Condition Monitoring of DC Motor using Artificial Intelligence Technique

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Abstract— The complexity of most steel industry always tends to create a problem in monitoring and supervision system. Prompt fault detection and diagnosis is a best way to handle and tackle this problem. DC motor plays a very vital role in steel industry and there is a strong demand for their reliable and safe operation. The history of fault diagnosis and protection of electrical machines is as old as such machines themselves. However, nowadays, condition monitoring of electrical machines has become increasingly essential. It plays a very important role in their safe operation and helps to avoid heavy production losses in industry. The conditioning monitoring and fault-detection techniques of electrical machines have moved in recent years into artificial intelligence techniques. When an artificial intelligence technique is used, fault detection and evaluation can be accomplished without an expert. In this paper, artificial intelligence (AI) techniques are used to build a condition monitoring system that has incremental learning capabilities. The condition-monitoring of dc motor using AI technique schemes have concentrated on sensing specific failure modes in field windings.

I. INTRODUCTION

Rotating electrical machines permeate all areas of modern life at both the domestic and industrial level. The average modern home in the developed world contains 20–30 electric motors in the range 0–1 kW for clocks, toys, domestic appliances, air conditioning or heating systems. Modern cars use electric motors for windows, windscreen wipers, starting and now even for propulsion in hybrid vehicles. A modern S-series Mercedes-Benz car is reported to incorporate more than 120 separate electrical machines. The majority of smaller applications of electrical machines do not require monitoring; the components are sufficiently reliable that they can outlive the life of the parent product. However, modern society depends, directly or indirectly, upon machines of greater rating and complexity in order to support an increased standard of living.

A. Need of condition monitoring

Condition monitoring of electric machinery can significantly reduce the cost of maintenance and the risk of unexpected outage by allowing the early detection of potentially catastrophic faults. In condition based maintenance, one does not schedule maintenance or machine replacement based on previous records or statistical estimates of machine failure. Rather, one relies on the information provided by condition monitoring systems assessing the machine's condition. Thus the key for the success of condition based maintenance is having an accurate means of condition assessment and fault diagnosis. The notion of the scheduled shutdown or outage introduces us logically to the case to be made on behalf of monitoring. By condition monitoring we mean the continuous evaluation of the health of plant and equipment throughout its serviceable life. Condition monitoring and protection are closely related functions. The approach to the implementation of each is, however, quite different. Also the advantages that accrue due to monitoring are entirely different to those to be expected from protection. This is principally because monitoring should be designed to pre-empt faults, whereas protection is essentially retroactive. Condition monitoring can, in many cases, be extended to provide primary protection, but its real function must always be to attempt to recognize the development of faults at an early stage. Such advanced warning is desirable since it allows maintenance staff greater freedom to schedule outages in the most convenient manner, resulting in lower down time and lower capitalized losses. Condition monitoring has to establish a map between input signals and output indications of the machine condition.[9] Classifying machine condition and determining the severity of faults from the input signals have never been easy tasks and they are affected by many factors. Electrical machines, both motors and generators are increasingly used as elements in bigger systems where operators are not necessarily experienced in their design.

B. Need of AI Technique

A human expert can be subject to influences that make quick and consistent judgments impossible, mainly when there are many machines in the plant. [6] Correct judgments may also depend on the knowledge and the experience of many experts who are not all available at the same time. Manufacturers are adding more functionality to new machines, while the utilities are more focused on aged, existing machines to extend their usable lifetime. It has been realized that human experts facing a condition-monitoring task will receive a large amount of data, some of which may be trivial while others important. The human manner of processing such data features parallelism. [1].

II. TROUBLESHOOTING OF DC MOTOR

Fig.1: EPRI and IEEE survey result
As per IEEE and EPRI survey most trouble come in the Bearing 41% and Stator winding 37%

III. CONDITIONING MONITORING

Condition Monitoring can be stated as a comprehensive program of data collection and analysis that will provide early detection of problem and identify the need for maintenance of the monitored machine in a planned and systematic manner before machine failure.

A. Advantage of conditioning Monitoring Technique

The problems of abnormalities and failures of electrical machines have frequently led to loss of production, high maintenance and operation costs. As the capital cost of modern machines is very high, the requirement of continuous and sustained operation becomes inevitable, to sustain economic operation. There has been a trend towards adoption of various forms of condition monitoring to know the deteriorating condition of a machine component, well in advance of a breakdown, for proactive maintenance which contribute to better health of electrical machines, reduced maintenance costs, efficient use of personnel and improved system efficiency.

B. Disadvantages of Condition Monitoring

There are, of course, some disadvantages also that must be weighed in the decision to use machine condition monitoring and fault diagnostics. These disadvantages are listed below,

- Monitoring equipment costs (usually significant), Skilled personnel needed, Strong management commitment needed, A significant run-in time to collect machine histories and trends is usually needed. Reduced costs are usually harder to sell to management as benefits when compared with increased profits. The sensors employed to take the measurement are quite costly as compared to other transducers, The set up required to diagnose the fault is very much complex.

IV. ONLINE CONDITIONING MONITORING

This type of monitoring Carried out while the motor is in operation. From this type of monitoring we have got the this type of data like (Current, Temperature, Vibration, Axial flux, speed)

A. Visual monitoring

This method ranges from a simple visual inspection by the unaided eye, through to the use of bore scopes for better access, microscopes to increase magnification, and closed circuit television cameras. Results are normally obtained immediately, but they are not recorded automatically, and photography or videotape recording may be required if trends are to be established

B. Motor current signature analysis

In electrical machines, some faults can be detected by measuring the currents or voltages in the machine windings. The magnetic field created near electrical machines changes when faults occur.

C. Vibration monitoring

This is a very widely used technique which commonly employs a piezoelectric device to sense the acceleration of a moving part. A similar system using a microphone can also be used, but this may be more prone to interference.

D. Temperature monitoring

Machine faults such as an unbalanced shaft will increase the friction in the bearings and therefore the temperature will increase. Thermal sensors can be used to detect such changes in temperature and therefore detect the fault

E. Flux monitoring

Flux monitoring is therefore to translate observed differences in the nature of the axial leakage flux into an indication of fault condition.

F. Using Thermography instrument

Infrared imaging cameras are widely used in plants to find overheated electrical joints and cables hotspot such cameras are sensitive to the infrared portion of the electromagnetic spectrum. Modern thermal imaging cameras contain computers to directly indicate the temperature of the surfaces, as well as to provide the ability to compare past images with the present image, enabling changes in the thermal image to be easily detected.

Fig.2: Online Monitoring process Block Diagram [9]

V. OFFLINE CONDITIONING MONITORING

This type of monitoring Carried out after stopping the motor but without any disassembly. From this type of monitoring we have got the data of Insulation resistance of field (ground to field winding resistance), Insulation resistance of field (turn to turn)

A. Insulation resistance (IR)

This test successfully locates pollution and contamination problems in windings. In older insulation systems, the test can also detect thermal deterioration. The IR test measures the resistance of the electrical insulation between the copper conductors and the core of the stator or the rotor. Ideally, this resistance should be infinite since; after all, the purpose of the insulation is to block current flow between the copper and the core. In practice, the IR is not infinitely high. Usually, the lower the insulation resistance, the more likely it is that there is a problem with the insulation. [10]

B. Polarization index (PI)

The PI test is a variation of the IR test. PI is the ratio of the IR measured after voltage has been applied for 10 minutes (R10) to the IR measured after just one minute (R1) PI=...
A low PI indicates that a winding may be contaminated or soaked with water.

C. DC high potential

The DC hipot test is an over potential test that is applied to stator and rotor windings of all types. Hipot is a short form for high potential. In this test a DC voltage, substantially higher than that which occurs in normal operation, is applied to the winding. The basic idea is that if the winding does not fail as a result of the high voltage, the winding is not likely to fail anytime soon due to insulation aging when it is returned to service. If a winding fails the DC hipot test, then repairs or a rewind are mandatory, since the ground wall insulation has been punctured. Stator windings are much more likely to be subjected to a DC hipot than rotors. [10]

VI. FUZZY LOGIC SYSTEMS

These are based on a set of rules. These rules allow the input to be fuzzy, i.e. more like the natural way that human express knowledge. ES becomes more practical with the use of fuzzy logic. The knowledge in an ES employing fuzzy logic can be expressed as fuzzy rules (or qualitative statements). A reasoning procedure enables conclusions to be drawn by extrapolation or interpolation from the qualitative information stored in the knowledge base.

As discussed before, a fuzzy set is totally characterized by the membership functions (MF). Fuzzification is the process of converting crisp numerical values into the degrees of membership related to the corresponding fuzzy sets. A MF will accept as its argument a crisp value and return the degree to which that value belongs to the fuzzy set the MF represents. The degree of membership returned by any MF is always in the range [0, 1]. A value will have a membership degree of 0 if it is wholly outside the fuzzy set, and 1 if completely within the fuzzy set, or any value in between. Since most variables in a fuzzy system have multiple MFs attached to them, fuzzification will result in the conversion of a single crisp value into several degrees of membership. Variables and MFs often have names attached to them, also referred to as the linguistic variables. This is one of the major advantages of fuzzy rule systems, as the linguistic variables can be much easier to comprehend than an equivalent crisp rule system. So, the steps in the fuzzification process are:

− Define a universe of discourse,
− Identify and define the linguistic variables,
− Define the membership functions for each linguistic variables bounded by the universe of discourse,
− Represent the membership functions graphically by choosing suitable membership functions [11].

VII. FAULT DIAGNOSES IN STATOR WINDING USING THIS TECHNIQUE

Using online technique

A. Turn to Turn short

Coils with shorted-turns operate at lower temperatures than coils without shorted-turns. This is because the heating resulting from I^2R losses are lower in the effected coil (the coil current is traversing a shorter copper path, therefore the coil resistance is lower). Due to that particular pole temperature will be down compare to other field pole.

B. Turn to Earth short

Coils with shorted with ground require more current compare to normal operation. So from that the I^2R losses will increase in particular pole and due to that its temperature also increase compare to other field pole.

C. Rotor/ Stator vibration due to unbalanced magnetic force

Shorted turns in field pole unbalance magnetic force. Shorted turns in one pole will reduce the flux generated for the pole and to a lesser extent the adjacent poles, but will have no effect on the opposite pole. The resulting unbalanced radial magnetic pull between the rotor and stator can cause vibrations.

This data will be compared with the reference data using programing in matlab after that this programe will found the daviation for each data and this data will use as a fuzzy logic input after applying fuzzy rule it will give the message for healthness of DC MOTOR field windings. From this fuzzy logic output we will be able to take decision for the offline condition monitoring. [4]

D. Using Offline condition monitoring

After the suggetion given by online condition monioring check the offline data and compared with the reference value of the dc motor. In the offline monitoring we will test the insulation and winding resistance of the field and armature circuit. If any deviation found in this data then take a corrective action for solve the problem. So from this we have able to take the corrective action of the particular field pole.

VIII. SIMULATION AND RESULTS

From the different reading like: field current, field temperature (All the Field pole), vibration (All field pole), bearing temperature and vibration of drive and non-drive side. This type of reading Taken when motor is running no load this reading taken after every 10-20 sec and after collecting 50 to 60 reading this is used in matlab script and find average difference for each data. And it will give output

A. Matlab script program output

```
field current = 5.071429 percentage
field wdg temp = -12.226891 percentage
```
vibration dr side = -25.535714 percentage
vibration nondr side = -36.250000 percentage
bearing temp dr side = -29.175824 percentage
bearing temp nondr side = -8.809524 percentage

This deviation given to the FIS (fuzzy inference system) in matlab (Figure: 3)

In FIS define its membership Function, and define rule for this function in the rule editor and after this FIS system give the report of healthness of particular field pole. (Figure: 4 and 5)

After this output reading will be given to the another script of the matlab and it will be give indication for corrective action and maintenance require or not LIKE:-

Field Winding pole 1 73.3% healthy
Field Winding pole 2 83% healthy
Field Winding pole 3 53.3% healthy
Field Winding pole 4 73.3% healthy
Go for offline monitoring and maintenance require of field pole 3

IX. CONCLUSION

Accurate means for condition monitoring can improve the reliability and reduce the maintenance costs of DC motors. Condition monitoring involves sampling sensor signals, processing these signals to extract features which are sensitive to the presence of faults, deciding if a fault exists and identifying its type. Condition monitoring has to establish a map between input signals and output indications of the machine condition. Classifying machine condition and determining the severity of faults from the input signals have never been easy tasks and they are affected by many factors. So using AI technique we will solve this problem easily.

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