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# DETAILED REPORT ON OVERHAULING OF 5.1 MW SYNCHRONOUS MOTOR (11-KBX-203) AT LDPE PLANT OF IPCL, BARODA

| | |
|---|---|
| Work Order Ref: | **BSE/3588123 dated 05.11.2005** |
| Duration: | **08.01.2007 to 24.01.2007** |
| Customer Co-ordinators: | **M.K. Shah, H. Vasavada & S. Bhatwadekar** |
| Site Engineers: | **Shashikant Utekar, Manohar Rahate & Julius Tuscano** |
| Report by: | **Aditya Korde & Shashikant Utekar** |
| Analysis by: | **Aditya Korde** |

# EQUIPMENT DETAILS

| | | | |
|---|---|---|---|
| **Application:** | 11-KBX-203 Hyper Compressor Motor | | |
| **Make:** | Jeumont Schneider, France | **Type:** | SAT 316-38-30 |
| **Serial Number:** | 156124 | **Poles:** | 30 |
| **RPM:** | 200 | **Voltage:** | 6600 V |
| **Capacity:** | 5100 kW | **Current:** | 461 Amps |
| **Insulation Class:** | B | **Duty:** | Permanent |
| **Cooling:** | IC W37 AT 81 | **IP:** | IP-45 |
| **Excitation Volts:** | 139 | **Weight:** | 38000 kgs. |
| **Excitation Current:** | 218 | **Stator Slots:** | 225 |

# DETAILED OVERHAULING PROCEDURE

## DISSASSEMBLY & INITIAL TESTING:

1. DTIPL team reported at site. Detailed plan for execution of work was chalked out in co-ordination with IPCL engineers.

2. Safety training was attended by DTIPL team.

3. Work was started on 08.01.2007 at 10:30 AM after obtaining required permits from IPCL.

4. The 6.6 kV stator & exciter power supplies were disconnected with proper marking.

5. The clearances between end-shields and shaft were measured & recorded at both ends.

6. The barring gear was disengaged.

7. Top and bottom end-shields were removed from either end.

8. The inlet and outlet water pipes of the heat exchanger were removed.

9. The heat exchanger of the motor was lowered.

10. The position of the stator before sliding was measured, marked & recorded.

11. The air-gap between stator & rotor as well as the exciter was measured & recorded at 12, 3 & 6 o'clock positions.

12. The coupling guard of the motor was removed.

13. The star point of the motor was opened for testing & inspection.

14. The stator foundation bolts were unbolted and removed.

15. The stator was lifted by about 2 mm with the help of jack bolts & the shims were removed. 5 mm x 400 mm metal bright bars were placed between the stator & foundation. The stator was rested on these rods.

16. The stator was shifted towards compressor with the help of jacking studs.

17. Thorough visual inspection of the stator & rotor was done after sliding of stator & rotor.

18. Initial electrical testing of stator, rotor & exciter was done.

## OVERHAULING:

1. Scaffolding was done to approach the stator & rotor area.
2. Stator wedge mapping work was done. It was decided to re-wedge 100% slots (225) with new wedges.
3. The old gaskets from the end-shields were removed.
4. The end-shields were cleaned & painted on the inside using Becktol Red.
5. De-wedging & re-wedging of all slots was completed.
6. All the wedges were tied with fiberglass cord & sleeve and Araldite applied on the lacing.
7. Final mapping of wedges was done in presence of IPCL engineers.
8. The stator & rotor were thoroughly cleaned by dry compressed air & washed with solvents.
9. The full flux loop test was conduct on stator for assessing the stator core condition and also for drying out the stator.
10. The rotor was heated by applying DC current through the rotor winding.
11. Additional strip heaters were mounted below the stator & rotor for heating.
12. The stator & rotor were heated upto to 65°C.
13. The stator, rotor & exciter were varnished by using epoxy Gelcoat & Becktol Red.
14. Final electrical tests were performed on the stator, rotor & exciter.

# POLE REPLACEMENT:

1. Visual inspection was done on individual poles (30 nos.) with Jeumont engineers, who recommended replacement of all the poles.
2. The work was started with permission of IPCL engineers.
3. The new poles were shifted to electrical workshop.
4. The weights of all new poles were measured and pole pairs were select for installation.
5. All new poles were tested (test report enclosed). Two of them were found faulty. These were rejected and the two old poles were chosen for installation.
6. All new poles' threads were cleaned and re-threaded by M36 special tap.
7. The varnish was removed from the damper winding joints of old poles and the joints were cleaned.
8. Dye Penetrant testing was done on some of the old joints.
9. The damper winding joints were de-brazed and cut by hacksaw.
10. The field winding joints were de-brazed and de-soldered.
11. The pole fastening nut locks were unlocked by grinding.
12. The pole fastening nuts were unlocked by motor operated hydraulic wrench.
13. The barring gear was unlocked, removed & hung by EOT crane.
14. The metallic clamps of cable for pole to pole joint were unlocked and removed.
15. The barring gear was installed again.
16. The rotor position for removal and installation of pole was set at 12º clock.
17. Pole nos. 2 & 3 were removed and two new poles installed as per selection chart.
18. The other poles also removed and installed as per selection chart.
19. The pole fastening nuts were tightened by motor operated hydraulic wrench at 300 bar pressure.
20. The pole fastening nuts were locked by a plate welded to the nuts.
21. The damper winding joints were brazed & resistance was measured between two joints.
22. The pole to pole field winding joints were brazed & soldered.

23. The field winding joints were taped and varnished.

24. The barring gear was again removed.

25. The voltage drop test were carried out on the field winding joints.

26. Pole nos. 1 & 30 (positive & negative ) were installed and connection were made.

27. The metallic clamp of cable for filed winding joints (pole-to-pole) were installed and locked.

28. The barring gear was finally installed and locked.

29. The rotor was again tested. All the results were found as per protocol.

30. The rotor was thoroughly cleaned by vacuum pump and instrument air.

31. The rotor was heated by applying DC supply (125 amps) upto 75º C temp for about 18 hrs.

32. The rotor was varnished by Gelcoat after achieving IR in Giga-ohms.

## FINAL TESTING OF MOTOR:

### Tests & measurements performed in the presence of IPCL engineers:

- Insulation Resistance measurement of stator & rotor.
- Insulation Resistance measurement of exciter stator & rotor.
- Polarization Index measurement of stator.
- Resistance and Inductance measurement of the stator.
- Resistance measurement of the rotor.
- Resistance and Inductance measurement of exciter stator and rotor.
- Resistance measurement of rotating diodes.
- Full flux loop test on stator.
- PI measurement after overhauling.
- Step voltage & dielectric discharge tests on the stator.
- Tan delta & capacitance test on the stator.
- Winding circuit analysis of the stator, rotor & exciter.
- Surge comparison test on the stator & rotor.

## FINAL ASSEMBLY OF MOTOR:

1. Visual inspection of stator and rotor was done in the presence of IPCL engineers.
2. The foundation of the stator was cleaned using vacuum cleaner and solvents.
3. New gaskets were stuck to the end-shields.
4. The stator was shifted to its original position using 5 mm rollers and sliding fixtures.
5. The air-gap between stator and rotor was corrected as per the original readings and the foundation bolts tightened.
6. The heat exchanger of the stator was assembled.
7. The end-shields were assembled and the clearances were maintained and recorded.
8. The 6.6 kV cables were connected to the stator as per original marking.
9. The 6.6 kV star point was connected.
10. Connections of the main rotor and exciter were done.
11. The motor was painted with enamel gray paint.
12. No load trial of the motor was taken.

## DISASSEMBLY, INSPECTION & ASSEMBLY OF BEARING:

1. The exciter end bearing housing oil was drained.
2. The top cover of bearing was removed.
3. Top half of the bearing was removed.
4. The bearing & housing area were cleaned.
5. The radial clearance of the bearing was measured using lead wire. The clearance was found to be 0.36 mm, which was as per the protocol.
6. DP test was carried on top half of the bearing. The results was satisfactory.
7. The bearing was re-assembled after getting clearance from IPCL.

# ELECTRICAL TESTS

## MAIN STATOR & ROTOR:

**1. Insulation Resistance, Dielectric Discharge & Polarization Index (at 2.5 kV) before overhauling (5 kV Metrel Tera-ohm meter):**

| Parameter | R – Phase | Y – Phase | B – Phase |
|---|---|---|---|
| $R_{01}$ (GΩ) | 3.35 | 2.86 | 4.59 |
| $R_{10}$ (GΩ) | 13.00 | 16.7 | 19.9 |
| $R_{30}$ (GΩ) | 19.9 | 42.2 | 33.6 |
| PI | 3.88 | 5.83 | 4.34 |
| DD | 2.59 | 1.96 | 1.48 |
| Volts (V) | 2644 | 2641 | 2643 |
| Leakage Current (nA) | 132 | 62.5 | 78.4 |
| Capacitance (nF) | 115 | 114 | 112 |

**2. Insulation Resistance, Dielectric Discharge & Polarization Index (at 5 kV) after overhauling (5 kV Metrel Tera-ohm meter):**

| Parameter | R – Phase | Y – Phase | B – Phase |
|---|---|---|---|
| $R_{01}$ (GΩ) | 3.17 | 2.87 | 2.67 |
| $R_{10}$ (GΩ) | 12.1 | 11.6 | 11.2 |
| $R_{30}$ (GΩ) | 19.3 | 17.3 | 17.8 |
| PI | 3.82 | 4.04 | 4.21 |
| DD | 2.19 | 2.25 | 2.66 |
| Volts (V) | | 5261 | 5260 |
| Leakage Current (nA) | | 303 | 295 |
| Capacitance (nF) | | 111 | 108 |
| | **R – Y** | **Y – B** | **R – B** |
| IR bet$^{n}$ Phases (GΩ) | 6.09 | 4.78 | 6.35 |

**3. Resistance of stator winding (AGRONIK digital micro-ohm meter):**

| | |
|---|---|
| R – Y Phase (mΩ) | 160.7 |
| Y – B Phase (mΩ) | 160.9 |
| B – R Phase (mΩ) | 161.2 |

### 4. Winding Circuit Analysis of stator (All-Test Pro AT-31):

| Parameter | Frequencies (Hz) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **R – Phase:** | | | | | | |
| | **400** | **200** | **100** | **60** | **50** | **30** | **25** |
| Impedance (Ω) | 40.2 | 20.4 | 10.3 | 6.18 | 5.17 | 3.13 | 2.63 |
| Frequency response (%) | -51 | -49 | -47 | -44 | -41 | -31 | -27 |
| Phase Angle ($^0$) | 84 | 79 | 68 | 57 | 53 | 38 | 34 |
| Phase balance (%) | 8 | 8 | 16 | 25 | 30 | 50 | 57 |
| | **Y – Phase:** | | | | | | |
| Impedance (Ω) | 40.2 | 20.4 | 10.3 | 6.18 | 5.18 | 3.13 | 2.63 |
| Frequency response (%) | -51 | -49 | -47 | -44 | -41 | -31 | -27 |
| Phase Angle ($^0$) | 84 | 79 | 68 | 57 | 53 | 38 | 34 |
| Phase balance (%) | 8 | 8 | 16 | 25 | 30 | 50 | 57 |
| | **B – Phase:** | | | | | | |
| Impedance (Ω) | 40.3 | 20.5 | 10.3 | 6.19 | 5.19 | 3.14 | 2.63 |
| Frequency response (%) | -50 | -49 | -47 | -44 | -41 | -31 | -27 |
| Phase Angle ($^0$) | 84 | 79 | 68 | 57 | 53 | 38 | 34 |
| Phase balance (%) | 8 | 8 | 16 | 25 | 31 | 50 | 57 |

### 5. Winding Circuit Analysis of rotor with old poles (All-Test Pro AT-31):

| Parameter | Frequencies (Hz) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **400** | **200** | **100** | **60** | **50** | **30** | **25** |
| Impedance (Ω) | 366 | 221 | 128 | 84.9 | 73.4 | 49 | 42.3 |
| Frequency response (%) | 29 | 38 | 42 | 42 | 42 | 42 | 42 |
| Phase Angle ($^0$) | 84 | 76 | 72 | 71 | 70 | 69 | 69 |

### 6. Winding Circuit Analysis of rotor with new poles (All-Test Pro AT-31):

| Parameter | Frequencies (Hz) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **400** | **200** | **100** | **60** | **50** | **30** | **25** |
| Impedance (Ω) | 357 | 230 | 135 | 90.1 | 77.9 | 51.8 | 44.7 |
| Frequency response (%) | -17 | -34 | -41 | -42 | -42 | -42 | -42 |
| Phase Angle ($^0$) | 82 | 73 | 71 | 70 | 70 | 69 | 69 |

**7. Resistance of rotor winding (AGRONIK digital micro-ohm meter):**

| | |
|---|---|
| With old poles | 477 mΩ |
| With new poles | 464 mΩ |

**8. Resistance of winding RTDs (multi-meter):**

| **RTD nos.** | **Resistance (Ω)** |
|---|---|
| 1 | 117.85 |
| 2 | 112.19 |
| 3 | 113.16 |
| 4 | 114.34 |
| 5 | 119.75 |
| 6 | 113.96 |

**9. Resistance measurement of space heaters (multi-meter):**

| Phases | Space heater 1 | Space heater 2 | Space heater 3 | Space heater 4 |
|---|---|---|---|---|
| R – Y | 223 | 224 | 439 | 223 |
| Y – B | 220 | 226 | 439 | 223 |
| B – R | 225 | 224 | 439 | 223 |

**10. Insulation Resistance of each new pole at 250 V (5 kV Metrel Tera-ohm meter):**

| **Pole No.** | **IR (GΩ)** | **Pole No.** | **IR (GΩ)** |
|---|---|---|---|
| 1 | 158.0 | 16 | 160.0 |
| 2 | 134.0 | 17 | 435.0 |
| 3 | 468.0 | 18 | 400.0 |
| 4 | 49.94 | 19 | 227.0 |
| 5 | 78.90 | 20 | 230.0 |
| 6 | 78.40 | 21 | 300.0 |
| 7 | 18.24 | 22 | 345.0 |
| 8 | 92.60 | 23 | 10.80 |
| 9 | 75.20 | 24 | 10.70 |
| 10 | 29.30 | 25 | 15.80 |
| 11 | 243.0 | 26 | 89.60 |
| 12 | 270.0 | 27 | 161.0 |
| 13 | 6.603 | 28 | 125.0 |
| 14 | 170.0 | 29 | 173.0 |
| 15 | 135.0 | 30 | 158.0 |

**11. Resistance between joints of damper winding of new poles after brazing (AGRONIK digital micro-ohm meter):**

| Pole no. | Compressor side joint (μΩ) | Exciter side Joint (μΩ) | Pole no. | Compressor side joint (μΩ) | Exciter side joint (μΩ) |
|---|---|---|---|---|---|
| 1-30 | 3 | 4 | 15-16 | 8 | 7 |
| 29-30 | 2 | 4 | 14-15 | 9 | 4 |
| 28-29 | 6 | 6 | 13-14 | 8 | 4 |
| 27-28 | 2 | 2 | 12-13 | 4 | 6 |
| 26-27 | 9 | 8 | 11-12 | 5 | 3 |
| 25-26 | 7 | 5 | 10-11 | 7 | 2 |
| 24-25 | 7 | 2 | 9-10 | 2 | 2 |
| 23-24 | 5 | 3 | 8-9 | 3 | 5 |
| 22-23 | 5 | 6 | 7-8 | 5 | 5 |
| 21-22 | 10 | 4 | 6-7 | 8 | 10 |
| 20-21 | 4 | 3 | 5-6 | 6 | 3 |
| 19-20 | 6 | 5 | 4-5 | 6 | 9 |
| 18-19 | 2 | 4 | 3-4 | 8 | 4 |
| 17-18 | 4 | 3 | 2-3 | 5 | 8 |
| 16-17 | 8 | 8 | 1-2 | 7 | 2 |

**12. Pole identification nos. after installation of new poles:**

| Old / New Pole No. | Old / Pole No. |
|---|---|
| 1 (positive) – 12 | 16 – 30 |
| 2 – 11 | 17 – 22 |
| 3 – 28 | 18 – 18 |
| 4 – 21 | 19 – 16 |
| 5 – 04 | 20 – 15 |
| 6 – 27 | 21 – 09 |
| 7- 03 | 22 – 17 |
| 8 – 13 | 23 – 01 |
| 9 – 2 (old pole, 1975) | 24 – 23 |
| 10 – 14 | 25 – 07 |
| 11 – 8 (old pole) | 26 – 25 |
| 12 – 29 | 27 – 26 |
| 13 – 10 | 28 – 19 |
| 14 – 24 | 29 – 06 |
| 15 - 05 | 30 (negative) - 20 |

**13. Full Flux Loop Test:**

Applied Voltage: 415 V
Number of Loop Turns: 48
Current: 70 A
Ambient Temperature: $30^0$ C
Duration: 2 hours
Temperature rise in 2 hours. $39.5^0$ C
Purpose: detection of stator core hot spots
Conclusion: Stator scanned by Raytek infrared temperature gun. No hot spots were found in the stator core.

**14. Surge Comparison Test (at 5 kV):**

No interturn shorts were found in the stator winding.

***Waveforms of pole nos. 2 & 8 did not match those for the other coils. These poles are probably defective & hence not used.***

**15. Winding Circuit Analysis of new poles before installation (All-Test Pro AT-31):**

| **Frequency** | **400 Hz** | **200 Hz** | **100 Hz** | **60 Hz** | **50 Hz** | **30 Hz** | **25 Hz** |
|---|---|---|---|---|---|---|---|
| **Pole 1 :** | | | | | | | |
| Impedance (Ω) | 8.48 | 4.52 | 2.40 | 1.46 | 1.19 | 0.74 | 0.62 |
| Phase Angle ($^0$) | 57 | 46 | 31 | 21 | 18 | 11 | 10 |
| Frequency response (%) | -41 | -37 | -26 | -17 | -14 | -6 | -5 |
| **Pole 2 :** | | | | | | | |
| Impedance (Ω) | 5.38 | 3.09 | 1.85 | 1.23 | 1.05 | 0.68 | 0.57 |
| Phase Angle ($^0$) | 42 | 32 | 22 | 16 | 15 | 10 | 9 |
| Frequency response (%) | -34 | -27 | -17 | -13 | -12 | -8 | -6 |
| **Pole 3 :** | | | | | | | |
| Impedance (Ω) | 8.23 | 4.34 | 2.29 | 1.39 | 1.16 | 0.71 | 0.59 |
| Phase Angle ($^0$) | 57 | 45 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -42 | -37 | -26 | -16 | -13 | -6 | -4 |
| **Pole 4 :** | | | | | | | |
| Impedance (Ω) | 8.24 | 4.35 | 2.30 | 1.39 | 1.16 | 0.72 | 0.60 |
| Phase Angle ($^0$) | 57 | 45 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -42 | -37 | -25 | -16 | -13 | -6 | -4 |
| **Pole 5 :** | | | | | | | |
| Impedance (Ω) | 8.24 | 4.34 | 2.29 | 1.39 | 1.16 | 0.71 | 0.59 |
| Phase Angle ($^0$) | 58 | 45 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -42 | -37 | -25 | -16 | -12 | -6 | -4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Pole 6 :** | | | | | | | |
| Impedance (Ω) | 8.35 | 4.37 | 2.30 | 1.39 | 1.17 | 0.71 | 0.60 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -37 | -25 | -16 | -12 | -6 | -4 |
| **Frequency** | **400 Hz** | **200 Hz** | **100 Hz** | **60 Hz** | **50 Hz** | **30 Hz** | **25 Hz** |
| **Pole 7 :** | | | | | | | |
| Impedance (Ω) | 8.17 | 4.33 | 2.30 | 1.40 | 1.17 | 0.72 | 0.60 |
| Phase Angle ($^0$) | 58 | 45 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -42 | -37 | -25 | -16 | -13 | -6 | -5 |
| **Pole 8 :** | | | | | | | |
| Impedance (Ω) | 6.23 | 3.67 | 2.11 | 1.33 | 1.12 | 0.70 | 0.58 |
| Phase Angle ($^0$) | 44 | 36 | 26 | 19 | 16 | 10 | 9 |
| Frequency response (%) | -33 | -29 | -21 | -16 | -14 | -7 | -6 |
| **Pole 9 :** | | | | | | | |
| Impedance (Ω) | 8.33 | 4.35 | 2.30 | 1.39 | 1.16 | 0.71 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -37 | -25 | -16 | -12 | -6 | -4 |
| **Pole 10 :** | | | | | | | |
| Impedance (Ω) | 8.38 | 4.36 | 2.29 | 1.38 | 1.16 | 0.70 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -38 | -25 | -16 | -12 | -5 | -4 |
| **Pole 11 :** | | | | | | | |
| Impedance (Ω) | 8.27 | 4.33 | 2.28 | 1.39 | 1.16 | 0.71 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -42 | -37 | -25 | -16 | -12 | -6 | -4 |
| **Pole 12 :** | | | | | | | |
| Impedance (Ω) | 8.36 | 4.34 | 2.28 | 1.38 | 1.15 | 0.70 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -38 | -25 | -15 | -12 | -6 | -4 |
| **Pole 13 :** | | | | | | | |
| Impedance (Ω) | 8.22 | 4.29 | 2.28 | 1.42 | 1.21 | 0.77 | 0.65 |
| Phase Angle ($^0$) | 59 | 46 | 29 | 19 | 16 | 10 | 9 |
| Frequency response (%) | -43 | -37 | -28 | -15 | -12 | -6 | -4 |
| **Pole 14 :** | | | | | | | |
| Impedance (Ω) | 8.32 | 4.34 | 2.29 | 1.39 | 1.16 | 0.71 | 0.60 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -37 | -25 | -16 | -13 | -6 | -4 |

| **Frequency** | **400 Hz** | **200 Hz** | **100 Hz** | **60 Hz** | **50 Hz** | **30 Hz** | **25 Hz** |
|---|---|---|---|---|---|---|---|
| **Pole 15 :** | | | | | | | |
| Impedance (Ω) | 8.29 | 4.32 | 2.28 | 1.38 | 1.16 | 0.71 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -38 | -24 | -15 | -12 | -6 | -4 |
| **Pole 16 :** | | | | | | | |
| Impedance (Ω) | 8.40 | 4.38 | 2.33 | 1.50 | 1.13 | 0.81 | 0.61 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 19 | 16 | 11 | 9 |
| Frequency response (%) | -42 | -39 | -31 | -10 | -12 | -6 | -4 |
| **Pole 17 :** | | | | | | | |
| Impedance (Ω) | 8.38 | 4.38 | 2.31 | 1.40 | 1.17 | 0.71 | 0.60 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -38 | -25 | -16 | -12 | -6 | -4 |
| **Pole 18 :** | | | | | | | |
| Impedance (Ω) | 8.38 | 4.38 | 2.31 | 1.40 | 1.17 | 0.72 | 0.60 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -38 | -25 | -16 | -13 | -6 | -4 |
| **Pole 19 :** | | | | | | | |
| Impedance (Ω) | 8.34 | 4.35 | 2.30 | 1.39 | 1.16 | 0.71 | 0.60 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -38 | -25 | -16 | -13 | -6 | -4 |
| **Pole 20 :** | | | | | | | |
| Impedance (Ω) | 8.28 | 4.32 | 2.28 | 1.38 | 1.16 | 0.71 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -37 | -25 | -16 | -12 | -6 | -4 |
| **Pole 21 :** | | | | | | | |
| Impedance (Ω) | 8.48 | 4.32 | 2.28 | 1.38 | 1.16 | 0.71 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -37 | -25 | -16 | -12 | -6 | -4 |
| **Pole 22 :** | | | | | | | |
| Impedance (Ω) | 8.37 | 4.36 | 2.28 | 1.38 | 1.15 | 0.70 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -38 | -25 | -16 | -12 | -5 | -4 |
| **Pole 23 :** | | | | | | | |
| Impedance (Ω) | 8.29 | 4.32 | 2.28 | 1.38 | 1.16 | 0.71 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -37 | -25 | -16 | -12 | -6 | -4 |

| **Frequency** | **400 Hz** | **200 Hz** | **100 Hz** | **60 Hz** | **50 Hz** | **30 Hz** | **25 Hz** |
|---|---|---|---|---|---|---|---|
| **Pole 24 :** | | | | | | | |
| Impedance (Ω) | 8.33 | 4.33 | 2.27 | 1.37 | 1.15 | 0.70 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -38 | -25 | -15 | -12 | -5 | -4 |
| **Pole 25 :** | | | | | | | |
| Impedance (Ω) | 8.60 | 4.49 | 2.38 | 1.39 | 1.17 | 0.71 | 0.60 |
| Phase Angle ($^0$) | 59 | 47 | 31 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -42 | -38 | -26 | -16 | -13 | -6 | -4 |
| **Pole 26 :** | | | | | | | |
| Impedance (Ω) | 8.39 | 4.37 | 2.29 | 1.39 | 1.16 | 0.72 | 0.60 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -38 | -25 | -15 | -12 | -6 | -4 |
| **Pole 27 :** | | | | | | | |
| Impedance (Ω) | 8.39 | 4.40 | 2.33 | 1.42 | 1.19 | 0.73 | 0.61 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -42 | -37 | -25 | -16 | -13 | -6 | -4 |
| **Pole 28 :** | | | | | | | |
| Impedance (Ω) | 8.43 | 4.53 | 2.41 | 1.43 | 1.20 | 0.73 | 0.61 |
| Phase Angle ($^0$) | 57 | 47 | 31 | 20 | 18 | 11 | 9 |
| Frequency response (%) | -41 | -37 | -26 | -16 | -13 | -6 | -4 |
| **Pole 29 :** | | | | | | | |
| Impedance (Ω) | 8.17 | 4.33 | 2.30 | 1.40 | 1.17 | 0.72 | 0.60 |
| Phase Angle ($^0$) | 58 | 45 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -42 | -37 | -25 | -16 | -13 | -6 | -4 |
| **Pole 30 :** | | | | | | | |
| Impedance (Ω) | 8.32 | 4.34 | 2.29 | 1.39 | 1.16 | 0.71 | 0.59 |
| Phase Angle ($^0$) | 59 | 46 | 30 | 20 | 17 | 11 | 9 |
| Frequency response (%) | -43 | -37 | -25 | -15 | -13 | -6 | -4 |

***The windings of pole nos. 2 & 8 are clearly defective, probably having inter-turn shorts. These were thus not used.***

**16. Values measured by DTIPL & Jeumont of new poles before installation:**

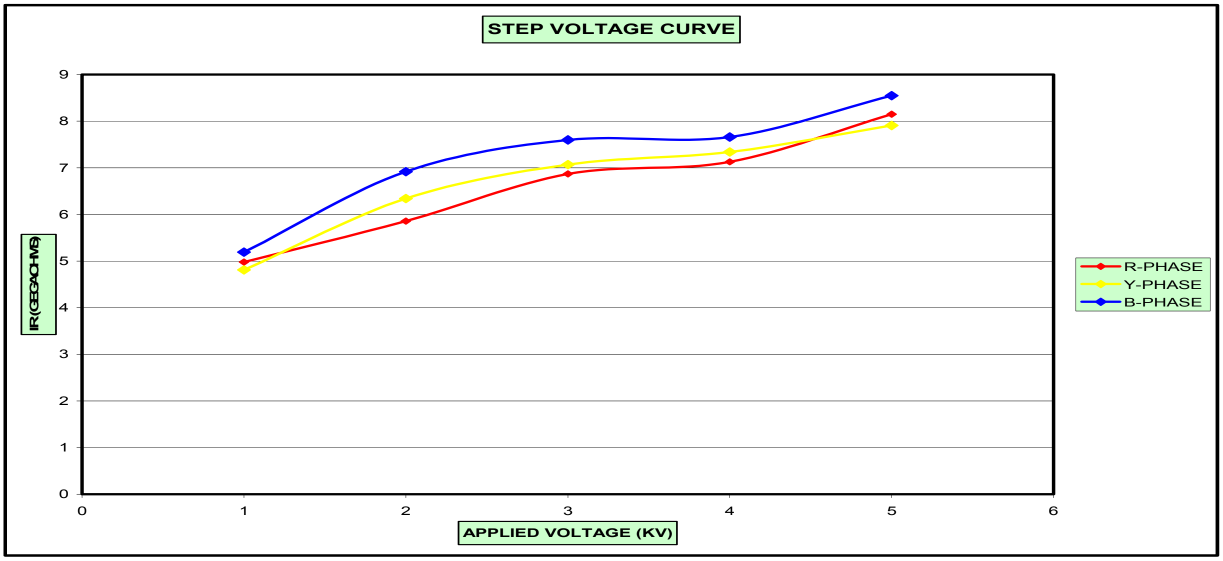
| Measured by DTIPL | | | | | Measured by Jeumont | | |
|---|---|---|---|---|---|---|---|
| **Pole no.** | **Weight of pole (at site)** | **Difference from median** | **R (mΩ)** | **L (mH)** | **Pole no.** | **Z (250 Hz)** | **Calculated inductance** |
| 1 | 171.9 | 0.45 | 15.20 | 3.4 | 3 | 5.61 | 3.573 |
| 2 | 172.4 | -0.05 | 15.11 | 2.9 | 5 | 5.54 | 3.529 |
| 3 | 172.5 | -0.15 | 15.25 | 3.4 | 7 | 5.55 | 3.535 |
| 4 | 171.7 | 0.65 | 15.40 | 3.4 | 1 | 5.62 | 3.580 |
| 5 | 172.5 | -0.15 | 15.50 | 3.4 | 6 | 5.53 | 3.522 |
| 6 | 172.1 | 0.25 | 15.06 | 3.4 | 9 | 5.50 | 3.503 |
| 7 | 172.3 | 0.05 | 15.30 | 3.4 | 2 | 5.54 | 3.529 |
| 8 | 172.3 | 0.05 | 15.00 | 3.2 | 4 | 5.60 | 3.567 |
| 9 | 172.3 | 0.05 | 15.60 | 3.4 | 14 | 5.56 | 3.541 |
| 10 | 172.7 | -0.35 | 15.30 | 3.4 | 8 | 5.60 | 3.567 |
| 11 | 172.2 | 0.15 | 15.31 | 3.4 | 23 | 5.54 | 3.529 |
| 12 | 171.5 | 0.85 | 15.30 | 3.4 | 10 | 5.60 | 3.567 |
| 13 | 171.9 | 0.45 | 15.31 | 3.4 | 22 | 5.56 | 3.541 |
| 14 | 172.1 | 0.25 | 15.33 | 3.4 | 30 | 5.54 | 3.529 |
| 15 | 171.9 | 0.45 | 15.30 | 3.4 | 28 | 5.56 | 3.541 |
| 16 | 172.6 | -0.25 | 15.30 | 3.4 | 11 | 5.63 | 3.586 |
| 17 | 172.5 | -0.15 | 15.30 | 3.4 | 17 | 5.62 | 3.580 |
| 18 | 172.9 | -0.55 | 15.20 | 3.4 | 25 | 5.56 | 3.541 |
| 19 | 173.0 | -0.65 | 14.90 | 3.4 | 20 | 5.50 | 3.503 |
| 20 | 172.5 | -0.15 | 15.20 | 3.4 | 24 | 5.65 | 3.599 |
| 21 | 172.6 | -0.25 | 15.25 | 3.4 | 27 | 5.59 | 3.561 |
| 22 | 172.0 | 0.35 | 15.00 | 3.4 | 15 | 5.59 | 3.561 |
| 23 | 172.3 | 0.05 | 15.20 | 3.4 | 21 | 5.51 | 3.510 |
| 24 | 171.9 | 0.45 | 15.10 | 3.4 | 26 | 5.54 | 3.529 |
| 25 | 172.9 | -0.55 | 15.60 | 3.4 | 29 | 5.65 | 3.599 |
| 26 | 172.6 | -0.25 | 15.20 | 3.4 | 12 | 5.56 | 3.541 |
| 27 | 172.4 | -0.05 | 15.42 | 3.4 | 19 | 5.59 | 3.561 |
| 28 | 172.8 | -0.45 | 15.61 | 3.4 | 13 | 5.62 | 3.580 |
| 29 | 172.4 | -0.05 | 15.20 | 3.4 | 16 | 5.56 | 3.541 |
| 30 | 171.9 | 0.45 | 14.50 | 3.4 | 18 | 5.53 | 3.522 |

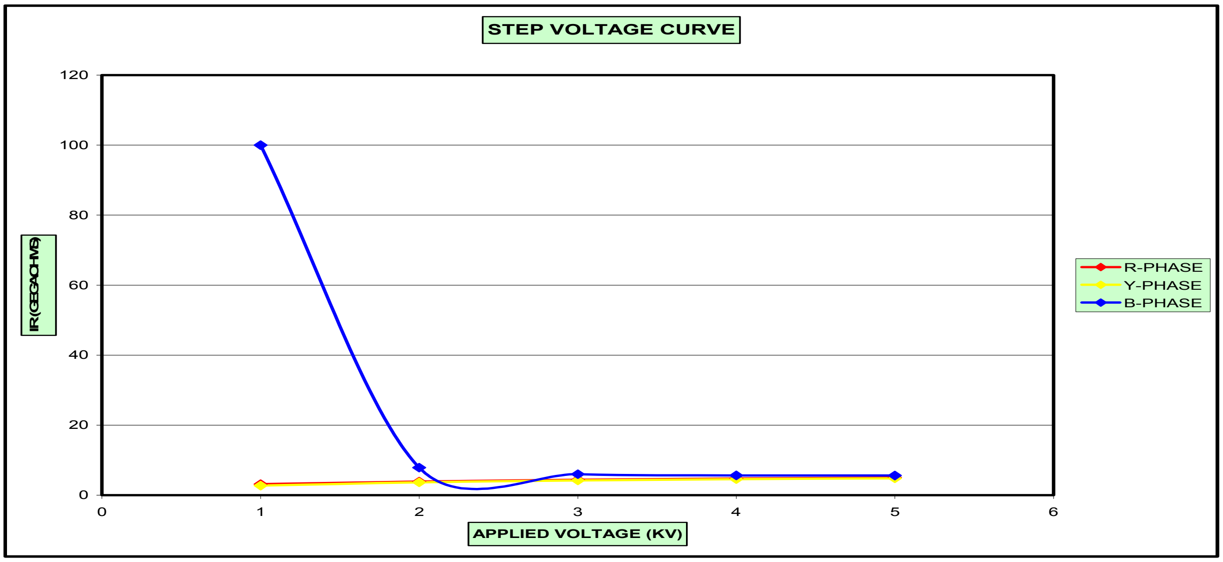
DTIPL pole number – written with white marker
Jeumont pole number – punched on each pole

**17. Voltage drop test after installation of new poles:**
All new poles were installed & connected with each other. Then; 63.8 V, 138 A DC was applied between pole nos. 1 & 30.

| Pole no. (in Between) | Voltage Drop (V) |
|---|---|
| 2-3 | 4.24 |
| 4-5 | 4.22 |
| 6-7 | 4.20 |
| 8-9 | 4.19 |
| 10-11 | 4.26 |
| 12-13 | 4.22 |
| 14-15 | 4.22 |
| 16-17 | 4.22 |
| 18-19 | 2.09 |
| 20-21 | 4.24 |
| 22-23 | 4.20 |
| 24-25 | 4.21 |
| 26-27 | 4.21 |
| 28-29 | 4.22 |
| 30-1 | 59.17 |
| 30 | 2.09 |
| 1 | 2.09 |

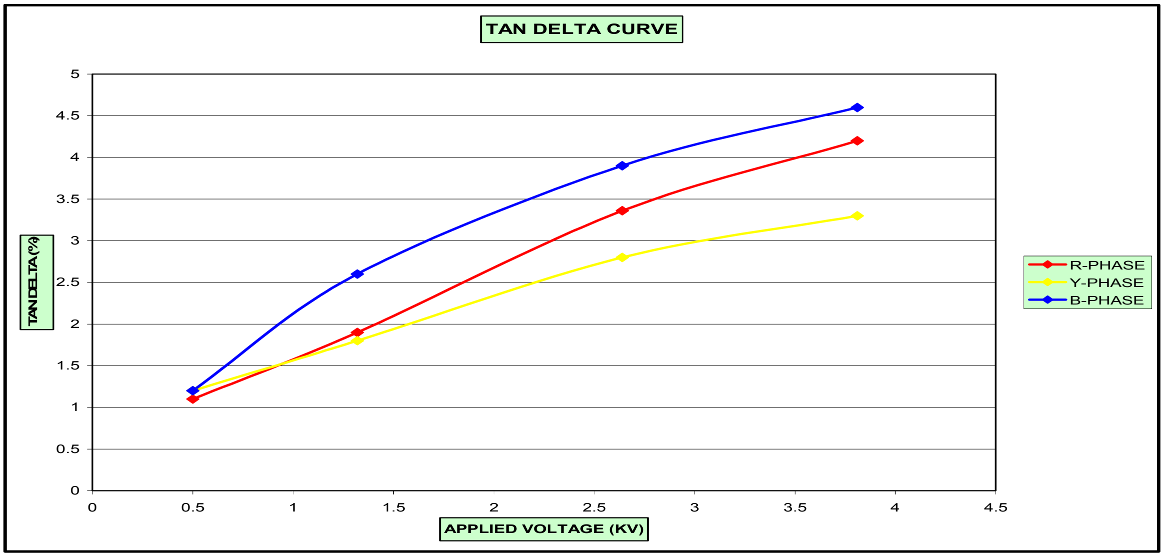
**18. Step Voltage test (at 5 kV) before overhauling (5 kV Metrel Tera-ohm meter):**

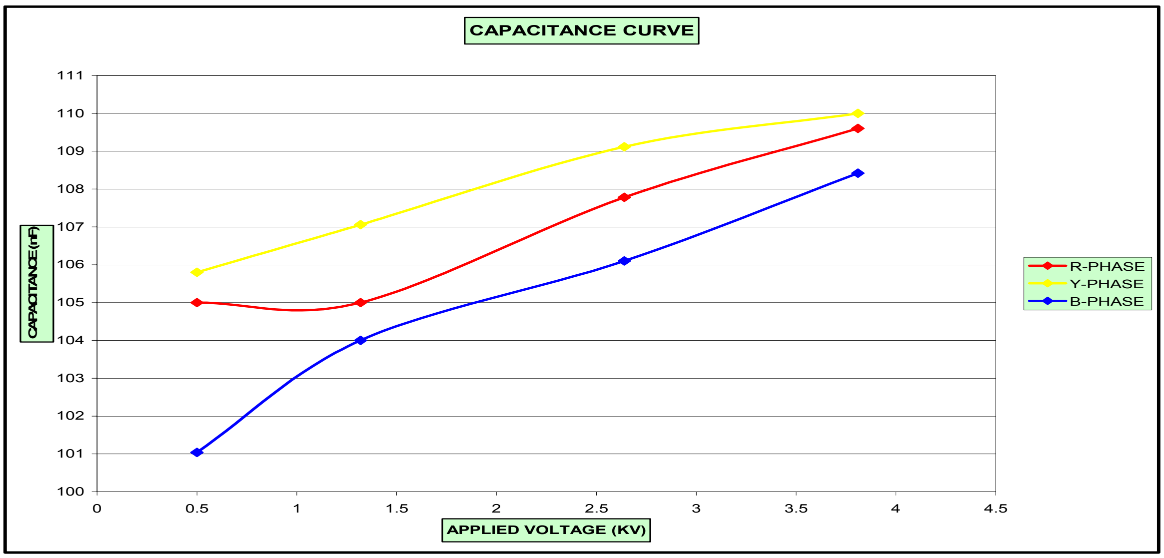



| Voltage (kV) | R – Phase IR (GΩ) | | Y – Phase IR (GΩ) | | B – Phase IR (GΩ) | |
|---|---|---|---|---|---|---|
| | before | after | before | after | before | after |
| 1 | 4.98 | 3.15 | 4.81 | 2.72 | 5.19 | 100.00 |
| 2 | 5.86 | 3.87 | 6.34 | 3.66 | 6.92 | 7.86 |
| 3 | 6.87 | 4.36 | 7.07 | 4.20 | 7.60 | 5.96 |
| 4 | 7.13 | 4.73 | 7.34 | 4.59 | 7.66 | 5.66 |
| 5 | 8.15 | 5.03 | 7.91 | 4.84 | 8.55 | 5.61 |

## 19. Tan Delta & Capacitance Results:




| APPLIED VOLTAGE (kV) | TAN DELTA (%) | | | CAPACITANCE (nF) | | |
|---|---|---|---|---|---|---|
| | R | Y | B | R | Y | B |
| 0.50 | 1.10 | 1.20 | 1.20 | 105.00 | 105.80 | 101.04 |
| 1.32 | 1.90 | 1.80 | 2.60 | 105.00 | 107.06 | 104.00 |
| 2.64 | 3.36 | 2.80 | 3.90 | 107.78 | 109.12 | 106.10 |
| 3.81 | 4.20 | 3.30 | 4.60 | 109.60 | 110.00 | 108.42 |
| TIP-UP (%) | 1.03 | 0.70 | 1.13 | 4.38 | 3.97 | 7.30 |

***The tan delta & capacitance tip-ups are extremely high, in absolute terms as well as in comparison with the other 5.1 MW motor. These indicate significant presence of voids as well as partial discharges in the winding insulation. Re-test motor within 6 months in order to plan action.***

## EXCITER STATOR & ROTOR:

**1. Winding Circuit Analysis of exciter stator & rotor (All-Test Pro AT-31):**

| **Frequency** | **400 Hz** | **200 Hz** | **100 Hz** | **60 Hz** | **50 Hz** | **30 Hz** | **25 Hz** |
|---|---|---|---|---|---|---|---|
| **Stator:** | | | | | | | |
| Impedance (Ω) | 496 | 287 | 167 | 113 | 97.3 | 65.5 | 57.0 |
| Phase Angle ($^0$) | 90 | 77 | 71 | 67 | 68 | 64 | 63 |
| Frequency response (%) | -17 | -39 | -42 | -41 | -42 | -41 | -41 |
| Phase balance (%) | | 23 | 9 | 8 | 7 | 4 | 6 |
| **Rotor:** | **+ ve Path** | | | | | | |
| | **200 Hz** | | | **50 Hz** | | | |
| | A-B | B-C | A-C | A-B | B-C | A-C | |
| Impedance (Ω) | 1.54 | 1.63 | 1.39 | 0.43 | 0.49 | 0.43 | |
| Phase Angle ($^0$) | 21 | 22 | 19 | 6 | 6 | 6 | |
| Frequency response (%) | -16 | -16 | -15 | -2 | -2 | -2 | |
| Phase balance (%) | 73 | 68 | 74 | 86 | 87 | 87 | |
| | **- ve Path** | | | | | | |
| | **200 Hz** | | | **50 Hz** | | | |
| | A-B | B-C | A-C | A-B | B-C | A-C | |
| Impedance (Ω) | 1.62 | 1.61 | 1.43 | 0.47 | 0.60 | 0.55 | |
| Phase Angle ($^0$) | 22 | 20 | 19 | 7 | 6 | 5 | |
| Frequency response (%) | -18 | -16 | -14 | -2 | -2 | -2 | |
| Phase balance (%) | 69 | 71 | 71 | 87 | 88 | 88 | |

**2. Resistance measurement of winding (AGRONIK digital micro-ohm meter):**

| **Test Circuit** | **Resistance** | |
|---|---|---|
| **Exciter stator** | 1.656 Ω | |
| **Exciter rotor** | **(+ve path)** | **(-ve path)** |
| A – B | 47.7 mΩ | 47.7 mΩ |
| B – C | 47.8 mΩ | 47.6 mΩ |
| A – C | 47.7 mΩ | 47.7 mΩ |

3. **Exciter rotating diode milli-volt drop (multimeter):**

| Diode number | +ve path | -ve path |
|---|---|---|
| A | 0.393 | 0.382 |
| B | 0.398 | 0.388 |
| C | 0.400 | 0.380 |

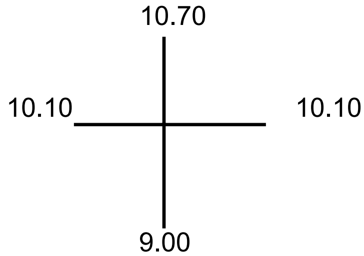
4. **Exciter stator IR at 250 V (5 kV Metrel Tera-ohm meter):** 34.4 GΩ

5. **Exciter rootr IR at 250 V (5 kV Metrel Tera-ohm meter):** 48.1 GΩ

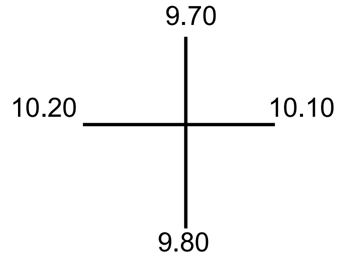
# MECHANICAL MEASUREMENTS

**1. Air Gap between stator & rotor (only approach is from compressor end):**

Before Dismantling

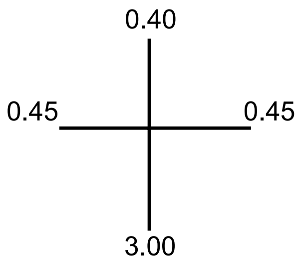



After Assembly

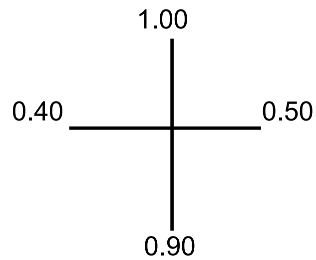



**2. Clearances between end shield & shaft before dismantling (in mm) :**

DE

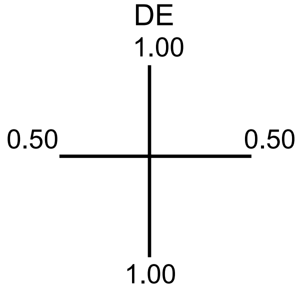



NDE

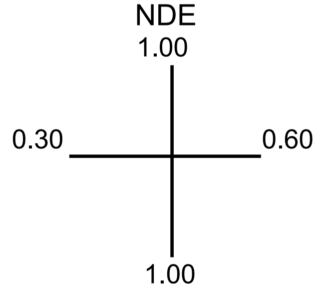



**3. Clearances between end shields & shaft after assembly (in mm) :**

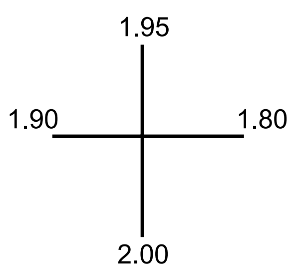
DE




NDE




**4. Air Gap between Exciter Stator & Rotor (in mm):**




**5. Radial clearance (with lead wire) of main bearing:**

0.35 mm

## ROTOR DRYING PROCEDURE CHART:

After completion of rotor pole replacement, it was observed that the rotor IR value was very low (in kΩ). Hence, rotor was thoroughly cleaned with compressed air & solvents. Heating by DC current injection was also carried out. IR value improvement chart was as under:

| Time | DC Current (Amps) | Temperature ($^0$C) | IR (at 250 V) |
|---|---|---|---|
| 1:00 hrs (21.1.07) | 100 | 32 | 211 kΩ |
| 3:00 hrs | 97 | 48 | 855 kΩ |
| 5:00 hrs | 97 | 51 | 980 kΩ |
| 7:00 hrs | 115 | 55 | 1.12 MΩ |
| 9:00 hrs | 113 | 57 | 1.24 MΩ |
| 11:00 hrs | 122 | 61 | 1.70 MΩ |
| 13:00 hrs | 122 | 62 | 2.98 MΩ |
| 15:00 hrs | 122 | 63 | 6.10 MΩ |
| 17:00 hrs | 122 | 64 | 6.44 MΩ |
| 19:00 hrs | 118 | 65 | 7.09 MΩ |
| 20:00 hrs | 120 | 65 | 16.15 MΩ |
| 22:00 hrs | 119 | 66 | 19.00 MΩ |
| 24:00 hrs | 119 | 67 | 28.50 MΩ |
| 2:00 hrs (22.1.07) | 119 | 67 | 29.90 MΩ |
| 3:00 hrs | 119 | 68 | 35.00 MΩ |
| 4:30 hrs | 119 | 69 | 130.0 MΩ |
| 7:30 hrs | 119 | 70 | 746.00 MΩ |
| 9:00 hrs | 119 | 70 | 1.22 GΩ |

## STATOR WEDGE MAPPING CHART:

Number of stator slots: 225
Number of wedges per slot: 2
Number of wedges: 450
Wedges found loose: 373
Wedges found OK: 77
**After wedge mapping it was decided with IPCL to rewedge all the 225 slots with new wedges.**

| Slot nos. | Wedge nos. | | Slot nos. | Wedge nos. | | Slot nos. | Wedge nos. | |
|---|---|---|---|---|---|---|---|---|
| | 'C' end | 'E' end | | 'C' end | 'E' end | | 'C' end | 'E' end |
| **1** | L | L | **53** | L | L | **104** | OK | OK |
| **2** | L | L | **54** | L | L | **105** | L | OK |
| **3** | L | OK | **55** | L | L | **106** | L | L |
| **4** | L | L | **56** | L | L | **107** | L | L |
| **5** | OK | L | **57** | OK | OK | **108** | OK | L |
| **6** | L | L | **58** | L | L | **109** | L | L |
| **7** | L | L | **59** | L | L | **110** | L | OK |
| **8** | L | L | **60** | L | L | **111** | L | L |
| **9** | L | OK | **61** | L | L | **112** | L | L |
| **10** | OK | L | **62** | OK | L | **113** | L | L |
| **11** | L | OK | **63** | OK | L | **114** | OK | L |
| **12** | L | L | **64** | L | L | **115** | L | OK |
| **13** | L | L | **65** | L | OK | **116** | OK | L |
| **14** | L | OK | **66** | L | L | **117** | L | L |
| **15** | L | OK | **67** | L | L | **118** | L | L |
| **16** | L | OK | **68** | L | L | **119** | L | L |
| **17** | L | L | **69** | OK | L | **120** | L | L |
| **18** | L | L | **70** | OK | L | **121** | OK | L |
| **19** | L | L | **71** | L | L | **123** | OK | L |
| **20** | L | L | **72** | L | L | **124** | L | L |
| **21** | OK | L | **73** | L | L | **125** | L | L |
| **22** | L | L | **74** | L | L | **126** | L | L |
| **23** | L | L | **75** | OK | L | **127** | L | L |
| **24** | OK | L | **76** | L | L | **128** | L | OK |
| **25** | OK | L | **77** | L | L | **129** | L | L |
| **26** | L | L | **78** | L | L | **130** | OK | L |
| **27** | L | L | **79** | OK | L | **131** | L | L |
| **28** | L | L | **80** | L | L | **132** | L | L |
| **29** | L | L | **81** | OK | L | **133** | L | L |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **30** | L | L | **82** | L | OK | **134** | L | L |
| **31** | L | OK | **83** | L | L | **135** | L | L |
| **32** | L | OK | **84** | L | L | **136** | L | L |
| **33** | L | L | **85** | L | L | **137** | OK | L |
| **34** | L | L | **86** | L | L | **138** | L | L |
| **35** | L | L | **87** | L | OK | **139** | L | L |
| **36** | L | L | **88** | L | OK | **140** | L | L |
| **37** | L | L | **89** | L | L | **141** | L | L |
| **38** | L | L | **90** | L | L | **142** | L | L |
| **39** | L | L | **91** | L | L | **143** | OK | L |
| **40** | L | L | **92** | L | L | **144** | OK | L |
| **41** | L | OK | **93** | L | L | **145** | L | L |
| **42** | L | OK | **94** | L | OK | **146** | L | L |
| **43** | L | OK | **95** | L | L | **147** | L | OK |
| **45** | L | L | **96** | L | L | **148** | OK | L |
| **46** | L | L | **97** | L | L | **149** | L | L |
| **47** | L | L | **98** | L | L | **150** | L | L |
| **48** | L | L | **99** | OK | L | **151** | L | OK |
| **49** | L | L | **100** | L | L | **152** | L | L |
| **50** | L | L | **101** | L | L | **153** | OK | L |
| **51** | L | OK | **102** | L | L | **154** | L | L |
| **52** | L | OK | **103** | L | L | **155** | L | L |
| **156** | L | L | **181** | L | OK | **206** | L | OK |
| **157** | OK | L | **182** | L | L | **207** | L | L |
| **158** | L | L | **183** | L | L | **208** | L | L |
| **159** | L | L | **184** | L | L | **209** | OK | L |
| **160** | L | L | **185** | L | L | **210** | L | L |
| **161** | L | L | **186** | OK | L | **211** | L | L |
| **162** | OK | L | **187** | OK | L | **212** | OK | L |
| **163** | L | L | **188** | L | L | **213** | L | L |
| **164** | L | L | **189** | L | L | **214** | L | L |
| **165** | L | L | **190** | OK | L | **215** | L | OK |
| **167** | OK | L | **192** | L | L | **216** | L | OK |
| **168** | OK | L | **193** | L | OK | **217** | L | OK |
| **169** | L | L | **194** | L | L | **218** | L | L |
| **170** | L | L | **195** | L | L | **219** | L | L |
| **171** | L | L | **196** | OK | L | **220** | L | L |
| **172** | L | L | **197** | L | L | **221** | OK | L |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **173** | L | L | **198** | L | OK | **222** | L | L |
| **174** | OK | L | **199** | L | L | **223** | L | L |
| **175** | OK | L | **200** | OK | L | **224** | L | L |
| **176** | L | L | **201** | L | L | **225** | L | OK |
| **177** | L | OK | **202** | L | L | | | |
| **178** | L | L | **203** | L | OK | | | |
| **179** | L | L | **204** | L | L | | | |
| **180** | L | OK | **205** | L | L | | | |

All the old wedges (450) were removed and installed new wedges with packers.