

Critical Maintenance for Circuit Breakers



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Introduction

Circuit breakers aren't much fun. They don't do a whole lot; just open contacts and close contacts. Pretty boring. However, if a breaker doesn't operate when it's supposed to, life can get *very* exciting! This paper will cover common maintenance problems and mistakes that are made by equipment owners and discuss what steps need to be taken to ensure a reliable and secure power distribution system.

Often when we arrive at a job site everything looks normal. The power system is up and running, there appear to be no issues affecting operation. Everything is happy in Neverland. Then the shutdown begins. Before you know it there are repairs going on all over the facility and the customer is not in a good mood. The most common questions we get are, "Why is there a problem now when we haven't had any before?" which really means, "Why did you break my equipment?" The second question often is, "How can that breaker have a problem when we never operate it?"

To understand the reason for preventive maintenance (PM) and the causes for problems, an understanding of the construction and operation of the typical stored-energy type circuit breaker is needed. This includes low-voltage and medium-voltage, air, SF₆, and vacuum power circuit breakers.

Happy Is As Happy Does

Or something like that. It is easy to see that if these components begin to gum up and slow down, the breaker won't operate properly. If the breaker is just sitting there, how does the grease get gummy? All lubricants dry out over time. Additionally, the grease is forced out of pressure points over time, the exact points that need lubrication the most. If the breaker is exercised it moves lubricants back into the pressure points. However, they still dry out over time. As the breaker carries load current heat is produced by the I²R losses. The higher the load current, the greater the losses will be and the more heat will be produced. This heat increases the rate at which the lubricants dry out, even if the breakers are exercised regularly.

The Number 1 Problem

Lack of lubrication is the number one problem we run into with circuit breakers. Typically, when we perform maintenance we find one breaker out of every four has lubrication issues. This results in breakers that won't open, breakers that won't close, or breakers that open after a delay. We were testing a breaker in a customer's facility, and when we hit the TRIP button nothing happened. The technician went to get his tools and fill out paperwork and approximately two *minutes* later the breaker popped open! Imagine if this had happened during a fault on the system!

All those little rollers and latch surfaces require lubrication. The old lubricant has to be cleaned off and new lubricant applied. It used to be that each manufacturer had a specific lubricant they recommended for their breakers, one for the current path and one for the operating mechanism. Nearly all manufacturers now recommend (or at least allow the use of) Mobil 28. This is a red, synthetic-based lubricant sold in tubes or in cans and can be used in both the current path and the operating mechanism. Many manufacturers "private label"

this lubricant, putting their own name and part number on it, so you may recognize it by some other name. (Tony Demaria has written an excellent article on lubricants, which also appears in this issue of *NETA World*.)

It isn't just the operating mechanism that requires lubrication. All circuit breakers have lubricant applied to the contact pivot points at the factory. During the course of time, this lubricant dries out, gets gummy, then flakes off and you now have metal-to-metal wear taking place. This really does bad things to the breaker, as wear is now greatly accelerated and parts become misaligned. The breaker also slows down, but you may not notice it unless you have a good breaker to compare it against.

The Current Path

Figure 1 is an ABB/ITE K-600 circuit breaker contact assembly. Note the number of points where wear takes place. The primary points of wear are at the arcing contact/tensioner contact (2) and the contact roller/tensioner contact (1). Lack of lubricant at point 1 causes wear across both contact faces, while lack of lubricant at point 2 causes the breaker to slow down and grooving to be cut into both the roller and the tensioner contact. Eventually the breaker will seize if the components aren't replaced and new lubricant isn't applied.

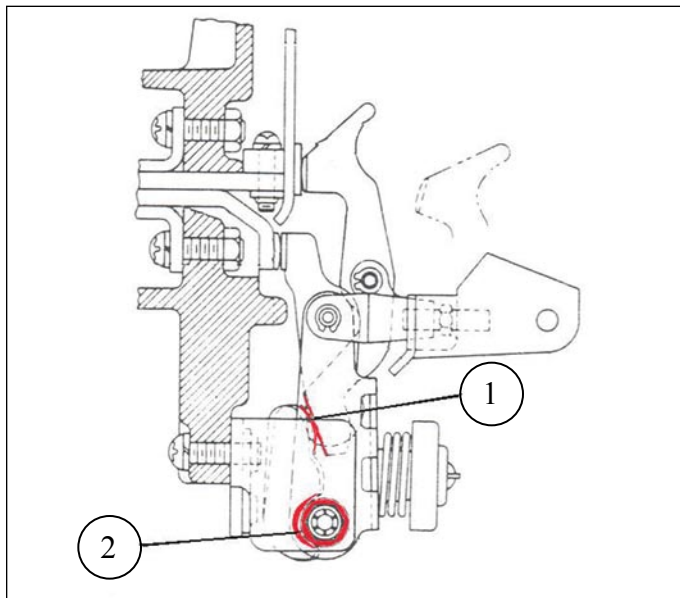


Figure 1 — ABB/ITE K-600 Contact Wear Points (Courtesy ABB Power T&D)

One of the evils we've seen is the use of a spray penetrating oil, such as WD40, sprayed into the contact pivot point or into the operating mechanism. It appears that the problem has been solved. The breaker functions like it should, opening and closing on repeated cycling. However, what one doesn't see is that any remaining lubricant has now been flushed out of the pivot points and replaced with a 30-day lubricant. *Maybe* a 30-day lubricant.

More than likely when the breaker heats up due to current flow through it the lubricant will quickly dissipate and some *real* wear can begin. Others use white lithium grease or some "magic" lubricant handed down through generations. None of these is acceptable, even if they seem to work.

One of the reasons manufacturers have been so specific about the lubricants used in their breakers is that the breakers will have to perform under a variety of conditions, many times in very adverse conditions. Using lubricants not designed or proven to function well in these conditions is shortsighted and can very possibly ruin an expensive breaker, or worse, cause it to seize during a fault condition.

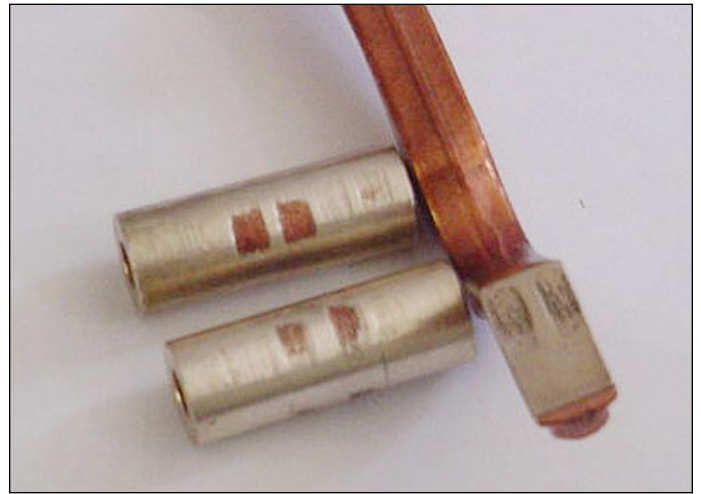


Figure 2 — ABB/ITE K-600 Contact Wear Points

Figure 2 is a picture of the arcing contact and roller from an ITE breaker showing the wear we often see. It isn't just ABB/ITE breakers, by the way. Lack of lubrication is a big problem in all breakers. The K-line breaker is well-built, so it actually suffers less than one not so well-built. Actually, most of the low-voltage power circuit breakers in service today should give reliable service without needing exceptional servicing. There are a handful of breakers that are sold on the basis of price or discounting that will cost more to own in the long run than others.



Figure 3 — Siemens MA-250 Contact Pivot Point Wear

Figure 3 is a photo of contacts from a Siemens MA-250 medium-voltage breaker we received into the breaker shop. The breaker was operating slower than normal and when it was disassembled, it was found that the contact pivot points had worn through the silver plating and into the copper. The surfaces showed signs of gouging and pitting. The only way to prevent this damage is to perform maintenance on circuit breakers. If this breaker had remained in service it could very well have seized during a fault, just like the breaker in Figure 4.



Figure 4 — Major Doo-Dah in the Powerhouse

The breaker in Figure 4 failed to open its contacts fully due to improper lubrication. Since it couldn't open far enough or quickly enough to clear the original fault, a fault occurred in the breaker contacts. The upstream breaker then had to clear the fault. Unfortunately, the upstream breaker saw this as a large overcurrent instead of a short circuit and took between 2 and 3 seconds to operate, instead of opening in cycles.

In addition to the damage caused to breakers, there are also issues involved with damage to the equipment the breaker is protecting as well as possible injury to personnel that may be working on the breaker when it fails to clear the fault. A delayed trip (or no trip) could push the incident energy well above the personal protective equipment the worker may be wearing.

The fix for this problem sometimes is not very straightforward. There's no way to see inside the pivot points, and it's too expensive to take the breaker apart just to see what's going on inside. For the contact pivot point area a micro-ohmmeter test (often referred to as a contact resistance test) can be performed, Figure 5. By measuring the resistance of the entire current path, any increase in resistance can be determined. In low- and medium-voltage power circuit breakers, a good part of that increased resistance is going to be due to the lubricant drying out. By measuring the resistance each year a trend can be established and when the resistance becomes too great, the breaker is due for a tear-down and relubrication.

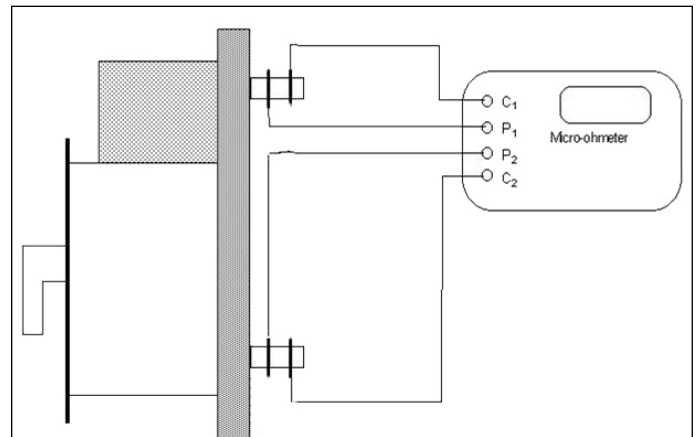


Figure 5 — Micro-Ohmmeter (Contact Resistance) Test

So what is too much resistance? That is a really good question. Too good. As a matter of fact, there is very little in documentation when this topic comes up. The loosest rule-of-thumb going is to have the contact resistance as low as possible and as even as possible within the three contacts. In general, that's good advice, but really doesn't help us diagnose problems. However, the lower the breaker's continuous current rating, the higher the contact resistance readings will be.

A 4,000 ampere 480-volt breaker should have a reading of something less than $30\mu\Omega$ if it's in good condition. Smaller breakers may have readings of 60 to $80\mu\Omega$. Molded-case circuit breakers can have contact resistance readings in the hundreds of microhms. I'm not (purposely) trying to confuse the issue, but it's not as simple as it should be. Occasionally a manufacturer will recommend values, but not often.

Typically the criteria for contact resistance is based on the ampere rating of the breaker rather than its voltage rating. A 2000 ampere medium-voltage circuit breaker will exhibit similar contact resistance to a 2000 ampere low-voltage breaker. An experienced maintenance group knows the normal average contact resistance for a given size circuit breaker. A value somewhat higher than that average may indicate that the lubricant is beginning to dry out but hasn't reached the problem plateau yet. The important part of this is to perform the test annually and trend the changes. Performing this test also exercises the breaker, which needs to be done as well.

Some systems are so redundant and so lightly loaded that they require far less maintenance than other systems do. One customer I visited had 1200 ampere breakers with 200 amperes of load current on them. They were installed in a positive-pressure, temperature-controlled vault that was cleaner than my home. The customer could probably defer maintenance on their system for 7 to 10 years without a negative effect. However, some systems are loaded to the maximum, and the switchgear is located in dirty, humid areas with ambient temperature extremes.

So, What About the Operating Mechanism?

Operating the breaker is good for the mechanism. It loosens up the grease that's still viable, spreads it around and, if we listen to the breaker and watch it when it operates, it can indicate when the breaker is in trouble. Listen to the sound the breaker makes when it operates. It should have a clear, solid sound. If you operate five breakers, you can tell if one of them is operating slower than the others. Look at the lubricant on latch faces and around rollers. If it's dirty, dusty, or thick, it needs to be replaced. If you operate a breaker and it won't reset until you've operated it a few times, BINGO! The mechanism is gummed up. In general, you can expect the mechanism to need cleaning at about the same time as the current path. This may not always be true, especially if the environment is dirty, humid, hot, cold, or otherwise less than ideal.

Figures 6a, 6b, and 6c show an ABB/ITE K-1600 operating mechanism. The arrow in Figure 6a is pointing to the main roller in the prop-and-roller mechanism. If this roller gums up, the breaker won't reset properly. Clean any accessible latch and roller surface you can reach and relubricate it. If a roller is sticky or hard to spin, it may need to be removed and lubricated. This can be more than a ten-minute job, especially if it is hard to get to.

Also be aware that some rollers may be under tension from latches or springs, and always be aware that these are spring-charged mechanisms that move very fast and with extreme force. You don't want to lose any body parts working on the breaker. Before starting any maintenance procedure on a breaker, always open and close the breaker to be certain the springs are discharged and the contacts are open. Figure 7 is a GE AK-75 operating mechanism.

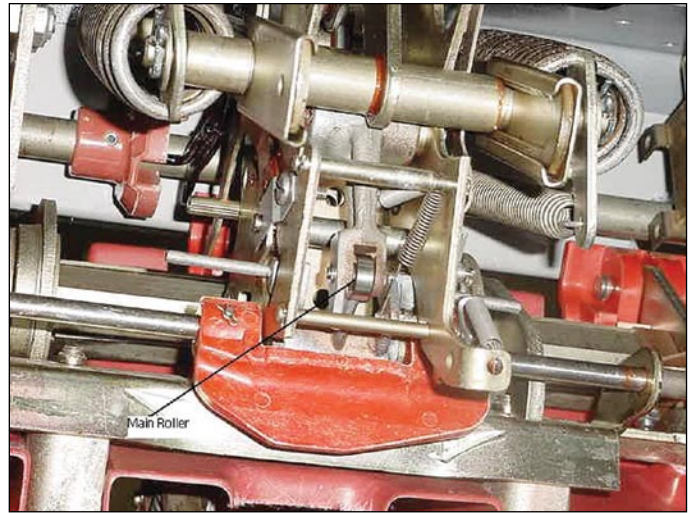


Figure 6a — ABB/ITE Prop and Roller Mechanism

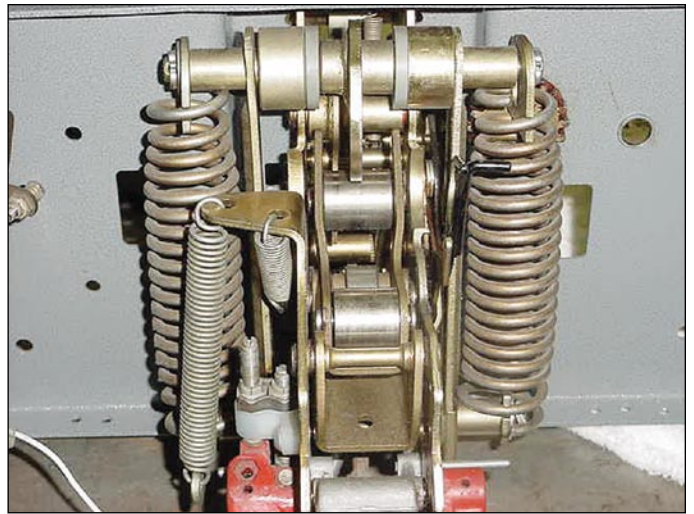


Figure 6b — ABB/ITE K-1600 Operating Mechanism Showing Various Rollers

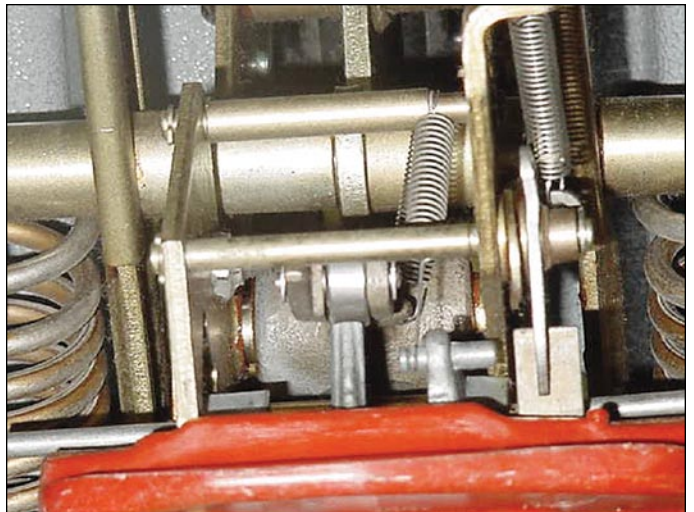


Figure 6c — ABB/ITE K-1600 Prop and Roller Close Up View

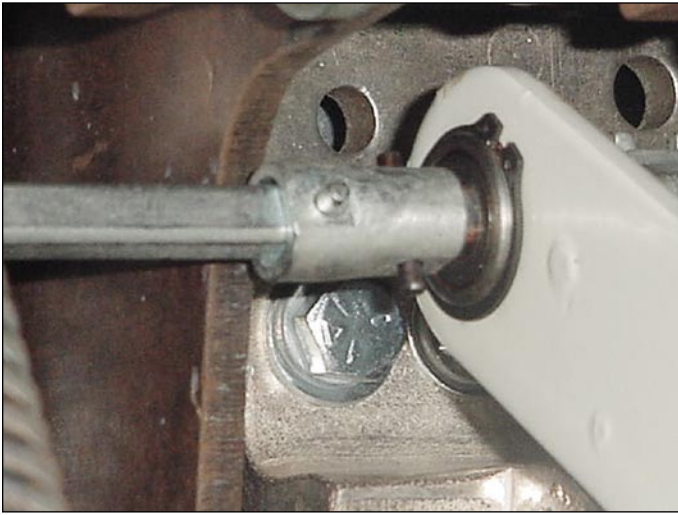


Figure 7 — GE AK-75 Trip Bar Bearing

The arrow is pointing to the bearings that we often find sticking, causing the breaker to trip slowly and not reset properly. This will cause the breaker to seem as though it is in a trip-free condition.

All of this can be a double whammy for a circuit breaker. Dirt, corrosion, heat, and vibration all act to shorten its life. Certainly lack of lubrication isn't the only issue with breakers, but it is by far the most common one.

Adjustments

Probably the second most common problem we see in our breaker shop is improper adjustment of the breaker. The mechanism adjustments are usually pretty close, because if they weren't the breaker wouldn't operate. However, poor adjustment of the contact assemblies often causes problems. There are three primary adjustments on low- and medium-voltage air breakers:

- Contact pressure or contact wipe
- Contact sequence or contact make
- Contact gap

Frequently we receive breakers that exhibit a number of problems directly associated with the adjustment of the contacts.

Contact Pressure

One might think that when it comes to contact pressure, the more you have the better. This isn't true at all. Too much contact pressure leads to a number of problems including cracked contact faces, excessive wear, and bending of components. A properly adjusted breaker will have enough contact pressure to reduce contact resistance to specifications but not so much that it damages the breaker. To measure contact adjustment, most manufacturers will have you measure the distance from a stationary part of

the contact assembly to the contact face with the breaker open. The same measurement is repeated after the breaker has been slow-closed. Slow-closing or maintenance closing allows the breaker contacts to be closed slowly by bypassing the spring-charging mechanism. Figure 8 shows a GE AK-75 breaker's lock-out pin being installed to restrain the closing spring (Items 2 and 3).

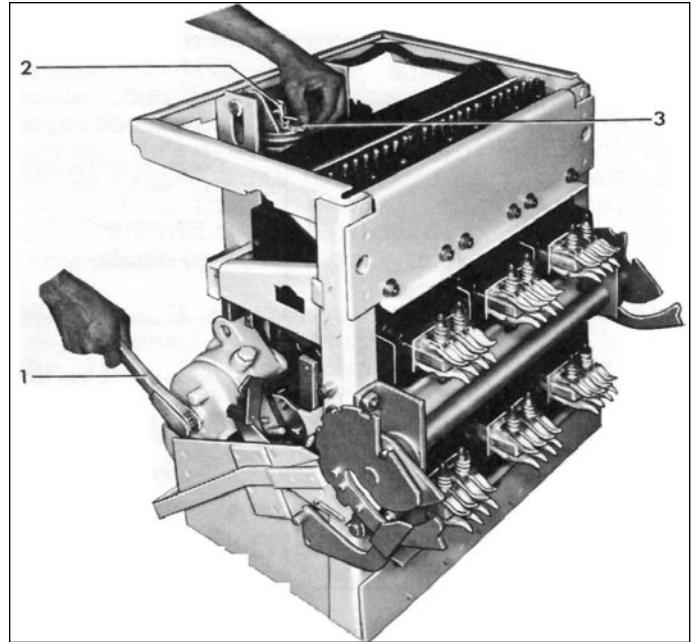


Figure 8 — GE AK-75 Slow Close Components (Courtesy GE Electrical Distribution & Control)

Contact Sequence

When a breaker closes, all three contacts should make at about the same time. If they are too far off, the arcing contacts will suffer accelerated wear, leading to failure of the main contacts. Most manufacturers of low-voltage power circuit breakers recommend that all contacts touch within 0.032" (1/8") of each other.

The easiest method for determining contact sequence is to use a light circuit as shown in Figure 9. A different color light is used for each phase and is powered by a battery. The breaker is slow closed until the first contact touches, then the other two phases are measured. There should be no more than the 0.032" or whatever the manufacturer's specification is.



Figure 9 — Light Circuit for Contact Sequence

When adjusting the breaker the contact pressure is usually performed first, then the sequence, and then the gap. It may be necessary to increase the pressure somewhat in order to get the contact sequence correct. If the contact assemblies are serviceable, all three adjustments should be within the manufacturers' tolerances. They may be at the maximum tolerances, but they should be within them. If the three adjustments cannot be achieved within the specified tolerances, then the contact assemblies need to be replaced. Figures 10a and 10b show the result of too much contact pressure.



Figure 10a — A-Phase Arcing Contact Showing Cracks in Face



Figure 10b — C-Phase Contact After a Short Circuit

The result of excess pressure shown in Figure 10a, is that the contact face cracked. Then during a fault, pieces of the face blew off the contact, and the entire contact melted as shown in Figure 10b. This is because the arcing contact face is made of an alloy of zinc, copper, and silver, whereas the portion under the face is only silver-plated copper. The damage to the contact face in 10a was not immediately apparent when an inspection was first made. Only after cleaning the contact surfaces did this damage show up. The by-products of arcing can cover up quite a bit!

Contact Gap

The contact gap is not quite as critical as the other two adjustments. Many times no specific gap is given in the manufacturer's instruction books. However, if the contacts don't open far enough, a breaker that looks like Figure 4 can be the result. Air is a dielectric, which is good. It is not a great dielectric and when contaminated with moisture, carbon, or other conductive particles or if there is an insufficient air gap between the contacts, a sustained arc can occur.

The contact gap is measured with the breaker open from the closest points between the stationary and moving contact assemblies. Figure 11 is a GE AK-75 breaker showing the measurement points. If the contact gap is too small, it can be adjusted using the same stud that is used for the other adjustments. Again, a properly adjusted breaker is going to be a compromise between all three specifications. A breaker with good contacts should fall within the manufacturer's tolerances for all three adjustments.

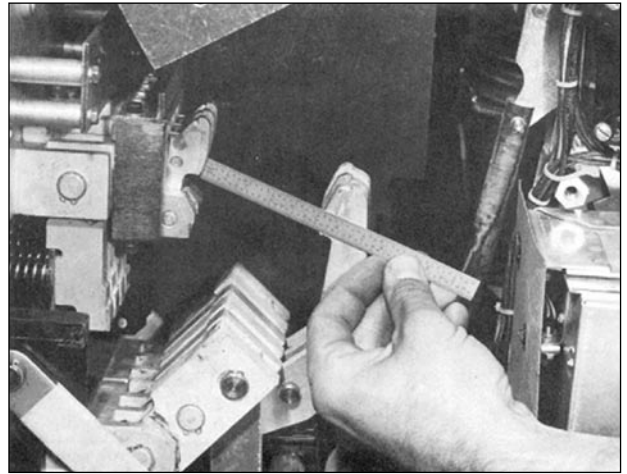


Figure 11 — Measuring Contact Gap (Courtesy GE Electrical Distribution & Control)

Don't try to get each adjustment in the center of its tolerance, as it probably won't be possible even if the breaker is brand new. If it is not possible to adjust the breaker so that all three adjustments are within tolerance, the contact assemblies should be changed for new ones. Never replace just the moving or just the stationary contact assembly, even if the other looks new. Always replace contact assemblies as sets, A-phase moving and stationary, B-phase moving and stationary and so on. It may not be necessary to replace all three phases just because one phase is worn, but some companies do so.

Although low-voltage power circuit breakers have been shown as examples for the most part, medium-voltage breakers are very similar in construction and their adjustments. Figure 12 is a Westinghouse DHP air-magnetic circuit breaker's pole unit showing its stationary and moving contact assemblies. Note that its basic construction is similar to that of a low-voltage breaker with the exception of the puffer tube. Note also that the moving contact assembly has a pivot (Item 2) similar to the low-voltage breakers. This is

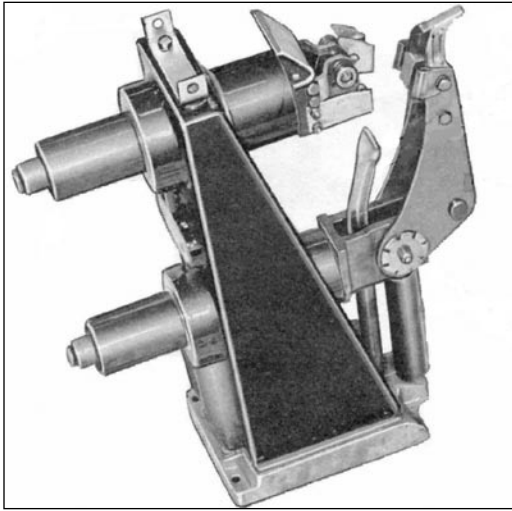


Figure 12 — Westinghouse DHP Pole Unit (Courtesy Westinghouse Electric Company)

a critical lubrication point for medium-voltage as well as low-voltage breakers.

Other Issues

After lubrication and contact adjustments, the number three problem is abuse and neglect, which are not too far removed from each other. Untrained operators frequently use excessive force when encountering interlocks or other resistance when racking the breakers in or out. The resulting damage can be dangerous to the power system and to themselves. An example is the racking gear in Figure 13. This came out of an ITE K-2000 breaker that had been racked in so hard that it bent the hardened stop pin (arrow). We receive breakers where these pins are missing completely! If that happens, the breaker will rack in, then, when it reaches the end of its travel, rack right back out. The cause, Magilla Gorilla has the racking handle! If the racking mechanism has been neglected, it may take Magilla to rack it in. As the lubricant gets gummy it will take more effort to rack in the breaker. If the stabs haven't been lubricated, it increases the force required to make the primary stabs connect. Add one overzealous operator and you've got problems!

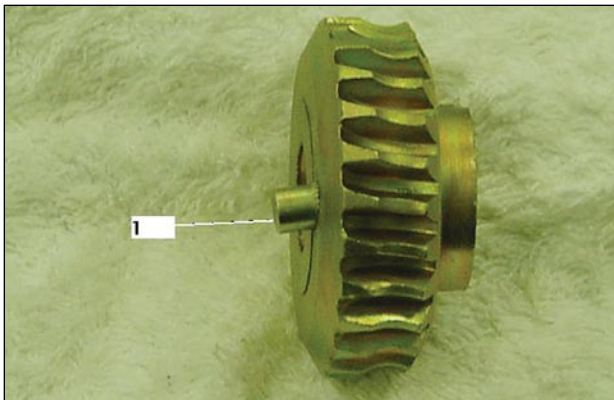


Figure 13 — ITE/ABB Racking Gear

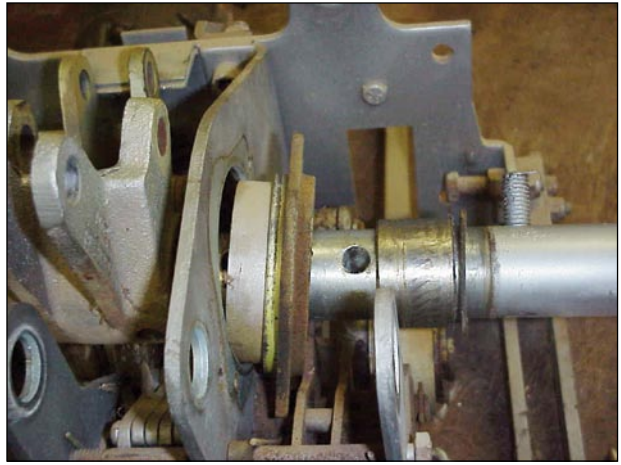


Figure 14 — Westinghouse DHP Neglect

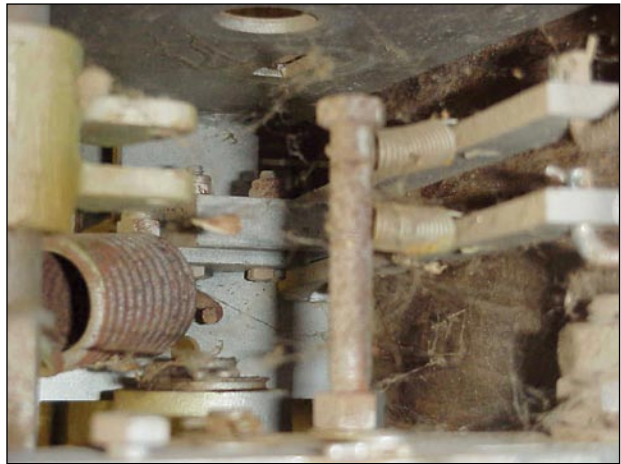


Figure 15 — Cobweb City

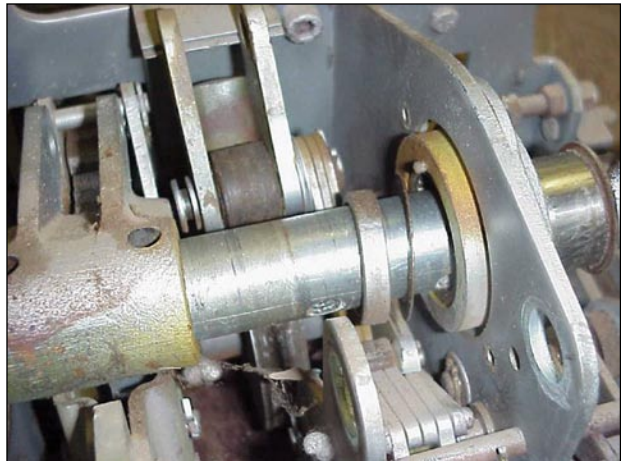



Figure 16 — Bearing Damage and Wear

Figure 14 is another shot of a neglected circuit breaker. Cobwebs can be expected, but heavy rust and corrosion should not be found (unless you have one of those special “underwater” circuit breakers). The breakers in Figures 15 and 16 are just neglected to the point of failure. Just as

in Figure 14, the breakers in Figures 15 and 16 probably wouldn't open if you dropped a hand grenade into them!

Summary

Circuit breakers are normally very hearty devices. Maybe because of this they are often abused and neglected. We can take the "If it ain't broke, don't mess with it" attitude, but that will cost much more over time. Regularly scheduled PM or using an RCM methodology will reduce operating costs, increase production, and decrease unplanned outages. This is not cheap maintenance, as the breakers must be removed from service, tested and then cleaned, inspected and relubricated. A competent technician can perform teardown, maintenance, and reassembly in eight hours if everything is in order. If lack of lubrication has caused wear, parts will need to be repaired or replaced. The costs and time increase from here. Don't neglect those protective devices – they are critical for production and worker safety. 

James R. White is nationally recognized for technical skills and safety training in the electrical power systems industry. He is currently the Training Director for Shermco Industries, a NETA Accredited Company. Jim has spent the last twenty years directly involved in technical skills and safety training for electrical power system technicians.