ReGENco™

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GENERATOR ROTOR INSPECTION & TEST REPORT

OKLAHOMA GAS AND ELECTRIC

MUSTANG TINKER STATION

UNIT 5

J03-01106

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1.0 SUMMARY / INTRODUCTION

This report covers the initial inspection of the Unit #5 generator rotor from the Oklahoma Gas and Electric, Mustang Tinker Generating Station. This Electric Machinery rotor was sent to the ReGENco repair facility in West Allis, WI for electrical testing to investigate a winding ground. In addition, a visual inspection of the shaft ends and end windings with the rotor coil retaining rings removed was performed. Initial findings are contained in this report.

2.0 REFERENCE INFORMATION

Manufacturer:	Electric Machinery
Rating:	46.5 MVA
Power Factor	0.90
Armature Volts:	13,800 volts
Phases:	3
Exciter Type	Brushless – shaft mounted
Rated Field Amps:	480 amps
Rated Field Volts:	250 volts

3.0 CONCLUSIONS – VISUAL INSPECTION FINDINGS

3.1 Rotor Rewind

ReGENco LLC Engineering recommends a complete rewind of this generator rotor. The fragile condition of this rotor's winding groundwall insulation system has created a number of locations where a direct failure to ground is imminent. Currently, there are a number of locations where high resistance grounds exist. The resistance of these fault locations was apparently low enough to trigger ground protection circuitry but sufficient resistance to avoid a double ground scenario where arcing damage could result to the rotor winding and forging.

There are approximately 1 dozen sub-slot bottom fillers that are clearly visiablely fractured and are likely sources of current high resistance grounds. (See Photos 1 & 2). These areas are potentially future sources for direct groundfaults. Fractured sub-slot filler will not have the mechanical strength to adequately support the groundwall slot channel. The lack of support to the slot channel provides another mechanism for direct ground condition.

There are also locations on the endwinding where it appears localized heating had occurred. Photo 3 illustrates one such example. It is likely that this represents a high resistance ground that generated heating during operation. Since the retaining rings' removal disturbed any confirming evidence of this theory, it is impossible to conclusively prove.

The endturn alignment is generally in good condition for both the exciter and turbine ends. Photo 4 represents coil stack alignment and support blocking condition typical to this entire machine.

No turn-to-turn winding shorts have been detected during the course of the stand still electrical testing of this inspection. The pole-to-pole balance testing and the coil-to-coil balance testing did not show voltage imbalances typically associated with stand still electrical shorts. The electrical testing performed to date during this inspection is not able to predict the condition of this rotor during operation, when it is subjected to the rigors of centrifugal loading at 3600 RPM.

Subsequently, the long-term reliability of this unit can be best served by a complete rewind of the rotor. ReGENco recommends that this rotor be rewound with all new insulation materials, and the existing copper conductors. The new insulation system would utilize class F temperature rated materials of current (non-asbestos) insulating material technology. Teflon slip planes and ReGENco's winding end turn blocking design would be employed to reduce future end winding distortion. The materials used in ReGENco's slot cell liners and fillers strips possess superior mechanical properties.

Reuse of the original winding conductors is recommended for cost and schedule savings. Additionally, the coil stack alignment is in generally good condition which further supports the recommendation for conductor re-use.

At the conclusion of the rotor rewind, a high speed balance is recommend to insure proper shaft dynamic balance is established for a reliable, trouble-free generator start-up.

3.2 <u>Rotor Rewind</u>

ReGENco LLC Engineering recommends a thorough and complete inspection of the rotating exciter's diode wheel and armature winding. The inspection of the rotating exciter would include:

- Extensive cleaning of both assemblies.
- "Match-marking" and labeling of all diode wheel components prior to any disassembly.
- Removal of the diodes and fuses on the diode wheel.
- Electrical testing of the diodes and fuses.
- Inspection of all diode wheel insulating washers, tubes, etc.
- Electrical testing of the armature assembly
- Final painting with insulating enamel

Components found to be defective would be recommended for replacement.

3.2 <u>Shaft Machining Recommendations</u>

Refer to Section 5.0 of this report.

4.0 ELECTRICAL TESTING

4.1 As Received Electrical Testing

The following electrical tests were performed upon receipt of the rotor at ReGENco. Results are as follows:

- Insulation Resistance at 500 VDC
  1 minute IR = 0 Ω
  10 minute IR = 30 kΩ
  Polarization Index = N/A

  Note 1: The fact that the insulation resistance became recordable late into the polarization index test indicates that the winding is not solidly grounded. Extremely low insulation resistance values are indications of compromised dielectric strength of the insulation, contaminated insulation, moisture, or a combination of these factors.

- Total Winding Impedance at 110 VAC
  Z = 24.56 Ω

- Pole Balance at 110 VAC
  The winding was energized with a 110 VAC energy source and the following voltage drops were measured across each pole.

  Pole 1 54.79 VAC
  Pole 2 55.21 VAC

  Note 2: Balanced (within 5%) pole voltage drops suggest that there is not a significant no shorted turn condition at standstill.

- Top Turn Impedance Testing
  The winding was energized with a 110 VAC energy source and the following voltage drops were measured through at the top turn of each coil through the ventilation duct in the rotor slot wedge. Since there are no ventilation ducts in the #1 coil wedges, the #1 coils could not be measured and evaluated with this test (both poles.)

Slot Number	Voltage Measured to Outboard Collector Ring (VAC)	Voltage Measured to Inboard Collector Ring (VAC)
1	N/A	N/A
2	21.53	106.01
3	18.41	91.76
4	18.74	91.34
5	36.04	74.09
6	36.41	73.69

7	32.20	66.72
8	33.73	67.67
9	73.35	36.89
10	73.67	36.37
11	91.22	19.21
12	91.45	18.90
13	105.83	4.37
14	N/A	N/A
15	N/A	N/A
16	106.06	4.28
17	91.83	18.75
18	91.49	19.02
19	74.10	36.43
20	73.58	36.75
21	55.35	55.04
22	54.91	55.45
23	36.74	73.68
24	36.28	74.11
25	18.98	91.40
26	18.62	91.75
27	4.34	106.11
28	N/A	N/A

Note 3: The top turn impedance data suggests that there are no shorted turns condition at standstill.

- DC Winding Resistance
  R_f = 0.392 Ω at 9.8°C (measured) average temperature
  R_f = 0.416 Ω at 25°C (calculated) corrected temperature
  R_f = 0.440 Ω at 40°C (calculated) corrected temperature

- DC Ground Investigation Testing
  A series of direct current tests were performed in an effort to specifically identify the location of the ground insulation deficiencies. Tests essentially involved energizing the winding with a low voltage, DC current source and measuring voltage drops at various winding locations to ground. Suspect areas were noted to be somewhere in 4 and 5 and 3 and 4 of pole 1. Because of the complete taping of the bottom winding turns and jumpers, further resolution of the ground location was not possible with out intrusive disruption of the tape insulation.

  Upon disassembly of the ventilation fans and retaining rings the visual inspection identified a multitude of potential dielectric deficiencies/failure. No further ground investigation tests were subsequently performed.

4.2 Turbine End Retaining Removed

After the disassembly of the turbine end retaining ring, the following tests were performed.

- Insulation Resistance at 500 VDC
  1 minute IR = 80 kΩ

- Total Winding Impedance at 110 VAC
  Z = 32.35 Ω

- Winding Pole Balance at 110 VAC
  Pole 1 55.26 VAC
  Pole 2 55.33 VAC

  Note 4: Because the bottom turns and bottom jumpers of each coil were fully taped, individual coil balance testing could not be performed without intrusive disruption of the tape insulation.

4.3 Both Retaining Removed

After the disassembly of the second (exciter end) retaining ring, the following tests were performed.

- Insulation Resistance at 500 VDC
  1 minute IR = 10 kΩ

- Total Winding Impedance at 110 VAC
  Z = 31.53 Ω

- Winding Pole Balance at 110 VAC
  Pole 1 54.99 VAC
  Pole 2 55.02 VAC

5.0 VISUAL INSPECTION - SHAFT

The following observations/recommendations are based on visual and dimensional information:

5.1 Bearing Journals

Both journals are well below our criteria for average out of roundness and lobe height. They contain a few minor circumferential scratches. Both journals should be super finished and polished to a 16 micro-inch finish.

5.2 Lathe Runout Indications

A complete run out survey of the rotor in the lathe indicated two questionable areas.

- Retaining rings - There was a large radial run out in the outer edge of the retaining rings (.037 inches on one end). We measured the thickness of the rings and found no indications that the rings were machined eccentric. They must have been cocked on the shrink fit. The position of the rings on the shrink fit will be closely monitored at installation.

- Coupling Hubs - The vertical faces on both coupling hubs had large axial run outs (.005 to .007 inches). It is believed we will not be allowed to cut these faces on this style of coupling. Once again extra care will have to be taken at assembly to insure the hubs are installed as straight as possible on the shaft ends.

- The run outs at all remaining locations were within our acceptable limits.

5.3 Retaining Ring Snap Rings
Both rings were badly damaged (expected) during the removal of the retaining rings. New snap rings will be manufactured for assembly.

5.4 Miscellaneous Rotor Components
The components removed from the shaft during the inspection are being cleaned prior to NDE inspection. Results will be available soon.

5.6 Retaining Ring Shrink Fits
There are some minor gouges and burrs on the retaining ring shrink fits and end wedges caused during the retaining ring removals. These areas will be cleaned up by local grinding and polishing.

5.7 Shaft Ends
The ends of the shaft were visually inspected and specific points of interest were noted.

6.0 PHOTOS

The following photographs were taken of Oklahoma Gas and Electric, Mustang Tinker #5 generator rotor in the ReGENco facility after the removal of the retaining rings.

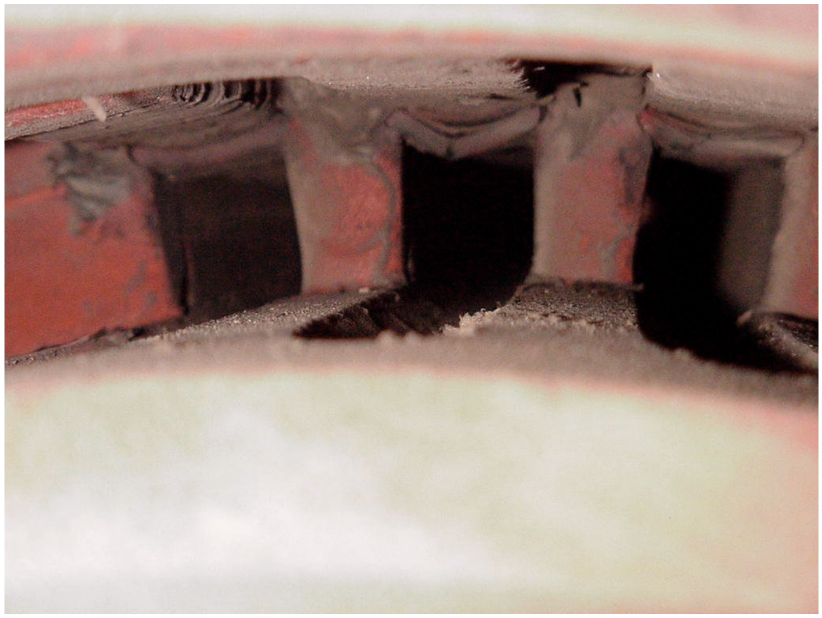

PHOTO 1, Fractured Sub-slot Filler, Exciter End

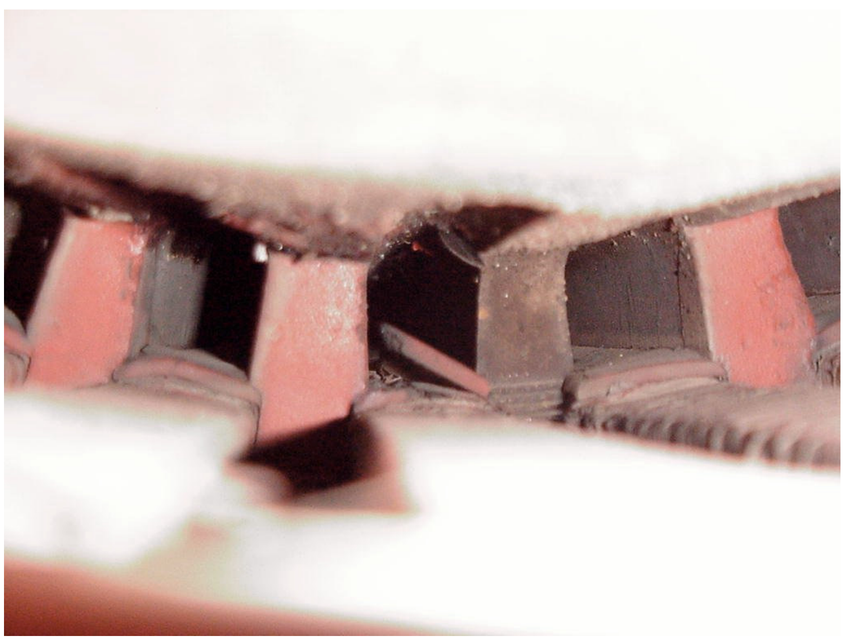

PHOTO 2, Fractured Sub-slot Filler, Turbine End

PHOTO 3, Localized Heating at Top Turn Exciter End

PHOTO 4, Turn Exciter End Endwinding