Electrophysics Resource Center:

Thermography

White Paper:

Guidelines for Performing Infrared Inspections of Motor Control Centers

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Guidelines for Performing Infrared Inspections of Motor Control Centers

Abstract

Whether it's your first infrared inspection or you're a veteran with hundreds of surveys under your belt, it is important to realize that in order to successfully identify and analyze thermal anomalies, it is beneficial to understand the operation of the equipment under inspection. This paper will provide guidelines for inspecting the motor control center (MCC), identifying key components and potential problem areas, illustrating both common and not-so-common thermal anomalies.

The Motor Control Center

A Motor Control Center, or MCC, is a modular cabinet system for powering and controlling motors in a factory. MCCs are quite common in factories having heavy machinery. Typically, an MCC cabinet consists of a metal enclosure with doors providing access. Although the contents may vary, normally the MCC contains a motor starter, circuit breaker and possibly a power transformer.

Figure 1: Motor Control Centers are common areas of interest for the infrared inspector. The numerous incoming 3-phase power wires are indicative of the many electrical connections inside that need periodic inspection.

The MCC enclosure protects personnel from contact with current carrying devices, and it protects the components from various environmental conditions. It is important that the enclosure is mounted to assure accessibility so that qualified personnel (such as a trained thermographer) can open the panel under load.

There are different classes and types of MCCs, but generally speaking, an MCC looks like a row of file cabinets with each cabinet representing an MCC section. The drawers of the file cabinet represent the plug-in units that contain the motor control components. Three phase power is distributed within the MCC by bus bars, large metal current carrying bars. The horizontal bus provides three-phase power distribution from the main power supply. Vertical bus in each section is connected from it to individual MCCs. Bracing and isolation barriers are provided to protect against fault conditions. The plug-in units of an MCC have power stabs on the back to allow it to be plugged into the vertical power bus bars of the structure.

Beginning Your MCC Infrared Inspection

Before opening the panel or door on a motor controller, prescan the enclosure to assure a safe opening condition. If excessive heat appears on the surface of the door, extra care should be taken when opening it. The thermographer or escort may decide to note the condition as unacceptable and not take a chance on opening it under load. Once the unit is open, begin with both an infrared and a visual inspection to assure no dangerous conditions exist.

Once the MCC cabinet door is open, begin with both an infrared and a visual inspection to assure no dangerous conditions exist.

Be systematic while conducting the infrared inspection. Remember the system must be under load to conduct the inspection. Work from left to right or follow the circuit through carefully, inspecting all of the components. Look for abnormal thermal patterns caused by high-resistance connections, overloads, or load imbalances. In three-phase systems this can be accomplished by comparing phases. Adjust the level and span on the infrared system to optimize the image. Proper adjustment will identify primary and secondary anomalies.

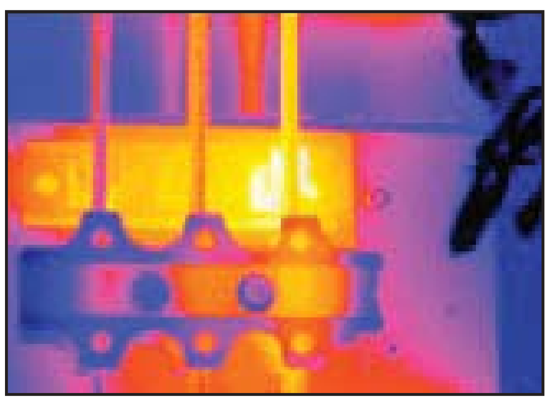

Figure 2: The bus stabs at the back of the MCC are where the incoming connections to the main horizontal bus occur. These are important IR inspection points and are often overlooked or misdiagnosed. The thermal image to the right reveals a hot spot indicating a potential problem.

The bus stabs and the connections to the main are important inspection points that are often overlooked or misdiagnosed. The incoming connection to the main horizontal bus is usually located behind a cover or panel that is not hinged. These are typically bolted connections and may have parallel feeders.

The bus stab connections on the back of the plug-in units are more difficult to inspect. The thermographer does not have direct view of the connection, and the first indication of a problem can be seen on the incoming conductors feeding the breaker or fused disconnect. Remember, even small temperature rises identified at this point could mean serious problems.

Motor Starters and Motor Controllers

The purpose of the motor starter is to protect the motor, personnel, and associated equipment. Over 90% of the motors used are AC induction motors, and motor starters are used to start and stop them. A more generic term would identify this piece of equipment as a motor controller. A controller may include several functions, such as starting, stopping, overcurrent protection, overload protection, reversing, and braking. The motor starter is selected to match the voltage and horsepower of the system. Other factors used to select the starter include: motor speed, torque, full load current (FLC), service factor (SF), and time rating (10 or 20 seconds).

Understanding the thermal patterns of this equipment is critical to a successful inspection. Also correctly identifying the source of the anomaly can make recommendations more valuable.

Motors may be damaged or their life significantly reduced if they operate continuously at a current above full load current. Motors are designed to handle in-rush or locked rotor currents without much temperature increase, providing there is a limited duration and a limited number of starts. Overcurrents up to locked rotor current are generally caused by mechanical overloading of the motor. The National Electric Code (NEC) describes overcurrent protection for this situation as “motor running overcurrent (overload) protection.” This can be shortened to overload protection. Overcurrents caused by short circuits or ground faults are dramatically higher than those caused by mechanical overloads or excessive starts. The NEC describes this type of overcurrent protection as “motor branch-circuit short-circuit and ground-fault protection.” This can be shortened to overcurrent protection.

The four common varieties of motor starters are: across-the-line, the reversing starter, the multispeed starter, and the reduced voltage starter. Motor starters are generally comprised of the same types of components. These include a breaker or fused disconnect, contactor and overloads. There may also be additional components, including control circuitry and a transformer.

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Overcurrent Protection

NEC requires overcurrent protection and a means to disconnect the motor and controller from line voltage. Fused disconnects or thermal magnetic circuit breakers are typically used for overcurrent protection and to provide a disconnect for the circuit. A circuit breaker is defined in NEMA standards as a device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without injury to itself when properly applied within its rating. If we look at a cutaway of a breaker, we can identify potential connection problems.

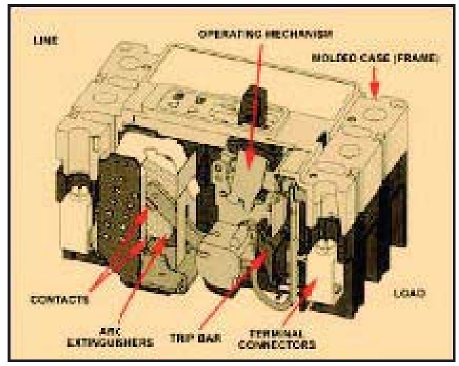
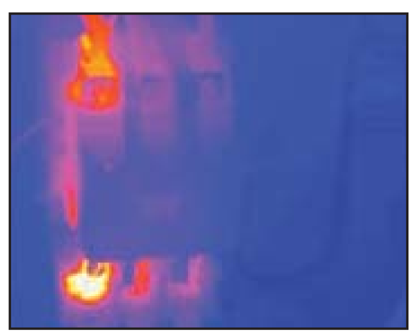


Figure 3: Cutaway of a molded case circuit breaker showing numerous infrared inspection points (courtesy of Cutler-Hammer University).

The line side and load side lugs are the most common source of abnormal heating, but many breakers have a second set of bolted connections on the back of the breaker. Heat from this connection can be misdiagnosed as the main lug. There are also internal contacts where current flow is interrupted by exercising the component. These contacts experience arcing each time the breaker is opened. An arc is a discharge of electric current jumping across an air gap between two contacts. Arcs are formed when the contacts of a circuit breaker are opened under a load. Arcing under normal loading is very small compared to an arc formed from a short circuit interruption. Arcing produces additional heat and can damage the contact surfaces. Damaged contacts can cause resistive heating. Thermal patterns from these poor connections appear as diffuse heating on the surface of the breaker. In addition, there are several types of breakers that have internal coils used for circuit protection. These coils have heat associated with them and can appear to be an internal heating problem, when in fact, it is a normal condition.

Figure 4: Line-side and load-side lugs are the most common source of abnormal heating, but many breakers have a second set of bolted connections on the back of the breaker. Heat from this connection can be misdiagnosed as the main lug.

Figure 5: Damaged breaker contacts can cause resistive heating. Thermal patterns from these poor connections appear as diffuse heating on the surface of the breaker.



Fused Disconnects

Fused disconnects are used to provide over-current protection for motor in the same manner as a breaker. Instead of opening contacts, fuses fail opening the circuit. When overcurrent protection is provided by fuses, a disconnect switch is required for manual opening of the circuit. The disconnect switch and fuse block are typically one assembly.

The hinge and blade connections on the switch are a typical source of overheating. High resistance from overuse or underuse is usually the cause. Fuse clips are also a weak connection point for some disconnect designs. Different types or manufacturers of fuses of the same amperage may produce different thermal signatures.

While different size or amperage fuses will also have a different thermal pattern, fuse bodies may appear warmer than the rest of the circuit due to conductor size.

Contactors

Starters are made from two building blocks, contactors and overload protection. Contactors control the electric current flow to the motor. Their function is to repeatedly establish and interrupt an electrical power circuit. A contactor can stand on its own as a power control device, or as part of a starter.

The coil of the contactor is usually the warmest part of the unit. High temperatures may indicate a breakdown of the coil. High resistance heating may be a result of poor connections. Heating from burned and pitted contacts may be thermally "visible" on the body of the contactor.

Contactors operate electromechanically and use a small control current to open and close the circuit. The electromechanical components do the work, not the human hand, as is the case with a knife blade switch or a manual controller. The sequence of operation of a contactor is as follows: first, a control current is applied to the coil; next, current flow into the coil creates a magnetic field which magnetizes the E-frame making it an electromagnet; finally, the electromagnet draws the armature towards it, closing the contacts.

A contactor has a life expectancy. If the contactor contacts are frequently opened and closed, it will shorten the life of the unit. As the contacts are exercised, an electrical arc is created between the contacts. Arcs produce heat, which can damage the contacts.

Contacts eventually become oxidized with a black deposit. This black deposit may actually improve the electrical connection between the contacts by improving the seat, but burn marks, pitting, and corrosion indicate it is time to replace the contacts.

The following thermal patterns are associated with contactors. The coil of the contactor is usually the warmest part of the unit. High temperatures may indicate a breakdown of the coil. Line side and load side lug connections may show high resistance heating from poor connections. Heating from burned and pitted contacts may be thermally "visible" on the body of the contactor.

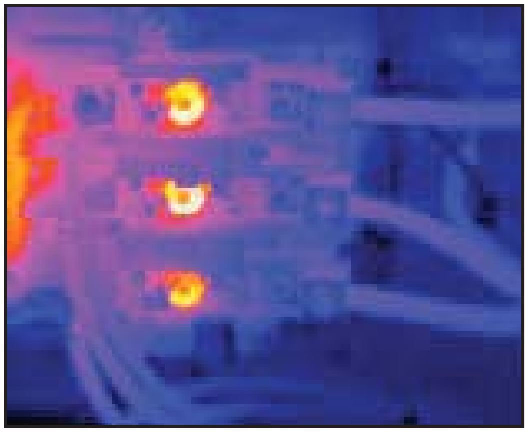


Figure 6: Thermal image of a normally operating overload on a specific piece of equipment. Contactors to the left side of the image are warm. The coil of the contactor is usually the warmest part of the unit. High temperatures may indicate a breakdown of the coil.

Overload Protection

The ideal motor overload protection is a unit with current sensing capabilities similar to the heating curve of the motor. It would open the motor circuit when full load current is exceeded. Operation of this device would allow the motor to operate with harmless temporary overloads, but open up when an overload lasts too long.

Typical thermal problems in overloads are found in the connections to the contactor, overload relay, or motor.

This protection can be provided by the use of an overload relay. The overload relay limits the amount of current drawn to protect the motor from overheating. It consists of a current sensing unit and a mechanism to open the circuit. An overload relay is renewable and can work for repeated trip and reset cycles. Overloads, however, do not provide short circuit protection. The melting alloy (or eutectic) overload relay consists of a heater coil, a eutectic alloy, and a mechanical mechanism to activate a tripping device when an overload occurs. The relay measures the temperature of the motor by monitoring the amount of current being drawn. This is done indirectly through a heater coil, which under overload conditions, melts a special solder allowing a ratchet wheel to spin free and open the contact.

A bimetallic thermal overload uses a U-shaped bimetal strip. In an overload condition heat will cause the bimetal to deflect and open a contact.

The solid state overload relay does not generate heat to cause a trip. Instead, it measures current or a change in resistance. The advantage of this method is that the overload relay doesn't waste energy generating heat and doesn't add to the cooling requirements of the panel.

Normal heating for an overload may look like a thermal anomaly. Heat generated in the coil or bimetal may look like a connection problem. Typical thermal problems in overloads are found in the connections to the contactor, overload relay, or motor.

Starters

Starters are the combination of a controller, usually a contactor and an overload relay. The above descriptions of the individual components apply to the starter systems. Reduced voltage starters are used in applications that involve large horsepower motors. They are used to reduce the in-rush current and limit the torque, and thus the mechanical stress on the load. The components of this type of starter should be inspected as the motor steps up to speed. A separate low-voltage starter circuit is used to step the motor up to speed. Once at operating speed, these components are de-energized.

Completing Inspections

Remember that primary anomalies are the problems that readily stand out while secondary anomalies may require that primary anomalies be adjusted into saturation to allow for the identification of a secondary anomaly. For example, different fuse types and sizes will cause different thermal signatures as will overload relays that are sized differently within the same circuit. Anomalies like this should be identified and reported.

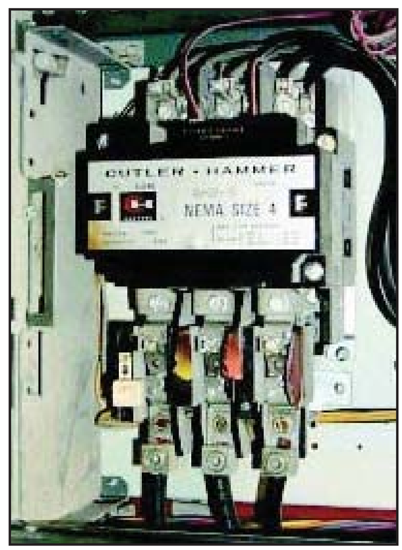


Figure 7: Visual inspection of equipment is also important and may reveal problems that go otherwise unnoticed.

Also note that when evaluating the severity of a problem, temperature is just one variable. All of the parameters involved with the severity of the anomaly should be considered. To improve temperature measurements, avoid low emissive surfaces. Look for cavity radiators or highly emissive insulation on conductors. Measure loads where component sizing, overloading, or load imbalances are observed. Beware of the effects of wind or convection on components. Note ambient temperatures, large thermal gradients, and the source of heating. Safety should be the top consideration.

Conclusion

Knowing the equipment under inspection allows for the correct identification of problems that could be misdiagnosed or overlooked. Analyzing unfamiliar thermal patterns on a component is easier when equipment design is reviewed. More precise repair recommendations can also be made.

Locating temperature differences qualitatively or quantitatively is the real benefit of infrared thermography. Knowing where to look for these temperature differences comes from knowledge of the equipment, and knowledge of the equipment will make a better thermographer.

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