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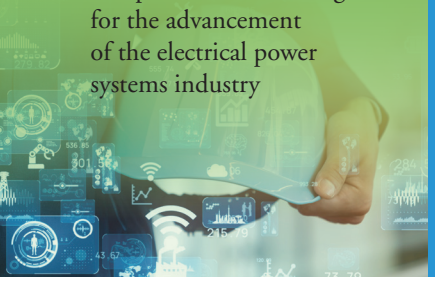

THE VALUE OF EMPLOYEE TRAINING PROGRAMS

BY CHUCK BAKER, SDMyers

As we watch trends within the power system maintenance labor force, we see a consistent decrease in expertise. The experts are retiring faster and faster, and those coming into this market have less experience than we have had in decades past. That means your training program will have a key impact on the long-term strength of your business.

This article is intended for companies looking at their current training strategy as well as current trainers who want to look at the logic and value of such an effort. Use this to review your current program, determine your end goal, and decide which changes you want to implement.

PURPOSE, BENEFITS, PAYBACK

Let's look at the purpose, benefits, and payback of a good training program and why it is a critical part of your business:

Safety

- Employees need to know all risks associated with their job.
- This requires that they receive all required training

Untrained employees = unhappy employees

- An employee who is not properly trained will feel they are not producing what they should. They will feel inadequate, which translates to unhappy.

Reduced production

- Untrained workers produce at a lower rate.
- This also includes lower quality, which can have high cost and long-term impact. It is not always easy to identify this, but we all agree in the logic of this important point.

Lost time and money due to mistakes

- When an untrained worker makes a mistake, the time and materials used are a loss. The work then must be done again.
- Worse, an inadequate product was delivered to the client. You can see how these can easily add up over time.

Increase in miscellaneous expenses

- Although difficult to connect to those who lack skills, this cost hits the bottom line. It includes the additional cost of repeating a function, including utilization of equipment and required materials, and the impact on production flow.

Lost customers

- Insufficient staff training means lost customers.
- All businesses are competitive, and if you are competing against organizations that have a higher and more sophisticated training program, it will be felt by the customer.

Significant cost of turnover

- There are a wide variety of calculations for the direct and indirect cost of unplanned employee turnover. Some experts say the total cost of unplanned turnover can be 50% of the employee's annual salary.
- This includes things like lost production, recruiting and training costs, decreasing other employees' output as they attempt to cover the vacant position, recruiter costs… you get the idea.

Required expertise

- If you are in an industry such as power system maintenance, the expertise of your employees is critical to your safety and the quality of services.

- We know hiring a fully trained expert is becoming more difficult, which increases the criticality of your training strategy.

TRAINING PROGRAM STRATEGY

Let's look at some of the key considerations you want to think through as you evaluate your current and/or continue building your program.

Categories

When we talk about the components and categories of a training program, there are three general categories.

1. Required/regulated components are those required by state or federal training requirements, such as sexual harassment training, safety training, and ethics training. You know these (or should) and are covering them.

2. Job qualification training relates directly to the employee's job responsibilities. This is where things become a little more complicated. It requires the program to lay out all key functions and have a method to monitor employee progress and status. You use this information to make decisions on your training implementation.

3. The edge on your competition comes from growing employees to fulfil their goals and maximize your company in a competitive market. This is where taking a deeper look into the key needs of a successful training program helps build your strategy

Understanding the Student

Another key component in building or expanding your training program is to understand the learning style of each student. You cannot customize all training, but you can present it using varied methods. To understand each employee's learning style, have them fill out a short survey. This allows you to maximize the training method and effect on each group of learners:

Visual learners

- Prefer seeing things such as pictures, drawings, etc.
- Use handouts, white board, have students draw

Safety, quality of expertise, growing expertise, and employee satisfaction are greatly impacted by a complete, creative, and customized training program.

Auditory learners

- Prefer to hear what is being taught vs. reading
- Give opportunities for to talk as well as listen

Kinesthetic learners

- Movement is important.
- Gather in groups, pick a side of the room to give the answer, have students come up to the white board, etc. Using tangible components can help these students gather and retain information.

Reading/writing learners

- Traditional teaching, reading
- Use books, internet searches, etc.

These are important considerations. We know that fixed programs will include all learning styles and that considering this when developing the program increases effectiveness.

Training Methods

In many cases, the training method is customized to a position. In general, there are four popular methods:

1. Traditional classroom is effective for larger groups. This is typically at a higher cost but is often required for effective training.
   a. Qualified instructor
   b. Slides, workbooks
   c. Teams and discussion groups

2. Collaborative training involves less reading and more action.
   a. Work case examples
   b. Role play
   c. Choices in various situations

We have found collaborative training to offer benefits for online training as well as traditional classroom. The student's ability to work in teams and with case-specific scenarios helps grow expertise and is an enjoyable process.

3. On-the-job training (OJT) involves more hands-on opportunities.
   a. Uses actual work responsibilities to teach
   b. Slower than normal but produces output

   In our field, OJT remains a key function of technical training. With an endless array of equipment to be serviced, OJT allows the trainee to perform the work under qualified expertise. Training in the field or — more economically — purchasing equipment for training purposes in your shop using this expertise is a valuable option.

4. Online training
   a. Includes things such as online courses, live webinars, videos
   b. Can be customized to the various learning styles

   Online training is becoming more and more popular, and the courses available online continues to grow. Online training can be done individually or as a group. In a classroom, view with a leader who can help coordinate questions while stopping periodically to customize what is being taught to the group.

CONCLUSION

My best example of creative training was the human resources manager who came onboard and immediately changed some of the training procedures. The manager met with every employee individually to understand each person's current role, level of expertise, what they would like to learn, and what the long-term goals were.

New approaches were employed, such as teaming a rookie with a pro for a one-hour meeting each week when the new employee could ask the more experienced employee their questions. This was interesting because the managers participated and prompted conversation on each point discussed. Every occurrence out of the norm was discussed at these weekly meetings including what happened, why it happened, and what the result was.

Safety, quality of expertise, growing expertise, and employee satisfaction are greatly impacted by a complete, creative, and customized training program. Decreasing production errors, lowering employee turnover, and raising the quality of employment in your organization are very positive…and profitable strategies.

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ELECTRICAL SAFETY: A PERPETUAL GIFT

BY COREY HANNAHS,
National Fire Protection Association

"It's the most wonderful time, of the yearrrr…" Yes, it's technically not Christmas, and I certainly can't carry a tune like Andy Williams, but gifts are in abundance this time of year if you know where to look for them. Birds singing, flowers blooming, gardens growing — these are just some of the things most people come to enjoy during the springtime months.

But for those of us who work with and around electricity, the month of May brings us a different kind of gift in the form of National Electrical Safety Month. The Electrical Safety Foundation International (ESFI), a non-profit organization dedicated exclusively to promoting electrical safety at home and in the workplace, promotes this campaign every year that focuses on educating key audiences on the steps that can be taken to reduce the number of electrically-related fires, fatalities, injuries, and property loss.

I know what you're thinking: "How can Electrical Safety Month be considered a gift?" For those who don't quite see that yet, let me explain further. This gift isn't typical. It does not come with a gift receipt and you can't return it. You either accept it, or you don't. It is, however, a one-size-fits-all kind of present. When accepted, this gift continues to keep on giving, mostly in the form of arriving home daily after work, kissing your spouse, and receiving those amazing "Mommy's home!" or "Daddy's home!" hugs from your children. You know — the things that matter most to you.

Being able to work daily in and around electricity in a safe manner allows us and our coworkers to return home unharmed to our loved ones at the end of every shift. It is my personal belief that safety can only happen with three key components all working together in unison: knowledge, application, and responsibility (KAR).

Knowledge is provided through adequate training. Application comes through applying the training received and following a well-designed electrical safety program (ESP). So who is responsible for driving the KAR down Electric Avenue (go ahead and sing it, I know you want to) everyday? Employers and employees each have a shared responsibility to one another for ensuring workplace safety:

- **Knowledge.** Employers must provide, at minimum, the training required for the employee to do their job safely. Employees must accept, and fully understand, the training provided. Employers and employees should work together to create an ESP that meets the needs of the job and is fully understood by all parties.
- **Application.** Employees must apply the knowledge they have received and implement the ESP in their everyday tasks without taking shortcuts or skipping processes. If job tasks or conditions change where employees recognize they don't have proper training to do the job safely, or the job is not defined within the ESP, they must speak up to their employer and get proper training before doing the task.
- **Responsibility.** Employers and employees have a shared accountability. Employers must provide the training necessary, develop an ESP for employees to follow, continually listen to employee concerns and, when necessary, be willing to sacrifice profits for safety. Employees must apply their knowledge and training every day, without taking shortcuts, and speak up when they do not have proper

training or understanding. If either party fails to provide or follow these guidelines, the safety of all will be lost.

The KAR acronym and associated thoughts behind it are mine and mine alone. They are by no means implied to be anything other than a mechanism I have found helps me personally understand what has been necessary for electrical safety to work.

NFPA 70E is utilized by an employer to help fulfill OSHA obligations and as a means to ensure the safety of a business's most valued asset: its employees.

RESOURCES

Employers should seek out training and workplace guidelines from Occupational Safety and Health Administration (OSHA) requirements and from recognized industry standards such as NFPA 70E®, *Standard for Electrical Safety in the Workplace*. The purpose of NFPA 70E is to provide a practical safe working area for employees relative to the hazards arising from the use of electricity. It is an internationally accepted American National Standard that provides safety policies, procedures, and process controls for installation as well as maintenance. NFPA 70E Article 110 also offers insight into the critical components of a well-designed, effective ESP. While not typically adopted legislatively, NFPA 70E is utilized by an employer to help fulfill OSHA obligations and as a means to ensure the safety of a business's most valued asset: its employees.

CONCLUSION

Although what drives it may change, few people ever lose the wonder and excitement that go along with Christmas morning. As children, we live for waking up way earlier than we typically would to run down the stairs and see what Santa has placed under the tree. As parents, our pleasure comes from seeing the joy on the faces of our children. If safety is the gift, then NFPA 70E is the beautiful wrapping and bow that make it a gift. Without it, it's just a box. NFPA 70E makes electrical workplace safety what it is. And accepting the gift of safety matters because of the things that matter the most to you.

COREY HANNAHS *is an electrical content specialist at the National Fire Protection Association (NFPA). In his current role, he serves as an electrical subject matter expert in the development of products and services that support NFPA documents and stakeholders. Corey, a third-generation electrician, holds licenses as a master electrician, contractor, inspector, and plan reviewer in the state of Michigan. Having held previous roles as an installer, owner, and executive, he has also provided electrical apprenticeship instruction for over 15 years. Corey was twice appointed to the state of Michigan's Electrical Administrative Board by former Governor Rick Snyder and received United States Special Congressional Recognition for founding the B.O.P. (Building Opportunities for People) Program, which teaches construction skills to homeless and underprivileged individuals.*

TESTING AND TROUBLESHOOTING LOW- TO MEDIUM-VOLTAGE CIRCUIT BREAKERS

TECHNICAL SUPPORT GROUP, Megger

Circuit breakers are a large part of the insurance of an electrical system. It might even be said they are the muscle behind the protection of an electrical system. Like an insurance policy, the purpose of a circuit breaker is to protect when needed. An insurance policy that fails to protect is of no value, just as a circuit breaker that does not serve its protective function has no value. When something goes wrong, and an emergency condition occurs, is not the time to learn whether a circuit breaker will provide the appropriate protection. At that point, it is too late.

This article presents a process to verify the proper operation of low-voltage (LVCB) and medium-voltage (MVCB) circuit breakers before an emergency or fault condition occurs. The perspective is based on the unique design and application of each class.

The definition of voltage classes can vary depending on utility and industry. However, for the purpose of this article, IEEE 100, *The Authoritative Dictionary of IEEE Standard Terms,* Seventh Edition, is used to differentiate between the classes.

1. **Low-Voltage.** An electric system having a maximum root-mean-square alternating-current voltage of 1,000 volts or less

2. **Medium-Voltage.** An electric system having a maximum root-mean-square alternating-current voltage above 1,000 volts to 72,500 volts.

CIRCUIT BREAKER BASICS

Circuit breakers range in current rating from less than one amp up to several thousand amps. Although circuit breakers are largely applied as overcurrent devices for the purpose of protecting the electrical system from abnormal current conditions, they can also function to isolate an electrical circuit for any number of conditions.

- The two classes of low-voltage circuit breakers are based on the insulating medium used in their construction. A molded case circuit breaker can be identified by the molded insulating material used to make its housing, which provides mechanical support and insulates energized components from the metal enclosure and personnel. An air frame circuit breaker has a grounded metal frame; the conductors and contacts are electrically isolated from the frame by air and other solid insulating barriers.

- Medium-voltage breakers are classified in terms of their construction and insulating medium. You may encounter medium-voltage switchgear insulated with air, oil, vacuum, or sulfur hexafluoride (SF_6).

Most of the component parts of a low-voltage circuit breaker are also common to medium-voltage circuit breakers. Each component part should be addressed in a periodic testing and maintenance program. Failure of any element will result in failure of the breaker.

- **Conducting Path.** The path used to conduct current from the line side to the load side of the circuit breaker is the conducting path. This path consists of load- and line-side connections, a conducting medium, stationary and moving contacts, and possibly current-limiting fuses. A circuit breaker may have a single conducting path or as many as three conducting paths, referred to as poles. Connections to the circuit breaker can be made with bolted connections, cables, or finger clusters. The use of bolted connections and cables is normal with molded

case circuit breakers, while it is common for modern air frame circuit breakers to use finger cluster/bus type connections. This allows the air frame circuit breaker to be removed and taken to a testing area.

- **Operating Mechanism.** The operating mechanism of a breaker is the means by which a circuit breaker is closed and opened. The operating mechanism must be able to receive energy, store the energy, and then release it to close or open the breaker contacts.

- **Insulation.** In a molded case circuit breaker, the case forms the major portion of the insulation, which forms the protective barrier between the conductors and ground and between the individual conductors. In an air frame circuit breaker, the insulation consists of insulating arms between the mechanism and the moving contact, barriers between the phases, and insulated arc chutes.

- **Tripping Device.** Besides voltage class, MVCBs differ mainly in design from LVCBs in that LVCBs have an integrated tripping device, while MVCBs are normally controlled through signals sent from an external tripping device that is not integral to the breaker; therefore, it does not rely on integrated decision-making to determine when it needs to trip. MVCBs must be told via an external relay or control signal that it is time to operate, while LVCBs have a tripping device that functions as the brains of the circuit breaker. MVCBs are "dumb" devices — they are simply a mechanical switch that must be told what to do and when to act.

MAINTENANCE

Maintenance frequency depends on the number of operations, the environment, and the manufacturer's recommendations. Frequent and infrequent operations can seriously affect a circuit breaker. Frequent operations may cause the contacts and the operation mechanism linkages to wear out, while infrequent operations may cause the operating mechanism to become stiff and inoperable. Circuit breakers that operate in wet or dusty environments need frequent maintenance. Moisture may cause the operating mechanism to corrode and freeze linkages and can also result in insulation failure. Dust increases wear on the operating mechanism, hardens lubrication, and can cause insulation to fail. Manufacturers normally recommend a maintenance schedule in the instruction manuals for their circuit breakers.

Conducting Path

Moving and stationary contacts are used for making and interrupting the circuit. The moving contact is driven by the operating mechanism during close and open operations. The moving contact mates to the stationary contact to complete the conducting path. The condition of these contacts is important. Poor connections will result in the circuit breaker overheating or, in the worst case, contacts fusing together. If fusing should happen, the circuit breaker will be unable to respond to an open operation. The condition of the contacts is determined mainly by resistance. A low-resistance ohmmeter is used to measure the resistance across the closed moving and stationary contacts. To test the conductive path, the circuit breaker must be in the closed position. A DC current is injected through the interrupter, and a voltage drop is measured; from these two values, resistance is calculated. For accurate measurements, a four-wire technique is used, making sure that the voltage-sensing leads are inside of the current leads. The measured value should be compared to the manufacturer's specifications.

Insulation

Insulation failure is the most serious problem that can occur in a circuit breaker. The result will be fire with loss of the circuit breaker and frequently major damage to the surrounding circuit breakers and enclosures. It is very important to properly maintain insulation.

One measure of insulation quality is the insulation resistance test. A fixed voltage, usually DC, is applied to the circuit breaker. The leakage current is measured, and a resistance value is determined by Ohm's Law. An insulation tester will give a direct reading of the resistance value. Three types of insulation tests must be performed:

1. From conductor to ground
2. From conductor to conductor
3. Across the open conductor

For a single-pole circuit breaker, the conductor to ground and the open conductor tests are performed. For two- and three-pole circuit breakers, all three tests are performed. For minimum test voltage recommendations, see the guidelines in ANSI/NETA ATS–2021, *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*.

For medium-voltage switchgear, NETA also recommends performing a power factor test. While insulation resistance is a DC test, power factor is an AC test. A fixed AC voltage is applied, and the leakage current is measured. The ratio of the resistive component of the current to the total current results in a power factor value. The three types of tests performed while measuring insulation resistance should also be measured while power factoring the breaker.

To verify the integrity of the vacuum in vacuum bottle breakers, an over-potential (hi-pot) test should be performed. Either AC or DC can be applied, but, if DC is applied, a test set that is full-wave rectified must be used to measure accurate results. The capacitance in vacuum interrupters is very low; half-wave rectified circuits can generate a pulse up to three times the value of the applied voltage, which can generate erroneous results as well as abnormal x-ray radiation.

Operating Mechanism

Maintenance of the operating mechanism involves checking for loose or damaged parts, lubricating the mechanism in accordance with the manufacturer's recommendations, exercising the mechanism to ensure it works, and checking tolerances. The mechanism will also be checked during electrical operation and testing of the circuit breaker. LVCBs have a tripping device; MVCBs do not and therefore rely on different methods to trip the circuit breaker.

Testing the tripping device (LVCB)

Primary current injection testing is one of the methods to verify proper electrical operational features of a circuit breaker. In cases where a circuit breaker is not controlled by a solid-state device, primary current injection may be the only way to verify proper operation.

In cases where circuit breakers have solid-state trip devices, either primary or secondary injection testing may be performed. However, primary current injection is preferable in testing low-voltage circuit breakers because it utilizes all the components of the primary conducting path, including current transformers (CTs) or transducers. Secondary signals that represent primary currents can be used to verify that the trip device is operating properly. This is referred to as secondary injection testing. This method of operational testing is less indicative of the health of the overall operating system in the sense that it does not verify all the integral components of the primary current path, including connections, CTs, and contacts.

Performing circuit breaker testing and maintenance is of the utmost importance in providing reliable system protection.

The tripping device is the brain of the circuit breaker. It monitors the load current, compares this current to preset conditions, and if preset conditions are exceeded, sends a trip signal to the operating mechanism.

Three methods are used to monitor overload currents: thermal, magnetic, and solid-state. All three are used in molded case circuit breakers. The magnetic and solid-state methods are used in air frame circuit breakers.

- **Thermal trip devices** are used to provide overload protection. Thermal trip devices pass a current through a heating element. As this element heats, it will deflect. When this deflection reaches a certain point, it will operate a tripping bar and the breaker will open. The operating curve of current versus time for the thermal element can be matched to the thermal characteristics for the electrical circuit. The use of thermal elements is generally limited to circuit breakers in the lowest current ratings because of the heat generated.

- **Magnetic trip devices** can be used to provide overload and instantaneous protection. In a magnetic trip device, current is passed through a solenoid. If the current exceeds a preset value, the solenoid will pull a plunger. The moving action of the plunger will result in the circuit breaker tripping. The disadvantage of this method is that the solenoid is in the current path. For air frame circuit breakers with a high current, this means using the current path to form a solenoid winding. In turn, this means that only a few windings can be used, which results in a loss of sensitivity.

- **Solid state trip devices** have many advantages over thermal and magnetic trip devices, including reliability, repeatability, improved sensitivity, and additional trip functions. These devices do not rely on heating or solenoids. Instead, the load current is monitored through current transformers and compared to a time-current curve that is stored in the memory of the device. When the time-current limits are exceeded, the trip device sends a signal to a trip actuator that trips the circuit breaker.

Four trip functions are commonly found in solid-state trip devices:

1. **Long time.** This is the overload function. There are two settings for this function. The first setting is pickup, which determines the level of load current that is acceptable before an overload condition occurs. For example, when the pickup of a 1,600-amp breaker is set to 0.75X, the overload condition starts when the current exceeds 1,200 amps. The second setting is time delay, which determines how long a given overload is acceptable. For example, if a 3,000-amp overload on the 1,600-amp breaker will cause thermal damage to the electrical system after 200 seconds, the time delay will be set to trip the circuit breaker in less than 200 seconds. Overloads frequently occur on electrical systems, but the systems are designed to withstand overloads. If the overload persists, the protecting circuit breaker must open, or the system will be damaged.

2. **Instantaneous.** Instantaneous means there is no intentional time delay for this function. When the current exceeds trip device settings, a trip signal is sent instantaneously to the trip actuator. This function only has a pickup setting. Instantaneous trips are caused by faults within the protected system. Failure of the circuit breaker to clear this fault may result in severe damage to equipment. Failure also means that an upstream breaker had to trip to protect the system, which will result in more of the electrical system being de-energized than necessary.

3. **Short time.** The difference between short time and instantaneous is that short time has an intentional time delay. This function has a pickup setting and a time delay setting. This allows the electrical system to have short-duration, high-current overloads. An example of this would be a motor start. It also allows for better selective coordination between protective devices in series. One example would be to allow a main circuit breaker enough delay to allow feeder breakers to clear downstream faults.

4. **Ground fault.** This function protects the system from insulation failures that allow higher than normal currents to flow in the ground path. In a balanced three-phase system, such as a motor, the sum of the three phase currents will equal zero. If ground fault current is going into the ground path from one of the phases, the currents will not sum to zero. This current value is compared to the ground fault pickup setting of the trip device. If the level is above the pickup point, the trip device will send a trip signal to the actuator after a predetermined time setting. In a three-phase system with single-phase loads, the three phase currents may not sum to zero. In this situation, the trip device won't recognize the difference between ground fault current and normal current. To overcome this, a neutral is added to the system. Any imbalance between the three phase currents returns on the neutral. The trip device compares the sum of the three phase currents to the neutral current. A difference indicates the presence of a ground fault.

Primary current injection testing involves injecting a current through the circuit breaker's conducting path that is of sufficient magnitude and time duration to meet a trip point. If the breaker operates within the manufacturer's specifications, it is

considered to be in working condition. If it fails to meet specifications, the reason must be determined and corrective action taken.

Time and travel analysis (MVCB)

For medium-voltage circuit breakers, correct operation of the mechanism must be verified using a time and travel recorder. The standard timing tests of close (C), open (O), close-open (CO) should be performed as well as open-close (OC) and open-close-open if the breaker is designed to perform reclose operations.

- **Close** time is defined as the time it takes from the initiation of the close operation to the instant when mechanical continuity is established.
- **Open** time is defined as the time it takes from the initiation of the open operation to the instant when the primary arcing contacts have parted.
- **Close-open** time is defined as the time from the instant mechanical continuity is established to when the primary arcing contacts part. This is often referred to as the trip-free or dwell time.
- **Open-close** or reclose time is defined as the time from initial parting of the primary arcing contacts to the time when mechanical continuity is once again established.

An open-close-open operation is performed to ensure the mechanism has enough energy to clear a fault and clear it again if the fault still remains on the reclose. Although all the standard tests should be performed, often only the close, open, and trip-free times are measured. All timing values should be compared to the manufacturer's specifications. In addition to the timing of the contacts, a transducer should be attached to measure the motion of the circuit breaker. Either a linear or rotary transducer may be used, but the intent is to measure the stroke of the interrupter, which is defined as the distance of the interrupter from the fully open position to the fully closed position. When the stroke is measured correctly, the velocities of the interrupters can be calculated in the arcing zone. The manufacturer should provide a set of speed calculation points for both the close and open curves. This is necessary in order to verify that the breaker will be able to extinguish an arc under fault conditions. Other parameters such as contact wipe, over-travel, and rebound can also be calculated. An illustration of the various parameters that are measured and calculated can be seen in Figure 1.

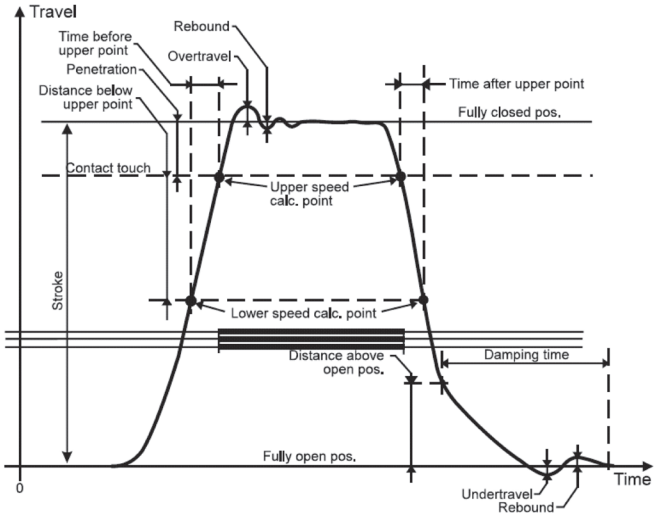

Figure 1: *Measured and Calculated Parameters*

Special Considerations

- **Current limiting fuses** are used where the interrupting rating of the circuit breaker is lower than the available fault current of the electrical circuit. This causes a problem during testing because these fuses must be removed and replaced with a bus to avoid blowing the fuse during a test. Another problem with current limiting fuses is that the line- and load-side finger clusters of air frame circuit breakers may not be in the same vertical plane. Finger cluster arrangements vary between circuit breakers, which makes it difficult to use a standard configuration for connecting to primary current injection test equipment.

- **DC offset** is a term used to describe an asymmetrical phenomenon resulting from a mismatch of phase angle relationships between voltage and current from the perspective of the source versus the perspective of the load. In this case, the primary injection test equipment would represent the source, while the circuit breaker with all of its connections would represent the load. The load has a representative amount of reactance (X) and resistance (R). The ratio of these load components will dictate the required phase angle relationship between voltage and current:

  $tan^{-1}(X/R) = Ø$

  where Ø represents that phase angle between voltage and current

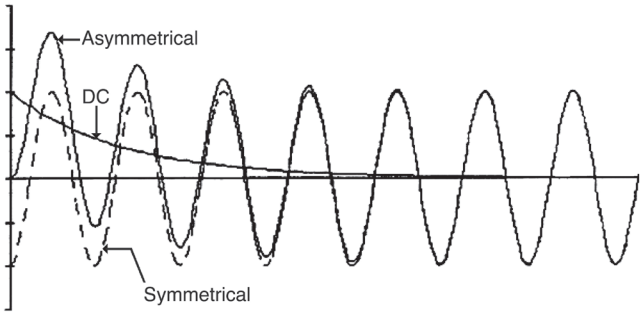

Figure 2: *Phase Angle Waveform*

DC offset occurs when the source and the load have differing ideas regarding what this phase angle relationship should be (Ø). The load always wins this battle, but it may take as many as four or five cycles for the source and load to settle their differences. The resultant waveform may look something like Figure 2.

Since this phenomenon typically only exists for a period of less than five cycles, it only applies to the instantaneous operations of circuit breakers. This could ultimately cause a discrepancy between the factory and the field engineer regarding the instantaneous pickup setting of the breaker.

Manufacturers of LVCB test equipment now design features into their products that allow users to address this phenomenon of DC offset. However, please keep in mind that not all manufacturers address this issue, and if they do, it may not be addressed in the full range of product offerings. This phenomenon can be addressed in two ways:

1. Allow the user to manually adjust the phase angle at which current is initiated from the test equipment to match that of the load
2. Design test equipment that will output a low-level, short-duration, pre-test signal to determine the optimum angle of current initiation by evaluating the phase angle response of the load.

These types of changes within the design of commercially available primary injection product offerings can help to negate such concerns in future electrical operational testing of LVCBs.

CONCLUSION

Circuit breakers are critical to the protection and safe delivery of electricity. Although they might sit idle for months or even years, they must operate in mere milliseconds when called upon to act. Therefore, performing circuit breaker testing and maintenance is of the utmost importance in providing reliable system protection.

All circuit breakers share common characteristics, whether they are rated for a few hundred volts or for thousands of volts. They must be able to conduct while closed, insulate while both closed and open, interrupt the current when tripping, and efficiently change between the open and closed state.

Each of these functions must be properly maintained and tested to ensure that the circuit breaker will protect the valuable assets within the electrical grid. To select the proper maintenance routine, the function being tested and the type and voltage class of circuit breaker must be considered. Using the standards set forth by IEEE and ANSI/NETA, as well as manufacturer recommendations, you can help ensure the safe delivery of electricity.

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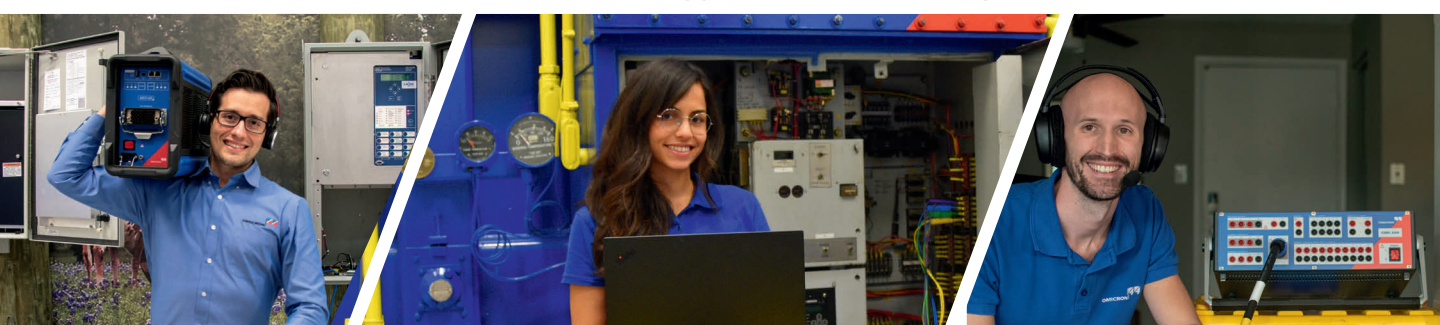

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- **Field Challenges of Measuring Transformer Winding Resistance and On Load Tap Changer Troubleshooting**
  June 18, 2021 | Presenter: Sameer Kulkarni
- **Testing of 61850 Based Protection, Automation and Control Systems**
  July 16, 2021 | Presenter: Abel Gonzalez
- **Ground Fault Location on DC Systems**
  August 20, 2021 | Presenter: Daniel Carreno
- **Special Applications of Narrow Band DFR Beyond Power Transformers**
  September 17, 2021 | Presenter: Diego Robalino
- **Advanced Recloser Testing**
  October 15, 2021 | Presenter: David Beard
- **Best Practices and Techniques for Cable Fault Location and Special Applications**
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- **Primary Current Injection Applications for Low Voltage Circuit Breakers, Reclosers, Sectionalizers and CTs**
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Previous Webinars

- **On-site Insulation Analysis for GIS using UHF and Acoustic PD Measurements**
  April 16, 2021 | Presenter: Charles Nybeck
- **Advanced Testing and Assessment of Instrument Transformers**
  March 19, 2021 | Presenter: Volney Naranjo
- **Understanding Different Transmission Line Protection Schemes**
  February 19, 2021 | Presenter: Sughosh Kuber
- **Fundamentals of Transformer Commissioning and Maintenance Testing**
  January 15, 2021 | Presenter: Sanket Bolar
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- **Transformer Management 3**
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