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Condition Monitoring and Life extension of Induction Motor

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Abstract:
Squirrel Cage Induction Motors are the most commonly used drives in industrial applications to drive majority of the production related Pumps and Compressors. Also their utilization is getting with the development of variable frequency drives for speed control. More than 50% of the world generated electrical energy is being consumed by these induction motors while driving their connected loads. They are more reliable, high efficient, rugged and simple in construction. Their cost is less when compared with others. Even though their designed shelf life is around 25 years, with proper Condition Monitoring, the breakdowns can be minimized and also their life can be extended. An attempt has been made in this paper to discuss about various faults associated with three phase Squirrel cage Induction Motor of LT category, different diagnosis methods applicable to them and the possible maintenance practices to enhance their life. One known case study is taken for analysis with its test details.

Keywords: *Index Terms-Squirrel Cage Induction Motor, Condition Monitoring, Shock Pulse, Leakage Current, Polarization Index.*

I. INTRODUCTION

Squirrel Cage Induction Motor (SCIM) is the most widely used in industries for pump and compressor applications. Due to their increased use; lot of research is being done to improve their efficiency, which has crossed 95% levels now [1]. Being faithful and more reliable equipment, it runs continuously with maximum efficiency, it requires regular health checkups to take care of wear and tear and to avoid breakdowns and halt to production in any industry. The major components in a SCIM are Stator, Rotor, Bearings, Shaft, Winding Terminals, Cooling Fan and associated hardware. The various types of faults occurred in SCIM, Testing or Diagnosis methods and required corrective actions with a case study are described in subsequent paragraphs.

II. TYPES OF FAULTS

The most common failure modes of SCIM are shown pictorially in fig 1 [2]. They are of as follows:

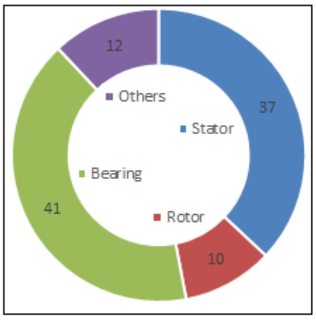

Fig 1 Type of SCIM faults

A. Stator winding faults: Insulation failure is the main factor in stator winding faults. The major causes of stator winding fault are shown in fig 2 [3] which are self-explanatory.

Stator fults:

* Insulation breakdown
* Circulating currents
* End winding fault
* Slot portion fault
* Core hot spots
* Core slackening
* Earth faults
* Phase to phase faults

Fig 2 Stator faults

B. Shaft and Rotor Faults: The main faults are bent Shaft, broken bars, cracked end rings etc. due to thermal, mechanical and dynamic stresses.

C. Bearing faults: High temperatures, poor lubrication, improper installation and material defects are the main causes of bearing failures. The common reasons for failure of bearings are shown in fig 3 [4].

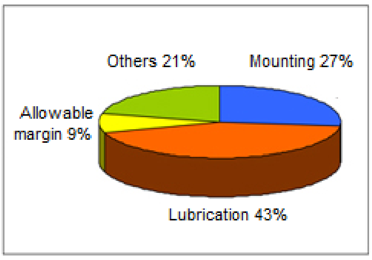

Fig 3 Causes of bearings failure

D. Others: There are some other faults due to irregular air-gaps, eccentricity issues and environmental conditions

III. Condition Monitoring Techniques and Tests

Even though SCIM are the most reliable electrical equipment, there are chances of failures due to various reasons mentioned above. These faults before leading to a major damage, to be identified along with a sound Condition Monitoring and Corrective Action System (CMCAS) to avoid future faults. This will avoid unwanted shutdowns and also enhances the life of motor. Also the present trend is to go for condition monitoring (CM) instead of traditional scheduled maintenance to cope up with the current to time and financial constraints.

A. Tests to be conducted on L.T. Motor: Following tests, to the extent possible at field, can be done to assess the condition of motor:

- Visual inspections.
- Measurement of Stator winding resistance.
- Measurement of IR, PI and DAR.
- Leakage Current Measurement.
- Flux loop test.
- Surge comparison test.
- No-load test.
- Load test.
- Alignment and Coupling.
- Shock pulse test and Vibration analysis.

B. Significance of Tests:

B1. Visual inspection: The Visual inspection includes checking of

- Cooling pins.
- Dust accumulation on body and cooling fan grills.
- Foundation, coupling and terminal box.
- On dismantling, checking wedge looseness, burnt markings, laminations etc.

The above inspections will ensure the healthiness of equipment and continuation in service with increased accuracy of visual inspections.

B2. DC Resistance of windings: This test indicates any inter-turn shorts, connection mistakes and unbalance between different phases. A shift from initial value indicates loose connections or defective brazing/soldering joints.

B3. Leakage Current Test: The main reason for failure or degradation of winding insulation is bad environment like temperature, humidity and moisture. An early detection of the degradation with the help of leakage current can eliminate the premature failures and reduces maintenance costs. While running, it can be measured either by measuring directly as load as shown in fig 4 or by voltage between a phase and ground. The maximum leakage permitted is 0.25 mA (unearthed equipment) and 0.75mA to 5% of total input current, as per IEC 60950[5].

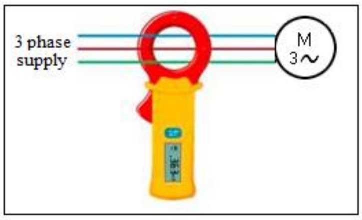

Fig 4 Leakage Current measurement

B4. Shaft Alignment: The proper coupling alignment with solid foundation ensures that the center of lines of motor Shaft and driven equipment are in line. This ensures that the vibrations are in limits, no to coupling failure, no foundation bolts problem etc.

B5. IR Test (Insulation resistance): It is a function of type and condition of insulating material used to evaluate the insulation. It is to be done by injecting 500V DC supply between a Conductor and body/ground, to know the healthiness of insulating material. The minimum value shall be KV+1 in Mega Ohms [6]. This value shall be taken after 60 seconds of injecting voltage and the readings will be of as shown in fig 5.

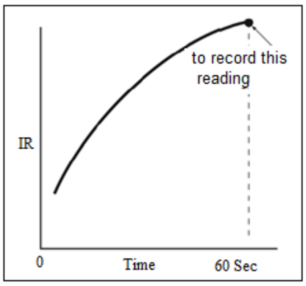

Fig 5 A typical IR Vs Time curve (Spot reading)

B6. DAR test (Dielectric Absorption ratio): For some of the equipment, where the absorption current(to be explained in next section) decreases, IR measurements after 30 seconds and 60 seconds will be taken to know the quality of insulation.

DAR= R_{60}/IR_{30} < 1.25 (Questionable, not good & requires re-insulation); < 1.6 OK (Adequate); >1.6 Good but DAR>1 is dangerous.

B7. PI test (Polarization Index): When D.C. supply given to insulation, the total leakage current(It) is divided into I_L, Ic, Ia and I_G as shown in fig 6 [7].

Capacitive current (Ic) : If a DC voltage is applied to an insulation, electrons will rush into the negative plate and be drawn from the positive plate. Initially, this current will very large but it will dies fast and reaches zero.

Absorption current (Ia) : The charges that form on the plates of the capacitor attract charges of the opposite polarity causing the charge movement and, thus current. Initially it is high but goes to lowest minimum in a few seconds.

Conduction current(Ic) : This is due to aging and degradation of insulation.

Leakage current (Il) : No insulator is perfect dielectric even as new and will have some leakages.

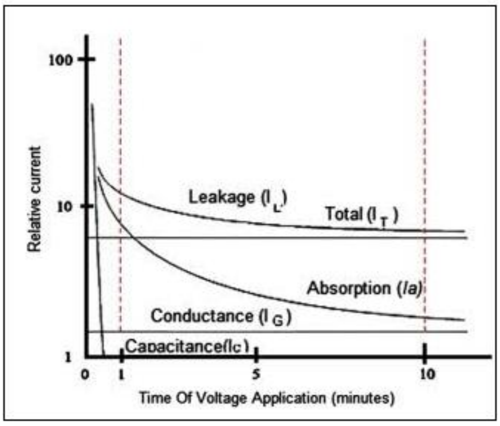

Fig 6 PI test on insulation

PI Value= IR after 10 minutes/IR after 1 minute. This value is used to assess the quality of insulation. The PI values signifies [6]

PI= 2 (minimum); <2 potential problems; >2 Excellent insulation.

So for values less than 2, a decision for re-insulation, if drying does not improve the PI value, is to be taken. However if the IR value is more than 5000 Mega ohms, there is no need to concentrate on PI [6].

B8. Flux-loop Test: With this test, the damages to thin stator laminations due to rubbing of stator and Rotor or other problems which reduces stator failures and core losses will be identified. This also helps in detecting hot spots of stator core and necessary corrective actions like re-staggering. This

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test is done by circulating the rated current over the core as shown in fig 7.

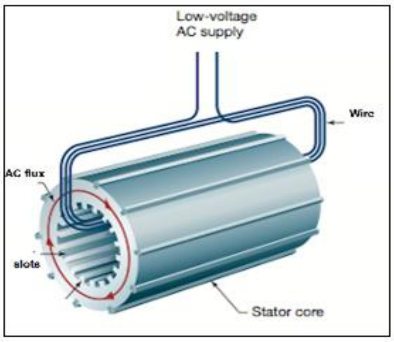

Fig 7 Flux-loop Test arrangement

B9. Surge comparison Test: It is used to find shorts and coil insulation weaknesses. A set of fast rising pulses are passed through the windings and the uniformity of all three waves indicates healthy winding.

B10. No-load and load Tests: These tests are done to ensure that the current, speed, losses and temperature rise are within the prescribed limits.

B11. Shock Pulse Test: This test is used to identify the condition of bearings, lubrication and remaining life with replacement. This is used by measuring the shock pulses of bearing with the help of Shock pulse Tester T2000 of SPM make, as shown in fig 8. Any bearing generates shocks whose magnitude varies based on the age and their condition. It is done by inputting the shaft diameter and RPM of Motor form which its initial shock value (dBi) is known, as shown in fig 9.

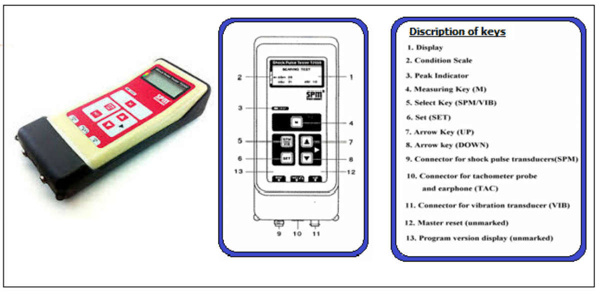

Fig 8 SP Tester

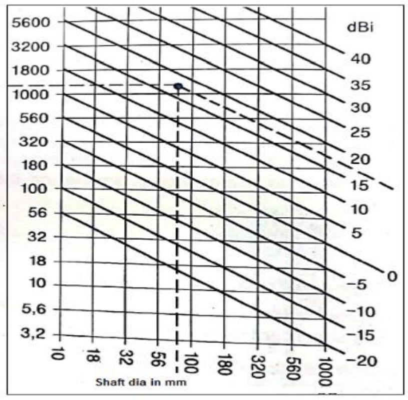

Fig 9 dBi Values chart

By measuring the carpet value (dBc of 15 to 35 is OK, which is due to aging) and maximum shock pulse value (dBm of above 35 is not acceptable.). Based on the results, the condition is known as Green (Ok), Yellow (caution) and Red (damaged and replacement is necessary). Pictorial view of dBi, dBc and dBm is shown in fig 10.

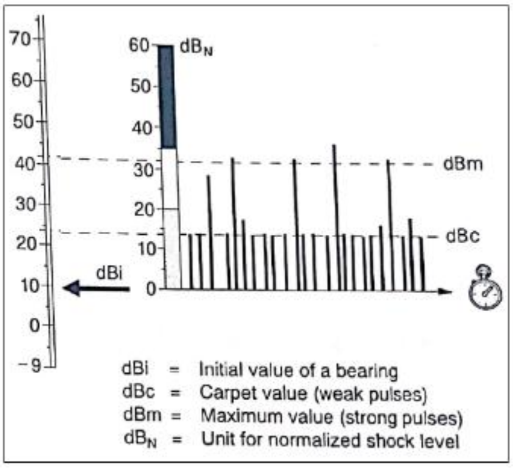

Fig 10 SP readings

B12. Vibration: Vibration measurement is an extended CM technique which is used to detect mechanical faults like bearings or mechanical imbalances. can be used to record vibrations. For normal motors, a maximum of 3 mm/Sec is acceptable as per ISO-2372[8].

IV. Experiential Result and Analysis

The systematic steps to be followed for CM are shown in the Flow chart, fig 11.

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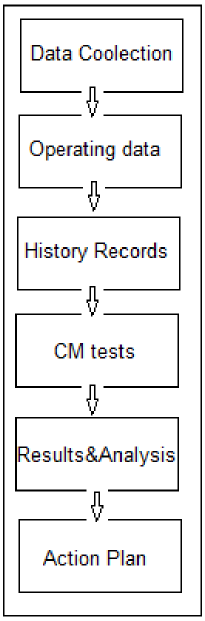

Fig 11 Flow chart for CM

To support the above mentioned tests and techniques, a recent case study of a motor is presented here.

A. Motor Name plate details are shown in table 1.

TABLE I Motor data

Supply	3 Ph, 415 V, 50 Hz
KW	185
Current (A)	307
RPM	1485
Temp Class	F
Efficiency & Power factor	95.25% & 0.90
Bearings(DE/NDE)	6319/6316
Resistance(Ohm)	0.20
Inductance(mH)	3.04
Shaft dia (mm)	95
Year commissioning	2005

B. No-Load data is shown in table 2.

TABLE II Motor No-load details

Current (A)	110
RPM	1495
Volts	430
Frequency	49.5 Hz
Max Body Temp(^{0}C)	72
KW	138

C. Load run data is shown in table 3.

TABLE III Motor Load run details

Current (A)	220
RPM	1495
Volts, freq.	430
Frequency	49.5 Hz
KW	138
PF	0.8

D. IR, PI and DAR tests on Stator are done with the available testing kits and the results are shown in table 4 and IR values are also shown pictorially in fig 12.

TABLE IV IR, PI and DAR

S. No	Between	Volts	Values in(GΩ)			PI	DAR
			30 Sec	300 Sec	600 Sec		
1	R-G	250	1.89	2.02	2.54	1.26	1.07
2	Y-G		1.71	1.86	2.40	1.29	1.09
3	B-G		1.67	1.71	2.01	1.18	1.02

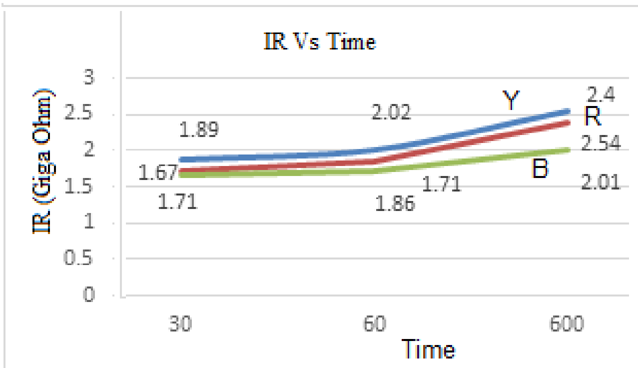

Fig 12 IR Vs Time

E. Leakage current test data shown in table 5.

TABLE V Leakage current test

Phase	Voltage	Leakage Current(nA)	1min IR Value(GΩ)
	250	156	1.66
	300	155	1.99
-G	350	156	2.31
	250	156	1.68
Y-G	300	151	2.03

	350	154	2.35
B-G	250	152	1.71
	300	153	2.03
	350	155	2.34

F. DC Winding Resistance (Stator) is shown in table 6.

TABLE VI Winding Resistance

Sl. No.	Current Injected (A)	Tested Phase	Winding Resistance (mΩ)
1	1.299	R-R	199.1
2	1.301	Y-R	181.3
3	1.301	B-B	180.3

G. Shock pulse readings are shown in table 7.

TABLE VII Shock pulse test

	End or Side	DE	NDE
1	RPM	1485	
2	Shaft dia in mm	95	80
3	dBi taken from graph	20	18
3	dBc measured	15	13
4	dBm measured	17	16
5	Vibration (mm/sec)	DE=1.1	NDE=1.3

H. Analysis:

- **IR, PI & DAR VALUES ARE NORMAL.**
- DC winding resistance test results are normal.
- Leakage Current Test results are normal.
- Shock pulse and vibration readings are in limits.

V. LIFE EXTENSION

As explained in preceding paragraphs, a sound CM policy with necessary follow up preventive measures will definitely increase the life of motors. An example of extending life with timely taken corrective action is shown in fig 13.

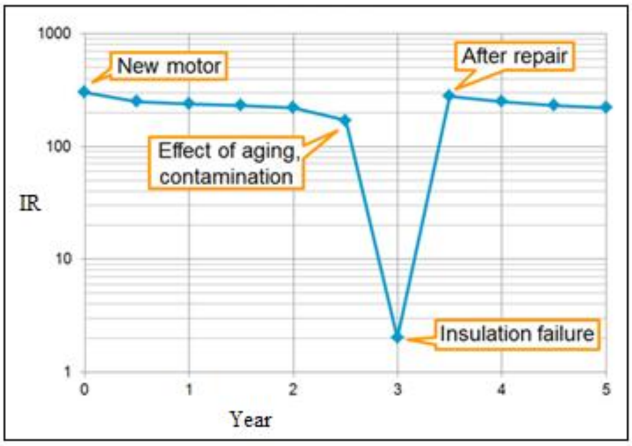

Fig 13 Life extension example

VI. CONCLUSION

SCIMS are more widely used in industries and other commercial establishments due to their rugged construction, economical operation and reliable service. A pre-mature failure or rigorous maintenance with more down time and costs of SCIMs are not acceptable in present modern industrial era. CM is the technique that is being extensively used aims in reducing motor failures and maintenance costs. With the practice of applicable conditions monitoring techniques and further corrective actions will increase the life of motors. Like regular medical checkups by Doctor for human to look for temperature, sugar levels and blood pressure etc., monitoring motor is required before its failure.

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