THE SIX MOST COMMON KILLERS OF YOUR ELECTRIC MOTORS WINDINGS & HOW TO AVOID THEM

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Contents

ACE Electric MOTOR & PUMP CO. since 1952

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Introduction

Electric motors are utilized for a wide variety of applications throughout homes and industries worldwide. While there are some standardized versions that have been designed for general purpose applications, some are required for particular tasks. This means that a number of factors need to be considered when selecting an electric motor. These factors include – but are not limited to - a thorough review of load characteristics, motor mounting, the motor enclosure, and motor drive.

The electric motors designed today are extremely reliable. However, just like any electromechanical device, they are prone to failure due to a number of reasons.

Understanding the Reasons of Electric Motor Failure

When it comes to the failure of electric motors, the cause can be categorized into three distinct categories:

1. **Electrical**
2. **Mechanical**
3. **Mechanical leading to Electrical**

According to statistics, as many as 80 percent of all electric motor failures are due to winding damage inside the motor stator. The damage to the winding can occur either due to overheating or voltage problems. Due to the fact that electric motors function by taking electrical energy and converting it into mechanical, the by-product of the process is ***heat***; excessive heat build-up can cause the motor to fail.

The aim of this book is to impart knowledge of the things that can have harmful and damaging effects on a motor. With the proper understanding of those factors, better care and preventive maintenance of electric motors can be carried to prolong their lifespan.

The guide is intended for all those people who are involved in the maintenance & care of electric motors or for anyone who wishes to gain an understanding of how they can maximize the life of their equipment in general.

Six Most Common Killers of Electric Motors

Electric motors are an essential part of our daily lives as many applications, systems, and services are dependent upon them. As previously stated, the motors designed today are extremely reliable and have a long life while requiring minimal maintenance.

However, in industries and large buildings, electric motors require maintenance at shorter intervals mainly because they are in constant operation. Preventive maintenance is also crucial because even a slightest of downtime can bring a company's operations to a grinding halt – translating into monetary loss.

To avoid such unscheduled seizure of operations, large organizations typically employ a motor maintenance program where the causes of failure of motors is determined and steps taken to either avoid them altogether, or minimize their impact at the very least.

Electric motors need to be inspected on regular intervals to spot any pending failures and prevent them. This is why it is crucial to understand the six most common causes of motor failure.

We will discuss each of these six causes in detail in this chapter.

Electrical Overload (Overcurrent)

In electronics, overcurrent is a condition where too much current starts to run through the circuit. This is a very common problem among electrical motors and other electronics in general. Various symptoms are associated with this problem, most of which – if not rectified – will cause permanent damage to the electric motor.

An overcurrent condition normally occurs whenever a device starts to draw in more current than it is designed to. This event occurs extremely rapidly and can damage a motor instantly. Shorts, unintended switching off/on of the electric motor, and blown fuses are some symptoms of overcurrent.

Let us now review some of the things that can lead to an overcurrent situation:

Faults

A fault is a generic term used to describe any malfunction of the motor's electrical wiring. Incorrect installation or damage to the unit can result in faults. In most cases, the electrical charge is transmitted over a route that is not supposed to carry any current. This causes the current to rise substantially, creating an overcurrent situation.

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Miswiring

Miswiring is yet another factor that can cause overcurrent in electrical motors. If the wiring has been incorrectly installed within the motor, it can lead to short-circuiting and other problems. Short-circuits can cause fire, and if not looked after, it can damage the motor beyond repair.

Correct wiring should be done based on the correct schematics of the motor and each wire should be inspected to make sure no fraying is present.

Phase to Phase Insulation

If this insulation breaks down, an overcurrent would be set up in the motor. The purpose of the insulation is to stop the current from locating a circuit where it is not supposed to flow. The insulation is wrapped around the wire to prevent conduction from one material to the surroundings. The insulation is not intended to respond to any kind of electrical changes; therefore, if it peels off from the metal (wire or otherwise), the charge will be conducted through an area that was not supposed to conduct the electricity. These 'grounding faults 'will lead to an overcurrent situation.

Low Resistance

One of the most crucial factors surrounding electric motor installations and maintenance takes into account the insulation resistance readings. This is carried out in order to verify an insulating material's integrity – regardless of whether it is a wire, cable insulation, or the winding of a motor/generator. An electrical insulation should have characteristics that are opposite to that of a conductor; that is, it should resist flow of current by keeping it inside the conductor.

While it is an established fact that no insulation has the perfect characteristics (which means infinite resistance); therefore, some electricity does flow through the insulation, eventually getting grounded through it. This current is referred to as the ***leakage current***. Even though this 'leaking current' accounts for only a few millionth of an amp, it is flowing nevertheless. Also, the higher the voltage, the greater the leakage will be – and this starts to become even worse when the quality of insulation begins to deteriorate.

A lot of motor failures result due to a low insulation resistance. While being quite common, this is among one of the most difficult issues to tackle. Whenever a motor is installed anew, the insulation resistance is found to be greater than 1 thousand megaohms (the unit for insulation resistance). However, with time and use of the motor, the capability of the insulation resistance begins to decline – many a times at an alarming rate.

Leakage of current is not a problem if good insulation is present. However, it tends to become a huge problem with deteriorating insulation resistance readings.

This brings us to the main question: what is 'good' insulation? Based on what we mentioned above, an insulation material with high levels of resistance would qualify as 'good insulation'. With that said, a method is needed to measure the resistance values of the insulation to keep track of the deterioration of insulation resistance in order to prevent motor failure. By taking regular readings, you can perform a trend analysis on your insulation material's integrity.

Measuring Insulation Resistance

An insulation resistance tester is a portable instrument that is used to measure a particular insulation material's resistance. It is essentially an ohmmeter that comes with a line-operated, or hand-cranked DC generator to develop a high DC voltage. The voltage (normally in excess of 500 volts) causes current to flow over the surface of, and through, the insulation material. Furthermore, the instrument provides a direct reading of insulation resistance in megaohms.

The readings can vary from one day to another as numerous factors are involved, including the temperature & humidity. Therefore, the readings are taken over a certain period of time and at regular intervals.

Over Heating

Maintenance experts concur that heat – or rather excessive heat – causes immense deterioration on a motor's winding insulation. Numerous performance issues surface due to excess heat, besides the deterioration of motor windings. A common rule of thumb is that for every 10-degree Celsius increase in temperature over the rated temperature, the life of the motor's insulation is cut in half. According to statistics, as many as 55 percent of all insulation failures are due to overheating issues.

There are five main causes of overheating: less-than-optimal power conditions, environmental conditions, overload, high effective service factor, and frequent starts and stops.

Power Condition

Over heating can result due to a variety of factors. Every electric motor has its own design temperature. If, for instance, a motor is started at a bad current value, it begins to operate at a warmer-than-design temperature. Hence, it becomes imperative that motors be operated on their ideal current values at all times to prevent overheating.

Environmental Conditions

Over heating is also caused whenever the motor is operated in an environment with high ambient temperature. This reduces the rate at which the heat is conducted from the motor quite severely. To avoid such a situation, it is important to operate motors at a place that has a proper ventilation/cooling system in place. The ventilation system should be able to take care of the temperature increase if the cooling system fails.

Overload

The stator current is regularly used to measure the load level; however, this can be masked if an overvoltage condition is present. A very common mistake that is often made is that a motor is operated at an overvoltage in order to reduce stator current, all in an attempt to reduce the heat. While the motor current can vary depending on the amount of overvoltage applied, it has been found that the effects of excessive heat on the motor would not improve.

In industries, ideal voltage conditions are significantly rare. However, it is important to understand that current is not the only source of heat. The bid to reduce heat by providing an overvoltage is actually very destructive to the windings and causes bearing damage.

Hence, a comprehensive knowledge of the operating load level is necessary.

High Effective Service Factor

The key to understanding the most common reasons behind overheating is to estimate the load level. This may be identified by observing the voltages and currents only. The formula for working out the effective service factor is as follows:

This factor will provide the maintenance professionals a solid idea of the kinds of stress that are being imposed on a motor in a certain application, allowing them to prevent a situation that leads to overload (see overload).

Frequent Starts and Stops

The frequency of starts and stops also has an important role to play in heating up a motor. When a motor is started, great load is imposed on it. Frequent starting and stopping, therefore, subjects a motor to greater load than it is exposed to in continuous operation.

$$\frac{\%\text{load}}{\%\text{NEMA derating}}$$

It is important to monitor the number of starts – on an hourly basis for small/ medium motors, and daily for larger ones.

Dirt

Dirt is known to damage electric motor’s mechanical components and has a major role to play in causing them to fail. Dirt can accumulate on a motor’s surface and block the cooling vanes as well as the fan, thereby causing an increase in its operating temperature. It may also be sucked into the motor where it erodes the shafts, insulation, and bearings.

If the accumulated dust and dirt manages to settle onto the windings, it may become embedded inside the winding insulation. This would reduce the insulating value, increasing the chances of insulation failure.

It is unfortunate that in majority of cases, motors are operated in areas that are typically dirty, such as mechanical rooms of buildings. Cleanliness of these areas is normally a low priority as these are accessed by maintenance and engineering staff only. Besides ensuring that the debris is cleaned from floors and the equipment, the people responsible for looking after the motors have to consider adding filters to filter the incoming air. However, if this is not possible and there is a lot of dust and dirt that cannot be managed, the motors need to be protected by installing shielding devices.

It should be noted that there are cases where one factor leads to another problem, which in turn results in the failure of motor. Dirt is one such example. Dirt prevents the ventilated air from cooling the electric motor's components, thereby causing it to overheat. The overheating problem further worsens the situation and increases the chances of motor failure.

Moisture

Just like dirt, moisture can also attack the electrical and mechanical components of a motor. Moisture can corrode the bearings, shafts, stator laminations, rotors, and the housings. It can even penetrate into the motor winding's insulation and cause failure of insulation.

Moisture has detrimental effects on the overall service life of any electric motor; however, it causes greater damage to those motors that are used on a seasonal basis. As compared to continuous applications, such intermittent use usually does not generate sufficient heat to allow the motor to drive off any moisture that may have accumulated within it.

Due to the fact that moisture can not only reduce the service life, but also cause motors to fail during operation, technicians and maintenance personnel should ensure that all motor installations are kept dry. If the level of humidity is high, then forced ventilation or dehumidification techniques should be utilized.

Effects of Moisture on Insulation

Motor windings that operate in damp environments need to be protected particularly when they are being placed out of service for extended periods of time. This is because the moisture can cause immense deterioration of the winding insulation as well as have corroding effects on the metal parts of the electrical motor. With that said, special provisions need to be made as those mentioned above.

Normally, if the motors are kept warm during their out of service periods, they can be protected from excessive moisture as condensation will be prevented.

The Internal Warming Method

The Internal Warming Method is utilized to keep out-of-service motors relatively moisture-free. This involves circulation a certain amount of current necessary through the windings to keep the motor warm enough. This produces heat in the area that is most effective in driving the moisture out: the windings.

The External Warming Method

This is the least expensive and most common method to warm up motors when they are not being operated. Electric-strip-type heaters are utilized and mounted against the metal frame of the motor; the heat is then conducted throughout the motor to prevent condensation.

Care has to be taken to ensure that the heater is not mounted in close proximity to the motor windings, as excessive heat will have a detrimental effect on their life.

Protecting Operating Motors

The best practice to protect operating electric motors from accumulating moisture is to use forced ventilation methods and dehumidification equipment – especially in areas with high humidity.

Vibration

Vibration in an electric motor can be caused by a number of issues, including misalignment of the motor. Some other factors of vibrations include:

- **Loose motor/load mountings**
- **Unbalanced motor/load components**
- **Worn out bearings that allow the shaft to move off-center**
- **Accumulation of grease, corrosion, or debris on the rotating parts**

With time, vibrations can tear down the bearings of a motor, leading to the formation of fatigue cracks within the motor winding's insulation.

It is recommended that maintenance personnel check the motor alignment at least on an annual basis. Also, when the motor is being serviced, the balance should be checked.

The motor and load mounting bolts should also be checked and tightened on an annual basis or during scheduled maintenance. During the inspection, the motor should be thoroughly checked to ensure that it has not accumulated any foreign debris, and if it has, the concerned parts should be cleaned.

Conclusion

Electric motors typically require additional care as even a slightest of factors can reduce their service life considerably. An unexpected motor failure can halt the operations in an industry, leading to considerable losses that could have been prevented had proper maintenance been conducted on them.

Maintenance programs designed for electric motors should start off with a complete inventory of the motors that are installed in a particular facility. This inventory should focus on more things than just the number of motors installed, the location, and the loads that they power. It should include the characteristics of a particular application (the application a motor is to perform) so the correct type & rating of motor can be installed.

This is critical because if a load and the motor are mismatched, regardless of how thorough a maintenance program is, it would not be able to effectively prevent failure of motors.

The maintenance program should give importance to the six factors discussed in this book to prolong the life of electric motors and to prevent failure during operation.

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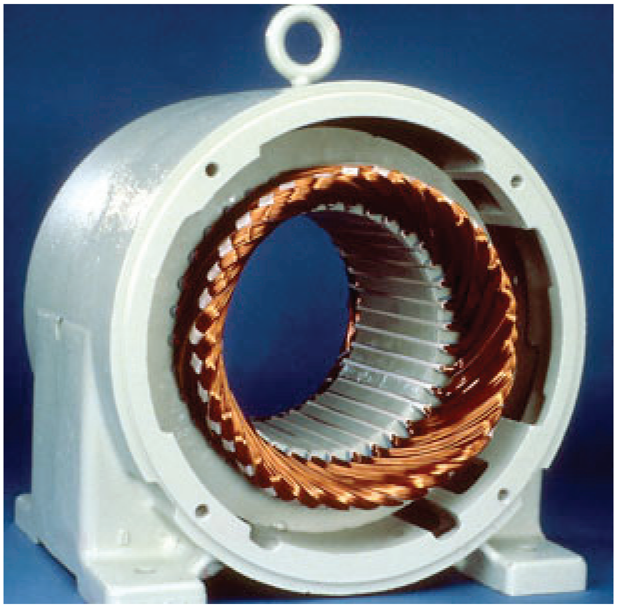


Good stator winding

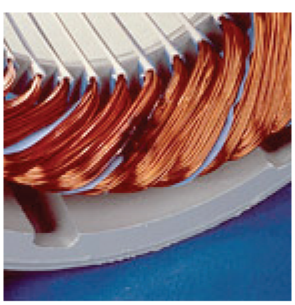
Unfavorable operating conditions—electrical, mechanical or environmental—can dramatically shorten the life of a three-phase stator winding. The winding failures illustrated below typify what can happen in such circumstances. They are shown here to help you identify the causes of failure, so that, where possible, you may take preventive measures. Compare the new stator winding (here) with the failed windings pictured below.

Winding single-phased (wye-connected)

A single-phased winding failure is the result of an open in one phase of the power supply to the motor. The open is usually caused by a blown fuse, an open contactor, a broken power line or bad connections.

Winding single-phased (delta-connected)

A single-phased winding failure is the result of an open in one phase of the power supply to the motor. The open is usually caused by a blown fuse, an open contactor, a broken power line or bad connections.



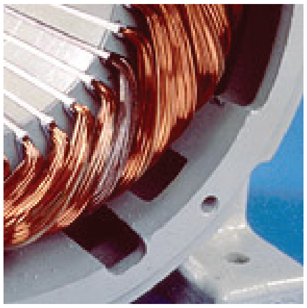
Winding shorted phase-to-phase

This type of insulation failure is typically caused by contaminants, abrasion, vibration or voltage surge.

Note: To obtain printed copies of EASA›s brochure Failures in Three-Phase Stator Windings, order online, or contact EASA Headquarters by e-mail (easainfo@easa.com), telephone (314-993-2220) or Fax (314-993-1269).

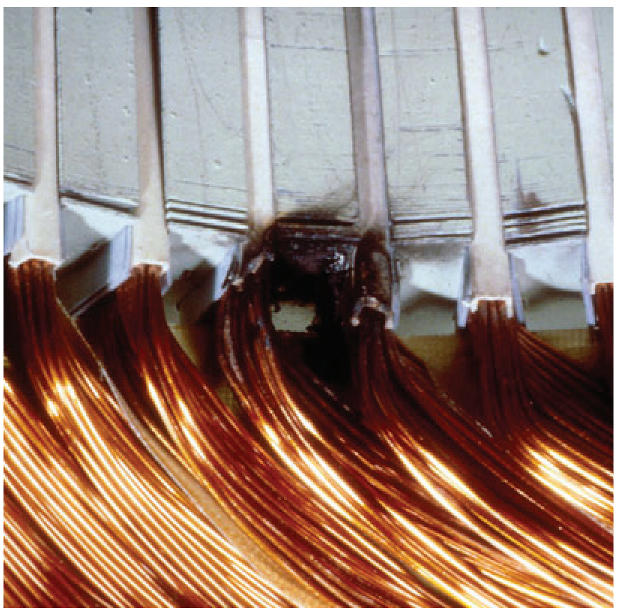
Winding shorted turn-to-turn

This type of insulation failure is typically caused by contaminants, abrasion, vibration or voltage surge.



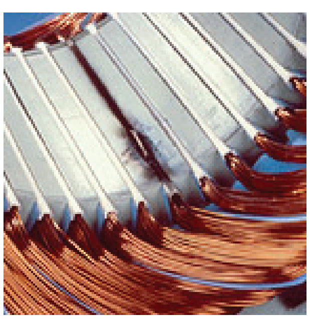
Winding with shorted coil

This type of insulation failure is typically caused by contaminants, abrasion, vibration or voltage surge.



Winding grounded at edge of slot

This type of insulation failure is typically caused by contaminants, abrasion, vibration or voltage surge.



Winding grounded in the slot

This type of insulation failure is typically caused by contaminants, abrasion, vibration or voltage surge.

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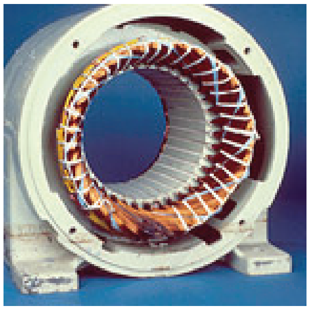
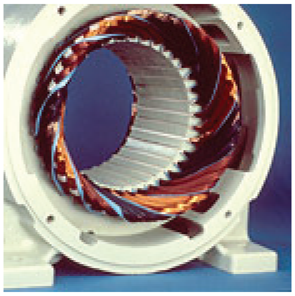


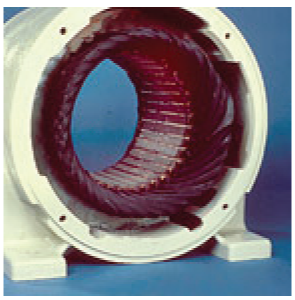
Shorted connection

This type of insulation failure is typically caused by contaminants, abrasion, vibration or voltage surge.



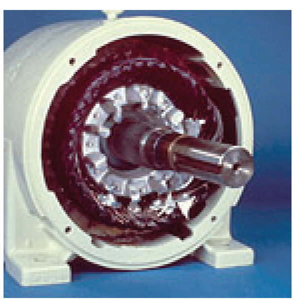
Phase damage due to unbalanced voltage

Thermal deterioration of insulation in one phase of the stator winding can result from unequal voltage between phases. Unequal voltages usually are caused by unbalanced loads on the power source, a poor connection at the motor terminal, or a high resistance contact (weak spring). Note: A one-percent voltage unbalance may result in a six- to ten-percent current unbalance.



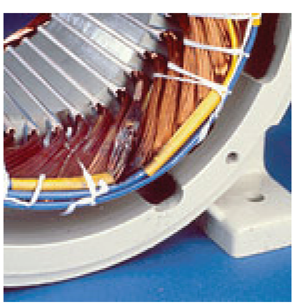
Winding damaged due to overload

Thermal deterioration of the insulation in all phases of the stator winding typically is caused by load demands exceeding the rating of the motor. Note: Under-voltage and over-voltage (exceeding NEMA standards) will result in the same type of insulation deterioration.



Damage caused by locked rotor

Severe thermal deterioration of the insulation in all phases of the motor normally is caused by very high currents in the stator winding due to a locked rotor condition. It may also occur as a result of excessive starts or reversals.



Winding damaged by voltage surge

Insulation failures like this usually are caused by voltage surges. Voltage surges are often the result of switching power circuits, lightning strikes, capacitor discharges and solid-state power devices.

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