

Molded Case and Low-Voltage Power Circuit Breaker Health

New advances in the life expectancy monitoring of low voltage circuit breakers

Publication/
presentation details

Advances in circuit breaker predictive diagnostics dramatically improve power system reliability and reduce operating costs

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Introduction

Why breaker health matters

Molded case circuit breakers (MCCBs) and low-voltage power circuit breakers (LVPCBs) provide vital functionality for low-voltage power distribution systems and processes – protecting connected devices from both overloads and short circuits. A safe, economical, and effective way to connect and disconnect loads from the electrical source, MCCBs and LVPCBs are pervasive and applied across industries, including applications where uptime is critical. In a hospital, for example, the cost of an unexpected outage ranges from \$800,000 to \$1 million each day.



Figure 1. MCCBs protecting critical equipment at the Eaton Bluegrass Data Center in Bluegrass, KY.

Simply put, both MCCBs and LVPCBs are used in nearly every application around the world to provide an essential function – personnel and equipment protection. To this end, the proper operation of circuit breakers is critical. These LVPCBs operate reliably in countless settings and when properly applied they perform as intended. However, an effective ongoing maintenance program is critical to supporting reliable operations and controlling costs.

How do you find the needle in the proverbial haystack – the device that should be replaced? For example, recently a paper mill with 876 MCCBs in operation in just one location, took a closer look at its devices as part of a robust preventative maintenance plan. Of those 876 devices, five needed to be replaced. This represents 0.57 percent of the total breakers in that part of the facility. The questions to ask become:

- How do you know with confidence which MCCBs (or another type of circuit breaker) needs to be serviced?
- How do you avoid investing the time and resources to inspect all 876 circuit breakers to identify the equipment that needs to be replaced or serviced?
- Is it difficult to determine the condition of MCCBs and LVPCBs?

While there are various types of circuit breakers, all are comprised of five components: the molded case or frame, an operating mechanism, arc extinguishers, current carrying path, and a trip unit. For MCCBs these components are sealed in the frame and maintenance has historically been limited to the mechanical mounting, electrical wiring, and manual operation of the mechanism. Low-voltage insulated case breakers, and LVPCBs have more options for maintenance of these components due to their unique construction.

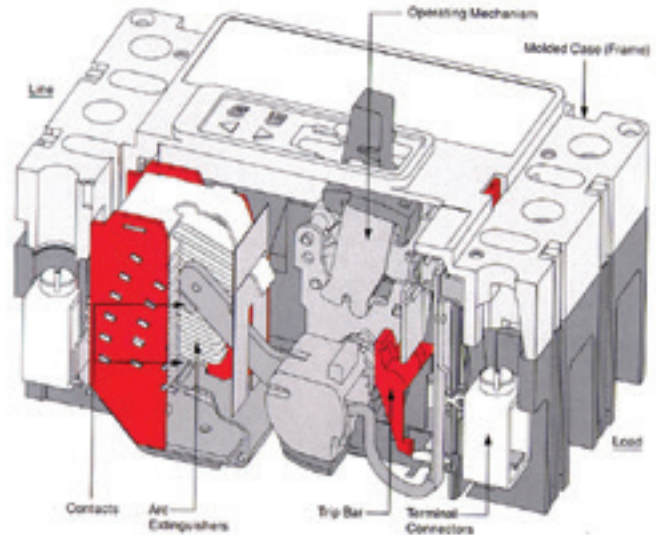


Figure 2. MCCBs include five basic components identified here

All circuit breakers have had an excellent service utilization record. The traditional challenge has been determining when circuit breakers, and especially MCCBs, need to be removed from service, as shown in the typical “bathtub” failure curve (see Figure 3). The important aspect of circuit breaker health to determine is when the relatively few problems occur on the bottom of the curve and where the wear out period begins to rise.

Environmental factors such as excessive temperature, moisture, dust, chemical vapor, and vibration can also have a major effect on the health of the breaker. Further, if the circuit breaker has been in service for a long period, has not been properly maintained, and subjected to excessive environmental and overcurrent conditions, it is difficult to know with confidence that the device is capable of performing its intended functions.

When a circuit breaker interrupts a high-level fault current at or near the device interrupting rating, there traditionally was not an easy way to determine if the circuit breaker that cleared the fault would be able to continue to protect the system. The internal damage that occurs during repeated fault current interruption could impact the breaker’s ability to interrupt a future fault – potentially compromising future performance

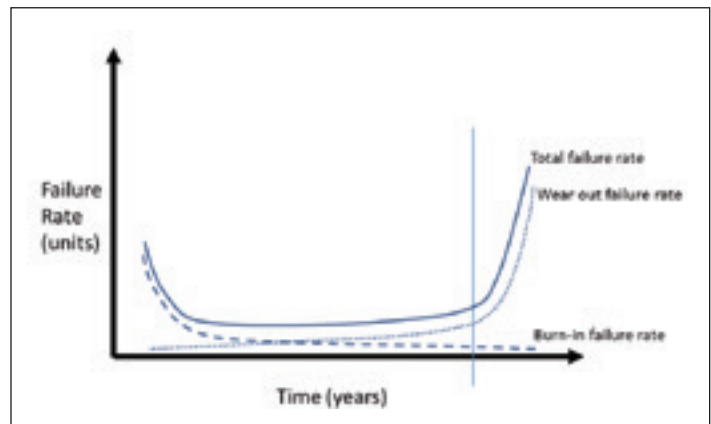


Figure 3. Bathtub failure curve

By understanding environmental conditions and electrical power system issues operations and maintenance (O&M) personnel can know when to replace the circuit breaker. A variety of innovations have made it simpler to determine the cumulative effect of these issues.

Early on, infrared (IR) technology was applied to get a better picture of breaker performance. While this method provided valuable insights, it required waiting for scheduled maintenance and IR scans. These IR scans are taken at one time and cannot provide a true 24/7 picture of the breaker's performance during all operating times and conditions. Also, they can pick up false positives; identifying circuit breakers for replacement that just have a loose terminal connection and could still work in the field (once the connection is fixed)

See Figure 4.

Recent innovations are yielding a new generation of circuit breakers including MCCBs and LVPCBs, that are more intelligent, connected, and contain more internal sensors to provide continuous monitoring and enable predictive maintenance. With self-diagnosing trip units, these circuit breakers can measure a variety of parameters in real-time and over time to provide better indication of when a breaker needs to be replaced before a problem occurs, averting downtime. Importantly, maintenance personnel are now able to proactively target their efforts towards circuit breakers that require service or replacement, rather than taking the time and effort required to inspect all the circuit breakers in a facility or system; yielding dramatic reductions in maintenance costs.

Safety standards apply

There are a number of existing codes and standards for circuit breakers that provide valuable information around testing, installing, and maintaining these devices.

MCCBs and LVPCBs are UL® 489-approved devices. This standard is jointly issued by UL, CSA® Group for Canada, and ANCE in Mexico for evaluating MCCBs and LVPCBs in North America. This standard requires all applicable circuit breaker designs to be subjected to thousands of endurance test operations at 100 percent of rated current. It also requires that devices are able to operate under multiple overload operations. All designs of applicable circuit breakers are subjected to calibration, overload, temperature, endurance, interruption, dielectric, high fault current testing, and other design requirements for corrosion protection, insulating materials, current carrying parts, and spacing. With the increase in electronics usage in circuit breakers, the standard includes EMC testing with software conformity and evaluation.

The Institute of Electrical and Electronics Engineers (IEEE®) published standard 1458, which provides the "Recommended Practice for the Selection, Field Testing, and Life Expectancy of Molded Case Circuit Breakers for Industrial Applications." The 2005 version of this standard established specific methods to determine when a MCCBs should be removed from service, and provides the procedures for field testing and determining the remaining life of molded case circuit breakers.

The National Electrical Manufacturers Association (NEMA®) published its AB-4 Standard, which provides the guidelines for inspecting and preventative maintenance of circuit breakers for both commercial and industrial applications. This standard provides information on inspection and testing procedures for circuit breakers in service.

NEMA AB-4

Basic guidance for testing and maintenance procedures includes:

- Terminal connection check
- Remove dust, dirt, soot grease, or moisture
- While de-energized, operate breaker mechanism to check mechanical linkages
- If possible, operate the breaker under load to clear contact debris/oxidation



Figure 4. IR cameras can be used to provide insight to see breaker health.

In other words, determining the health of a circuit breaker involves investigation along a spectrum of parameters in order to determine which circuit breakers need to be replaced. Contact wear, which can sometimes be singled out as a critical parameter, is one factor among many that needs evaluated. There are some low-voltage circuit breaker manufacturers who offer contact erosion alarm as a health diagnostic. If contacts were the only, or just the major cause of circuit breakers needing to be replaced, then this method would be a great fit. Yet, these circuit breakers are made up of hundreds of parts with many different functions. A range of parameters, well beyond contact wear, need to be monitored in order to have a holistic picture of whether a device will be able to continue to perform as intended.

Maintenance basics and new innovations in predictive diagnostics



Figure 5. Eaton PXR 25

Circuit breakers are designed to meet the demanding test requirements of standards in North America, as well as a range of standards from around the globe to support long-term reliability. Each of these breakers are rigorously tested in manufacturers' factories to ensure quality and consistency. NEMA AB-4 and IEEE 1458 test standards offer excellent step-by-step instructions on ways to field test MCCBs to determine the circuit breakers' condition even if it is factory sealed.

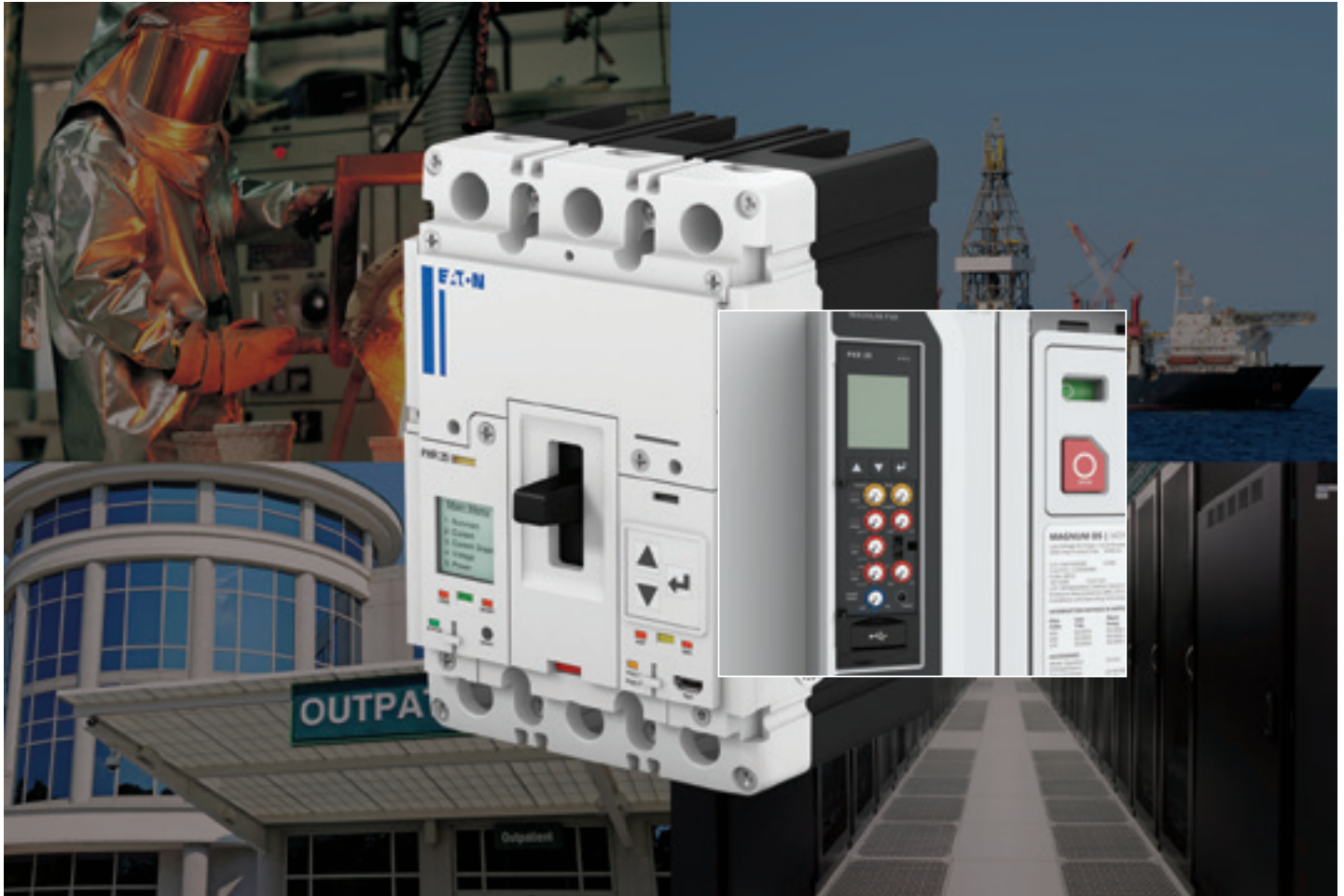
Eaton's Power Xpert® Release (PXR) trip units are a step change improvement over traditional breaker inspection procedures, as they provide powerful data analytics and predictive diagnostics of MCCBs and LVPCBs. This critical information can be used to make more informed decisions about actual equipment conditions. These intelligent circuit breakers can display an easy-to-understand data summary of the breaker's full health that can be easily leveraged by a customer or maintenance person.

The parameters that are monitored by Eaton's PXR trip units include short-circuits, overloads, operations, temperature, and run-time. These parameters can provide a host of individual insights while the combination of all of them provide an overall picture of the condition of the breaker that can be used for predictive maintenance and furthermore system reliability. Specific insights include:

- Operation data provides insight on when the breaker mechanism was last exercised, and if the mechanism was bound or jammed.
- Total number of operations can provide indication of the endurance wear on the circuit breaker mechanism and indication of contact wear.
- Number of interruptions, and the magnitude of the energy interrupted, are vital parameters to the contact wear indication and the arc chute condition.
- Overload interruptions have less of an effect than short-circuits, but they are included in the calculation and weigh in on the health.
- Short-circuits can be damaging to the contacts, integrity and dielectric strength of the circuit breaker. The magnitude of a short-circuit event is compared to the rating of the circuit breaker and weighed as another factor in the health of the circuit breaker.
- Run-time is also considered and demonstrates how long the breaker has been in use with current flowing through it.
- The environmental temperature is one of the most important measurements; this is the highest temperature recorded and the date and time of that temperature is saved in the analysis

All of these parameters are saved in the nonvolatile memory of the PXR trip unit. The data may be retrieved locally or remotely via control or communication systems for further analysis and data recording that drive improved operating efficiency to keep downtime to a minimum. Alternatively, on some models of the PXR trip units a summary of this data is available graphically on the unit's LCD screen, to easily convey the status of the breaker, and give operation and maintenance staff the information they need to determine if the breaker needs to be replaced.





Embedded intelligence supports circuit breaker and electrical system health

The fundamental function of circuit breakers is evolving to not only provide personnel and equipment protection, but to also support higher-level system visibility and predictive diagnostics. New electronic trip units are supporting both intelligence and connectivity at the circuit breaker level – supporting monitoring of breaker health, sensor data that generates more information, and connectivity to a user's building management system, their network, or the cloud. Ultimately, while the data generated by the breakers can be used to monitor and trend energy usage, it can also be used to contribute to improvements in equipment utilization and the condition of electrical system components, leading to more informed and predictive maintenance and lower operating costs.

At the breaker, monitoring of operating and ambient conditions can be coupled with electronic sensors that communicate health status. Today, electronic trip units can monitor mechanical wear, fault current, ambient temperature, run-time, and the total health profile to provide real-time data. With the ability to communicate the information to a network, new and more usable analytics about the circuit breaker and a greater understanding of what's happening in the system and its conditions in real-time as well as over a period of time are available.

Now, facility managers can have a more accurate picture of circuit breaker health and system status; supporting enhanced safety and efficiency across a range of parameters that advance a more fail-safe

and lower cost power system. Through increased intelligence and understanding at the circuit breaker level, the following system level impacts can be realized.

- **Maintenance model** – moving from maintenance that impact operations, to a level of system visibility that makes it possible and easier to shift critical loads so that maintenance does not impact critical functions
- **Fewer maintenance resources** – breaker health diagnostics coupled with real-time system data enable maintenance personnel to lower their operating costs by only performing maintenance on the system when it is required; freeing up resources for other activities
- **Electricity consumption** – full system visibility enables facility and maintenance personnel to see and target inefficiencies (previously undetected)
- **Regulatory compliance** – expediting and simplifying compliance with real-time data
- **Outage restoration** – enabling personnel to quickly identify the fault through more intuitive systems that process the data, so as to allow rapid power restoration and the ability to rapidly pinpoint the condition that caused the fault in the first place
- **New equipment installation** – expanding on an electrical system typically requires a full power system study; today, the capacity and capability of the system is readily available

Conclusion

At the end of the day, the reliable, safe performance of processes, facilities, and circuits is critical. In a data center application, for example, even if less than one percent of a critical load is lost, there is a direct impact on the bottom line; the enormous costs of downtime in data center environments are well documented and are now in the range of \$9,000 per minute or \$540,000 each hour. Equipment reliability, safety, and maintenance-related expenses are top priorities and new technologies are providing ways to boost predictive maintenance methods efficiently. With data-driven insights, organizations can increase equipment uptime and reduce the effort and costs involved in determining which equipment needs to be serviced or replaced, dramatically reducing the cost and effort required to determine service needs, while also boosting system reliability.

The new predictive maintenance technology built into PXR trip units can be used to automatically identify potential failure points that can be addressed during scheduled outages instead of waiting until the failure occurs and shuts down the center or process. While there may be some manufacturers making decisions based solely on contact life, or field inspection of an IR image as a onetime snapshot, analytic data diagnostics that operate 24/7 with prudent

maintenance practices is the best method to yield the highest uptime performance. Even if the impact is on a small number of installed devices, the potential ROI to avoid downtime and improve maintenance practices by informing personnel of potential issues – moving beyond simply scheduled maintenance to a more dynamic and potentially effective model.

Decades of circuit breaker design, testing, and field analysis knowledge are being applied to the development of intelligent algorithms. These algorithms are programmed to provide simple, powerful, and previously unavailable diagnostic indicators about the breaker. By leveraging these “smart,” communicating circuit breakers at all levels of the power distribution system, there are enormous system benefits that can be realized. The data collected from the circuit breaker can be communicated to intelligent dashboard HMI displays that are distributed on the equipment or in the facility, which can in turn communicate information to BMS, SCADA, or other network systems. In other words, the real-time information from the circuit breaker can be leveraged to support an electrical system that is fully integrated and automated with the overall facility or building system and advance a fail-safe facility and dramatic reductions in maintenance costs.

About Eaton

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Printed in USA
Publication No. WP012010EN / VCG
November 2023