secure. Complete table 5 in inspection report

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Step 2: Continuity Test (Control Cabinet)

- **Identify Windings:** Using the turbine's electrical schematics, identify the terminals corresponding to each of the three phases of the yaw motor windings (typically labelled U, V, and W).
- i) **Continuity Check:** Using a multimeter set to continuity, test for continuity between each pair of phases (U-V, V-W, W-U). There should be continuity between each pair. If no continuity is found, this indicates an open circuit in the winding, and further investigation is required. Document the results of each continuity test in table 5 of the inspection report.

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Step 3: Insulation Resistance Test (Control Cabinet)

- **Equipment Setup:** Connect the multifunction tester according to the manufacturer's instructions for insulation resistance testing.
- **Between Windings:** Test the insulation resistance between each pair of phases (U-V, V-W, W-U). A low insulation resistance indicates a potential short between the windings. Record the insulation resistance value for each pair. Consult the manufacturer's specifications for acceptable minimum insulation resistance values.
- **Between Windings and Casing:** Test the insulation resistance between each phase (U, V, W) and the motor casing/ground. A low insulation resistance indicates a potential short to ground. Record the insulation resistance value for each phase

to ground. Consult the manufacturer's specifications for acceptable minimum insulation resistance values.

Step 4: Resistance Balance Test (Control Cabinet)

Equipment Setup: Set the multimeter to measure resistance.

- j) **Resistance Measurement:** Measure the resistance of each phase winding (U, V, W) with respect to a common point (if available) or between each pair as in the continuity test. Record the resistance value for each phase in table 5 of the inspection report.
- k) **Balance Assessment:** Compare the resistance values of the three phases. The resistance should be relatively balanced. A significant difference in resistance between phases indicates a potential problem with the windings. Calculate the percentage difference between the highest and lowest resistance values. Consult the manufacturer's specifications for acceptable balance tolerances. Document the resistance of each phase and the calculated percentage difference in table 5 of the inspection report.

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Step 5: Yaw Motor Windings Inspection (At the Motor)

- **Terminal Box Access:** Carefully access the yaw motor terminal box.
- **Repeat Tests:** Repeat the continuity, insulation resistance, and balance tests described in Steps 2, 3, and 4 at the motor terminals. This provides a direct measurement of the winding condition at the motor itself, eliminating any influence from the cabling between the cabinet and the motor. Document all readings obtained at the motor.

Step 6: Assessment and Reporting

- **Condition Assessment:** Based on the results of the visual inspection and the electrical tests, assess the condition of the yaw motor windings. Consider the following:
 - l) Low insulation resistance readings indicate potential shorts and require further investigation.
 - m) Significant resistance imbalance indicates a potential problem with the windings.
 - n) Open circuits identified during the continuity test require immediate attention.
 - o) Any visual damage should be documented and addressed.



- p) Detailed Report: Complete the relevant sections of table 5 and 8 summarising the inspection findings. Include all measured values (continuity, insulation resistance, and resistance balance) and the location of each measurement (cabinet or motor). Clearly state the assessed condition of the motor windings (e.g., "windings appear to be in good condition," "suspected short in phase V to ground," etc.). Recommend any necessary repairs or further investigations. Include photographs of any observed damage or abnormalities.

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2.4 Exercise 3 – Yaw motor brake test

Yaw Motor Brake Test Procedure

This procedure outlines the steps for assessing the yaw motor brake, including visual inspection, electrical testing, and torque testing. Accurate assessment of the brake's functionality is crucial for safe and reliable turbine operation.

Step 1: Visual Inspection

- **Brake Assembly:** Carefully inspect the yaw motor brake. Look for signs of physical damage, such as cracks, wear, or corrosion.
 - **Wiring and Connections:** Inspect the wiring and connections to the brake solenoid from inside the terminal block. The wires connected to the rectifier will be the connected to the brake solenoid. Look for frayed wires, loose connections, or any other signs of damage. Ensure the wiring is properly routed and secured.
- q) Documentation: Document all observations in table 6 of the inspection report. Include photographs of any damage or abnormalities.

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Step 2: Solenoid Coil Resistance Test

- **Identify Terminals:** Locate the terminals on the brake solenoid coil. Consult the motors operating instructions manual if necessary.
- **Resistance Measurement:** Using a multimeter set to measure resistance, measure the resistance of the solenoid coil.
- **Comparison with Specifications:** Compare the measured resistance value with the manufacturer's declared range for the solenoid coil. A significant deviation from the specified range indicates a potential problem with the coil.
- **Documentation:** Record the measured resistance value and the manufacturer's specified range in the inspection report. Note any deviations.



Step 3: Solenoid Coil Ground Test

- **Equipment Setup:** Set the multimeter to measure resistance or continuity.
- **Test Procedure:** Test for continuity or low resistance between each solenoid terminal and the brake housing or ground. A reading of continuity or low resistance indicates a short to ground, which is a serious safety hazard and requires immediate attention.
- **Documentation:** Record the results of the ground test in the inspection report. Clearly indicate whether a short to ground was detected.

Step 4: Brake Torque Test

- **Preparation:** Ensure the yaw system is locked out and tagged out (LOTO) before proceeding with the torque test. Consult the turbine's maintenance manual for the specific torque value required for the yaw brake (typically 13 Nm, but this may vary).
 - **Torque Wrench Setup:** Use a calibrated torque wrench capable of measuring the specified torque value. Set the torque wrench to 13Nm.
 - **Test Procedure:** Apply the torque wrench to the designated point on the brake mechanism (consult the turbine's maintenance manual). Gradually increase the torque applied to the brake until the torque wrench click or the shaft slips.
 - **Torque test results:** If the torque wrench clicks, the brake is sound. If the shaft slips the brake has failed and the motor needs replacing.
- r) Documentation: Record the results in table 6 of the inspection report. |

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Step 5: Functional Test (Post LOTO Removal)

- **LOTO Removal:** After the torque test is complete, and if the results are satisfactory, remove the LOTO devices following the proper procedures.
 - **Operational Check:** Operate the yaw system and observe the brake's performance during normal operation. Verify that the brake engages and releases smoothly and reliably. Listen for any unusual noises or vibrations.
- s) **Documentation:** Document the results in table 6 in the inspection report. Note any issues encountered.

Step 6: Report Completion



The Yaw Motor Brake Test Report should include the following information:

- **Turbine Identification:** Record the specific turbine identification.
- **Date and Time:** Record the date and time of the inspection and test.
- **Technician Name:** Record the name of the technician performing the test.
- **Visual Inspection Findings:** Document all observations from the visual inspection, including photographs.
- **Solenoid Coil Resistance:** Record the measured resistance value and the manufacturer's specified range.
- **Solenoid Coil Ground Test Results:** Clearly state the results of the ground test (pass/fail).
- **Brake Torque Test Results:** Record the outcome of the torque test as pass or fail.
- **Functional Test Results:** Document the observations from the operational check.
- **Overall Assessment:** Provide an overall assessment of the brake's condition (e.g., "brake appears to be functioning correctly," "brake requires further investigation," etc.).
- **Recommendations:** Recommend any necessary repairs or further investigations.

By following this procedure and completing the report thoroughly, you can ensure the yaw motor brake is functioning correctly and contributing to the safe and efficient operation of the wind turbine.

2.5 Exercise 4 – Rectifier test

Rectifier Test Procedure

This procedure outlines the steps for assessing a rectifier using a multimeter with a diode testing function, including individual diode tests and voltage drop tests in both forward and reverse bias. Accurate assessment of the rectifier's functionality is crucial for proper electrical system operation.

Step 1: Visual Inspection

- **Rectifier Assembly:** Carefully inspect the rectifier assembly. Look for signs of physical damage, such as cracks, burns, or corrosion. Check the connections to the rectifier and ensure they are secure.



- **Wiring and Connections:** Inspect the wiring connected to the rectifier. Look for frayed wires, loose connections, or any other signs of damage. Ensure the wiring is properly routed and secured.
- **Documentation:** Document all observations in the inspection report. Include photographs of any damage or abnormalities.

Step 2: Individual Diode Test

- **Identify Diodes:** Identify the four diodes within the rectifier circuit. Consult the turbine's electrical schematics if necessary. Diodes are typically labelled D1, D2, D3, and D4.
- **Multimeter Setup:** Set the multimeter to the diode test function (typically indicated by a diode symbol).
- **Diode Testing:** For each diode:
 - a) **Forward Bias:** Connect the multimeter's positive (red) lead to the anode of the diode and the negative (black) lead to the cathode. The multimeter should display a voltage drop (typically between 0.5V and 0.8V for a silicon diode). This indicates the diode is functioning correctly in the forward direction.
 - t) **Reverse Bias:** Reverse the leads, connecting the positive (red) lead to the cathode and the negative (black) lead to the anode. The multimeter should display "OL" (overload) or a very high resistance. This indicates the diode is blocking current in the reverse direction, as it should.
- **Documentation:** Record the voltage drop in the forward direction and the reading in the reverse direction for each of the four diodes in the inspection report.

Step 3: Voltage Drop Test (Rectifier Circuit)

- **Identify Input and Output:** Identify the AC input terminals and the DC output terminals of the rectifier circuit. Consult the turbine's electrical schematics if necessary.
- **Multimeter Setup:** Set the multimeter to measure DC voltage.
- **Forward Bias (Positive DC Output):** Connect the multimeter's positive (red) lead to the positive DC output terminal of the rectifier and the negative (black) lead to





the negative DC output terminal. Measure and record the DC output voltage. This test verifies the rectifier converting AC to DC.

- **Reverse Bias (Negative DC Output):** Caution: This test requires careful consideration of the circuit and should only be performed if specifically indicated in the turbine's maintenance documentation. If the circuit allows, carefully reverse the leads, connecting the multimeter's positive (red) lead to the negative DC output terminal and the negative (black) lead to the positive DC output terminal. The voltage reading in this configuration should be very close to zero, indicating the rectifier is effectively blocking reverse current. If a significant voltage is measured, it indicates a possible failure in the rectifier. Consult the turbine's maintenance manual before attempting this test.
- **Documentation:** Record the DC output voltage in both the forward and (if performed) reverse bias configurations in the inspection report.

Step 4: Assessment and Reporting

- **Condition Assessment:** Based on the results of the visual inspection and the electrical tests, assess the condition of the rectifier. Consider the following:
 - a) Any significant deviation in forward voltage drop for an individual diode suggests a potential problem with that diode.
 - u) A reading other than "OL" or very high resistance in reverse bias for an individual diode indicates the diode is leaking current and should be replaced.
 - v) A low or unstable DC output voltage suggests a problem with the rectifier circuit as a whole.
 - w) A significant voltage reading during the reverse bias test of the rectifier circuit indicates a potential short in the rectifier.
 - x) **Detailed Report:** Complete the relevant sections of table 7 and 8 summarising the inspection findings. Include all measured values (forward voltage drop and reverse reading for each diode, DC output voltage in both configurations). Clearly state the assessed condition of the rectifier (e.g., "rectifier appears to be functioning correctly," "diode D3 shows signs of leakage," etc.). Recommend any necessary repairs or further investigations. Include photographs of any observed damage or abnormalities.

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By following this procedure and completing the report thoroughly, you can ensure the rectifier is functioning correctly and contributing to the safe and efficient operation of the wind turbine's electrical system.

2.6 Exercise 5 – Inspection report

Wind Turbine Inspection Report Completion Procedure

This procedure outlines the steps for completing a comprehensive wind turbine inspection report, incorporating results from various tests, including yaw motor brake testing, rectifier testing, and yaw motor winding inspection. The report should provide a clear assessment of the equipment's condition and justify any recommendations made.

Step 1: Overall Assessment

- **Summarise Findings:** Provide a concise summary of the condition of each component tested (yaw brake, rectifier, and yaw motor windings).
- **Identify Potential Issues:** Highlight any readings or observations that fall outside of acceptable ranges or indicate potential problems.

Step 2: Recommendations and Justification

- **Specific Recommendations:** Based on the test results and observations, provide specific and actionable recommendations. Examples:
 - a) "Replace yaw motor due to failure of the brake torque test."
 - y) "Replace rectifier due to reverse leakage."
 - z) "Replace yaw motor to investigate potential short in yaw motor windings due to low insulation resistance between phase U and ground."
 - aa) "Tighten loose connections in the yaw motor control cabinet."
- **Justification:** For each recommendation, provide clear and concise justification based on the data collected. Explain why the recommendation is necessary. Examples:
 - a) "The yaw brake pads are worn below the minimum acceptable thickness as measured during the visual inspection. This requires replacement to ensure adequate braking performance."
 - bb) "Diode D3 exhibited a low resistance in the reverse bias test, indicating leakage. This can affect the efficiency and reliability of the rectifier and requires replacement."

Commented [KK12]: If the intention is to produce one final report, then it would be beneficial to include tables for recording measurements from the previous sections. Throughout the document, the phrase "document the result" is repeatedly used, but there is no clear indication of where or how these results should be documented. The structure would be significantly improved if there were an inspection report divided into the four exercises, with each section containing a table to input comments, numerical data, or signal readings. Without such a framework, each training session risks being conducted differently, leading to a lack of repeatability and consistency.

cc) "The insulation resistance between phase U and ground was measured at 1 MΩ, which is below the manufacturer's recommended minimum of 5 MΩ. This indicates a potential short and requires further investigation to prevent a more serious electrical fault."

- Prioritisation (If Applicable): If multiple recommendations are made, prioritise them based on safety and operational impact.

Step 3: Review and Sign-off of Inspection Report

- Review: Carefully review the entire inspection report for accuracy and completeness.
- Sign-off: Sign and date the report.

By following this procedure and providing clear justifications for your recommendations, you can create a comprehensive and valuable inspection report that contributes to the safe and efficient operation of the wind turbine.



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