Hard to Find Maintenance Tips for Electromechanical Relays

Glenn Goldfarb
ABB
Coral Springs, Florida USA
glenn.goldfarb@us.abb.com

Abstract-- **Tens of thousands of electromechanical (EM) relays, are still in service and are not going away any time soon. EM relays are manufactured and supported to this day and are the backbone of today's modern power system. Electromechanical relays are known for their secure reliable service and longevity. The EM relay life span can typically be from 20 to 40 years depending upon the relay type, application and environment.**

Well educated and experienced technicians and engineers know the benefits of proper relay maintenance; however many of the requirements recommended by the relay manufacturer are often overlooked. In fact, the relay technician can even *"hurt"* the EM relay when procedures are not adhered to. This paper will guide and enlighten certain technical personnel who are either new to the business of maintaining EM relays or are interested in relay maintenance requirements for the relay population in their power system. In order to fully understand the numerous ways aging can affect EM relays in service, a detailed description of hard to find maintenance tips has been collected and documented in this paper.

I. Introduction

A. Test switches

An EM relay can be tested either in or out of its associated case by opening individual knife blade switches on the test switch. Test switches and test plugs have all the features for applications requiring the safe measurement and isolation of individual currents, voltages, and digital I/O signals to facilitate testing of substation instrumentation and protection relays. The proper sequence must be followed in order to prevent relay misoperation. For example, the relay trip circuit must be opened first, which in the electromechanical world is typically relay switchjaw terminals 10 (DC+) and 1 (DC-), then the current and potential test switch blades can be opened. Conversely, after the relay tests have been completed, the trip circuit, terminals 1 (DC-) and 10 (DC+) is closed last. Also, if the right test tools are not used, an open CT condition can occur which can be detrimental to both the technician and the power system. The *"individual current test plug" (SafePlug)*, sometimes referred to as a stab because it stabs into the current test jack, provides a safe, simple, fast and reliable method to isolate, and monitor CT current without disturbing the power system. The 10 position *"separate source test plug"* is used for testing the relay with external test equipment. This test plug is used to insert into the relay switchjaw block with all test switch blades in the open position. The separate source test plug has an insulating barrier designed to interrupt current test jacks. It is very important that this barrier be fully intact and inserted into the current test jacks to isolate the test equipment from the CT's. If the relay case current test jacks are not fully open circuited, damage to test equipment or a relay misoperation can occur. The 10 position *"single source test plug"* is used for monitoring voltage and current when the test switch blades are in the closed position.
[See figures 1 and 2]

Figure 1: Individual Current Test Plug (SafePlug)

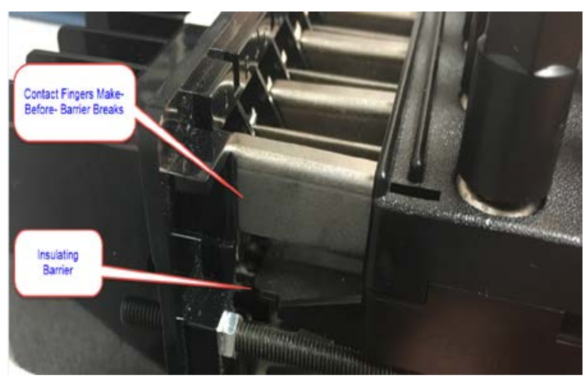

Figure 2: Contact Fingers Make Before Insulating Barrier Breaks

II. SAFETY

Personnel safety must always be the main focus of concern. The potential exposure to thousands of volts at exactly the same moment in time that a user is interacting with the test switch can be a recipe for disaster. Significant mitigating factors come into play. Most of the mitigating factors are inside the test switches, but the technician must be well trained for the potential danger. Since technicians extend the circuit under test with current and voltage meters which use leads, the shock risk is no longer contained. One relay technician who shared his experience removed an EM relay live not knowing there was a missing shorting spring inside the case. He clarified "there were allot of sparks spitting from the relay case." Fortunately, due to knowledge of the dangers of an open CT condition, and some very quick reflexes; he reinserted the EM relay back into the case, then immediately closed the test switch blades without causing an incident to himself or the power system. By inserting the relay back into the case and closing the associated test switch blades, the relay current terminals were reconnected to the CT secondary circuit, thereby squelching the potentially high voltage output. [See figures 3 and 4]

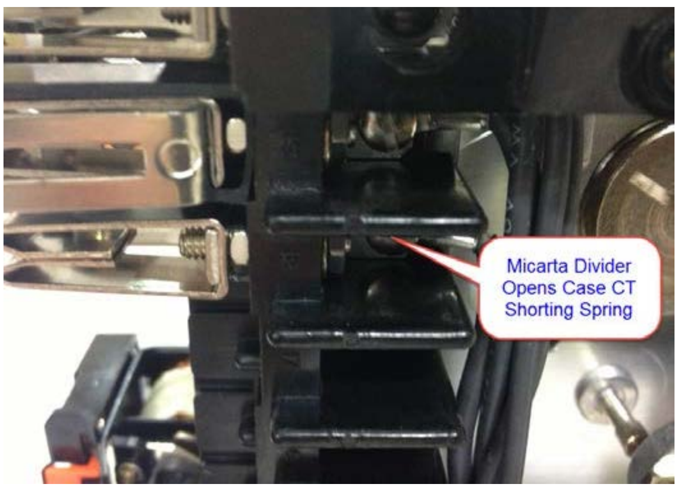

Figure 3: EM Relay Micarta Divider

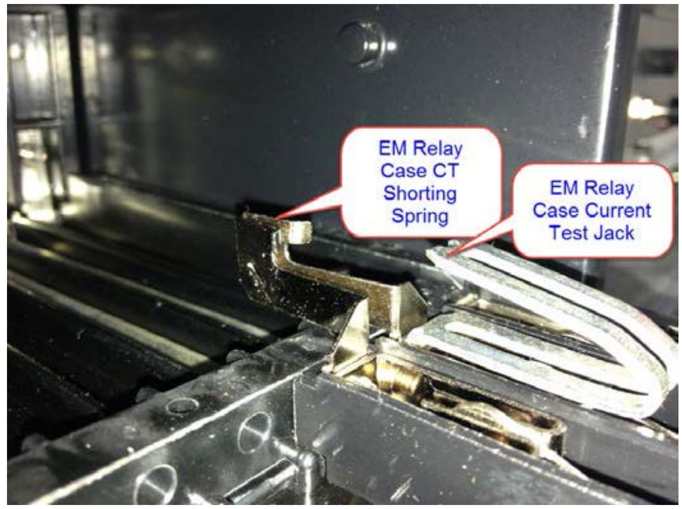

Figure 4: Electromechanical Relay Case CT Shorting Spring

When using the 10 position separate source test plug while the relay under test is in its associated case, first insert the test plug into the relay and then affix the test set leads. When testing is complete, the test leads must be removed, then last, the test plug afterwards. This important test procedure will prevent a current differential fault in the power system since digital test sets have sneak paths to earth ground. Beware since the separate source test plug fingers can make an electrical connection from the test set to the relay power system before the current jacks are opened by the test plug insulating barrier. It is also important not to insert test leads into the individual relay switchjaws unless the lead is the same thickness as the separate source test plug fingers. Otherwise a spread switchjaw can be the result which can cause an intermittent or insufficient electrical connection when the mating test blade is closed. Just because someone has never used the right tools *(separate source test plug)* for the last 20 years, does not make it right. Like the proverbial phrase; *"always use the right tool for the right job"*.
[See figures 5 and 6]

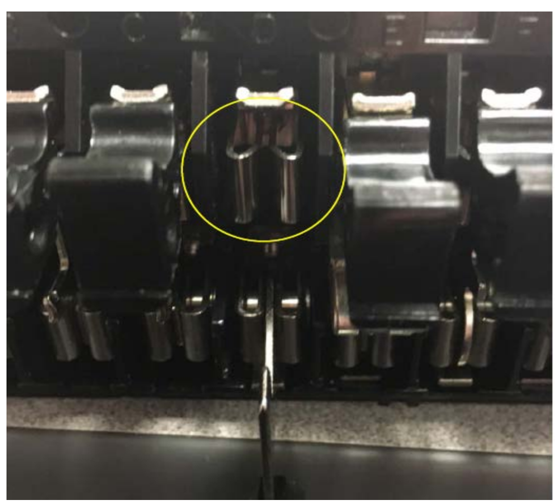
Figure 5: Damaged Spread Switchjaw From Using Large Test Lead

Figure 6: Separate Source Test Plug with Warning Label

III. VISUAL INSPECTION

General visual mechanical inspection can include the inspection of hardware, wire leads, insulation, screw connections, coils, springs, bearings, solder joints, electrical components (especially capacitors) and contacts. Any form of corrosion, rust, burning, loose or stripped hardware, discoloration, dirt, dust, rust, particles, pitting, cracking, fraying, peeling, leaking or any damage must be identified and documented before the relay maintenance is performed.

A. Friction

Foreign material lodged in moving elements can cause friction in EM relays and for those that have dealt with EM relays know that *"friction"* is the *"enemy"* of EM relays. Friction can also be described as the inability for the EM relay to repeat either its' mechanical or test parameters and therefore, not perform as intended. The induction disc element for example, may not return to the contact backstop after a fault is removed due to metal particles caught under the permanent magnet. Even the spiral spring which is used in both the induction disc and cylinder unit elements should not have its convolutions touch each other. In some cases the cylinder unit contacts may stick closed and not reset because of a bent pin bearing, damaged or cracked jewel bearing, foreign material in the moving element or chemical residue.

There was a case when a couple of KD compensator distance relay cylinder unit contacts were sticking closed after a trip during acceptance testing. These were new relays which was very unusual behavior since they had all passed the factory computer aided test. Upon further analysis it was discovered that the vendor who manufactured the cylinder unit stationary contact barrel had used a protective lubricant which had adhered to the silver contact button. Therefore when the relay tripped during acceptance testing by the end user, the contacts were sticking and intermittently remained closed after the test fault current was removed. In this case, the stationary barrel contacts had to be replaced. Historically speaking, it is highly recommended that no chemicals be used to clean or lubricate EM relays. If the EM relay does not respond to or repeat the required test parameters, friction is often the failure cause.

One of the most important tools in a skilled technician's tool kit for EM relay maintenance is the contact burnishing tool. The contact burnishing tool is basically a fine metal file which removes oxidation and residue from the relay's pure silver contacts. Not only should the contacts be cleaned with the burnishing tool, but the backstops or area behind the contact needs to be burnished or cleaned as well.

B. Outgassing

Oxidation and out gassing of a material or chemical solution forms a residue that causes sticking or a film on the contacts and moving elements which can often lead to relay misoperation. A case example of outgassing can be caused by aged neoprene rubber material. There were some AR auxiliary relays which were mounted in the FT -22 case which were left in stock in a very humid environment for many years. The neoprene gasket material on the relay case covers became soft and gel like which formed an outgassing that affected the silver contacts and actually prevented a trip operation. The AR relay silver contact surfaces became green and needed to be cleaned with a burnishing tool as a result. All of the affected relay case covers were replaced and the relay contacts were cleaned with a burnishing tool which resolved the issue. [See figure 7]

Figure 7: Recommended Burnishing Tool

C. Poly Vinyl Chloride (PVC)

Until 1991 Poly Vinyl Chloride (PVC) wire was used throughout the electrical industry since its inception in the 1960's. The problem associated with PVC wire is the formation of white powder or green goo deposits that leach out of the wire insulation. The white powder is formed as a result of a hot dry environment and the green goo is formed by a hot humid environment. The affected wire insulation deteriorates over time which inhibits flexibility causing embrittlement and minimizes its dielectric capabilities. The leaching deposit formations are chloride based and are hazardous but not considered to be highly toxic. The deposits have been known to cause skin and eye irritation, so handling of the affected EM Relay with gloves is recommended. The lesson here is the possibility of the white powder or green goo to form on relay contacts, behind the contact at the backstop or simply fall into any moving element of the EM relay. There have been reports of the green goo and white powder causing the contacts to either not make due to the material's insulating properties or cause the contacts to stick in the open position and not operate even when test or fault current was applied. If the EM relays in the power system are affected, recommendations are to attempt to clean the white powder and green deposit residue with paper towels or a lint free cotton cloth. If the outbreak is excessive, replacement is in order. [See figure 8]

Figure 8: PVC Wire White Powder and Green Goo Formation

D. Metallic whiskers

Metallic (tin) whiskers have been reported and can affect not only EM relays, but solid state relays alike. Metallic whiskers can be formed on virtually all metallic surfaces which can include tin, zinc, silver and even gold. The structures often require a flashlight and magnifying glass for visual indication. The metallic whiskers are (conductive) crystalline structures that are capable of causing mechanical misoperation as well as electrical short circuits. Mechanical misoperation is often caused by the whisker obstruction formed between moving mechanisms such as the auxiliary telephone relay armature and the adjacent coil pole face. The ICS (indicating contactor switch) is another critical unit to inspect whereas the tin or zinc whiskers can be formed on the armature. Tin whiskers can form under the induction disc relay permanent magnet which can slow or stop the moving disc from resetting after a fault condition is removed. Metallic whisker formed short circuits are often caused by bridging electrical contacts or electrical component lead connections of adjacent components. Recommendations are to attempt to clean the surface with a lint free cloth or paper towel. Masking or double sided tape can be used between the permanent magnet and the disk to remove metal particles. [See figure 9]

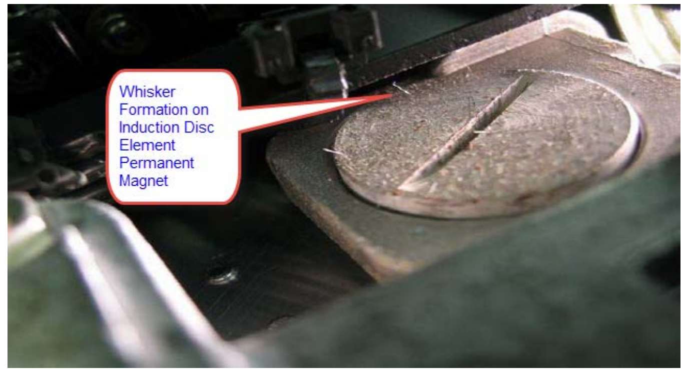

Figure 9: Nickel Whiskers Formation on Permanent Magnet

E. Capacitors

Oil-filled capacitors have been used in most types of EM relays for many years and have an expected service life of 20 plus years. Most of the capacitors in today's EM relay in-service population can be affected since they are reaching or have reached their end of life. Aged capacitor failure modes can include loss of capacitance, shorting internally and leaking oil at the terminals and the metal can seams. KD relay capacitors C3C in particular runs hot and has a high voltage applied from the in series XL coil. This cap historically has caused issues and has often caused tomato shaped impedance circles which should be round when plotted. Capacitors manufactured in the 1970's used polychlorinated biphenyls (PCB's) which are an excellent dielectric due to its insulating properties and perform well under high temperature exposure and over time. However, PCB's have been known to be linked to certain health hazards and therefore extreme care must be taken when handling. Users of PCB capacitors must dispose of them per applicable EPA (environmental) requirements. After 1978, PCB capacitors were no longer manufactured and the caps were labeled "No PCB" on the can. In many instances, capacitors can be replaced; however the maintenance technician must be aware since it is likely relay calibration adjustments have been made to compensate for the continual drift in capacitance. This is sometimes referred to as *"chasing the cap"*.

The other capacitors in question are the wet slug type tantalums or electrolytic type typically identified by a silver colored body with a band at one end and manufactured with an elastomeric seal. According to a capacitor manufacturer; at higher ambient temperatures and high ripple voltage riding on the dc voltage, this type of sealed capacitor may tend to leak over time. A common mode failure occurs whereas the sealed capacitor may tend to leak its electrolyte. When this occurs, a greenish gel type substance or white crystals form from one or both ends of the capacitor. This anomaly can cause corrosion around the soldered terminals or dark spots on the body of the capacitor. This may eventually lead to module circuit damage or relay failure. Older LCB II current differential solid state relays have been linked to false trips due to leaking tantalum caps. Preventative maintenance annually by visual inspection and capacitor replacement can prevent this common mode failure characteristic. In newer designs, the capacitors have

been permanently replaced by improved hermetically sealed capacitors.
[See figure 10]

Figure 10: Oil Filled PCB Capacitors - Replaced after 1978

F. Adjustable Resistors

Adjustable ceramic slide adjusted resistors are typically wound with fine wire whereas a slide is used to set a certain value along an exposed area. If the slide strap is not loosened or is tightened down too tight, damage to the fine strands can occur. The adjustment should not be along the edge of the open area since ceramic material can interfere with the electrical connection. Also the resistor slide strap can be damaged or broken if proper care is not taken when tightening. The higher the resistor value the finer the wire strands.

G. Paint

Black enamel paint is used to seal laminations and was often used to keep the cotton cloth coils and bobbins from fraying. The paint also protected solid copper wire leads and re-enforced the relay's dielectric capability. Peeling paint on aged EM relays can be a concern because the paint particles can possibly become lodged in moving elements such as the induction disc, cylinder unit or even between trip contacts. Today's EM relays still use black enamel paint to seal laminations and protect copper wire coils and electromagnets. Peeling paint can be serious and can be cleaned out of the relay however if the peeling is excessive relay replacement can be in order. [See figure 11]

H. Oil can effect

Oil canning or oil can springs typically have a toggling pop in and out effect. Oil can springs when dealing with EM relays has a negative connotation. EM relay springs must move back and forth smoothly without any toggling or popping effect. Examples of oil can springs can be found in Indicating Contactor Switch (ICS) cover leaf springs and polar unit armature contact fingers. In respect to polar unit contact fingers, if the contact does not reset, this can be the cause. There is no method to correct this issue, therefore replacement is the only option.

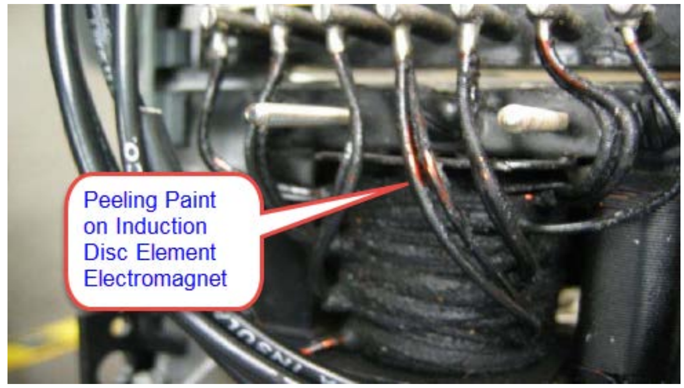

Figure 11: Peeling Paint on Aged Painted Cloth Type Electromagnet

IV. MAINTENANCE TESTING

EM relay functional testing ensures relay calibration is maintained. Relay testing should be performed per the relay instruction book acceptance test or performance checks. Sometimes taps or settings need to be changed in order to perform a particular test so careful documentation needs to be noted for the as found state. Certain tests require specific settings and calculations for a particular application. The EM relay instruction book (I.L.) must be the source of reference when testing is performed.

From a manufacturer's standpoint, EM relay maintenance should be performed every 1 to 2 years which includes relay testing. This requirement is often documented in the relay instruction book prior to the acceptance test or performance check. The frequency when EM relay maintenance should be performed is also dependent upon the relay type, environment and how often the relay is operated. Relay training is crucial for personnel who deal with EM relays. Factory authorized training is available for EM relays which includes relay applications, mechanical and visual inspection, acceptance testing and maintenance.

Sometimes relay contacts need to be blocked open or closed in order to sense or verify continuity that a certain relay element is functioning properly. This can be achieved by using a small folded piece of paper between the relay contacts, contact backstop or moving element; i.e. relay disc and frame. White paper can also be used as a lighted background when trying to see clearances and particles between the induction disc and electromagnets and permanent magnets. A folded five dollar bill is often used since no respectable relay technician will leave his money in the relay when all tests are completed and the relay cover is put back on.

EM relays are often referred to as *"Silent Sentinels"* and will remain silent, operating only for a fault condition within the power system. Proper training and experience are a good mix for preventing a relay misoperation and keeping the technician safe. EM relays that are properly maintained in today's modern power system are our assurance that electric power will remain reliable and secure while preventing:

- Power System misoperations (blackouts)
- Damage to overall equipment the relay was designed to protect
- Personnel safety (shock hazard)

With due diligence, relay maintenance, proper use of test equipment, test tools and knowing what to look for; risk can be mitigated.

REFERENCES

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[2] A. Elmore, *Protective Relaying: Theory and Application*, Marcel Decker, Inc., 1994.

[3] *IEEE Standard for Relays and Relays Systems Associated with Electric Power Apparatus*. IEEE Std. C37-90, 2005

BIOGRAPHY

Glenn Goldfarb has been best known as "the Answer Man" during most of his career at ABB. Currently, Senior Marketing Engineer at ABB's Coral Springs, Florida, plant, he has been the go-to person for questions about electromechanical relays and FT switches. He has also been responsible for high-voltage microprocessor-based relays in ABB Allentown, Pennsylvania, and for recloser control products at ABB Lake Mary, Florida. He has a total of 38 years of experience with Westinghouse and ABB relay products and is the primary instructor for Electromechanical Hands-On Relay Training. In fact, it's his job to answer application and other technical relay questions.