Proceedings of the International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT 2023)
IEEE Xplore Part Number: CFP23CV1-ART; ISBN: 978-1-6654-7451-1

2023 International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT) | 978-1-6654-7451-1/23/$31.00 ©2023 IEEE | DOI: 10.1109/IDCIoT56793.2023.10053524

MSCP Based Stator Fault Identification in Induction Motor Using Power Quality Analyzer

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Abstract— Most of the machines are driven by Induction motor nowadays. Induction motor gets failure due to various reasons. This fault mostly occurs in the stator. By measuring the current of a motor and comparing it to a fixed value, any fault can be detected. Different kind of faults exhibits different types of electrical current profile. The nature of this current is measured by a Power Quality Analyzer and converted into waveforms and spectrums. By looking closely at these three-phase current readings, one can predict when a machine is about to fail. Motor Stator Current Profile (MSCP) based method is proposed to identify the different stator faults.

Keywords—— Induction Motor (IM), stator turn to turn short or inter turn fault, Stator current pattern monitoring, MSCP.

I. Introduction To Fault Detection

Machines help a lot in energy conversion. Electricity is one of the most essential in today's modern world to run various types of machinery. A motor is what converts this electrical energy into mechanical energy that can rotate. Induction motors drive most of the machinery in industrial plants. Their maintenance and installation costs are very low [1]-[3].

Although operating an induction motor is easy, early detection of faults in them is currently a very challenging task. Monitoring the induction motor requires some form of artificial intelligence. It is imperative that the inputs given to that artificial intelligence are very carefully selected [4]-[5].

II. Block Diagram

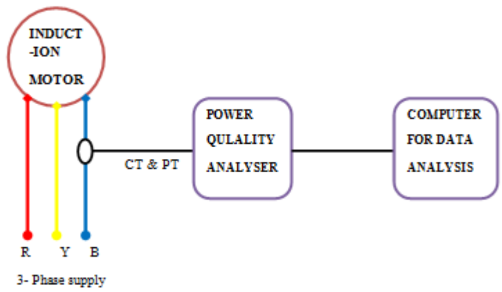

Fig.1. Conceptual diagram of stator fault monitoring system

The conceptual diagram in Fig.1 shows the method of measuring the stator fault monitoring system. Power quality analyzer is connected to measure the line and phase parameters from the induction motor.

III. Motor Current Pattern Analysis

The electrical pressure and current of an induction motor in normal condition are recorded by the power quality (PQ) analyzer. An induction motor is allowed to run at no load and the corresponding observations are noted. Gradually the load is applied to the machine and the three-phase current/voltage readings are measured. The time differences, root mean square magnitude, and cycles completed per seconds from the terminal are measured at each load level and these quantities are taken as standards. [6].

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IV. The Major Faults Of Induction Motor

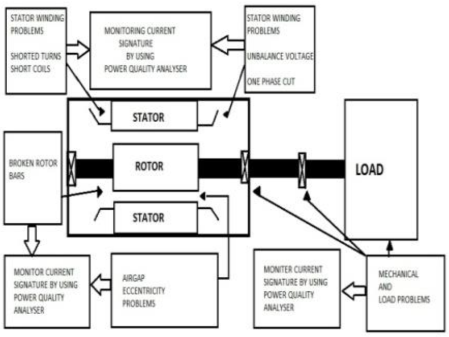

Fig.2. Different faults and monitoring systems in Induction Motor

The gap (μ_r=1) between stationary part and the rotating part of the machine is not in uniform. Because of the non-uniformity, the different faults happening in the motor and it are shown in figure 2.

The faults occurring in the rotating transformer is tabulated as per the IEEE Std. 493-1997 in table 1. General Electric (GE) conducted a test and presented the result. The results are shown in table 2.

TABLE I. Statistics Report On Motor Fault And Failures

Type of faults	Number of faults/failures				
	Induction motor	*Synchronous Motor*	*Wound-rotor Motor*	*DC Motor*	*All total Motors*
Bearing	152	2	10	2	166
Winding	75	16	6	_	97
Rotor	8	1	4	_	13
Shaft	19	_	_	_	19
Brushes or slip ring	–	6	8	2	16
External Device	10	7	1	_	18
Others	40	9	_	2	51

TABLE II. Abnormal Fault Occurrence Possibilities On Induction Motor

Studied by	Bearing fault (%)	Stator fault (%)	Rotor fault (%)	Others (%)
IEEE	42.5	28.4	8.3	22.5
EPRI	41.5	36.7	9.6	14.5

V. Motor Specification

TABLE III. Motor Specification

Specification	Values
Rating	1.1 KW
Voltage	400 V
No. of pole	4
No. of phase	3
Type of connection	Delta
Speed	1500 rpm
Slip	4%
Enclosure	TEFC
Type of bearing	Ball bearing
Resistance	19.3Ω
Reactance	24.5Ω
Impedance	31.3Ω
Coil per phase	4
No. of turns pre coil	40
SWG	10
Resistance per coil	4.825 Ω

The motor stator and rotor electrical parameters are listed in the above Table III.

VI. Mechanical Specification

TABLE IV. Mechanical Specification

Specification	Values
No. of stator slots	24
No. of rotor slots	18
Core length	75 mm
Rotor outer diameter (ROD)	71 mm
Stator inner diameter (SID)	73 mm
Air gap per side	1 mm
End ring thickness	8 mm
Slew angle	16°
Type of rotor	Squirrel cage aluminum die cast
Insulation class	E class

The motor's mechanical load parameters are listed in the above Table 4. Brake drum is used to load the machine from zero load current to 100 % of load current.

VII. Stator Faults

The possibilities of three phase star connected phase of a motor are shown in figure 3. The fault can be between the turns (inter-turn fault) or infinite resistance fault (open circuit of phase winding) or zero resistance fault (short circuit of phase winding). These faults need to be addressed immediately and the insulation strength loss due to ageing of winding insulation by flow of current can

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also be predicted by current pattern profile as per the IEEE standard [7].

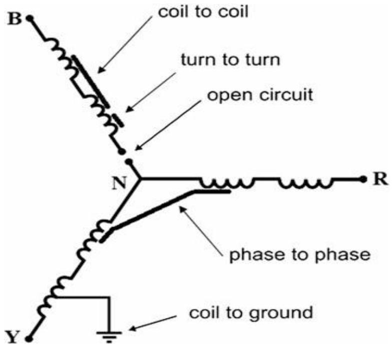

Fig.3. Possibilities of fault condition in three phase star connection

VIII. Creating Short Circuit Between The Turns In Stator Winding

In motor there are four coils in each phase, in only three coils will be running and one coil will be discarded in that one phase at running time. Each phase consists of four coils and each coil consists of forty turns. The fault will be created on single coil. So that the forty turns are disconnected. Hence the motor runs in three coils. The winding inter-turn is shown in fig 4. Figure 5 shows the corresponding line voltage and current waveforms. The current and electrical pressure (V) profile can be analyzed by Image deblurring techniques [9].

Fig.4 Stator inter-turn fault

IX. Procedure

Step 1: Motor runs in normal condition.
Step 2: During running time of motor single coil is disconnected using SPST switch. Hence remaining three coils are made to run the motor.
Step 3: By the help of PQA to monitor the voltage and current value.

TABLE V. STATOR WINDING FAULT

TEST	VRY (V)	VYB (V)	VBR (V)	IR (A)	IY (A)	IB (A)	Speed (RPM)	S1 kg	S2 Kg
No load	396	389	397	1.5	1.3	1.6	1474	0	0
With fault	400	403	404	1.6	2.5	2.1	1482	0	0
Case 1 Load 1.8A	392	393	395	1.8	1.5	1.7	1428	4	1
With fault	400	397	399	1.9	2.7	2.0	1430	4.5	1
Case 2 Load 1.9A	383	382	387	1.9	1.5	1.9	1389	7	2
With fault	395	395	399	2.0	2.8	2.1	1374	7	2
Case 3 Load 2.0A	392	394	400	2.0	1.7	2.2	1440	6	2
With fault	397	396	400	2.2	2.8	2.1	1426	6	2

The value of line voltages, currents, speed and the load value during the stator winding fault condition is tabulated in Table 5.

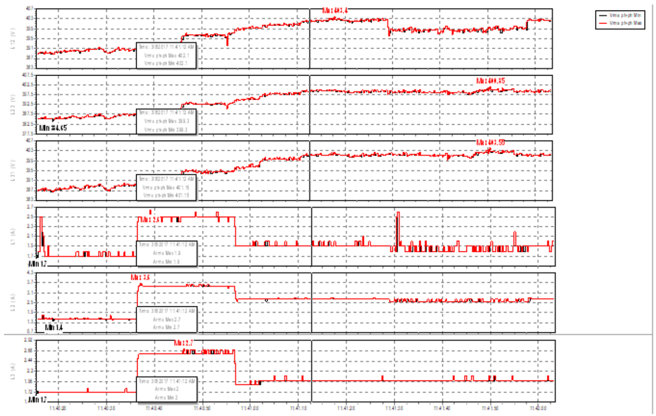

Fig.5. Voltage & Current Waveform of Stator Inter-tern Fault Condition

X. Single Phasing Condition

In R, Y and B phase of a machine, if any one of the phases either R-phase or Y-Phase or B-Phase is failed and other two phases are in healthy condition.

XI. Creating Faults In Stator

In R Y B, we discarded Y phase alone by using SPST switch and remaining R & B phase are taken into account. Initially the motor rotates in three phase supply mode. At running time of induction motor single phase is eliminated from the power supply. This led to single phase cut fault. This is shown in figure 6 and the corresponding line electrical pressure (V) and flow of electronics (I) waveforms are shown in figure 7.

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Fig.6. One phase cut using switch

XII. PROCEDURE

Step 1: To connect all three-phase wire to the induction motor, and turn on the supply.
Step 2: By the help of DPST switch to eliminate one phase.
Step 3: After saturate one phase absorb voltage and current value by the help of PQA.

TABLE VI. SINGLE PHASING FAULT

TEST	VRY (V)	VYB (V)	VBR (V)	IR (A)	IY (A)	IB (A)	Speed (RPM)	S1 Kg	S2 Kg
1ph cut No load condition Initial (before cut)	412	412	411	1.6	1.6	1.5	1494	0	0
1ph cut No load condition After cut (Y ph. cut)	294	337	409	2.0	0.3	1.9	1488	0	0
1ph cut load 1.8A condition Initial (before cut)	399	398	398	1.7	1.7	1.6	1410	5	1
1 ph. cut Load1.8 A	MOTOR FAILS								

The value of line voltages, currents, speed and the load value during the single-phase fault condition is tabulated in Table 6.

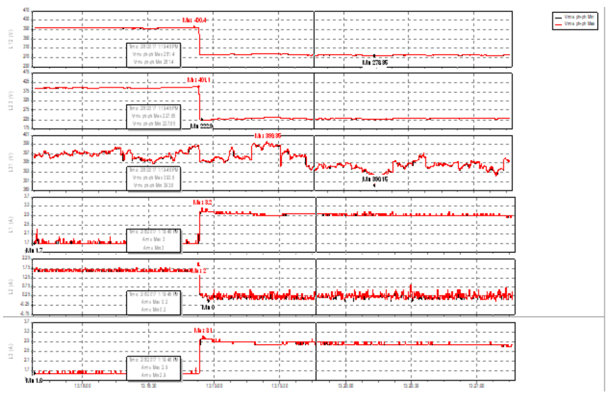

Fig.7. Voltage & Current Waveform of Single Phasing Fault Condition

XIII. UNBALANCE VOLAGE FAULT

Due to the mismatch in the number of turns in R-phase or Y-Phase or B-phase windings, the unbalanced voltage fault occurs in the motor itself. Resistance in all the phases is not equal in magnitude due to number of turns.

Fig.8. Unbalance voltage is created with help of external resistor

XIV. CREATING FAULT

The same unbalance voltage fault is recorded in the soar PV system with different current and voltage profile [10]. To create an unbalance voltage, the external resister is connected in each phase, why we need external resistor means, by varying the resister, voltage is drop at a particular phase. So, there will be an unbalance voltage in that particular phase [11]. External resistance: 50 Ω. This is shown in fig 8.

XV. PROCEDURE

Step 1: PQ Analyzer CT and PT are connected in each phase.
Step 2: External resistor are connected in each phase.
Step 3: By saturating the value of external resistance by
Case (I) R=50Ω Y=0Ω B=0Ω
Case (ii) R=0Ω Y=50Ω B=0Ω
Case (iii) R=0Ω Y=0Ω B=50Ω
The waveform of line voltages and currents value during the unbalanced voltage fault condition is tabulated in figure 9.

TABLE VII. UNBALANCE VOLTAGE FAULT

TEST	VRY (V)	VYB (V)	VBR (V)	IR (A)	IY (A)	IB (A)	Speed (RPM)	S1 Kg	S2 Kg
No load condition									
Initial Condition	400	403	401	1.5	1.5	1.5	1462	0	0
R phase 25 Ω Added	401	400	379	1.3	1.6	1.4	1416	0	0
R phase 50 Ω Added	398	402	358	1.1	1.8	1.5	1398	0	0
load condition 1.6A									
Initial Condition	399	400	401	1.8	1.7	1.7	1300	5	1
R=25Ω Y=0Ω B=0Ω	385	390	387	1.4	1.9	1.6	1240	5	1
R=50Ω Y=0Ω B=0Ω	368	394	340	1.2	2.0	1.6	1111	5	1
load condition 1.7A									
R=0Ω Y=0Ω B=0Ω	384	387	389	1.7	1.6	1.7	1298	6.5	2.5

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TEST	VRY (V)	VYB (V)	VBR (V)	IR (A)	IY (A)	IB (A)	Speed (RPM)	S1 Kg	S2 Kg
R=25Ω Y=0Ω B=0Ω	360	375	344	1.5	1.9	1.6	1278	6.5	2.5
Load condition 1.8A									
R=0Ω Y=0Ω B=0Ω	385	386	386	1.8	1.7	1.8	1388	7.5	2.5
R=25Ω Y=0Ω B=0Ω	370	386	353	1.6	2.2	1.7	1378	7.5	2.5
R=50Ω Y=50Ω B=0Ω	MOTOR FAILS								

The value of line voltages (V), currents (I), speed (N) and the load value during the unbalanced voltage fault condition is tabulated in Table 7. Similar kind of voltage and current waveforms are recorded during the unbalanced fault in planetary gearbox coupled induction motor stator faults [12].

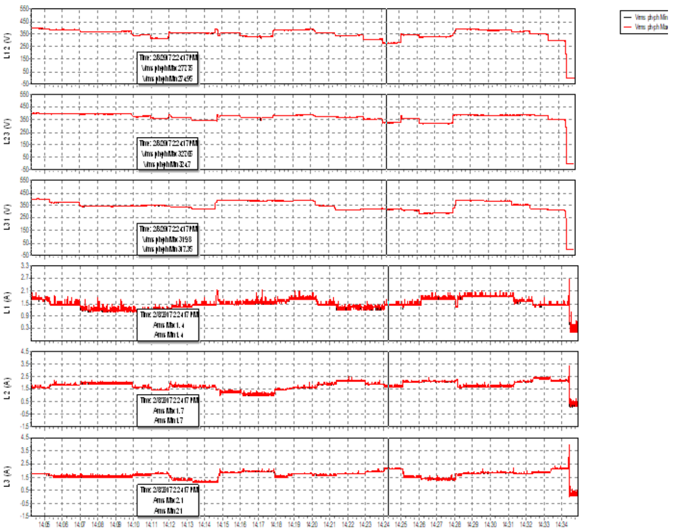

Fig.9. Voltage & Current Waveform of Unbalance Voltage Condition

XVI. Conclusion

Faults occurring on the stationary part of the induction motor are simulated artificially by suitable experiment setup and the readings are taken with the help of power quality meter (PQM). Electrical pressure at each phase and current at each winding are recorded and compared with the already taken standard values. The ageing of motor winding, open circuit or infinite resistance conditions and zero resistance condition or inter turn fault conditions are measured and successfully identified by the current profile.

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