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Monitoring Of Inter-Turn Insulation Degradation In Induction Motor Using Spirit Thermometer And Integrated Programmable Platform

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Abstract - Inter-turn stator short circuits can develop quickly leading to serious damage of an electric machine. The proposed method is only applicable to turn insulation failure detection. Its viability under different load conditions is validated for a small-sized induction motor with simulated turn insulation fault. The status of the stator windings can be continuously monitored and the insulation degradation can be detected before it reaches severe state. The main contribution of this paper is analysis of the impact of thermal ageing on the electrical properties of the thin film winding insulation. The losses in electrical machines causes decreasing of machine lifetime and breaking down of insulation. However, the stator winding and insulation is designed for safety operation but the winding temperature can be risen under special conditions such as motor stall, jam, overload, unbalanced operation, and situations where the cooling ability of the motor is accidentally reduced.

Keywords--Induction machines, turn insulation degradation, Integrated Programmable Platform.

I INTRODUCTION

The need for reliable, versatile and simple apparatus that can convert electrical energy into mechanical energy led to the invention of induction motors (IMs). Unlike DC motors, IMs are employed to operate over a large speed range with solid state power electronic control. IMs are widely used in many industrial applications as the main prime movers. Therefore, any malfunctions due to their failure can cause substantial damages and significant costs.

According to, low voltage induction motor stator faults account for only 9% of total failures. In medium voltage induction motors, the percentage increases to 35-40%, whereas for high voltage it is more than 65%. Among all possible stator faults, inter-turn stator faults are of particular interest because they are challenging to detect, especially at low severity levels, however they can evolve quickly leading to serious motor damage [1].

Moreover, these faults are difficult to discriminate from stator voltage supply imbalances. Thermal, vibration, electrical, and environmental stresses are key factors causing winding failures. These types of fault began from a local weakness in insulation material between two turns in a coil and rapidly expand to more severe faults [2].

If undetected at its initial formation, it eventually may result in entire process shut down in a few seconds after occurrence. Unscheduled downtime caused by stator winding faults will result in loss of production and significant maintenance costs. Therefore, the detection of stator winding insulation deterioration immediately following its occurrence has become a major concern. During the past decades, researchers tried to develop condition monitoring systems and test methods for assessment of the stator winding insulation material [3].

A new condition monitoring system is proposed aiming to continuously monitor the health condition of IM and detect the turn-to-turn insulation failure at its incipient stage. The aim is to model the initial stages of the SWID and then detect it as soon as it starts to take place. Hence, the condition of the machine during operation will be continuously monitored and when SWID starts to happen, it will be detected [3].

The effect of unbalance supplying voltage investigated on the motor temperature rising. For this purpose, by construction of the rotor and stator monitoring system, different unbalancing types have been applied on the 1.1 kW/50 Hz/ 1400 rpm motor and finally by different tests such as no-load, half load and full load. The effect of any type unbalancing on the temperature rising have been tested [4].

Even though induction motors are frequently used electromagnetic devices in industries owing to their high reliability, high efficiency, and low maintenance requirements, they are prone to various faults and failures [5]

However, condition monitoring fault diagnosis has to establish a map between motor signals and indications of the fault condition of motor. Classifying motor condition and estimating the severity of faults from the signals have never been easy tasks and they are affected by many factors. Condition monitoring and fault diagnosis of induction motor has attracted a great interest of researchers in the past few years [9].

II MONITORING AND CONTROL

The electrical motor condition monitoring is a growing technology to detect the fault of an induction motor. Condition monitoring of induction motors is a fast emerging technology for online detection of incipient faults. It avoids unexpected failure of a critical system. Approximately 30–40% of faults of induction motors are stator faults. Some 7500 motors were extensively surveyed and the results showed stator faults to be responsible for 37% of the failures. Therefore, implementing predictive maintenance on motors for stator faults requires diagnostic tests sensitive to the stator winding condition. If the insulation condition can be assessed online, more accurate and reliable diagnostic information on insulation condition and its remaining life can be provided to the machine user or operator. In addition, the measurements can be obtained under actual operating conditions without an outage with initial investment for the dedicated sensors and a means of processing the data for trending.

In this paper we are going to monitor the three phase AC induction motor for major faults astemperature rise and overloading.Temperature of the motor will increase beyond permissible limit when run motor over a long period, or when large current circulated through the windings of motor. The increase in temperature will damage the winding insulation.

III WAYS TO MONITOR AN INDUCTION MOTOR

The methods available for online stator insulation monitoring include thermal monitoring, chemical monitoring (ozone, tagging compound monitoring), phase and ground fault relays, and online partial discharge monitoring. The primary purpose of online thermal or chemical monitoring is to detect severe thermal problems in the insulation when insulation failure is imminent (they are only considered to be cost effective for large machines). Phase and ground fault relays are installed in a machine to prevent severe machine damage caused by insulation failure; however, they are of go/no go type monitoring and do not provide true monitoring capability. Online partial discharge monitors can detect partial discharge activity, which is one of the most important symptoms of severe insulation degradation leading to failure.

The most accepted and widely used offline stator insulation tests include the insulation resistance (polarization index), high potential (ac and dc), capacitance, dissipation factor (tip-up), surge comparison, and offline partial discharge tests, where each test is effective for diagnosing certain types of insulation problems. The main limitation of offline testing is that the machine must be removed from service.

IV TEMPERATURE RISE AND CLASS OF INSULATION FOR AC MOTORS

The correct class of insulation is essential in terms of a satisfactory operational life of AC motors, particularly in Middle East high ambient operation. The motor operational life is dependent upon a number of factors the winding insulation class, ambient temperature, motor efficiency, Copper/Iron mass of the stator and windings, voltage fluctuation & phase imbalance, winding temperature, bearing operating temperature and lubrication specification and load on the motor.

The winding operating temperature directly effects the life of winding insulation materials plus the bearings. Winding temperature rise is directly related to the efficiency of the motor, which is the power output at the shaft divided by the power input at the supply side. In general, motors are 85% efficient unless high efficiency motors are requested, in which case the efficiency would be 90-95%.

The heat generated is dissipated to the ambient air through the external surfaces of the motor and assistance of air forced over the surface in the stator/rotor air gap. For every 10degf (5.5degC) winding temperature rises above the insulation rating of the motor, the motor operating life will be reduced by 50%. Motor insulation temperature rise allowable for each class of insulation is always based upon an ambient of 72degf (40degC) which is the air on temperature to the motor for cooling purposes.

The service factors that should be specified are 1.10, 1.15 or 1.2 which provides a 10, 15 or 20% overload; sales people should not accept a service factor of 1.0. It is very easy to overload motors especially during pull down, increased air flow changes in air density/humidity or due to power supply voltage fluctuations or phase imbalances. Under such conditions a thermal reserve will allow the motor to operate without exceeding their class rating by using some or all of their thermal reserve. The temperature rise for motors with 1.0 service factor is as follows.

INSULATION CLASS	A	E	B	F	H	F WITH CLASS B RISE
TEMPERATURE RISE OF WINDING	60	75	80	100	125	80
AMBIENT TEMPERATURE	40	40	40	40	40	40
ALLOWANCE FOR HOT SPOTS	5	5	10	15	15	15
THERMAL RESERVE	0	0	0	0	0	20
TOTAL WINDING TEMPERATURE	105	120	130	155	180	155

Table 1 Different class of insulation

V WHY DO WE NEED INSULATION MONITORING

The losses in electrical machines causes decreasing of machine lifetime and breaking down of insulation. Therefore, in order to extend the insulation life, it is critical to monitor the stator and rotor temperature and protect the motor under thermal overloading conditions. However, the stator winding and insulation is designed for safety operation but the winding temperature can be risen under special conditions such as motor stall, jam, overload, unbalanced operation, and situations where the cooling ability of the motor is accidentally reduced. In this study the effect of unbalance supplying voltage on the motor temperature rising has been investigated. For this purpose, by construction of the rotor and stator monitoring system, different unbalancing types have been applied on the 1.1 kW / 50 Hz/ 1400 rpm motor and by doing different tests such as lock rotor, no-load and etc the effect of any type of unbalancing on the temperature rising has been investigated.

Squirrel cage induction motors are the most important ac machines in industries. Low cost, high reliability, low inertia and high transient torque capacity are among the advantages of these motors. Many resources show that 35%–45% of motor failures are caused by stator insulation breakdown. For small induction machines, thermal overloading is one of the major causes of the stator winding insulation degradation process. Therefore, in order to extend the insulation life, it is critical to monitor the stator winding temperature and protect the motor under thermal overloading conditions such as motor stall, jam, overload, unbalanced operation, and situations where the cooling ability of the motor is accidentally reduced.

VI BLOCK DIAGRAM

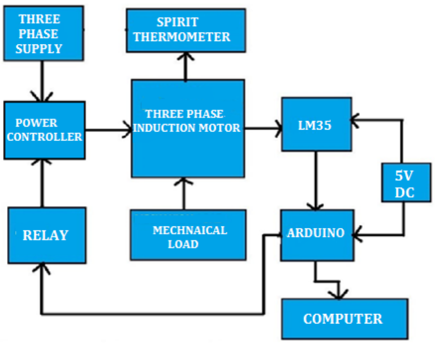

Fig 1 Block Diagram

Here AC supply isgiven to three phase squirrel cage induction motor of 1.1 kW / 50 Hz/ 1400 rpm. Temperature sensor, LM35 will be fixed in stator windings of induction motor and a

5V DC supply will be given from the battery. It will measure the temperature around it.

A microcontroller will be programmed to obtain the output showing the level of insulation digitally. Arduino board will be used as microcontroller. It is provided with a supply of 7-12v from a battery.Simulation process is carried out by using MATLAB software which is installed in the computer. The output will be shown digitally.Mechanical load will be used to load the induction motor.A sprit thermometer is used to show the temperature of the winding as a analog output corresponding to digital output.

The LM35-series devices are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ± ¼ °C at room temperature and ± ¾ °C over a full −55°C to 150°C temperature range.

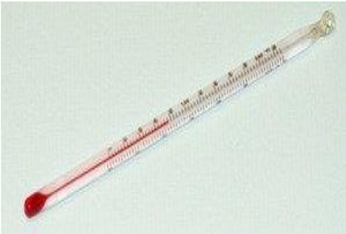

Fig 2 Spirit Thermometer

The alcohol thermometer or spirit thermometer is an alternative to the mercury-in-glass thermometer and has similar functions. Unlike the mercury-in-glass thermometer, the contents of an alcohol thermometer are less toxic and will evaporate quickly. The ethanol version is the most widely used due to the low cost and relatively low hazard posed by the liquid in case of breakage.

An organic liquid is contained in a glass bulb which is connected to a capillary of the same glass and the end is sealed with an expansion bulb. The space above the liquid is a mixture of nitrogen and the vapour of the liquid. For the working temperature range, the meniscus or interface between the liquid is within the capillary. With increasing temperature, the volume of liquid expands and the meniscus moves up the capillary. The position of the meniscus shows the temperature against an inscribed scale.

The liquid used can be pure ethanol, toluene, kerosene or isoamyl acetate, depending on manufacturer and working temperature range.[1] Since these are transparent, the liquid is made more visible by the addition of a red or blue dye. One half of the glass containing the capillary is usually enamelled white or yellow to give a background for reading the scale.

The range of usefulness of the thermometer is set by the boiling point of the liquid used. In the case of the ethanol-filled thermometer, the upper limit for measurement is 78 °C (172 °F), which makes it useful for measuring daytime, night-time and body temperatures, although not for anything much hotter than these.

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

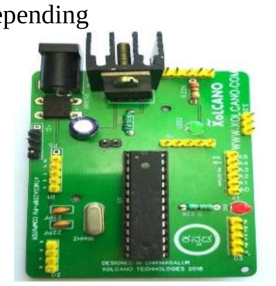

Fig 3 Arduino board

The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board – you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

VII EXPERIMENTAL SETUP AND RESULTS

The induction motor is energized and no load reading will be taken in the operating temperature. During load condition, motor is gradually loaded mechanically to increase the temperature of the stator winding. The increase in temperature will be sensed by the sensor, LM35 and the value of temperature will be sent to the arduino. The arduino will convert the analog signal into digital signal and then it sent to computer. During simulation process using MATLAB program, the output will be in the form of graphs showing stator temperature versus insulation level.
The same procedure is carried a new healthy motor and also for old motor. This will give the comparison of insulation level as per the load changes in both the motors.

Fig 4 Experimental setup for Old and Healthy Motor

Results compares the readings of the two motors which are given below.

A. Old Motor Reading

SL.NO	W1 in kg	W2 in kg	CURRENT in A	VOLTAGE in V	ANALOG TEMPERATURE in Degree Celsius
1	0	0	3.2	370	38
2	1	0	3.3	370	40
3	2	0	3.4	370	42
4	4	0	3.4	380	44
5	5	0	3.5	380	51

Table 2 Tabulation of Results of Old Motor

B.Healthy Motor Reading

SL.NO	W1 in kg	W2 in kg	CURRENT in A	VOLTAGE in V	ANALOG TEMPERATURE in Degree Celsius
1	0	0	1.6	400	28
2	1	0	1.6	400	30
3	2	0	1.8	400	32
4	4	0	2.2	400	34
5	5	0	2.2	400	36

Table 3 Tabulation of Results of Healthy Motor

The above reading in tabulation gives the comparison between two motors as this, the old motor due to the ageing process which has come under many abnormal conditions has become prone to insulation degradation which results in drawing high current due to increase in losses and also temperature in the stator winding increases as the load increases. The new motor which has does not experienced any abnormal conditions before, will perform at its best level without drawing high current and temperature will not increase steeply when the load is increased.

By consolidating the results, it can be seen that the value of temperature and current is more in old motor compared to new motor. From this it is concluded that ageing of motor under abnormal conditions the level of insulation decreases.

C. Simulation Results

The graphs obtained in the MATLAB Simulink are shown below.It is observed that as the load increases in the motor side, temperature increases which can be seen from the simulated graphs

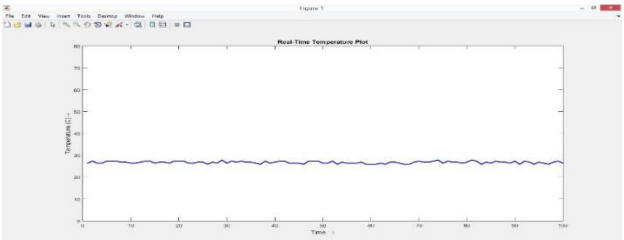

Fig 5 Simulation of Healthy Motor under No Load condition

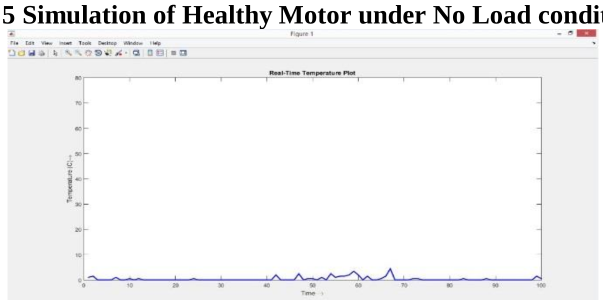

Fig 6 Simulation of old Motor under No Load condition

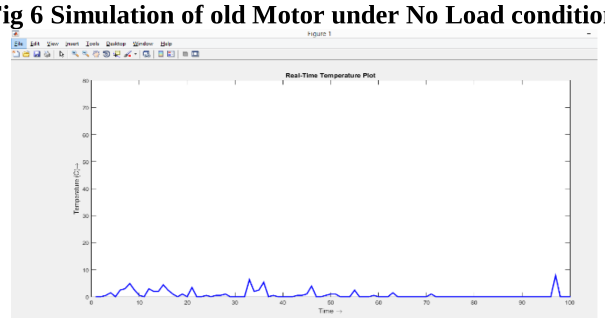

Fig 7 Simulation of Old Motor under Full Load condition

The difference in the graph level between the used motor and healthy motor indicates that the insulation level in the old motor is comparatively lesser than the new motor. It provides a brief conclusion that the loss in the old motor is far greater than the healthy one.

The temperature in an induction machine is an important criterion, as it is seen by controlling the temperature level the operating life of an induction machine will be increased, the losses in an induction machine can also be reduced

During no load condition, the temperature in the motor will be constant and hence losses will be low. The graph shows a constant state of insulation operation. When the load is applied, the graph increases gradually by simulating the healthy motor insulation and it attains peak level under full load condition of the motor.The simulated graphs are used to compare the insulation characteristics between healthy motor and used motor.

CONCLUSION

The proposed method is only applicable to turn insulation failure detection. Its viability under different load conditions is validated for a small-sized induction motor with simulated turn insulation fault. Using the proposed model, the status of the stator windings can be continuously monitored and the insulation degradation can be detected before it reaches severe state.

The insulation level of a three phase induction machines can be controlled by the proposed model using the tripping circuit. As the load increases insulation level starts degrading and the temperature increases, the tripping circuit acts as a controlling device which trips off the circuit when temperature increases beyond the fixed value.

The temperature in an induction machine is an important criterion, as it is seen by controlling the temperature level the operating life of an induction machine will be increased, the losses in an induction machine can also be reduced. Efficiency is improved.

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