

Power System Studies and Field Services

Contents

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Overview of Eaton's Electrical Engineering Services & Systems	41.0-2
Eaton's Electrical Services & Systems (EESS) Team	41.0-2
Expertise on Products from Eaton and Other Manufacturers	41.0-2
Commissioning of Electrical Services	41.1-1
Training	41.1-2
Extended Warranty Programs	41.1-3
Power System Studies	41.2-1
Complete North American Coverage	41.2-1
Traditional Engineering and Analysis Offerings	41.2-1
Advanced Design and Analysis Offerings	41.2-3
Arc Flash Safety Solutions	41.3-1
Safety Means...Knowing Your Hazard Level	41.3-2
Superior Protection with the Right Products and Services	41.3-3
Broadest Range of Solutions to Improve Safety in Your Industry	41.3-4
Advanced Arc Flash Technology to Enhance Personal Safety	41.3-5
A Comprehensive Arc Flash Hazard Analysis	41.3-6
An Industry-leading Arc Flash Safety Training Program	41.3-6

Power System Monitoring Services	41.4-1
Instant Response Center Services	41.4-1
Power System Predictive Diagnostics Services	41.4-2
Transformer Predictive Diagnostics	41.4-3
Circuit Breaker Conversion and Replacement Services	41.5-1
Reconditioning Service for Low Voltage Power Circuit Breakers	41.5-1
Retrofit Service—Digitrip Microprocessor Trip Unit Kits	41.5-5
Replacement Service for AR Series Low Voltage Breakers	41.5-8
Low Voltage Breaker Drawout Vacuum Starter Replacement	41.5-10
VR Series MV Vacuum Replacement Circuit Breakers	41.5-12

Specifications

See Eaton's *Product Specification Guide*, available on CD or on the Web.

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Eaton's Electrical Engineering Services & Systems

Eaton's Electrical Engineering Services & Systems (EESS) group operates through regional service centers throughout the U.S. and Canada. Service centers are equipped with the most technologically advanced test and diagnostic equipment. With over 1000 Field Service Representatives in North America, Eaton expertise is available where and when customers need it. This integrated team of technical experts, logistics specialists, and customer support associates provides 24 hours a day, 7 days a week, factory-certified direct service.

Within and across these regional service centers, specialists collaborate as cohesive, virtual teams. For example:

- The Power Systems Engineering group uses industry standard software with advanced modeling and analysis capabilities to design power systems for new construction and facility upgrades

- The Power Systems Automation (PSA) group provides full-service systems integration, ensuring that hardware, software and communication networks from various manufacturers perform as a seamless system
- Power Breaker Reconditioning Centers (PBRC) furnish specialized services, such as Class 1 reconditioning of power circuit breakers (described later in this section)
- Division-wide Safety and Quality Programs ensure customer satisfaction while maintaining safety as a first priority

Eaton has one of the largest teams of Power Systems Engineers in the industry, strategically located throughout the world. Many of these professionals have influenced industry standards and are sought after for their expertise. Eaton operates a central training facility where our team members return for continuing education on the latest products, system upgrades and diagnostic tools.

Expertise on Products from Eaton and Other Manufacturers

Our experienced Professional Engineers, Graduate Engineers, Field Engineers and Technicians are trained on products manufactured by Eaton, as well as other manufacturers. As a result, EESS services can be applied to products manufactured under the following brands: Cutler-Hammer®, Powerware®, Westinghouse®, Square D®, General Electric®, ITE/BBC/ABB®, Allis-Chalmers/Siemens®, Federal Pacific® Challenger®. With their extensive industry experience, our engineers can also provide expert technical assistance on many models of obsolete equipment.



Design Build Support

Table 41.0-1. Engineering Services Capabilities—Total Life Cycle Solutions by Eaton

				
Power System Automation	Power System Engineering	Turnkey Projects	Field Services	Equipment Life Extension and Modernization
■ Protection and control systems ■ Dashboards ■ Foreseer and Power Xpert ■ Enterprise solutions ■ Power Xpert Energy Optimizer™ controller ■ Substation automation ■ Distribution automation	■ Power systems studies ■ Harmonic studies ■ Load flow analysis ■ Arc flash and safety studies ■ Integrated Volt-VAR Control (IVVC) ■ CYME power engineering software ■ NERC compliance assistance ■ Selective coordination study	■ Modular integrated transportable substation (MITS) ■ Project management ■ Engineer, procure and construct (EPC) ■ Equipment install ■ Crisis response ■ Microgrid energy system ■ Grid storage	■ 24/7 emergency response ■ Site acceptance testing ■ Startup and commissioning ■ Maintenance and testing ■ Service contracts ■ Embedded service personnel ■ Training services	■ MV and LV power circuit breaker replacements ■ Equipment rebuild and reconditioning ■ Life extension and modernization ■ Bus bracing and gear evaluation studies ■ Arc flash mitigation

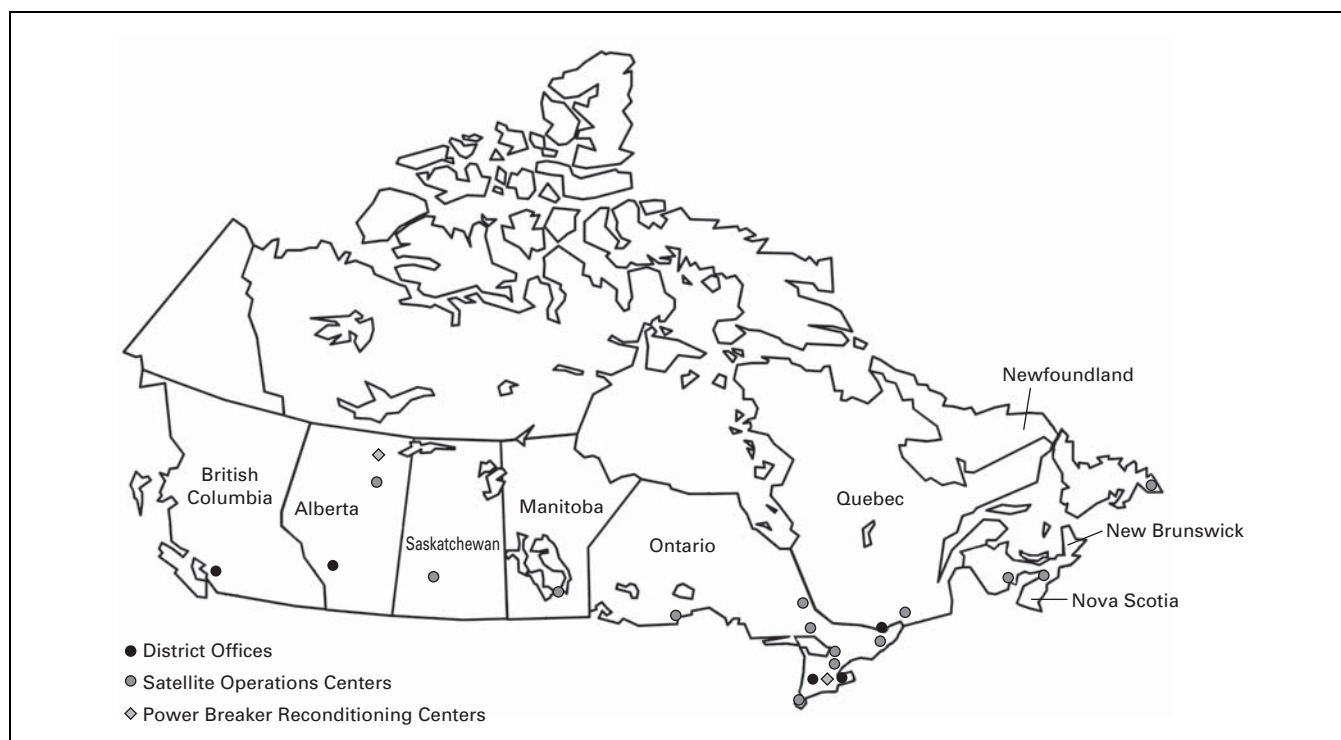


Figure 41.0-1. Canadian Service Locations

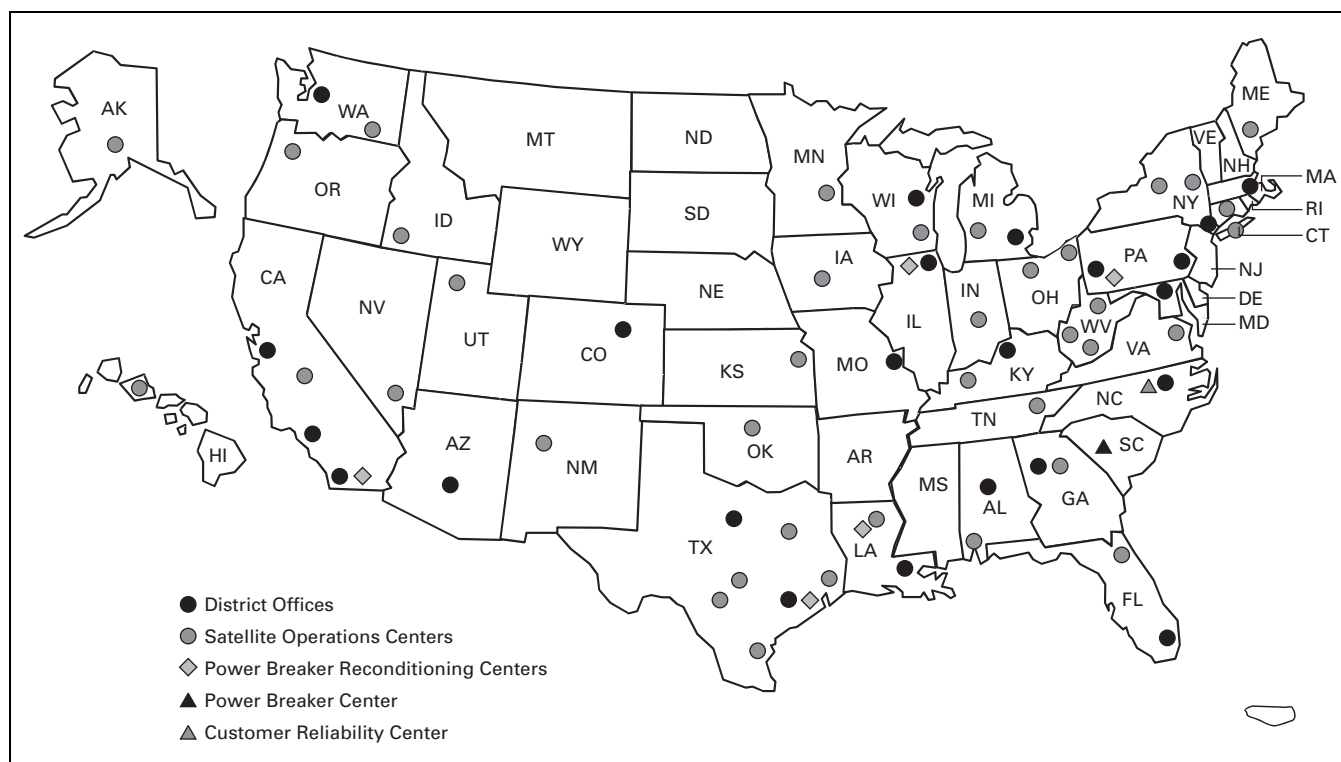


Figure 41.0-2. U.S. Service Locations

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Commissioning of Electrical Services



Commissioning of Electrical Services

On a new construction project, or modification to an existing electrical system, the verification that a system is performing in accordance with the design professional's plans and specifications is one of the most important functions performed during a construction project. The best equipment, if not commissioned properly or protective device settings not properly configured, will fail to protect the end user's capital investment and provide system continuity in accordance with the design. The design professional must specify these services, which include installation support and supervision, site acceptance testing, startup, energization, training of end user personnel and a follow-up thermographic survey. Additional commissioning items that can be specified for complex systems include functional performance tests and integrated system tests.

- **The value of using manufacturer services.** Electrical distribution equipment is getting more complex to provide end users greater system continuity and uptime, protection of their capital investment and safety features to protect their employees from electrical hazards. A manufacturer of the equipment is best qualified to determine that the equipment is operating as designed, installed and configured for optimal protection and system continuity.

Eaton personnel also benefit from factory training, therefore obtaining a clear understanding of the entire assembly process and new technology. This can be very beneficial in the field, during startup, commissioning or troubleshooting. Direct access to factory personnel is also an advantage in the efficient commissioning and startup of power equipment. By having Eaton provide and commission the user's electrical equipment, it enables the design professional and installing contractors a center point for resolving issues related to equipment operation and installation. **In addition, Eaton provides an additional year of warranty, beyond our standard warranty, when these services are performed by Eaton's Electrical Engineering Services & Systems field service organization.**

- **Installation support and supervision.** Electrical construction of sophisticated power distribution equipment requires support and/or supervision by factory-trained personnel. Proper installation techniques have been proven to reduce short-term operation problems and downtime.
- **Site acceptance testing.** Proper site acceptance testing not only ascertains the proper functioning of new/upgraded equipment, it provides baseline data for designing predictive maintenance programs. We store all test data in a world-wide database, which gives a comprehensive basis for comparison across millions of installations.

- **Startup and energizing.** Eaton specialists perform safe equipment startup, with attention to voltage levels, phasing and proper grounding. Specific equipment testing and adjustments are made to ensure that all electrical safety interlocks are operational and ready for long-term service.

- **Ground fault certifications and ground grid testing.** Experienced field service personnel verify low-ohmic ground paths, points and grids, plus ground trip pickup points, bus/wiring and operation. Secondary or primary injection can be used. Neutral sensor location and polarity is verified. Touch point potential measurements, usually done in outdoor substations, can also be performed. Ground grid integrity and low resistance are paramount for personal safety, equipment protection, transient voltage surge suppression, ground fault and relay performance.

- **Cable testing and fault identification.** Cable testing identifies, locates and isolates potential and actively faulted cables. Trained specialists use care in using the right equipment, voltage and test setup to ensure that the test doesn't damage cable or connected equipment.

- **Relay testing and calibration.** Among the most critical parts of the electrical system, relays serve as the brains to breakers and switches. Coupled with the coordination study, we test relays, verify pickup points and time delay settings, and verify unit operations on the basis of the settings in the study. This procedure also tests control power pickup and dropout affecting relay operation.

- **Predictive and preventive program design and implementation.** Following construction, EESS can develop a long-term predictive/preventive maintenance program. This allows for recording of the necessary baseline data required for effective predictive maintenance programs.

■ **Thermographic surveys.** A thermographic survey performed after the facility reaches its established baseline load can verify improper installation and serve as a baseline for future surveys. Hot spots in electrical equipment can be an indicator of improper connections, insulation damage and mechanical failure. Experienced thermographers take pictures or video of electrical equipment to find trouble before it becomes a catastrophe. Infrared ports can now be added to new gear or retrofitted into existing gear, which reduces the time and cost of thermographic testing and reduces exposure to arc flash hazards.

■ **Independent third-party testing services.** Consultants sometimes specify independent testing service organizations to perform acceptance testing on electrical manufacturing equipment. Some third-party testing organizations imply that manufacturer's service organizations may hide defects, from a liability and ethical standpoint it simply makes no sense for any company to hide known defects. Eaton's service organization can implement repair of damaged equipment during site acceptance testing. Eaton's service group is responsible for continuous product and service improvements. It is our responsibility when providing site acceptance testing, warranty services and long-term maintenance contracts to identify product deficiencies.

When you use Eaton's service organization for site acceptance testing and providing the short circuit and coordination studies for your electrical equipment, Eaton provides an additional year of warranty, beyond our standard warranty.

Many of these independent testing companies are "for profit" members of an organization that self-certifies paying members with a specification that excludes non-members. A number of these "independent" testing service company members have an associated company in other geographic locations that are either wholly owned subsidiaries, or have a franchise service agreement with an electrical equipment manufacturer.

Some independent testing organizations test the equipment but fail to fully commission the equipment for energization. Protective relays, circuit breaker trip units, meters, etc., that require control power to fully configure, are left in the factory default state and may not properly record a desired fault or transient. In addition, specific safety interlock checks are not included in many independent specifications but are included in manufacturer guidelines and service manuals.

Independent Testing Organizations lack specific training on the equipment they are testing to properly commission the equipment. Equipment can be damaged during testing if not tested per the manufacturer's guidelines and void manufacturer warranty.

Electrical equipment, that is listed, has already been evaluated by a third party for proper design performance in accordance with national standards. The use of an "independent" testing organization is unnecessary and is not required or recommended by the NEC or NFPA 70B.

Eaton's Electrical Engineering Services & Systems is NOT just a testing company, but a full-service division of a major electrical manufacturer with the knowledge of not only how to test your equipment, but to understand how it should be installed and operated.

Training

We offer training on all new products supplied by Eaton's electrical business. The construction phase is a beneficial time to incorporate training, from an equipment and funding standpoint. During this phase, we can train your operators to proficiently perform power protection equipment startup, shutdown and maintenance.

Conducting training sessions during or immediately after the startup of new equipment can dramatically reduce training costs. Travel and setup costs are minimized, and plant personnel observe the operation of all associated electrical equipment as part of the training session.

If desired, Eaton can provide additional training after installation, at your location, in one of our plants, or in our own National Training Center. System documentation can be consolidated and provided in a variety of media.

Distribution Systems Analysis Training

Plant engineers require an understanding of the dynamics of electrical power distribution systems. This training addresses topics to improve existing electrical systems, as well as to plan for future expansions. Life extension of the power distribution system requires a proper analysis by the plant electrical engineer. Appropriate investigations can be completed and recommendations planned for implementation.

Power Quality and Grounding Training

Power quality and grounding issues are affecting sensitive new process equipment. This training can provide short- and long-term solutions, as well as recommending methods to accurately measure power quality.

Electrical Equipment Maintenance Training

Completing proper and timely maintenance on electrical equipment will improve reliability and reduce downtime. This training identifies simple yet effective maintenance tasks that can be completed by plant personnel. Proper equipment maintenance extends system life by reducing failures. In addition, training in-house personnel to complete several maintenance duties can reduce costs.

Customized On-Site Training

In conjunction with new construction, training can also be integrated to include existing electrical components, regardless of manufacturer. This approach allows for effective one-time training, on-site if desired, and is incorporated into the construction project.

A site review would be conducted to identify training needs and associated equipment. A plant-wide custom training program can address specific reliability needs as well as goals for reduced downtime. Cost reductions can be achieved by providing maintenance training to operation personnel, thereby possibly combining operating and maintenance duties.

Electrical Equipment Specification and Maintenance Training at the Factory

Factory visits represent some of the most overlooked training opportunities, offering a great value at low cost. Nothing can replace the firsthand experience of seeing equipment being manufactured at the factory in a broad range of options and configurations.

Factory meetings during the pre-engineering phase can really help you visualize your options and develop specifications to meet your requirements. Factory sessions during on-board review/approval of submittal drawings help, but this scheduling has more limited bearing. Finally, a factory witness test lets you verify that everything in your project was built to specifications—especially helpful when dealing with complex automatic transfer or protection schemes.

We also offer training courses on equipment operation and minor maintenance at our factories. Knowledgeable factory engineers and workers train small groups in hands-on operation and review of schemes and periodic maintenance. These highly practical training sessions are prescheduled by the factories and can also be specially arranged for groups.

*Maintenance Training and Courses***Extended Warranty Program**

Many end-users have expressed a need for equipment extended warranties that include periodic inspections. These can be specified by the design professional so the cost is incorporated into the project. In addition, other selected end-users have interest in being notified of potential failure indicators, which would act to improve system uptime and reliability. Eaton's Extended Warranty Service Contracts provide the following:

- Peace of mind, allowing customer focus on core business functions
- Fixed contract spending, including options to bundle (capitalize) longer-term equipment warranties and inspections with an initial equipment purchase agreement
- Equipment periodic inspections, analysis and recommendations to maximize uptime
- Experienced experts to support current and future electrical needs
- Improved electrical equipment uptime and reliability via alarms resulting from potential failure indicators

Eligibility

Eaton's Electrical Engineering Services & Systems (EESS) completes all power distribution equipment acceptance testing, power system studies (preferred) and commissioning services to ensure proper and safe equipment installation and performance, therefore providing Eaton warranty coverage for the 1st and 2nd year.

Offerings and Deliverables**Table 41.1-1. Service Contract Offering**

Service Contract Offerings	Deliverable
Time period	3, 4 or 5 years
Uptime Service Contract	
Periodic inspections and audits	■
Audit analysis and recommendations	■
Applications/operations call-in support	■
Extended Warranty Service Contract	
Labor included for warranty repairs	■
Parts included for warranty repairs	■
5 x 8 response	■

Uptime Service Contracts

Uptime Service Contracts are designed to maximize the equipment uptime and reliability. This includes site inspections, analysis and reports with recommendations.

Contract Deliverables

Customer shall receive a site inspection completed by EESS personnel as described below. The customer will also receive a formal report identifying findings, recommendations and also any conditions that would provide for improved uptime and reliability. This may include environmental improvements (moisture, humidity, etc.) or other concerns that are subjecting the equipment beyond the original specifications.

18-Month Inspections**Site Data**

- A. Record site information (company, street address, city, state, product name, model and serial number)
- B. Record site contact personnel (company name, phone, e-mail address)

General Environment

- A. Verify clear access to electrical equipment room, including egress. Note any improper conditions
- B. Verify clear access to electrical equipment for observation and operations. Note any improper conditions
- C. Using temperature probe, verify electrical room or area temperature
- D. Verify or note cleanliness of electrical equipment room and electrical equipment
- E. If applicable, verify electrical room has proper ventilation, air conditioning or other environmental controls
- F. Check and operate any metering systems and record existing and maximum values (if applicable)
- G. Record any unusual sounds emitting from electrical equipment
- H. Inspect any potential sources of moisture, water, dirt or contamination in the area of the electrical equipment

- I. If possible, request owner to exercise and/or operate selected electrical equipment (only with owner approval)
- J. Review electrical equipment labeling
- K. Review any log books located in electrical room
- L. Review any drawings or operating procedures posted in electrical room
- M. Review electrical room security
- N. Record any recommendations for owner to maintain contract terms

Report and Recommendations

- A. Provide a report of all findings
- B. Include general recommendations for improvements in:
 - 1. Equipment reliability
 - 2. Personnel safety
 - 3. Equipment operation
 - 4. Emergency response capabilities
- C. Include any recommendations to maintain contract terms

Contract Deliverables

Customer shall receive the following deliverables:

- A. Site inspection as described above
- B. Formal Report and Recommendations as described above
- C. EESS Technical Application Support to provide Q&A support 5 days/week, straight-time

Extended Warranty Service Contracts

Extended Warranty Service Contracts expand our uptime offerings by also providing for the repair and/or replacement of components included in the contract.

Deliverables

Customer shall receive the following deliverables:

- A. Site inspection as described above
- B. Formal Report and Recommendations as described above
- C. EESS Technical Application Support to provide Q&A support 5 days/week, straight-time
- D. Replacement parts for any failed component that is part of this contract
- E. Labor to replace any defective parts (5 x 8 response)

Program Deliverables by Contract Term

3-Year Service Contract

Customer shall receive the following deliverables:

- A. Site inspection as described above
- B. Formal Report and Recommendations as described above

During these intervals:

- A. Month 18

4-Year Service Contract

Customer shall receive the following deliverables:

- A. Site inspection as described above
- B. Formal Report and Recommendations as described above

During these intervals:

- A. Month 18
- B. Month 36

5-Year Service Contract

Customer shall receive the following deliverables:

- A. Site inspection as described above
- B. Formal Report and Recommendations as described above

During these intervals:

- A. Month 18
- B. Month 36
- C. Month 54

Note: Uptime Service Contracts include all items EXCLUDING any repair or replacement of failed components. Eaton Extended Warranty Service Contracts include all items INCLUDING repair and replacement of failed components that are included in the contract.

Power System Studies

Eaton's Electrical Engineering Services & Systems (EESS) offers a comprehensive portfolio of services tailored for every stage of a power system's life cycle and offers a broad range of engineering, design, analysis and consulting services for the design professional. We can assist the consultant at every stage of the power system: from substation and distribution system design engineering to renewable energy and smart grid engineering; from safety- and reliability-focused studies to power quality and grounding-related audits and analysis.

Complete North American Coverage

Eaton has the largest and most experienced team of power system engineers in the industry, with industry-standard software and advanced modeling and analysis capabilities at their fingertips. Eaton's power system engineers bring extensive skills and expertise to power system analysis and design. Active participation in technical societies such as IEEE and collaboration with a variety of utilities and industries ensures that our engineers are knowledgeable about today's cutting-edge engineering techniques.

The power system engineering team includes over 135 engineers in the U.S. and Canada, with licensed professional engineers in most states and provinces. They provide engineering, design, analysis and consulting services for systems ranging from low voltage to over 345 kV, that focus on understanding your requirements and setting strategies for your power system to satisfy your business needs.

With an emphasis on precision and accuracy, Eaton's engineers provide a focused and systematic approach to enhance your system's performance and to ensure that your electrical systems operate more reliably, efficiently and safely. These engineers include authors of industry standards and have an average of 12 years of experience engineering and analyzing systems containing multiple manufacturers' equipment.

Traditional Engineering and Analysis Offerings

We offer more than 15 standard and specialized power system studies to precisely target specific power issues, using a variety of measurement instruments and specialized analysis software packages. Power system studies offer the most focused and systematic approach available to enhance power system performance and to identify inefficient system designs, incorrect equipment selection and potential problems between your equipment and the rest of the power system. Our traditional engineering and analysis offering include the following:

Short-Circuit Analysis

Calculates the available short-circuit currents at equipment locations throughout the power system. Evaluation of equipment ratings ensures equipment can withstand, and, where applicable, can interrupt an electrical fault. Results are critical for proper system design, including specification and selection of equipment. If the study reveals problems, the study will recommend changes to improve system performance.

Protective Device Coordination

Determines the characteristics, ratings and settings of overcurrent protective devices that will ensure that the minimum unfaulted load is interrupted when the protective devices isolate a fault or overload anywhere in the distribution system. In addition, the devices and settings are selected to provide satisfactory protection against overloads on equipment and to interrupt short circuits as rapidly as possible. The coordination study evaluates protective relay characteristics and settings, fuse ratings, and low voltage circuit breaker ratings, characteristics and trip settings.

Selective Coordination

Utilizes time-current coordination curves and manufacturers' tested combinations to determine the tripping sequence of breakers to ensure that a fault is isolated and downtime is limited to the effected circuits. This work is performed based on National Electrical Code® requirements for emergency and critical operating circuits in conjunction with local and state requirements.



Coordination Study

Arc Flash Risk Assessment

Calculates arc flash hazards associated with energized work at locations throughout the power system in accordance with NFPA 70E, IEEE 1584, National Electric Safety Code and Z462 requirements. Calculations include flash protection boundary and incident energy, with the resulting information being provided on arc flash warning labels to be installed on the distribution system electrical equipment.

Load Flow Analysis/Power Factor Correction Study

Analyzes the system capability to supply the connected load under steady-state conditions, the determination of appropriate continuous ratings for electrical equipment, and the optimal placement and characteristics of reactive power compensation equipment. If the study results indicate that power factor correction equipment is necessary, the appropriate hardware will be properly specified and located to maintain desired power factor at the metering point.

Motor Starting Study

Evaluates the motor's impact on the power system and the power system's impact on the motor. Motor starting studies are typically performed for new motor installations to ensure system reliability, to provide data for motor protection, and to identify any system modifications that may be necessary to avoid starting problems. The study will recommend solutions, such as reduced voltage starting techniques, to address any problem discovered.

Power Quality Site Surveys and Disturbance Monitoring

Evaluates the equipment malfunction and the incompatibility between the source of power and the load. This ensures the powering and grounding of sensitive electronic equipment in a manner that is suitable to the operation of that equipment. Evaluation includes any power disturbance event that poses a threat to the continuous operation of the equipment in question. After completion of the site survey, the power system engineer will identify any system problems and will recommend action for their elimination. Recommendations typically include uninterruptible power supplies, power conditioning devices, automatic transfer switches and/or standby generation to assist sensitive electronic equipment to ride through power system disturbances.

Field Harmonic Measurements

Determines the sources and magnitudes of harmonic currents and voltages that are present in the electrical power system. Measurements are used to verify harmonic generation from all significant harmonic sources and to demonstrate the effect of system resonance caused by power factor capacitors. Power system engineers use the recorded measurement data in the analytical modeling of the system.



**Energy Monitoring and
Power Quality Screen Shots**

Harmonic Analysis Study

Calculates system harmonic voltages and currents throughout the electrical distribution system. This determines the effect of adding harmonic producing loads into a system. If the calculated magnitudes of harmonic voltages and/or currents are excessive, engineers will determine the optimal corrective solution to reduce the harmonic quantities to within acceptable limits. When a harmonic filter is recommended, a complete equipment specification will be developed. A case study will be conducted to verify that the harmonic filtering equipment will reduce harmonic levels to within acceptable standards.



Harmonic Analysis

Advanced Design and Analysis Offerings

In addition to our traditional offerings, Eaton offers several advanced design and analysis options. Advanced design and analysis offerings include:

Distribution Systems Reliability Analysis

Evaluates the present statistical availability of the power system down to the level of the critical components and loads. The present state of the existing protective equipment is evaluated according to the age of the equipment and to the present methods of and frequency of equipment maintenance. Knowing which equipment needs to be protected and which can be protected at a lower level are key elements to ensuring maximum return on investment (ROI). Recommendations will include upgrading critical elements of the power system, modernizing the system or simply rehabilitating the system—the most cost-effective method of improving the reliability prior to a failure.

Distribution System Design

Design and specification of the electrical distribution system from the point of interconnection to generation equipment.

Substation and Ground Grid Design

Complete substation design service is available, including ground grid analysis and design, substation layout, equipment specification, protection and control.

Protection and Control Design

Design of advanced electrical protection and control, including transmission line protection, system automation, advanced metering and smart grid capabilities.

Bus Bracing Analysis

Provides recommendations to place supports to increase the short-circuit rating beyond its original factory design parameters utilizing field evaluations of existing bus bracing. This is often performed where the cost to replace the equipment is cost-prohibitive or the logistics of equipment replacement is not an option due to physical space limitations.

Transient Stability Study

Evaluates dynamic behavior of the renewable source and system voltages during transient conditions such as system faults or startup. Typical recommendations include details of the load shedding scheme, including the sequence of load separation, critical clearing time and type of relay.

Switching Transient Analysis

Analyzes system behavior during switching conditions to identify possible damaging voltage transients. An insulation coordination study, which compares surge arrester ratings with equipment BIL, will be completed to confirm the recommended surge protection system for the circuit being investigated. Results are used to design and to specify mitigation equipment such as snubbers.

Dynamic Simulation

Models and simulates interaction between the power system and controlled devices (inverters, generators, motors and so on) in response to various system conditions. This analysis is often performed in conjunction with Eaton's design of alternative energy and battery storage systems. Results may be used to modify control parameters and to enhance system design.

Alternative Energy Applications

Eaton's engineering expertise extends beyond traditional power systems. Current and past projects include development and application of battery storage systems, electrical design and analysis for wind and solar energy projects, and implementation of smart grid and micro-grid concepts for utility, military and institutional clients.

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Arc Flash Safety Solutions

An arc flash event releases a tremendous amount of energy in the form of thermal heat, toxic fumes, pressure waves, blinding light, sound waves and explosions that can result in serious injury including critical burns, collapsed lungs, loss of vision, ruptured eardrums, puncture wounds and even death.

According to the National Fire Protection Association (NFPA), an arc flash occurs "when an electric current passes through air between ungrounded conductors or between ungrounded conductors and grounded conductors." Temperatures can reach 35,000°F, more than three times hotter than the surface temperature of the sun. These excessive temperatures cause the air and metal in the path of the arc to expand and explode, creating an arc blast.

Throughout the world, arc flash threatens personnel safety, and companies face lost man-hours, lawsuits, fines, equipment damage, facility downtime and lost production.

Many companies have already established and implemented enterprise-wide arc flash compliance programs that ensure employees are safe from arc flash hazards. The 2011 National Electrical Code and the NFPA Standard 70E mandate required safety practices for personnel working on energized electrical equipment.

Compliance with the latest OSHA standards involves adherence to a six-point plan:

- Document calculations for the level of incident energy
- Issue proper personal protective equipment (PPE) for workers
- Training for workers on the hazards of energized electrical work, including electrocution and arc flash
- Provide appropriate tools for working on energized electrical equipment
- Affix arc flash warning labels on equipment where energized electrical work could be performed

A conscientious safety program incorporates an arc flash hazard analysis, the implementation of mitigation techniques, and training for personnel who operate and maintain energized electrical equipment.

Eaton can help with all three.

Total Arc Flash Solutions from the Industry Experts

Eaton's arc flash solutions stress prevention, protection and preparation. Our products, engineering experience and industry know-how create a total arc flash solution to meet your company's needs. We offer a complete arc flash hazard analysis focusing on:

- **Enhanced Safety**
Improve your facility's overall arc flash safety through training, labeling, analysis and products that reduce or eliminate exposure to dangerous situations. Meet or exceed the latest arc flash related standards, including NFPA 70E "Standard for Electrical Safety in the Workplace" and IEEE 1584 "Guide for Performing Arc Flash Hazard Calculations"

- **Operating Cost Efficiencies**
Reduce or eliminate unplanned downtime, equipment damage, fines, lawsuits, injuries and fatalities through improved system design and safety practices

Best Products. Best Services. Best Solutions.

Eaton offers the industry's widest range of arc flash related products and services. Our electrical services group is comprised of industry-leading engineers who not only understand how to properly apply today's safety standards, but many have been tapped for their expertise by committees who develop the codes that help protect what you value most.

Our Commitment to Help Companies Protect What They Value Most

Eaton understands that arc flash safety is tremendously important to businesses striving to protect their most valuable assets—their people. That's why we've made a \$500,000 contribution to the IEEE and the NFPA Arc Flash Phenomena Collaborative Research Project. As a platinum level sponsor of this important initiative, we are supporting efforts to improve electrical safety standards, to predict the hazards associated with arcing faults and accompanying arc blasts, and to provide safeguards for employees.



Safety Means... Knowing Your Hazard Level

Ensuring that your facility has the best possible arc flash safety plan in place is vital to the safety of your employees and to the continued success of your business. While current arc flash safety standards are being enforced ever more strictly, they may not provide the specific attention to detail required for a safe work environment, even under “worst case” conditions.

The standards are open to interpretation, so it's up to you or your staff to draw conclusions from the general guidelines. There may be instances where you think you've achieved compliance, when in fact, you haven't because you misinterpreted the standards. Eaton has the experience and expertise to help you quantify the level of arc flash hazard in your facility and to optimize your system performance and safety program accordingly.

An important first step to ensure the safety of your workplace and employees is a high-level assessment of your company's readiness to deal with arc flash hazards using the checklist below. If you answer no or not sure to any of the questions, you need to address your arc flash safety program immediately. Your business may be noncompliant with industry safety standards and at risk for an arc flash incident.

Table 41.3-1 Checklist for Arc Flash Safety ①

Your System Today	Yes	No	Unsure	Your Improved System Eaton Provides
All persons who operate/maintain energized electrical equipment are trained for the voltage class equipment they operate/maintain.				Electrical safety training for operators and maintenance personnel.
All persons who operate/maintain energized electrical equipment have been trained on both shock and arc flash hazards.				Arc flash hazard training for operators and maintenance personnel.
All persons who operate/maintain energized electrical equipment have access to the proper personal protective equipment (PPE) to protect them from both the shock and arc flash hazards.				Arc flash hazard training focusing on selection and use of the proper PPE.
One-line diagram, including current protective device settings, exists, is legible and accurate.				Development of one-line diagram of your facility.
All persons who operate the power system have easy access to the current one-line diagram.				Electrical safety training.
Equipment is labeled correctly, and in accordance with existing safe work practice codes and standards.				Arc flash hazard training, labeling, protection boundaries, PPE.
De-energized procedures and equipment exist and are used.				Lockout, tagout, proper grounding; Remote Power Racking to safely de-energize breaker.
Written safety procedures and energized work permitting processes exist and are followed.				Electrical safety training.
Equipment is grounded and ground system is tested periodically.				Grounding studies, electrical safety training.
Proper maintenance practices are followed, especially for fault protection equipment.				Electrical safety training, Performance Based Maintenance (PBM), IR Windows and Arcflash Reduction Maintenance System™ for safer maintenance.
Recent (less than five years old) relay/fuse coordination study exists, and relays are calibrated to the setting recommended.				Coordination and short-circuit studies.
Arc flash analysis has been performed for this site (calculations, labeling and arc flash boundaries).				Arc flash hazard analysis.

① Checklist adapted from IEEE Guide for Maintenance, Operation and Safety of Industrial and Commercial Power Systems (Yellow Book)
Document Number: IEEE 902-1998

Superior Protection With the Right Products and Services

Eaton's arc flash solutions encompass the industry's broadest range of arc flash related products and services. From a comprehensive arc flash hazard analysis to highly engineered

Eaton products and expert services, Eaton has the experience and applications expertise to develop a total arc flash solution for your facility.

This electrical room illustration shows how Eaton's products can be applied to mitigate arc flash hazards. Please refer to **Pages 41.3-4** and **41.3-5** for a

brief description of each product and **Page 41.3-6** for a hazard analysis and training overview.

To view an interactive version of this electrical room, visit www.arcflashsolutions.com.

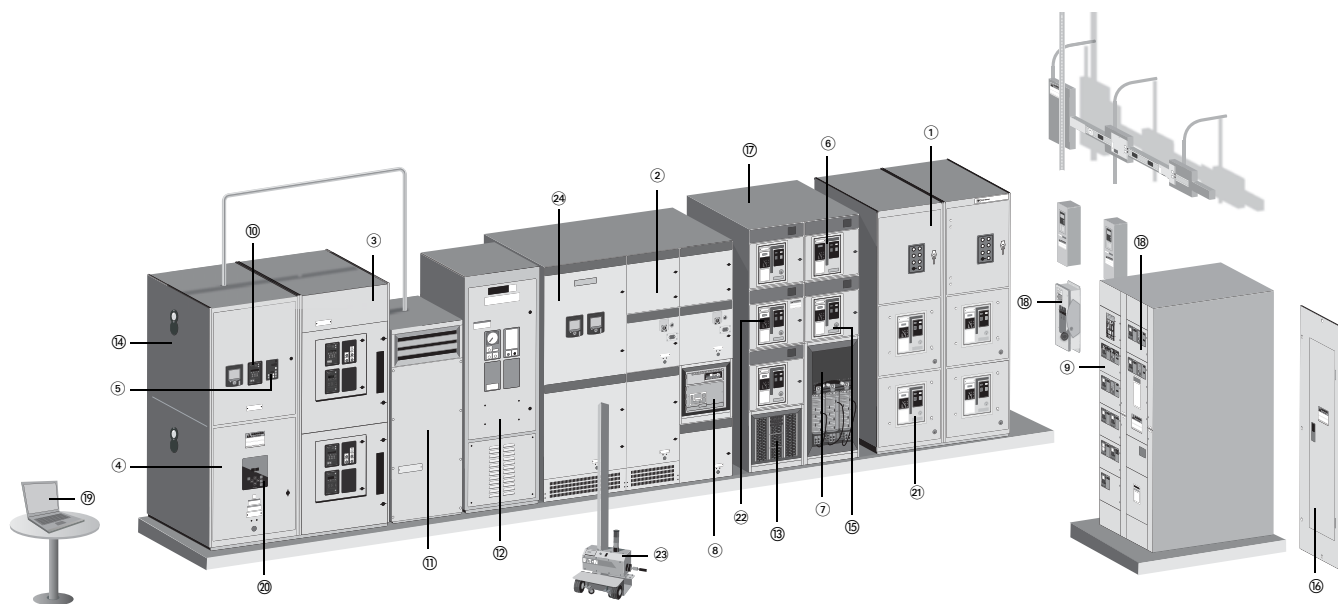


Table 41.3-2. Low and Medium Voltage Equipment to Limit Exposure of Personnel to Arc Flash Hazards

	Limits Frequency of Arc Flash Incidents	Reduces Arc Flash Event Durations	Reduces Arc Fault Currents ^①
① 1200 A bypass isolation ATS	■		
② Arcflash Reduction Maintenance System		■	
③ Arc-resistant medium voltage control	■		
④ Arc-resistant switchgear	■		
⑤ Bus differential schemes		■	
⑥ Circuit breaker trip units with zone selective interlocking		■	
⑦ Current limiting reactors			■
⑧ Digitrip™ trip unit with Arcflash Reduction Maintenance System		■	
⑨ FlashGard® motor control center	■		
⑩ Feeder protective relay with Arcflash Reduction Maintenance System settings		■	
⑪ High impedance transformers			■
⑫ High resistance grounding systems	■		■
⑬ Insulated bus in switchgear	■		
⑭ Infrared (IR) windows	■		
⑮ KIRK® key interlock	■		■
⑯ Lighting panelboards	■		
⑰ Low voltage switchgear with Arcflash Reduction Maintenance System		■	
⑱ MCC bucket and safety switch with viewing window	■		
⑲ Online infrared (IR) monitoring	■		
⑳ Partial discharge sensors	■		
㉑ Protective devices with current limiting and high speed operation	■	■	
㉒ Remote monitoring, control and diagnostics	■		
㉓ Remote power racking	■		
㉔ Secondary fault clearing using conversion of primary breaker		■	

① Caution: Lowering the fault current may result in a longer clearing time by the upstream device. Please contact Eaton to ensure proper application.

Broadest Range of Solutions to Improve Safety in Your Industry

① 1200 A Bypass Isolation ATS

The bypass isolation transfer switch capitalizes on Eaton's experience in designing and building low voltage switchgear. Many features from our Magnum® switchgear have been incorporated for improved safety and reduced arc flash hazards, including dedicated wireway and safety barriers isolating personnel from line and load.

② Arcflash Reduction Maintenance System

Available as a trip unit conversion to a low voltage power breaker, the Arcflash Reduction Maintenance System uses technology to reduce fault clearing time and to lower the available arc flash energy at the connected downstream devices. The system may be activated at the breaker or from a remote location. The result is a reduction of the incident energy, allowing for improved personnel safety while eliminating the need for higher levels of costly personal protective equipment (PPE).

③ Arc-Resistant Medium Voltage Control

AMPGARD® medium voltage control affords the highest levels of safety and flexibility in the industry. The SL-400 vacuum contactor has the highest interrupting rating (8500 A), providing full coordination with the starter main fuses. The isolation switch is rated for 10,000 mechanical operations, offering reliability even when the switch is frequently operated. The unique features of arc-resistant AMPGARD ensure that the highest energy levels are directed to the rear of the structure and away from the operator.

④ Arc-Resistant Switchgear

In addition to providing maximum safety through circuit separation and isolation preventing access to live parts, Eaton's arc-resistant medium voltage switchgear incorporates sealed joints, top-mounted pressure relief vents, reinforced hinges or latches, and "through-the-door racking," minimizing exposure to harmful gases and significantly reducing the risk of injury to facility personnel in the event of an arc flash event.

⑤ Bus Differential Schemes

Bus differential schemes are coordinated zones of protection within your electrical system. When a fault is detected, tripping occurs instantaneously for faults only within that particular zone, leading to greater reliability throughout the facility, increased personnel safety, and elimination of intentional time delay. Eaton can engineer a system of bus differential schemes on new or conversion equipment.

⑥ Circuit Breaker Trip Units with Zone Selective Interlocking

Zone selective interlocking deactivates the preset delay on the circuit breaker closest to the fault, which then trips with no intentional delay. This reduces the amount of time current flows and the amount of arc flash energy and stress (I^2t) the system encounters during fault conditions, resulting in improved personnel protection and prolonged equipment life.

⑦ Current Limiting Reactors

Current limiting reactors connected in series are primarily used to reduce fault currents and to match the impedance of parallel feeders. For example, low voltage motor control centers can be supplied with three single-phase reactors that limit available short-circuit current, providing a reduction in the available fault and arcing current at the equipment.

⑧ Digitrip Trip Unit with Arcflash Reduction Maintenance System

Eaton's Digitrip trip units for low and medium voltage applications feature an integral selector switch with five arc flash reduction settings, enabling the operator to pre-select the maximum arc flash reduction level possible to avoid nuisance tripping during maintenance operations. Testing has confirmed the maximum protection setting can significantly reduce incident energy, resulting in a lower incident energy and thus, reduced PPE requirements.

⑨ FlashGard Enhanced Motor Control Center

Eaton's motor control centers are built on "arc free" designs intended to drastically lower the probability of the creation of an arc flash. The features of this motor control center include: three-position MCC bucket (connected, test and withdrawn), through-the-door racking mechanism and high short-circuit ratings.

⑩ Feeder Protective Relay with Arcflash Reduction Maintenance System Settings

When properly applied to a power breaker, the FP-5000 feeder relay and a selector switch use control logic to automatically change the overcurrent settings to reduce fault clearing time and to lower the available arc flash energy at the connected downstream devices. The result is a reduction of the incident energy, allowing for improved personnel safety while eliminating the need for higher levels of costly PPE.

⑪ High Impedance Transformers

Eaton's transformers with increased impedance values drastically reduce the available arc fault current. The lower arc flash energy in a system generally translates into improved personnel safety.

⑫ High Resistance Grounding Systems

Eaton's high resistance grounding system limits the magnitude of current during a ground fault, thus reducing arc flash energy to increase personnel and equipment protection. Operators are alerted to faulted conditions and can easily locate the ground source via built-in fault tracing. Application of high resistance grounding systems limits the current and resulting energy in the event of a single-line to ground fault, significantly increasing personnel safety.

Advanced Arc Flash Technology to Enhance Personal Safety

- ⑬ **Insulated Bus in Switchgear**
Insulated bus bar systems within switchgear reduce shock hazard in the event of accidental contact when an energized system is undergoing maintenance. Insulated bus is standard in all of Eaton's medium voltage breaker assemblies. Contact Eaton regarding insulated bus in medium voltage metal-enclosed switches and low voltage breaker assemblies.
- ⑭ **Infrared (IR) Windows**
IR windows in electrical equipment allow an operator to complete a thermal inspection of electrical switchgear without opening cabinets or doors. Using infrared thermography technology, the operator is able to safely and quickly assess potential problems in the equipment while the circuits are energized and under load.
- ⑮ **Kirk Key Interlock**
A Kirk Key Interlock system ensures that a specific sequence of operations is followed to avoid human error. Eaton can engineer a specific configuration of interlocked breakers that can be energized only with a key. This eliminates excessive fault current that could result from unintentional paralleling of transformers and helps to keep personnel safe.
- ⑯ **Lighting Panelboards**
Eaton's EZ™ trim on lighting panelboards offer additional protection from faults and the resulting arc flash caused by loose trim hardware falling off on to live parts, when installed per the manufacturer's instructions. The reason... the EZ trim has no loose hardware or screws.
- ⑰ **Low Voltage Switchgear with Arcflash Reduction Maintenance System**
When an Eaton Magnum breaker equipped with the Arcflash Reduction Maintenance System is added to low voltage switchgear feeding motor control centers or other equipment, maintenance becomes much safer. When engaged, the arc flash energy is significantly reduced, resulting in a lower incident energy and thus, reduced PPE requirements.
- ⑱ **MCC Bucket and Safety Switch with Viewing Window**
Provides a positive visual confirmation that the circuit is de-energized, eliminating the requirement to open metal door and expose live parts.
- ⑲ **Online Infrared (IR) Monitoring**
For those locations where the incident energy levels are excessive and conventional arc flash solutions are not practical, Eaton has an online infrared sensing system that allows monitoring without cover removal, therefore eliminating the need to ever open the cover when energized.
- ⑳ **Partial Discharge System**
The InsulGard™ partial discharge system provides an early indication of insulation failure in switchgear, bus duct, power centers, generators, transformers and motors. Deteriorating insulation is the leading cause of electrical failure and results in partial discharge, or arcs, that typically occur within or between insulation materials. Early detection is key to a predictive maintenance program, and repairing the system prior to a full-fledged insulation failure can possibly avert an arc flash explosion.
- ㉑ **Protective Devices with Current Limiting and High-Speed Operation**
Eaton's molded-case and power breakers with current limiting and high-speed operation provide complete system protection against faults, including overloads, low-level short circuits and high-level short circuits. Due to their high interrupting capacity, the current limiting devices will interrupt high arcs quickly, thus reducing arc flash in a system and increasing personnel protection.
- ㉒ **Remote Monitoring, Control and Diagnostics**
Eaton's power management software enables an operator to remotely monitor, control and diagnose the power distribution system from a remote location (outside the arc flash protection boundary). When maintenance is required, the switchgear can be de-energized through the software, thus keeping personnel away from a potentially hazardous situation.
- ㉓ **Remote Power Racking**
Many arc flash incidents occur when personnel insert or remove (rack) power breakers from low or medium switchgear cubicles. Eaton's remote power racking system (RPR-2) provides a means of remotely racking most breakers that use the rotation of a shaft for insertion or removal, enabling personnel to stand outside the arc flash protection boundary.
- ㉔ **Secondary Fault Clearing Using Conversion of Primary Breaker**
Excessively high arc flash incident energies at the secondary of the transformer (and line side of the downstream main breaker) can be reduced by tripping a transformer primary protective device (circuit breaker). The tripping signal originates from current sensors mounted on the transformer secondary terminals. Eaton has conversion solutions to replace or modify that primary device, even if it is a fuse, MV breakers (or LV as appropriate), which result in a system that provides superior arc flash protection at the transformer secondary. This solution is especially useful for installations that do not use a secondary main (NEC 6-disconnect rule).

A Comprehensive Arc Flash Hazard Analysis

An arc flash hazard analysis is critical to the safety of plant personnel working on or near exposed energized electrical equipment. The analysis will quantify the release of thermal energy associated with potential arc flash hazards and will describe safety recommendations such as establishing protection boundaries and specifying protective equipment for personnel.

Many offer this service, but few offer such extensive expertise backed by a full line of mitigating products and services as Eaton.

Eaton's highly qualified power systems engineers (PSE) have performed thousands of studies for all types of industries. Every PSE has access to a variety of analysis tools to best address the safety risks of your unique system. Our combined use of commercial and proprietary software uses IEEE and NFPA equations and methods for comprehensive and accurate calculations, including fault current momentary duty, device clearing time, arcing fault currents, duration of arc and incident energy. Eaton's PSEs draw on past experience, training and understanding to analyze the figures and to develop recommendations that are compiled in a written report. Upon request, the PSE will verbally present the findings in clear and easily understandable terms.

A comprehensive arc flash hazard analysis includes the following services:

- Arc flash system studies, calculations and consulting
- Arc flash labeling
- Creation and/or verification of one-line electrical drawings
- Short-circuit and coordination studies
- Recommendations to help achieve a safer environment for personnel include:
 - Arc flash boundaries
 - Safe working distances
 - Practical methods for reducing arc flash hazards
 - Required protective flame-resistant clothing
 - Personal protection equipment (PPE)
 - Safe work practices

You can be certain that Eaton's extensive experience in arc flash hazard analysis will provide the best solutions to protect what you value most.

An Industry-Leading Arc Flash Safety Training Program

A top-notch safety plan incorporates not only arc flash hazard analysis recommendations, but also practical training for personnel who operate and maintain energized electrical equipment. Eaton offers both.

While some trainers simply recite information from published manuals, Eaton's trainers are the same electrical engineers who perform arc flash hazard analyses and install, commission, troubleshoot and maintain electrical equipment every day. When you train with us, you're assured of getting the most current information, techniques and procedures available to keep your personnel safe and your processes running.

Education—The Key to Better Arc Flash Safety

Eaton's arc flash safety training will show you how to determine the incident energy value and flash protection boundary distances for the equipment in your facility. You'll learn to use that information in selecting electrical components designed to minimize arc flash hazards, and how to choose personal protection equipment (PPE) according to the National Fire Protection Association's Standard 70E (NFPA 70E). And because we know that PPE can be bulky, uncomfortable, limit dexterity and expose workers to heat exhaustion problems, we continually search for, and incorporate into our training, safe ways to minimize the use of PPE. Our training will reveal how a proper examination of your power distribution system can help you avoid "overdressing" for necessary operational and maintenance tasks.

We understand that a "one-size-fits-all" approach to training doesn't fit every situation, so in addition to our power systems training classes, we offer customized training specifically designed for your company's unique requirements. Furthermore, if it's not practical for your staff to train at one of Eaton's facilities, we can conduct the training at your site.

The following is a brief overview of Eaton's one-day "Understanding Arc Flash" training program.

- Existing and proposed standards
- Determining safe approach distance
- Methods for calculating prospective short-circuit current
- NFPA 70E methods for calculating flash protection boundary distance and incident energy value
- IEEE standard 1584 methods for calculating arc flash protection boundary distance and incident energy value
- Selecting protective clothing and PPE using incident energy exposure value and the PPE matrix
- Arc ratings for common types of garments
- Practical methods for reducing arc-flash hazards

Eaton can award 0.8 CEUs for the successful completion of this training.

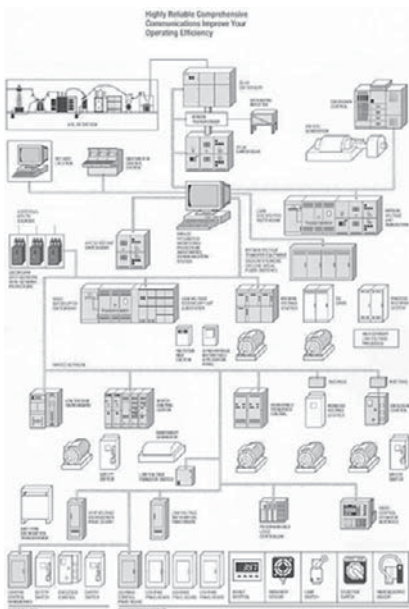
To learn more, contact Eaton's electrical training group at 724-779-5852 or EETraining@eaton.com.

Partnering with Eaton to perform arc flash analysis, to implement mitigation techniques, and to train your personnel will give you confidence that you have an enterprise-wide arc flash compliance program that ensures employees are safe from arc flash hazards.

Power System Monitoring Services

Electrical distribution systems are being subjected to higher loads and greater harmonics than ever. Real-time monitoring and remote control of power systems helps identify problem areas, pinpoint the root cause, enable quick resolution, and if necessary, enact remote control of power distribution equipment. These actions prevent costly outage and loss of productivity and equipment, while extending the life of the electrical system.

In addition, with the advent of utility deregulation, having accurate power usage values enables you to negotiate a better position for power purchases.



Plant-Wide Electrical Power Monitoring and Control

Plant-wide electrical power distribution system monitoring and control can be cost-effectively implemented during new construction. Eaton electrical products allow for communications through all levels of the power distribution and power protection network. For example:

- Eaton's Power Xpert® Architecture allows for plant-wide monitoring and control from a single workstation or from any number of workstations connected to a plant LAN, company, intranet or Internet
- Power Xpert and Foreseer® systems give administrators full visibility over networked UPSs across the enterprise, along with other elements of the critical facilities infrastructure

- The InsulGard and BushingGard relay remote monitoring offering can provide advanced notification of impending failure of equipment in time to have it repaired before catastrophic failure and longer more expensive downtimes occur

Instant Response Center Services

General Description

Eaton's Instant Response CenterSM (IRC) is staffed by power systems engineering and power quality experts, monitoring your electrical distribution system in real-time. The IRC continuously monitors power distribution equipment for changes in performance or other conditions that could signal an impending power failure. When changes exceed predetermined thresholds, the IRC issues alerts to service personnel via Internet, e-mail, text or voice messages and wireless page.

Eaton power systems experts can then remotely and securely access real-time data from the subscriber's system, often correcting a problem before electrical service is impacted, delivering to customers a quantifiable return on investment based on maximum uptime, extended equipment lifetime, and reduced energy costs.

System outages can be prevented or mitigated, equipment life extended, and operating, maintenance and energy costs reduced by monitoring key system wellness parameters such as:

- Current, voltage and energy
- Power quality and harmonic content
- Partial discharge
- Vibration
- Temperature
- Power factor (transformer bushings)
- Key events (oscilligraphy)
- Energy monitoring
- Inverter monitoring
- Environmental condition monitoring such as humidity, temperature, dust, smoke and the presence of water

The Instant Response Center is the vanguard of Eaton's Knowledge Management Services. Knowledge Management is a broad term that describes the application of a variety of related technologies and expert analytical services that transform data into information, and information into knowledge. Data is collected by remotely monitoring customers' electrical distribution and related systems via the Internet, and trending key parameters related to energy and utilities, power quality, predictive diagnostics, environment and key events. This data is converted to information through expert analysis by power systems engineering, power quality and energy management experts. This information is then transformed into knowledge using data mining techniques and the application of predictive algorithms to extract trends and patterns that will predict equipment failure, provide short- and long-term maintenance recommendations and identify energy cost reduction opportunities.

Using the latest communications technologies, such as wireless videography, it is also possible to extend this high-end expertise to field technicians or customer personnel to guide them through sophisticated problem diagnosis, troubleshooting or repairs.

Benefits

- Experts are readily available
- Eliminates the cost of bringing experts on site
- Event analysis
- No employee turnover



Eaton's Instant Response Center

Power System Predictive Diagnostics Services

Electrical outages can result in extensive downtime and loss production. Critical systems should be investigated to determine the cause of such outages, as they occur. This investigation leads to corrective actions that should prevent a recurrence.

However, with the growing pressure for “five-nines” and even “six-nines” system availability (99.9999 percent), it’s no longer enough to respond quickly to power problems. Being able to predict and forestall trouble is essential in utility, industrial and commercial markets.

Eaton leads the industry in predictive diagnostic tools and services, such as Eaton predictive diagnostics for online monitoring of electrical insulation systems, environmental parameters and the Eaton Foreseer system for proactive monitoring of UPSs plus many other elements of the critical facilities infrastructure, such as HVAC, power distribution, generator, fire-detection and security systems from dozens of manufacturers.

Services are implemented through the network of EESS field locations. The predictive diagnostics service provides online monitoring services of insulation systems via the effective measurement and analysis of partial discharges for electrical distribution equipment at 4.16 kV and above. This process detects traditional corona damage, or surface tracking, prior to equipment failure. This advanced technology is applied to medium voltage systems such as: generators, motors, switchgear, transformers and cable systems.

Partial Discharge Testing of Medium Voltage Equipment

Partial Discharge Testing—Application

The EESS group has developed state-of-the-art technology to enable long-term predictive diagnostics of MV equipment. New or existing MV switchgear lineups are equipped with partial discharge sensors to measure partial discharges within the cubicles. The sensing technology measures all discharges through noninvasive sensing of the electrical power signal. Measurements are performed online, while switchgear equipment is energized under normal operational conditions, using equipment specifically designed for this purpose.

Partial Discharge Testing—Functionality

Partial discharge (PD) sensors detect partial discharges, which are the initial indicators of corona or surface tracking—primary root causes of insulation deterioration in MV electrical equipment. The sensitivity of PD sensors and measurement technology is sufficient to detect early stages of defect development by measuring PDs of low levels (less than 50 pico-coulombs). PDs occurring within the cubicles as well as PDs emanated by external sources (cable terminations, cables, bus ducts, connected transformers, motors and so on) within a limited distance are identified.

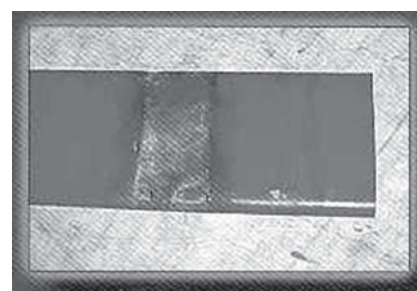
Sensors allow for periodic partial discharge sensing from the front of each switchgear cubicle without the need to open cubicle doors, using measurement equipment specifically for this purpose. Eaton provides a partial discharge sensor for each cubicle in the switchgear lineup. Eaton deems it insufficient to have sensors only at the ends of switchgear lineups, due to the signal attenuation of partial discharges. Sensing must occur in individual cubicles to ensure maximum sensitivity and predictive value of the measurements.

Partial Discharge Testing—Calibration and Baseline Measurements

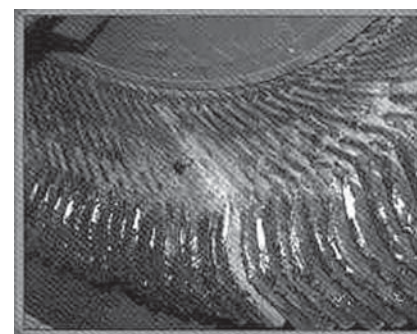
New switchgear can be monitored at the factory before shipment, and a baseline signature of partial discharges is provided with the switchgear. Field startup service includes obtaining a post-installation signature of the partial discharges. In-service MV switchgear that is converted with PD sensors will have an initial baseline measurement obtained, whereas our database of switchgear PD measurements does allow us to provide immediate results concerning the insulation condition.

Partial Discharge Testing—Instrumentation (for periodic PD measurements)

Eaton measurement and analysis instrumentation can be used to periodically detect partial discharges related to MV switchgear, MV motors and generators, MV cables, transformers and other MV electrical equipment. This instrumentation completes concurrent sampling of a minimum of four channels, and is able to effectively suppress electrical noise, eliminate cross-coupling of measured PD signals, maintain a detection sensitivity of 50 pC or better, and disseminate the type of discharge measured. Immediate report documentation is incorporated in the instrumentation software, with analysis and recommendations included in the final report.



Surface Tracking on Bus Duct



Corona Damage on the Motor Windings

Transformer Predictive Diagnostics



Bushing Power Factor, Partial Discharge and Vibro-Acoustics

Transformers, with a primary voltage at or above 68 kV, and containing capacitive taps on the primary bushing, should be equipped with a continuous monitoring system to allow for pre- and post-shipment measurement of bushing power factor and internal partial discharges.

Transformer Bushing Monitoring System

Eaton's system monitors the changes in bushing insulation, for the set of three bushings in a group, based on changes in bushing capacitance or bushing power factor. The system detects changes of power frequency current through the bushing insulation. If the transformer has six or nine bushings (two or three windings), additional systems can be installed as required. The measured current through the bushing insulation cannot be less than 2 mA. The system also provides for connecting instrumentation for periodical partial discharge measurements using portable equipment—without requiring a transformer outage or any modifications to the sensing circuit.

Transformer Bushing Monitoring—Sensors

The power factor sensors are connected to the bushing capacitance taps. All sensors are designed for outdoor installation within the ambient temperature minus 50 °C to plus 50 °C. Insulation level (withstand 1 minute AC voltage) between primary and secondary circuits is: bushing sensor 1.5 kV plus overvoltage protection;

neutral sensor 15 kV; tank, core or cable shield grounding 2.5 kV; and isophase sheath 1.5 kV. The sensor system also includes overvoltage protection to suppress all overvoltages, arising during transformer operation, below this level. Temperature sensor, if used with a digital device, is of a standard RTD type. Sensors also have provisions for periodic partial discharge measurements online, using separate instrumentation designed for this purpose.



Online Transformer Insulation Monitoring System

Transformer Bushing Monitoring—Instrumentation

Eaton predictive analysis instrumentation delivers precise continuous measurement of capacitive current through the bushing insulation while the transformer is energized. The minimum detectable change in current is 0.1% of initial current. Temperature deviation of the signal is the same order. The display is available from the bushing monitoring instrumentation for one complex PF signal per bushing group, which will include the display of the current power factor value. The following output signals can also be provided as required: two alarm signals (dry contacts) for a local alarm system, and additionally 4–20 mA DC output for an analog re-transmitting or serial interface for digital re-transmitting. Instrumentation is completely isolated from high voltages and features immunity to high voltage transients. Full field calibration procedures are supplied with the instrument's operation manual. All necessary connections for the selected options are supplied with startup and baseline calibration.

Transformer Bushing Monitoring—Software (Digital Option)

The Eaton monitoring software is compatible with systems using Microsoft® Windows® 95 or higher operating systems. With this software, an analyst can display power factor (PF) value for the group of three bushings (up to three groups), store and trend PF value for all monitored groups (up to three), show trends of PF readings versus temperature, set alarm thresholds, receive alarms when PF values reach preset thresholds, and print and plot historical data.

Transformer Bushing Monitoring—Calibration, Manuals and Baseline Measurements

Eaton provides full field calibration and startup. A separate independent power factor test is performed of each bushing as part of the startup and calibration process. Transformer bushings are calibrated and baseline measurements obtained. Part of the field startup service includes obtaining post-installation baseline measurements to ensure no defects have resulted during bushing installation and/or transformer transportation, installation and startup. A report with any recommendations is also provided. A complete manual is supplied for both the instrumentation and the software, describing the operation of the instrumentation, calibration and troubleshooting.

Online Transformer Partial Discharge Monitoring

Eaton also installs partial discharge sensors to allow for online PD measurements within a transformer. Partial discharge measurement can be periodically obtained while the transformer is online and in normal operation, using separate instrumentation designed for this purpose. The measurement system can assess the insulation condition based on PD measurement of the bushings and transformer windings insulation. The system is also capable of detecting sparking in the core, sparking associated with connections, and sparking associated with the static electrical discharges.

Online Transformer Monitoring— Sensors and Instrumentation

Sensors are noninvasive and have no connection to the energized components. Sensors are designed for outdoor installation, to plus or minus 50°C of ambient temperature. Sensors are connected, as required based on the field conditions, to the following locations: bushing capacitor taps, transformer neutral connection, tank grounding, core grounding, electrostatic shield grounding, surge arresters, isophase bus enclosure bonds and grounds. The sensor frequency range of operation is 500 kHz to 50 MHz. Insulation level (withstand 1 minute AC voltage) between primary and secondary circuits is: bushing sensor 1.5 kV plus overvoltage protection; neutral sensor 15 kV; tank, core or cable shield grounding 2.5 kV; and isophase sheath 1.5 kV.

The sensor system also includes overvoltage protection to suppress all overvoltages, arising during transformer operation, below this level. Part of the field startup service includes obtaining post-installation baseline measurements to ensure no defects have resulted during bushing installation and/or transformer transportation, installation and startup. A report with any recommendations is also provided.

Online Transformer Monitoring— Measurement Parameters

The Eaton instrumentation measures the following: apparent partial discharge magnitude of each impulse, number of impulses per cycle, phase position of each discharge impulse, impulse repetition rate, impulse discharge power, and peak discharge magnitude of the impulses.

The following quantities are plotted and displayed in a report format: apparent discharge magnitude of each impulse, number of impulses per cycle, phase position of each discharge impulse, impulse repetition rate, impulse discharge power, peak discharge magnitude of the impulses, impulse count and PD magnitude versus phase position representation and impulse PD power. This information is provided to support the findings and recommendations, which are contained in a field report.

Online Transformer Monitoring—Periodic Partial Discharge Analysis Software

The Eaton expert monitoring system applies analysis software, during periodic measurements, with the following features: display of PD data, statistical processing of the PD data, data storage and editing, and instrumentation control. All data from the test is automatically saved to a database and stored on a hard disk in a data format compatible with Microsoft Windows applications such as Word®, Excel® and Access®. All standard Microsoft Windows control functions, such as printing and cut-and-paste operations, are available within the software. Upon initiation, the software performs self-diagnostic procedures to ensure all components are operating correctly.

Online Transformer Monitoring— Calibration, Manuals and Baseline Measurements

Part of the field startup service includes obtaining post-installation baseline measurements to ensure no defects have resulted during bushing installation and/or transformer transportation, installation and startup. A report with recommendations is also provided.

Traditional Transformer Startup and Acceptance Testing

The transformer predictive diagnostics and field startup tests described in this section are completed by Eaton personnel, in addition to traditional transformer factory and field acceptance testing, in accordance with ANSI, IEEE and other applicable testing standards. For example, a separate independent power factor test is required of each bushing as part of the startup and calibration process. These additional tests immediately indicate any problem related to manufacture, transportation, installation and startup. In addition, Eaton predictive diagnostics provides a method to complete future predictive diagnostics, online, without any equipment outage, therefore extending equipment life and enhancing equipment uptime.

Partial Discharge Testing of Medium and High Voltage Equipment

Online Monitoring and Partial Discharge Analysis

Approximately 80 percent of all equipment failures occur on a random basis and are not age-related. Certainly, a well-designed, time-based preventive maintenance program can reduce failure rates, but what about these 80 percent of equipment failures that occur on no timetable? You could increase the rate of preventive maintenance activities, but that is no solution. These activities tend to be invasive, introducing new defects that can actually increase failure rates, resulting in infant-mortality failure patterns.

Under pressure to deliver ever higher levels of availability, facilities managers are looking for a better way. Predictive technologies increase system reliability without undue, invasive preventive maintenance tasks. Eaton predictive diagnostics offers predictive diagnostic equipment and systems for medium and high voltage equipment. Much of our technology is based on the measurement and analysis of partial discharges (PD). Partial discharges are a well-known and an industry-accepted indicator of insulation deterioration that lead to equipment failure.

InsulGard Predictive Relay for Continuous Monitoring and Analysis of Partial Discharges

The InsulGard system can be used for applications rated for 4000–38,000 V, including the following equipment:

- Motors/generators (RTDs are also used as sensors)
- Switchgear systems
- Bus ducts
- Power center transformers
- Gas insulated substations
- Splices and terminations of cables

Eaton has a complete suite of predictive diagnostic solutions as shown in **Table 41.4-3**.

Table 41.4-3. Predictive Diagnostic Solutions

Predictive Solution	Voltage Class	Equipment Type	Components
InsulGard (see Page 41.4-4)	13 kV, critical at 38 kV and above	MV switchgear and switches MV bus duct MV generators MV motors	
FaultGard SM (visit Eaton.com)	13 kV and above (transformers)	MV transformers Internal components	
BushingGard SM (visit Eaton.com)	13 kV and above (transformers)	MV transformers External bushings	

InsulGard G2—Transformer Monitoring System

Bushing failures are responsible for up to 35 percent of all large power transformer failures, and more than half of these failures are violent in nature, which presents concerns about safety and environmental damage. The EESS group can continuously monitor the changes in C1 capacitance, as well as any changes in the dielectric losses of the bushing (bushing power factor). This service is like having a continuous online Doble test of the bushings under true electrical stress and temperature. Eaton can also periodically test bushings and power transformer windings for partial discharge, while the equipment is in operation.

Eaton's comprehensive transformer monitoring system incorporates permanent partial discharge sensors to detect a wide range of electrical problems (PDs, surface tracking, arcing, sparking) in bushings, winding insulation, core, laminations, tap changer connections, ground connections, pressboard barriers and so on. Couple this system with Eaton's Eaton Predictive Diagnostics to analyze critical equipment, reduce the risk of failure and increase uptime.

**Online Transformer Insulation Monitoring System****Benefits of InsulGard Systems**

- Tests are performed continuously, online with no human intervention required, and no loss of asset productivity. Tests are accurate, because they are conducted under actual operating conditions
- Testing does not produce the “infant-mortality” patterns that are common with invasive testing procedures
- Finding a problem is not left to chance (as it is with interval testing); you will know when a problem started and how rapidly it is progressing
- Always aware of conditions and problems, you can eliminate surprises and forced outages while increasing safety
- Understand trends in other variables that affect PD activity, such as load, temperature and humidity
- With continuous testing and accurate data on which to base decisions, you can evolve from interval/chance maintenance to predictive/condition-based maintenance—effectively prioritizing maintenance, reducing costs and eliminating unnecessary maintenance

**InsulGard Predictive Relay**

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Circuit Breaker Conversion and Replacement Services

Eaton has more than 50 years of experience in manufacturing power distribution and protection systems, is a member of the National Electrical Manufacturers Association (NEMA®), has representation on IEEE/ANSI C37 Switchgear Working and Balloting Groups, and owns and operates an engineering services organization with more than 30 field service locations. You can count on Eaton for effective conversion and replacement products and services to modernize your circuit breakers and motor control systems.

Conversion and replacement services are performed by experienced, factory-trained field engineers and technicians who are familiar with the installation and startup of replacement products and retrofit kits—as well as testing and commissioning procedures required for failsafe operation. Field engineers have product expertise that enables them to offer initial training to the owner's on-site operators and maintenance personnel while commissioning new/replacement equipment.

Representative services:

- LV and MV recondition and remanufacture
- LV breaker conversions for all OEM products
- AR Series LV air replacement breakers
- VR Series, medium voltage (MV) vacuum replacement circuit breakers for many OEMs
- MCC recondition and remanufacture
- Network protector service
- Navy shipboard breakers
- Commercial products for dedication in Nuclear Class 1E safety-related applications

Reconditioning Service for Low Voltage Power Circuit Breakers

General Description—Application

Low voltage power circuit breakers are designed to be serviceable over a long service life. These breakers and associated switchgear have been available in the industry for more than 50 years, and there is a large installed base of equipment from many manufacturers throughout the United States and Canada.

The low voltage switchgear is essentially static. It consists of structures, buswork, control wiring and metering components. If periodically cleaned, it will last almost indefinitely. Low voltage power breakers are the essential elements of the switchgear. These devices are required to properly conduct the normal load current for the vast majority of time, and still provide the means of interrupting an overload or fault current whenever it may occur.

These breakers contain insulation systems (600 Vac normal three-phase voltage or less), conductors (from 225 to more than 6000 continuous amperes), a mechanism to open and close the breaker, a trip system to provide protection of the circuit and the circuit breaker, and an interruption system (arc chutes and contact structures) that can handle fault currents as high as 200,000 A.

While some breakers are fixed mounted (bolted into the switchgear), most are drawout versions for ease of inspection and maintenance, as well as to provide maximum isolation of the load. These drawout breakers include primary disconnects (for the three-phase conductors), secondary disconnects (for breaker control wiring), a levering-in mechanism (to assist in the insertion and withdrawal of the breaker) and an interlock system (to ensure that a closed breaker cannot be inserted or withdrawn from the connected position).

Additional common options to low voltage power circuit breakers include electric operation of the mechanism, shunt trip and close coils for remote operation of the breaker, undervoltage trip systems, and additional auxiliary switches for annunciation and control schemes.

Factors that affect the life of these circuit breaker subsystems include: time, ambient temperature, humidity, cleanliness of the environment (contamination and corrosive elements), number of normal load operations, number of fault current interruptions, load current magnitude and maintenance cycle.

While periodic maintenance, cleaning, lubrication and testing of the circuit breaker can and will prolong its life, at some point, the circuit breaker must either be completely reconditioned or replaced. Failure or mis-operation of any of the breaker's subsystems will render it ineffective for its intended purpose and dangerous for personnel or downstream equipment.

Class 1 reconditioning of the low voltage power circuit breaker is a cost-effective method to restore all of the breaker's subsystems to full functionality and prolong the life of the breaker for many additional years.

Reconditioning Service for Circuit Breakers from Many Manufacturers

Class 1 reconditioning is available for all major manufacturers' low voltage power circuit breakers that have been produced over the last 50 years. These breakers are rated at 600 Vac, 225–6000 A continuous, 15,000–200,000 A interrupting. Manufacturers include, but are not limited to:

- Westinghouse
- Cutler-Hammer
- General Electric
- ITE
- ABB
- Allis-Chalmers
- Siemens
- Square D
- Federal Pacific
- Federal Pioneer

Advantages of Eaton Reconditioning Services

Eaton's electrical business is the world leader in low voltage power circuit breaker and trip systems technology. Our EESS group is uniquely positioned to provide Class 1 reconditioning of low voltage power circuit breakers.

All Class 1 reconditioning is done at Eaton's Power Breaker Reconditioning Center (PBRC) facilities dedicated to this purpose. These facilities use state-of-the-art equipment to clean, plate, assemble and test the breakers. Each facility uses identical standards and procedures in the reconditioning process. Reconditioned breakers are tested to the same standards as new production breakers. Breaker test results are stored in a North American database, which facilitates predictive maintenance and trending. All manufacturers' breaker information is stored in our Power DB Database and is available to every PBRC performing the work. Original OEM replacement parts are exclusively used to replace broken, out of specification or missing components.

Supported Standards for Circuit Breaker Reconditioning

The converted breaker will be designed, manufactured, applied, installed and certification tested in accordance with the latest applicable sections of the following industry standards:

- IEEE/ANSI C37.13
- IEEE/ANSI C37.16
- IEEE/ANSI C37.17
- IEEE/ANSI C37.50
- IEEE/ANSI C37.59-1996
- IEEE/ANSI C37.100
- UL 1066 (for originally UL listed and labeled designs)

Quality Control and National Standards

All reconditioning will be conducted under the direction of a quality control and reconditioning standard, pursuant to ISO®-9001 certification. A quality certificate will document the progress of each breaker through the reconditioning process. Eaton has multiple locations (minimum of five) strategically located throughout North America that share best practices of reconditioning and work to a consistent national standard. They use the same task-specific equipment for cleaning and testing at all locations to ensure the quality of the product.

Receiving and Data Collection

Upon receipt at the reconditioning center, the following process will be performed on each breaker:

- Assign a unique job and breaker identification number
- Record all nameplate data, customer identification, existing trip settings, and all numbers unique to each breaker by direct entry into a national computer database archive for future use and retrieval
- If electrically operated, record all accessories included on the circuit breaker, as well as the close, trip and charge volts. The latest copy of the customer's control schematic will be obtained prior to disassembly and/or test. Eaton can retrieve control schematics for the breakers it manufactured
- The circuit breaker will be inspected for physical damage. Parts that need to be replaced will be recorded. A quotation will be issued to the customer for replacement of the defective part(s)

Preliminary Testing and Inspection

The breaker will be manually and/or electrically operated. The following tests will be performed.

- Tests for all breakers:
 - Each primary pole insulator will be tested for dielectric integrity by applying 1000 Vdc between each conductor and ground, and between line and load
 - With the breaker closed, the contact resistance using a 10 A conductor will be measured
 - Measure the trip bar force using a force gauge

- Measure the trip button/actuator device force using a force gauge
- Verify continuity of current limiting fuses (if equipped) and measure the resistance using a 10 A conductor; check blown fuse indicators' integrity
- Verify overcurrent trip device operation via primary injection (not required if a trip unit retrofit is to be installed)
- Additional tests for electrically operated breakers:
 - Charge the breaker; close and trip electrically
 - Verify undervoltage, pickup and dropout (if equipped)
 - Check auxiliary switch operation and condition

The results of all the above tests and measurements will be entered into the Eaton centralized database.

Breaker Disassembly, Cleaning and Preparation

- The circuit breaker will be completely disassembled to its component parts. All parts will be inspected for wear and physical damage
- All heavily carbonized components will be cleaned and degreased in a Vaque® Wet Blast System to produce a smooth finish without degrading the component's surface
- All current carrying parts, main/ arcing contacts, ground contacts and primary disconnects will be cleaned, burnished and polished in a TOREX® vibratory system loaded with a medium specifically designed to clean silver plating. Dry blasting or other abrasive cleaning systems that can remove silver plating or distort the contacts' surfaces will not be used
- All pole piece moldings and insulating components will be cleaned in a Giant™ ceramic polisher that cleans and polishes the components surface without scratching. After cleaning, each component shall be dried to obtain 1000 megohms when megger tested at 1000 Vdc. They will be sealed with a dielectric grade sealant

- All heavily soiled and/or greasy items including mechanisms will be initially cleaned in a nonabrasive agitator filled with a biodegradable cleaning solution capable of degreasing, de-scaling and deburring without degrading the components surface and without the introduction or embedding of grit or other abrasive materials
- All frames will be stripped to bare metal in preparation for plating
- After cleaning, all ferrous metal frames, mechanism parts and linkages will be plated with yellow zinc dichromate to provide superior rust resistance to exposed and hidden surfaces. Painting of covers, handles and indicators will be done
- A detailed inspection will be performed on all mechanism components and linkages to detect stress fractures and excessive wear that can cause premature failure. Magnification will be used on small components if necessary
- Arc chutes will be hand-wiped and cleaned with a clean dry cloth. They will be megger tested at 1000 Vdc. If the megger value is less than 1000 megohms, the arc chute assembly will be dried and retested. If the retest value is greater than 1000 megohms, then arc chute surface will be sealed with the manufacturer's recommended dielectric grade clear sealant. If the retest value is still less than 1000 megohms, then the arc chute will be replaced
- Charging motor (if so equipped) will be removed. The drive shaft bushings will be inspected and replaced if worn. The motor will be cleaned and reconditioned. All ratchet pawls and springs will be inspected and replaced or repaired if necessary
- Gearbox (if equipped) will be removed, disassembled and fully inspected. Any defective or leaking components will be repaired and cleaned

Circuit Breaker Reassembly and Adjustment

The process includes the following steps:

- Reassemble the circuit breaker frame using new yellow zinc dichromate-plated hardware
- Search the database of manufacturer specifications to determine the originally recommended lubricants. If the original lubricant formulation is no longer available, substitute a comparable or superior alternative designated by the new breaker design group
- Reassemble, lubricate and reinstall the operating mechanism on the circuit breaker frame
- Reassemble, lubricate and install the main and arcing contact components as recommended by the original manufacturer's Information
- Reassemble, lubricate install and align the racking mechanism and electrical and/or mechanical charging mechanism (if applicable)
- Install all electrical components and secure wiring harness (if applicable)
- Align the contacts for proper surface wipe and mating. Perform a contact wipe test. Verify that the percent contact wipe and the wipe width are per the original manufacturer's information
- Adjust the main contacts for proper gap, pressure and contact resistance, and adjust arcing contacts for proper gap per the original manufacturer's Information
- Install new Eaton Digitrip microprocessor trip system where specified
- When a new trip device is added to the breaker or when changes are made to the original mechanism or arc interruption system, an additional nameplate shall be installed in accordance with IEEE/ANSI C37.59-1996 section 8.3 and shall include the unique serial/identification number

Test Procedures

General Production Testing

Each reconditioned LV power circuit breaker will be tested to the applicable sections of IEEE/ANSI C37.50 Section 6 and UL® 1066 if the breaker was originally UL labeled. The testing will include but not be limited to:

- Measuring and recording trip bar force
- Setting of the microprocessor trip
- Performing control and secondary wiring and device check tests
- Performing dielectric withstand tests
- Performing no-load operations tests
- Verifying interlock and cell interface
- Test position dielectric withstand (original UL labeled breakers only)

Trip Bar Force Measurement

Measure and record the circuit breaker's trip bar force.

Microprocessor Trip Device Setting

Direct-acting trip devices will be tested/calibrated to determine their conformance to published trip characteristic curves. Each breaker will be primary injection tested using a sinusoidal-wave-shape, single-phase 60 Hz current at a convenient voltage. The primary injection test device will be computer controlled to ensure accuracy in the applied currents. The primary injection test device will be capable of direct output of the test results to a printer or storage device. The applicable tests will be performed.

- Long-time-delay-element pickup
- Short-time-delay-element pickup
- Instantaneous-element pickup
- Time delay of long-time-delay element
- Time delay of short-time-delay element
- Ground-element pickup
- Time delay of the ground element

Control, Secondary Wiring and Devices Check Test

Perform control, secondary wiring, and devices checks per IEEE/ANSI C37.50.6.3 to verify that all connections are correct per the wiring diagram. Those circuits for which operation or testing is not feasible will be checked for continuity.

Dielectric Withstand Tests

Perform dielectric withstand tests per IEEE/ANSI C37.50.6.4. The applied test voltages will be essentially sinusoidal (within 20% of the rated frequency of the circuit breaker being tested) and will have a minimum crest value equal to 1.414 times the specified test voltage potentials. The potential will be increased gradually from zero so as to reach the required test value in five to ten seconds, and will be held at that value for one minute, except for the momentary control voltages (listed in No. 4 below).

The following test values are applied to Class 1 reconditioned LV power circuit breakers:

1. 2200 Vac for the primary circuit of a completely assembled circuit breaker.
2. 1500 Vac for secondary control wiring and control devices, including current sensors and magnetic latch, except (3), (4) and (5).
3. 1000 Vac for new or reconditioned motors.
4. 500 Vac momentary for control devices and circuitry operating at 80 Vac rms (110 Vdc) or less that are not connected directly to the primary circuit or external, secondary control circuits.
5. Twice rated voltage plus 1000 Vac for undervoltage trip devices operating at a voltage above 250 Vac.

No-Load Operation Test

Perform no-load operation test per IEEE/ANSI C37.50.6.5.1 (for electrically operated breakers).

- Five closing and five opening operations at minimum control voltage
- Five closing, five opening, and five trip-free operations at maximum control voltage
- Two operations to check anti-pumping, which will be performed in the following manner:
 - Apply uninterrupted control power to the closing circuit of the open circuit breaker as the closing signal
 - Trip the circuit breaker; the circuit to remain open until closing circuit power has been interrupted and then restored
- Check all other devices, both electrical and mechanical, for proper operation

Perform no-load operation tests per IEEE/ANSI C37.50.6.5.2 (for manually operated breakers):

- Five closing and five opening operations
- When shunt trip is used, a minimum of five openings using the shunt trip at the minimum control voltage specified for the coil
- Five trip-free operations
- Check all other devices for proper mechanical operation

Interlock and Cell Interface

Verify the functional operation of all circuit breaker interlocks and cell interfaces in a cell structure, preferably a cell in the reconditioner's facility.

Test Position Dielectric Withstand (UL Listed Breakers Only)

Original UL-listed breakers will have their dielectric withstand verified by placing the breaker in the test position, closing the breaker, and applying 2200 Vac across the cell's primary conductors for one minute. No dielectric breakdown shall occur.

Open-fuse Trip Device (if Included)

Test the trip device mechanically or by application of proper voltage to the device to establish positive tripping of the fused circuit breaker.

Undervoltage Test

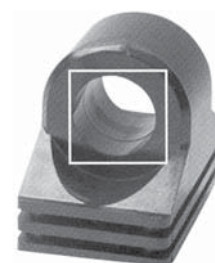
The undervoltage device will be tested for pickup and dropout voltages.

Storage of Breaker Data History

All breaker information, unique identification number, and Eaton test results shall be recorded on the reconditioner test form and in the Eaton centralized database to track each breaker for predictive maintenance. A copy of the test form, with the test results and a quality certificate, shall be delivered with each circuit breaker.

Two-Year Warranty on Reconditioned Breakers

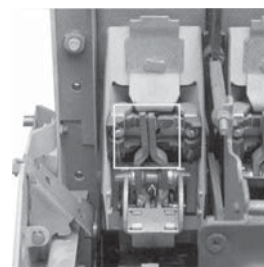
Each Class 1 reconditioned LV power circuit breaker will include Eaton's 2-year warranty.



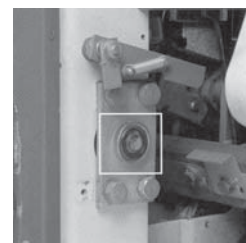
Hidden cracks or defects in insulation material may exist and can only be detected by component level disassembly and cleaning.



Critical silver-plated surfaces may have plating removed by harsh cleaning methods.



Misaligned contacts can occur if the reconditioner doesn't follow the original manufacturer's adjustment information.



Improperly cleaned and lubricated bearings can cause premature failure of the mechanism or failure to latch when closing.



Reconditioned and retrofitted with new trip system.

Retrofit Service—Digitrip Microprocessor Trip Unit Kits

General Description—Application

In the past, there have been three types of automatic control for low voltage power breakers:

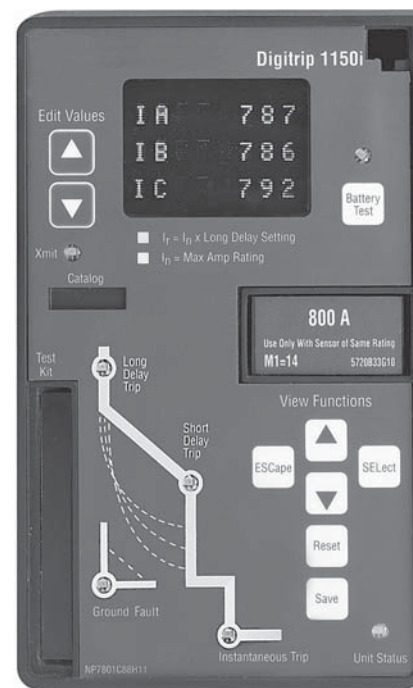
- **Electromechanical (EM) trip units**, were initially used in the early 1950s and phased out by all manufacturers in the mid-1970s. These trip units were comprised of solenoid, springs, diaphragm, seals and air venting apertures. Three trip units were required per breaker. Due to age or harsh environments, these devices would fail or lose calibration, and they required a great deal of preventive maintenance
- **Solid-state peak sensing trip units** were an improvement and provided improved reliability and accuracy. Only one trip unit was required per breaker; however, peak sensing trip units were not able to handle harmonic conditions. They caused nuisance tripping and unnecessary downtime
- **State-of-the-art true rms sensing trip units** enable the measurement of current rather than the sensing of current. As microprocessor-based digital devices, these trip units can take discrete samples of the current waveform in each phase. By applying a mathematical algorithm, current is accurately mapped out and measured. This method of measurement adapts to changing harmonic content while providing repeatable and reliable protection

Eaton's type Digitrip RMS retrofit kits are fully engineered, field installable retrofit kits that enable the user to completely replace an existing tripping system with the third type of technology. These kits are applicable to (600 Vac) low voltage power breakers and can be applied to Eaton power breakers and non-Eaton power breakers.

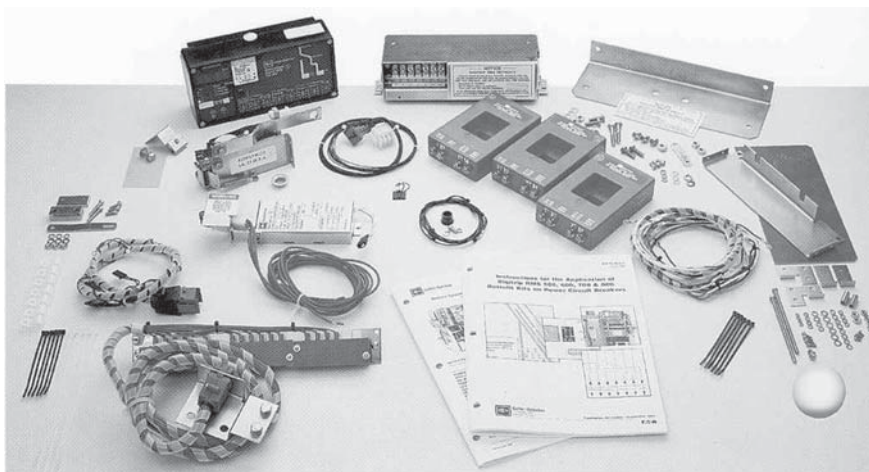
Digitrip RMS retrofit kits provide true rms sensing, the most accurate and current state-of-the-art technology for measuring amperage loads. True rms sensing removes the possibility of false tripping due to harmonic distortion of the power waveform and enables greater accuracy in selective coordination of the power distribution system. The microprocessor-based Digitrip trip unit also allows communications for remote monitoring to a host computer or local AEM via the PowerNet communication system.

Digitrip RMS Sensing Trip Unit Ratings

Digitrip RMS retrofit kits are available for a wide variety of both Eaton and non-Eaton low voltage power breaker frames. Ratings range from 100 A to 4000 A. Digitrip retrofit kits provide the user with adaptive flexibility due to multi-tapped current sensors and interchangeable rating plugs and programmable pickup and time delay settings.



**Advanced Trip Unit for Retrofit
to Existing DS and DSII Breakers
(International Version Shown)**



Digitrip RMS Retrofit Kits for Low Voltage Power Breakers

Kit Components—Features

Digitrip retrofit kits come in several different model types (see **Table 41.5-1**) that provide a variety of features:

- True rms measurement and protection is extremely accurate and able to accommodate harmonic content and disturbances
- Ground fault protection may be added to an existing power breaker (in a three-wire and a four-wire version)
- Zone interlocking is available on the short time and ground fault modes of protection. This enables enhanced selectivity for high fault and ground fault coordination between the main and feeder breakers
- Local monitoring via a red LED display enables the user to step through and read currents and energy readings for each phase and ground
- Remote monitoring via the PowerNet communications system enables a host computer or local display monitor to display all pertinent information regarding static and dynamic operation of the breaker

Trip Functions

All Digitrip RMS retrofit kit types are available with the necessary combinations of Long, Short, Instantaneous and Ground Fault (LSIG) modes of protection as depicted and deemed necessary by industry standards. The combinations of modes of protection are:

- LI
- LS
- LSI
- LIG
- LSG
- LSIG

Packaged Digitrip RMS Retrofit Kit

Each Digitrip RMS retrofit kit includes a Digitrip trip unit, an auxiliary CT module, a Direct Trip Actuator (DTA), quantity (3 or 4) current sensors, a rating plug, interconnecting wiring harnesses, mounting brackets, copper connectors (when required), hardware and installation instructions. Digitrip RMS retrofit kits are complete tripping systems engineered specifically for each breaker type and frame rating. All kits are designed for field installation.

Application and Service Condition

In order to ensure that Digitrip RMS retrofit kits are successfully applied, installation must only be done by a qualified individual. Appropriate testing must be performed to qualify the retrofitted breaker before placing the breaker in service. Digitrip RMS retrofit kits will provide protection in accordance with their published time-current characteristic curves and in accordance with the original breaker manufacturer's specifications on breakers that have been maintained properly and operate in accordance with the original manufacturer's operating instructions.

Service Life

The physical structure, bus assemblies and control wiring of switchgear are normally in good condition. The replacement of the trip system coupled along with either refurbishment or reconditioning of the breaker will prolong the life of the switchgear and provide modern state-of-the-art protection.

Availability of Digitrip Retrofit Kits

Digitrip retrofit kits are currently available for select breaker frames for the following manufacturers:

- Cutler-Hammer
- Westinghouse
- General Electric
- ITE
- Allis-Chalmers
- Federal Pacific
- Roller Smith
- Siemens-Allis
- Retrofit kits using OPTIM 750 and 1050 trip units are available for use on DB and DS breakers
- Retrofit kits using Magnum 520M, 520MC and 1150 trip units are available for use on DB and DS breakers

Table 41.5-1. Kit Type

Digitrip Kits Features	RMS 510	RMS 510 Zone	RMS 610	RMS 810	RMS 910
Cause of trip LED indicators	■	■	■	■	■
Integral self test	■	■	■	■	■
Trip reset button	■	■	■	■	■
Thermal memory hardware driven					
Thermal memory software driven selectable (on/off)	■	■	■	■	■
Discriminator circuit on LS and LSG protection modes					
Discriminator circuit on LS and LSG protection modes selectable (on/off)	■	■	■	■	■
Zone protective interlocking for short time and ground fault modes of protection		■	■	■	■
Auxiliary contact for long time, short circuit and ground fault functions		■	■	■	■
Local display of phase currents			■	■	■
Local display of ground currents			■	■	■
Local display of cause of trip			■	■	■
Local display of energy (MWh)				■	■
Local display of peak demand (MW)				■	■
Local display of present demand (MW)				■	■
Communication with PowerNet communicated data includes: All display values Trip unit status High load alarm Cause of trip Rating plug status Breaker status Reason for breaker status				■	■
Trip settings				■	■
Power factor				■	■
Control via the PowerNet system (open/close)				■	■
Voltage phase-to-phase, displayed on trip unit and communicated via PowerNet communication					■
Total current harmonic distortion (THD); phase A, B, C. Displayed on trip unit and communicated via PowerNet communication					■
Total current harmonic distortion per harmonic from the 2nd through the 27th harmonic displayed on trip unit and communicated via PowerNet communication					■
System power factor. Displayed on trip unit and communicated via PowerNet communication					■
Waveform analysis data to PowerNet computer					■

Information Required to Order the Proper Kit

In order to obtain the proper Digitrip RMS retrofit kit, the following information should be provided to Eaton:

- Breaker nameplate information, including manufacturer, breaker type, ampere frame size, and whether the breaker is manually or electrically operated
- Drawout or fixed mounting
- Fused or non-fused
- Digitrip trip unit type required: 510, 610, 810, 910
- Protective functions required: LI, LSI, LS, LIG, LSG, LSIG
- Continuous current rating required (trip rating of breaker)
- Three-wire or four-wire system (determines number of sensors required)

To properly select options for the Digitrip RMS retrofit kit, the following questions need to be answered:

- Will the customer supply 120 Vac control power or is breaker-mounted CPT needed? (Applies only to Digitrip 610, 810 and 910)
- Are zone interlocks required?
- Does the application require relay outputs from the Digitrip 610, 810 or 910 for remote indication?
- Does the breaker have an existing Amptector or Digitrip trip unit installed? If so, what is it?

Table 41.5-2. Further Information

Description	Publication
Sales brochure for Digitrip RMS retrofit kits	B.22D.01.S.E
Instructions for the application of Digitrip RMS retrofit kits on power circuit breakers	AD 33-855- 4
Digitrip RMS 510 trip unit	IL 29-885-B
Digitrip RMS 610 trip unit	IL 29-886-A
Digitrip RMS 810 trip unit	IL 29-888-A
Digitrip RMS 910 trip unit	IL 29-889-A
Time current curves for DS and DSL circuit breakers	AD 32-870
Retrofit kit product guide call 1-800-937-5487	Doc. #9375487
Illustrates catalog number system for each engineered kit	YES Catalog Tab 17

Replacement Service for AR Series Low Voltage Breakers

Application

Replacement parts for old breakers are becoming harder and harder to find as technology continually advances. However, replacing these breakers is desirable, as new breakers will greatly extend equipment service life.

Eaton resolves the parts availability issue with AR Series replacement breakers. AR Series breakers, brand new from the ground up, are designed to be electrical and mechanical equivalents of the breakers they replace. These units are not "retrofits," and no parts are reused from the original breakers.

Mechanism parts and control components are current production items and are in stock. Additionally, AR Series breakers use common components across the product line. This can save in future spare parts investment.

Cell modifications, if required, are kept to a minimum. This reduces out-of-service time, yielding consistent product designs, while reducing initial installation costs. AR Series breakers correctly interface with compartment cell switches, and safety interlocks are maintained or improved.

Reduce Maintenance Cost and Downtime with Reliable Magnum DS Breaker Technology

Maintenance procedures commonly associated with vintage air magnetic circuit breakers take 8–12 hours on average per breaker. Eaton's Magnum DS breaker technology reduces normal maintenance to 2–6 hours per breaker. The arc chutes, contacts, mechanism and control components can be easily inspected, and minor maintenance (such as lubricating the mechanism) can be easily accomplished.

Arc chutes can easily be removed with two bolts and be visually inspected or replaced. By removing the arc chutes, viewing the main contacts along with their contact wear indicator results in a quick and simple decision to replace if necessary. Spare parts inventory is considerably reduced because AR Series breakers use common parts throughout the entire product line, including new Magnum DS switchgear assemblies.

Increase Interruption Rating

Dynamic changes resulting from larger transformers, bus ties, parallel generation and new sources of incoming power can drastically increase the level of available short-circuit current in LV power distribution systems. The bus system's momentary capability can be increased and the entire switchgear structure can be re-certified to the new higher levels by Eaton's factory qualified service engineers. Many of the AR Series breakers are available to increase interrupting capabilities while still maintaining the original circuit breaker dimensions. This provides a savings versus the cost of replacing the switchgear. Cell-to-breaker coding systems are maintained or corrected to comply with IEEE/ANSI standards.

Increase Continuous Current Rating

Changes to industrial and commercial facilities, such as increased manufacturing operations, will typically increase the demand for electrical power within the facility. Often, an increase in electrical demand can cause the load on a circuit to exceed the circuit breaker's continuous current rating. Eaton's factory-qualified service engineers can inspect existing LV metal-enclosed switchgear, including the existing breaker cubicles, line and load power stabs, load cables and bus system to verify the application for a circuit breaker ampacity upgrade. Many of the AR Series breakers are available with increased continuous current ratings.

Standards

All AR Series LV power air circuit breakers are designed and tested to meet or exceed IEEE/ANSI C37.59-2002 standards. This ensures compatibility with existing installations and IEEE/ANSI application guidelines. IEEE/ANSI certification and certified factory production test reports are available.

Features

- AR Replacement Breakers are 100% rated, UL listed, and built and tested in an ISO 9001 and 14001 certified facility
- Safety: the cell door can remain closed with the breaker in connect, test or disconnect position. Simultaneously the trip unit, open-close controls and breaker nameplate data are all readily visible
- Designed for easy access, inspection and minimal maintenance. The stored energy mechanism, control devices, accessories and secondary contacts are easily accessible by removing the front cover. The contact wear indicator eliminates the need for elaborate testing to determine if the contact assembly needs replacing. The arc chutes can also be easily removed and inspected
- Installation savings and robust interface reduce installation and commissioning time with our unique design concept. No modifications required to the original line/load power stabs or secondary disconnect contacts. Modifications to the original cubicle are often eliminated with an easy-to-install cubicle adapter (cassette). The cassette includes new extension rails and levering-in adapters, resulting in a more robust breaker-to-cubicle interface. We also provide a new door to match the replacement breaker

Availability

Designs are available for:

- Westinghouse
- General Electric
- Allis-Chalmers
- Federal Pacific
- ITE/ABB



FP-25 Original Magnetic Circuit Breaker



FP25-AR Air Replacement Breaker

Table 41.5-3. Further Information for Low Voltage Power Air Replacement Breakers

Description	Publication
Allis-Chalmers Types LA-600 and 800 Federal Pacific Electric Type-25 Federal Pacific Electric Type-50	PA01906001E PA01906002E PA01906003E
Federal Pacific Electric Type-75 and 100 General Electric Type AK-2A-50 General Electric Type AKR-4A-30 and 30H	PA01906004E PA01906005E PA01906006E
Westinghouse TYPE DB-25 and 25L Westinghouse TYPE DB-50 and 50L Westinghouse TYPE DB-75	PA01906007E PA01906008E PA01906009E

Low Voltage Breaker Drawout Vacuum Starter Replacement



DB-25 LV-VSR

General Description

Eaton's low voltage VSR is a self-contained vacuum starter replacement for a low voltage drawout air circuit breaker used for motor starting applications.

In some cases, LV air circuit breakers are used for motor starting applications. Air circuit breakers are not designed to withstand the frequent switching service and mechanical stresses associated with repetitive motor starting duty. This is due to the breaker mechanism that must be designed to close and latch against a fault. In order to meet these requirements, the mechanism must close at high speeds with a great deal of force. Frequent closing operations stress and deteriorate the breaker mechanisms.

Eaton's LV-VSR is a self-contained replacement vacuum starter for an LV drawout air circuit breaker. The LV-VSR is interchangeable with the drawout breaker element and requires no cell modifications.

Features

Advantages

The use of an LV-VSR vacuum starter can prolong device life and significantly reduce maintenance repair and downtime.

A low voltage air circuit breaker has an effective life of 4000 operations while an LV-VSR vacuum starter has an effective life of 1,000,000 operations. For example, a motor starting application that required two starts per hour on continuous duty would require a major rebuild of the LV breaker within three months.

The expected life of an LV-VSR vacuum starter would be over 50 years.

The LV-VSR vacuum starter uses state-of-the-art Eaton vacuum interrupters. The interrupters employ the latest vacuum technology with long life, resistance to environmental contaminants, and positive contact wear indicators.

The integral, solid-state trip units used on the air circuit breakers are designed primarily for cable and transformer protection. Motors require more precisely set overcurrent devices that prevent motor damage as well as avoiding nuisance tripping. A solid-state relay, Eaton Type C440, provides overload protection and phase unbalance protection. This relay was exclusively designed for motor protection.

Motor Starter

The LV-VSR consists of an Eaton V201 vacuum contactor, Class J current limiting fuses, multi-function motor protective relay, three current transformers and an integral control power transformer.

Vacuum Contactor

Eaton's V201 vacuum contactor is designed for starting and controlling three-phase, 50/60 Hz AC motors. Current interruption is contained within the vacuum bottles and no arc byproducts are vented to the outside environment. Contact condition is given by wear indicators.

Series Current Limiting Fuses

Class J current limiting fuses provide short-circuit protection and allow a combination rating of 100 kA at 480 V or 600 V.

C440 Electronic Overload Relay

Eaton's C440 multi-function electronic, motor protection relay provides the following features:

- Overload protection, Class 10A, 10, 20 or 30
- Phase unbalance protection, selectable (ON/OFF)
- Ground fault selectable (ON/OFF)
- Remote reset
- Alarm relay output contact
- LED status indication
- Communication modules
 - Modbus RTU RS-485
 - DeviceNet with IO
 - PROFIBUS with IO

VSR Designs

- Westinghouse DS
- GE
- ITE
- and others

Contact EESS at 877-276-9379 for more details.

Life

Exceptional electrical and mechanical life is offered by the V201 contactor—up to 1,000,000 electrical operations and 2,500,000 mechanical operations, even under harsh conditions.

Drawout Capability

The LV-VSR is mounted on a drawout frame and maintains the safety interlocking system of the LV switchgear.

Ease of Installation

The LV-VSR may be inserted into a standard breaker compartment without modification to the compartment. The primary and secondary contact structures and drawout mechanism are identical. The LV-VSR control scheme will interface with standard switchgear wiring with no cell modifications and remote control schemes, if existing, are maintained.

Safety Features

The LV-VSR vacuum starter retains all the safety features of the LV switchgear including:

- Racking the LV-VSR vacuum starter is prevented while the contactor is in the closed position. Closing the LV-VSR vacuum starter is prevented while racking
- Breaker position indication is provided (connected, test, disconnect, remove)
- The LV-VSR vacuum starter is padlockable (optional) in either the connect, test or disconnect positions
- Positive ground connection is maintained
- Closed door tripping
- Closed-door control, if existing, can be maintained

LV-VSR Control Features

LV-VSR vacuum starter offers the following standard control features. Other devices can be supplied on request.

- Start-stop pushbuttons and run pilot light
- Eaton C440 electronic overload relay
- 2A/2B auxiliary contact
- 1A/1B trip contact (overload or short circuit)
- Provision for remote control operation
- Integral control power transformer
- Custom-designed wiring schemes

Ease of Maintenance

The LV-VSR control components are front mounted for easy access.

The LV-VSR uses the same line and load finger clusters, secondary contact assemblies and drawout mechanism as the original circuit breaker. Renewal parts are readily available.

Technical Data and Specifications

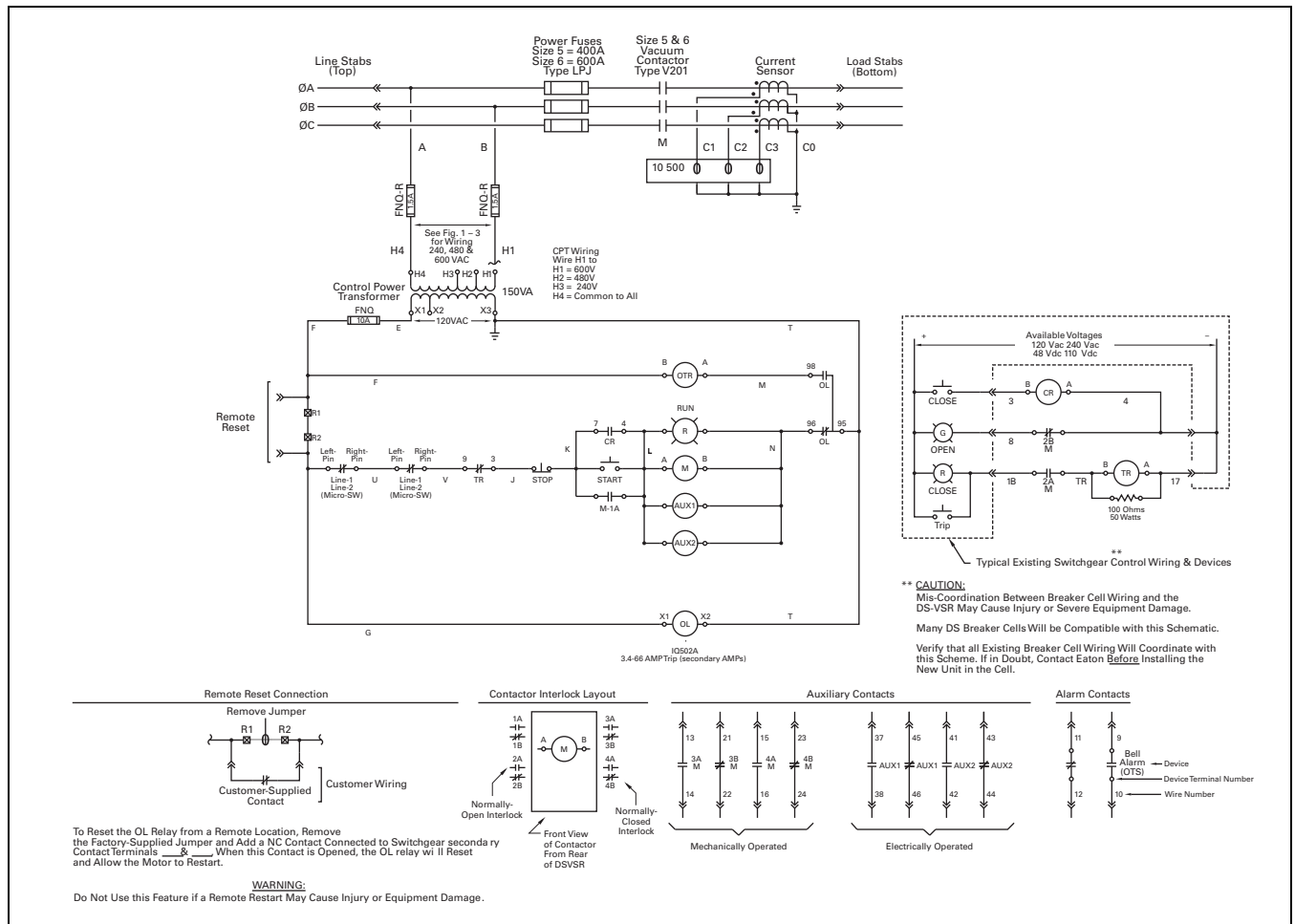
Ratings

The LV-VSR vacuum starter is rated as follows:

- Maximum continuous current—425 A
- Maximum voltage rating—600 V
- Short-circuit rating at 240–600 V 200 kA
- Maximum motor hp at 480 V, 235 hp
- Maximum motor hp at 240 V, 117 hp
- Maximum motor hp at 600 V, 294 hp



Westinghouse DB-25 Vacuum Starter Replacement



VR Series MV Vacuum Replacement Circuit Breakers

General Description

Breaker problems? If your electrical power system uses vintage medium voltage (MV) switchgear and air-magnetic power circuit breakers, you may be experiencing some common problems. Age, the lack of maintenance, environment, duty cycle, changes in system fault levels and regulatory changes can turn relatively benign devices into problematic drains on system reliability, safety and profitability.

Because they are the main arteries for incoming power, MV power circuit breakers are often omitted during routine maintenance outages. Lack of maintenance and lubrication slows mechanism opening and closing speeds. As breakers age and accumulate operations, regular and frequent maintenance must be performed to ensure interlock functionality to protect employees and to prevent breaker failure. Replacement parts are more difficult to find and their costs increase at alarming rates. Deterioration in performance will eventually dictate more frequent and extensive maintenance.

Exposure to moisture, contaminants and excessive heat causes a loss of insulation dielectric strength. This leads to an increase in partial discharge, corona and possible BIL failure.

Incoming system changes can increase short-circuit currents to levels greater than existing breaker ratings and render them inadequate to interrupt a fault. A failure to interrupt a primary fault can damage a plant's entire electrical system and injure nearby employees.

Many power circuit breakers are improperly applied as motor starters. High inrush currents and frequent operation erodes contacts, shortens mechanism life and requires additional maintenance. The level of maintenance will increase and the time between maintenance intervals will decrease to a point where it seems maintenance is a constant requirement.

Most MV air-magnetic circuit breakers also contain asbestos in their arc chutes. Asbestos is a hazardous material that should be removed. Replacement asbestos-free arc chutes, if available, are expensive. This makes the cost of rebuilding MV breakers prohibitive because interruption relies heavily on the performance of the arc chutes. In most cases, asbestos arc chutes can not be effectively maintained and their performance decays at an undetectable rate.

Breaker Solutions

There are three possible solutions to the problems.

- Replace the switchgear and breakers with new equipment. This approach eliminates the issues but is very expensive and requires an extensive outage—and generally requires installing new MV cables
- Existing structures can be retro-filled with breaker mini-modules and bus modifications to accept current production vacuum breakers. This also requires an extensive outage, is slightly less expensive than the first option, and cables can usually remain unchanged
- Replace the existing air-magnetic devices with new vacuum replacement circuit breakers (VR Series). This approach provides the most complete and cost-effective solution

VR Series breakers provide modern vacuum interrupter technology without requiring an outage to replace the switchgear and cables. Usually, no structure modifications are required to accommodate the VR Series breakers. Short-circuit levels can also be increased within the same physical size and bus bracing can be increased and the structures certified to match the new momentary levels of the higher short-circuit ratings.

Eaton manufactures an extensive line of VR Series breakers (over 200 different ratings) to replace air-magnetic circuit breakers manufactured by:

- Westinghouse
- General Electric
- Allis-Chalmers (Siemens)
- ITE (ABB)
- Federal Pacific Electric

All VR Series breakers are available with Eaton's Sure Close MOC operator technology. Sure Close is guaranteed not to stall a circuit breaker during closing and prevents damage to existing MOC switches. VR Series breakers are design tested to applicable IEEE/ANSI Standards.

A line of fused MV breaker-to-motor starter replacements (MV-VSR) is also available for the most popular 4.76 kV breakers. The MV-VSR is designed to provide more than 150,000 operations (a performance level that no circuit breaker can achieve, regardless of technology) and can start motors up to 2500 hp. The MV-VSR is fully interlocked, has anti-pump control circuits and latching contactors, and is design tested to replace breakers that are being used as motor starters.

Application Description

Most medium voltage air magnetic power circuit breakers have been in service for 30 years and some for as long as 70 years. They were reliable and for many years and maintainable. Increased short-circuit capabilities in utility and industrial power systems have created "over-duty" situations with many of these breakers. Parts availability has also increased the cost of maintaining the breakers in peak condition.

In the mid 1970s, circuit breaker manufacturers began introducing vacuum technology for MV power circuit breakers. It was desirable and feasible to incorporate the advantages of vacuum technology into replacement breakers that would interchange with the existing MV air magnetic power circuit breakers to extend the useful life of their existing switchgear. Most users wanted a replacement that was functionally interchangeable, both electrically and mechanically, with their existing MV air magnetic power circuit breakers that required little or no cell modifications.

The market responded by offering "retrofits" that used the existing breaker trucks (frames) and vacuum circuit breaker modules. These alternatives provided extended life for electrical equipment, reduced maintenance, and allowed increased capabilities for many distribution systems. IEEE/ANSI established a standard for conversions (IEEE/ANSI C37.59) in 1991 that put consistency in the conversion process and established design testing requirements.

However, conversions were costly, caused inconvenience for users, required months to complete, and the lack of configuration control made it difficult to standardize designs. Eaton now offers new VR Series vacuum replacement circuit breakers that can be supplied in place of the old conversion technology. Unlike conversions, VR Series breakers are new from the ground up and offer improved performance, maintainability and convenience over conversions. They can be supplied in large quantities to facilitate complete substation upgrades in a single outage. System upgrades to handle higher short-circuit levels are available.

Eaton VR Series vacuum replacement circuit breakers are fully engineered and tested for modernizing electrical power distribution systems. In most cases, VR Series breakers extend the life of the metal-clad switchgear while improving performance and system reliability.

When upgrading systems to use VR Series breakers, EESS engineers can perform on-site cell alignment, breaker levering system repairs and control system modifications. Under supervision and approval of an Eaton Registered Professional Electrical Engineer, they manage computer-generated short-circuit, coordination and load flow studies for final breaker trip settings.

Ratings

VR Series vacuum circuit breakers are available for 5 kV through 15 kV distribution systems.

- Maximum voltages: 4.76 kV, 8.25 kV and 15 kV
- Interrupting ratings: 4.76 kV: 250 MVA (29 kA), 350 MVA (41 kA)
8.25 kV: 500 MVA (33 kA), 15 kV: 500 MVA (18 kA), 750 MVA (28 kA), 1000 MVA (37 kA), 1500 MVA (63 kA)
- Continuous current: 1200 A, 2000 A, 3000 A (5–15 kV), 4000 A forced cooled (5–15 kV)

Features

Eaton is a world leader in circuit breaker technology and is the world's largest producer of vacuum interrupters. In fact, Eaton's vacuum interrupters are used in many manufacturers' switchgear breakers worldwide. The same reliable vacuum technology is used in our VR circuit breakers. The contact structure of Eaton's vacuum interrupters is up to 70 percent larger than competitive interrupters of the same ratings. Many of the components and sub-assemblies in our MV VacClad-W metal-clad switchgear are the same as those used to manufacture the VR product line. This commonality helps reduce spare parts inventories and the amount of required maintenance training.

Eaton vacuum technology reduces maintenance. Because the contacts are sealed from contaminants in the environment, no adjustments or cleaning of the main contacts are required, and the main contacts require no special gauges or devices to measure wear or contact pressure. Condition-based maintenance, lubrication and testing can be performed in a fraction of the time required for air magnetic circuit breakers.

The Eaton non-sliding current transfer system eliminates the need to check and tighten connections between the vacuum interrupter stem and the main conductors or the circuit breaker. The connection is permanent and provides high conductivity without creating hotspots and Holm effect as found in half-clamp connections.

SURE CLOSE MOC operators are available to provide dependable MOC operation that is decoupled from the main closing function of the VR Series breaker mechanism. This prevents the VR Series breaker from stalling or failing to latch during the closing operation. SURE CLOSE mechanisms also have adjustable stop positions to control over-travel of MOC switch operators.

Service Life

As long as the bus structures, insulation systems and general mechanical condition of the switchgear cells/structures are maintained in good condition, equipment life can easily be prolonged with the addition of VR Series vacuum replacement circuit breakers.

Availability

VR Series vacuum replacement circuit breakers are available in a wide range of ratings and models to replace medium voltage (MV), air magnetic circuit breakers originally manufactured by:

- Westinghouse
- General Electric
- Allis-Chalmers/Siemens
- Federal Pacific Electric
- ITE/ABB

Required Information

In order to obtain the correct VR Series breaker, the following information should be provided to Eaton:

- Original switchgear manufacturer
- Original breaker manufacturer
- Breaker type or catalog number
- Maximum voltage rating continuous current rating and maximum short circuit or MVA rating
- Control voltages
- List of options and/or modifications
- Copy of schematic and wiring diagram
- Year of manufacture of original breaker and switchgear
- MOC requirement

For site-specific specifications, contact your local General Field Sales Force office, your local Engineering Services center, or call 1-877-276-9379.

Detailed Requirements

This section covers the design, testing and manufacturing requirements for new MV vacuum replacement (VR Series) circuit breakers for use in medium voltage (MV) metal-clad switchgear. The VR Series circuit breakers will be functional replacements (both mechanically and electrically) for the air magnetic circuit breakers they replace. The VR Series vacuum replacement circuit breakers will be interchangeable (within the limits of the original switchgear) between different types of cells (structures) of the same voltage, MVA and ampere class with minimum or no cell (structure) modifications.

Conversions, as defined by IEEE/ANSI C37.59-2002 6.1.4.2, are not covered and will not be considered as an alternative or substitute for new VR Series vacuum replacement circuit breakers.

Scope of Work

The EESS group will provide all project management, factory and field engineering, short-circuit and coordination studies (if required and at an additional charge), supervision, labor, material, tools, rental, test equipment and transportation as defined for a complete VR Series circuit breaker replacement of the required existing medium voltage switchgear circuit breakers. The VR Series vacuum replacement circuit breakers will be designed for maximum voltages of 4.76 kV, 8.25 kV or 15 kV as required.

MVA Ratings

The available MVA rating of the VR Series vacuum replacement circuit breakers are as follows:

Table 41.5-4. Ratings

Volts kV	MVA	
	Original	New
4.76	100–250 ①	250
4.77	100–250 ①	350
8.25	150–500	500
15	150–500	500
	150–500	750
	150–500	1000
	750	1000
	150–1000	1500

① 26-inch (660.4 mm) wide cells only.

All Eaton switchgear structures designated for VR Series vacuum replacement circuit breakers with increased MVA levels will have the existing bus bracing analyzed. EESS will determine if bus bracing is capable of withstanding the maximum (peak) momentary ratings per ANSI C37.09.4.6.2.4 and ANSI C37.20.2.5.2.4 capabilities of the new VR Series vacuum replacement circuit breakers. EESS will provide documentation to verify that the switchgear bus is sufficiently braced to handle the new ratings or supply the cost as a separate item to increase the bus bracing of all designated switchgear structures in the lineup to comply with the increased MVA ratings. Following the study and/or the bracing modifications, Eaton's service engineer will affix a nameplate to each switchgear structure stating the new MVA rating, the manufacturer's name and the date of verification or upgrade.

Cubicle Modifications

The VR circuit breakers shall be interchangeable with existing breakers of the same continuous current and MVA ratings with little or no required modifications to the existing cubicles. Existing cell coding systems shall be retained where possible. VR Series vacuum replacement circuit breakers with upgraded/increased MVA or continuous current ratings do require modifications to the cubicle coding system to prevent the insertion of breakers that do not have the same ratings as the upgraded VR Series vacuum replacement circuit breakers. Any required cell modifications should be reversible.

Applicable Standards

All VR Series breakers are designed, manufactured and tested in accordance with applicable sections of the following standards:

- ANSI C37.59-2007 (cell interface and testing criteria), ANSI C37.04, ANSI C37.06, ANSI C37.09, ANSI C37.20.2, ANSI C37.55, ANSI C37.100
- IEEE STD 4-1995

Materials

All materials used in the manufacturing of the new VR Series breakers will be new and unused. No parts or materials from the original air-magnetic circuit breakers will be reconditioned and reused in the manufacture of the new VR Series breakers. All components used in the manufacturing of the new VR Series breakers, including mechanism, vacuum interrupters and frame components will all be manufactured by Eaton to ensure single-source reliability and responsibility.

Vacuum Circuit Breaker Module Features

The VR Series breakers will use vacuum circuit breaker modules manufactured by Eaton. Acceptable conversion modules are the VCP-18WR, VCP-20WR, VCP-29WR and the VCP-29WRSE.

Common Pole Shaft

The circuit breaker mechanism will open and close all three phases and any auxiliary devices via a common operating shaft to ensure consistent and simultaneous operation of the main contacts. The shaft will be supported at the ends and along its length with bearings. The main drive shaft will be connected to the individual vacuum interrupters via insulated drive links.

Insulated Drive Links

The mechanism drive shaft will be connected to each moving contact via an insulated drive link made of glass-reinforced polyester for element types VCP-18WR, VCP-20WR and VCP-29WR and cycloaliphatic epoxy for the VCP-29WRSE. The insulated link material is nonhygroscopic and meets the flame-retardant requirements as set forth in ANSI C37.20.2.5.2.7. The drive links are easily removable with single clevis pins at each end and spring retaining clips.

Shock Absorber System

The mechanism will contain a shock absorber system to dampen the opening force of the circuit breaker. The shock absorber has sufficient resilience to prevent contact bounce that could cause a re-strike of the main contacts during the opening of the circuit breaker or during a spring discharge. The VCP-20WR, VCP-29WR and VCP-29WRSE vacuum conversion element's mechanism consists of a series of parallel steel plates with spring separators that spread the plates during breaker opening. The shock absorber has a design life of 10,000 breaker opening and closing cycles without the need for repair, replacement or adjustment. The VCP-18WR has a sealed replaceable shock absorber and can be adjusted if replaced or during initial mechanism assembly.

Manual Trip and Close

The mechanism has front-accessible manual close and trip operators that are directly connected to the breaker operating mechanism and are an integral part of the electrical close and trip coils.

Operations Counter

Each VR Series vacuum replacement circuit breaker mechanism has a five-digit non-resetting mechanical operations counter connected to the operating shaft.

Spring Charged Indicator

Each operating mechanism will be equipped with a visible indicator to show the state of the stored energy mechanism. The indicator will show when the spring is fully charged or discharged.

Auxiliary Contacts

The breaker will have a low inertia, rotary operated auxiliary switch connected to the main pole shaft assembly. Connections will be made via insulated ring-tongue terminals.

Vacuum Bottle Assembly

The vacuum bottle assembly will be constructed from virgin materials and manufactured by Eaton. The contacts will be principally composed of powdered metal, chromium-copper contact material. The powdered metal is fused under high pressure to form a consistent contact material. The contacts are machined to form spiral petal contacts to assist in the swirling of the arc during interruption.

The edges of the ceramic components will be "metalized" and fired before assembly. The components are inspected and assembled in a Class 1000 clean room prior to sealing the components. The components are inserted into a vacuum heat chamber and sealed under vacuum. No "pinch tubes" are used.

A stainless steel corrugated bellows achieves isolation of the ambient air and the vacuum. The moving contact stem of the vacuum interrupter has a machined groove to prevent rotation of the contact within the vacuum chamber.

The vacuum interrupter has a visual method of identifying contact wear without the use of gauges or other devices. In addition, a separate visual "T-cutout" is used to verify that the mechanism is applying adequate spring pressure to the contacts when the breaker is in the closed position.

The contacts are self-aligning and do not require adjustments for the life of the vacuum interrupter assembly. The contacts also have a spring system to apply proper contact pressure. The operation of the contacts cause a wiping action to clean the contact surfaces.

Insulated Pole Assemblies

Pole assemblies are insulated from ground with non-hydroscopic insulating materials manufactured from glass-reinforced polyester.

Current Transfer System

The current transfer from the conductor stem to the primary bushing assemblies is via a non-sliding current transfer system consisting of a fused stem assembly and a V-Flex silver-plated copper leaf conductor or folded leaf copper shunts. The stems have the adjoining conductors mechanically fused with the stem material. This junction forms a solid current transfer.

Trip-Free Operation

The new VR Series vacuum replacement circuit breaker operation mechanism is a "true Trip-Free" design. When the trip function is mechanically engaged and held and the close function is initiated either electrically or mechanically, the contacts do not close. The contacts are restricted to 10% of the total travel.

Mechanical Status Indicator

Each new VR Series vacuum replacement circuit breaker has a mechanical status indicator with the word "CLOSED" on a red background when the breakers are closed and the word "OPEN" on a green background when the breakers are open.

Breaker Truck/Frame Assembly Frame Materials and Plating

The frame is constructed from steel, using a combination of bolting and welding to assemble the frames. All frames are zinc-plated with a yellow dichromate finish (commonly referred to as yellow-zinc dichromate).

Wheels and Casters for Transport

VR Series vacuum replacement circuit breakers are supplied with a transport system that is a functional replacement of the transport system of the original design. The transport system conforms to the requirements of the original design.

Hardware

All hardware is a minimum Grade 5, zinc-plated or black oxide.

Bushing and Interface Conductor Material

Primary and power frequency interface conductors are constructed of 100% IACS electrical grade conductive copper. Conductors are either silver- or tin-plated to a thickness of 0.0001–0.0002 for non-sliding surfaces and 0.001–0.002 for sliding surfaces. The power frequency conductors are sized to carry the full load ampacity of the circuit breaker without exceeding the temperature rise established in ANSI C37.09.

Insulation Systems

All bushings use either glass-reinforced polyester or molded cycloaliphatic epoxy insulation systems or engineer approved equal. Fluidized epoxy coatings are used to insulate interface conductors when necessary.

Phase barriers are manufactured from GPO-3 glass-reinforced polyester or equivalent and designed to isolate individual phase conductors. Openings are minimized to reduce the possibility of ionized gas propagation between phases.

Corona Shields

All 8.25 kV and 15 kV class breakers have internal corona shields when bushings are mounted on metallic back planes. The corona shields are permanently grounded. Bushings mounted on non-metallic back planes do not have internal corona shields.

Primary Connections

Primary connections (finger clusters) are new and designed to carry the full nameplate rating of the replacement breaker without exceeding the allowable temperature rise as stated in ANSI C37.04.5.4.2-1979. In addition, the primary connections are capable of withstanding the full momentary/close and latch rating as well as the K*I current rating for 2 seconds without melting, arcing or pitting the contact surface.

Ground Contacts

A metal-plated, self-coupling, separable grounding contact shall be supplied.

Control Circuit Wiring

Control wiring is SIS cross-linked polyethylene, #14 AWG minimum except for short runs such as coil and motor leads. Insulated ring tongue terminals are used. Solder or "fast-on" type connections are not used. Upfront, easy access terminal blocks are provided for maintenance and troubleshooting.

Stored Energy Discharge

The replacement breaker incorporates a manual and an automatic system to completely discharge all stored energy before the circuit breaker is fully withdrawn from the switchgear housing. The system will never intentionally discharge the stored energy while in the connected position.

Passive Interlocks

The mechanism will have a passive interlock to block the insertion or removal of a closed breaker. The system also prevents the insertion of the levering tool at any time the breaker is in the closed position.

Active Interlocks

Each breaker has an active interlock system. The system is operated by the insertion or removal of the VR Series vacuum replacement circuit breaker. In the event the passive interlock is defeated, active interlock system will trip and open a connected, closed breaker if an attempt is made to remove it from the connected position. The system also holds the breaker in the "trip-free" position at all times between the test and fully connected positions.

Locking Means

Locking means is provided to lock the circuit breaker while in the fully connected or disconnected positions. The lock prevents the insertion or removal of the breaker. The lock will not prevent the breaker from being operated while in the fully connected position.

Secondary Contact Block

Control wiring connections between stationary structure and the removable breaker are provided with automatic, self-coupling contacts. The secondary blocks will be mold cycloaliphatic epoxy insulation. The pins are drilled and tapped to accept standard 8-32 screws for ease of maintenance and wiring changes. The secondary contact block is made of cycloaliphatic epoxy.

MOC Operator

All breakers will be furnished with MOC operators unless specified. The MOC operator will have sufficient power to operate the largest MOC switch or combination of switches in the switchgear lineup without affecting the breaker's ability to completely close and latch. The MOC driver is completely "decoupled" from the main breaker operating shaft and shall be powered by separate operating springs. The system is SURE CLOSE as manufactured by Eaton's electrical business.

Cell Coding System

Eaton will supply or interface with the cell coding system to prevent the accidental insertion of a breaker into a cell of a different voltage, current, interrupting capacity or physical arrangement than the type intended for the switchgear cell receiving the breaker.

Design and Certification (Type) Testing

Each new VR Series vacuum replacement circuit breaker supplied will have type tests performed on its base design to certify it to IEEE/ANSI standards. All Certification (Type) will be performed in a switchgear cell/structure when required or an equivalent structure where permitted by ANSI C37.09. Written test reports, data logs and digital reproductions of the pulse used to perform the BIL test will be on hand for review by the buyer. BIL—60 kV for 4.76 kV applications, 95 kV for 8.25 and 15 kV applications as a minimum> crest with 1.2 μ sec x 50 μ sec x 50% wave shape per ANSI C37.09.4.5.4.

The tests will be conducted per IEEE STD 4-1995. This test shall be performed in a breaker cell or cell equivalent with controlled humidity levels. Corrections for barometric pressure and ambient temperature will be applied to the test parameters. The breaker must pass a total of 54 shots.

Mechanical operations tests of each breaker design are performed in a switchgear cell designed to accommodate MOC switches. The maximum number of auxiliary MOC devices or their equivalent force will be applied during the test to ensure that the vacuum breaker has sufficient power to operate the auxiliary devices, successfully closes and latches during each operation, and that no fatigue or failure occurs. Consideration is given to designing a system that will not damage the MOC switch in the switchgear cell structure.

Momentary tests per IEEE/ANSI C37.20.2.5.2.4 will be performed of the completed vacuum replacement breaker including the vacuum breaker element, bushings, primary disconnects (finger clusters), all bus in the breaker unit, and all insulators and braces per ANSI C37.09, 4.6.2.4. This test is to prove the mechanical strength and integrity of the conductor and frame assembly of the complete new vacuum replacement breaker. This test is performed in a switchgear cell designed to accommodate the circuit breaker being tested. Anti-rotation devices may be added to the cell if required to prevent rotation. If anti-rotation devices are used in the test breaker, then they will be installed in all the switchgear cells intended to accommodate the new breakers.

Short-time current tests for 3 seconds at $K \cdot I$ current will be performed to confirm the breakers I^2t capability. The test will be performed in a switchgear cell.

Continuous rated current testing per ANSI C37.04-1979 without exceeding 65°C hotspot rise with a maximum ambient not to exceed 40°C. This test is performed in a breaker cell or a cell structure of the same equivalent volume, dimensions and ventilation as the original switchgear structure. Low Frequency Withstand—19 kV rms for 4.76 kV applications, 36 kV rms for 8.25 kV and 15 kV applications—per ANSI 37.09, 4.5.3.1. Interlock functional test per ANSI C37.20.2, 6.2.4. All production tests as stated in ANSI C37.09-1979.5. Timing values per pole will be provided for the vacuum element in msec.



VR Series Breakers

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