WHITE PAPER

ENHANCING GRID RESILIENCY IN AN ERA OF EXTREME WEATHER

R-MAG® medium voltage outdoor circuit breaker

Rated for extreme conditions, ABB's R-MAG outdoor circuit breaker reduces outage risk, extends asset life, and helps safeguard personnel and infrastructure, supporting resilient, cost-effective grid operations.

North America's electrical power infrastructure is fast approaching a critical inflection point. Extreme weather events are increasing in frequency and severity, even as electrification and economic growth drive steadily rising demand for reliable power. At the same time, population growth in coastal communities, wildfire-prone landscapes, river floodplains, and arid regions is placing far more people and critical assets directly in harm's way.

Today's electrical utilities must ensure outdoor equipment is designed to withstand conditions far beyond historical expectations. In particular, medium voltage outdoor circuit breakers require robust protection against moisture, dust, temperature extremes, ice, and corrosive atmospheres to maintain reliable service and manage rising risk exposure. This white paper looks at the NEMA standards for environmental protection and explains how the R-MAG magnetically actuated outdoor circuit breaker leverages these standards to deliver exceptional performance and resiliency in extreme conditions.

ENGINEERED
TO OUTRUN

THE ESCALATING IMPACT OF EXTREME WEATHER

Extreme weather events are fundamentally reshaping the operating environment for electrical grid infrastructure, as equipment designed for historical weather patterns now routinely faces conditions that exceed original design specifications. Between 2000 and 2021, 83% of major U.S. power outages were weather-related.[1] In 2022 alone, 18 natural disasters caused more than $1 billion in damage each—up from only three such events in 1980.[2] While some years are worse than others, these data make clear the structural shift in operating conditions that threatens grid reliability nationwide.

Regional risk is intensifying

Regional environments intensify the challenge. Coastal areas face stronger hurricanes with higher wind speeds and storm surges that exceed design limits, along with persistent salt spray that accelerates corrosion. In arid, fire-prone regions, wildfire smoke and soot build up on insulators, creating conductive paths for partial discharge. Western regions endure record-breaking heat that reduces equipment capacity, while the Midwest and Northeast experience unprecedented ice storms in which ice accumulation on enclosures inhibits access and operability.

83%

of major U.S. power outages between 2000 and 2021 were weather-related.[1]

18

billion-dollar natural disasters in 2022 alone.[2]

Outdoor equipment must withstand environmental stressors ranging from heavy rain and wind-driven moisture to salt-laden coastal air, dust and heat.

THE CONSEQUENCES OF INADEQUATE ENVIRONMENTAL PROTECTION

For outdoor medium voltage circuit breakers, these environmental stressors create critical vulnerabilities that directly threaten operational reliability. The failure to provide appropriate enclosure protection results in cascading impacts across utility operations.

Operational failures
Equipment is more likely to fail without proper environmental protection, leading to unplanned outages that can cost tens of thousands of dollars per hour.

Safety hazards
Moisture intrusion increases arc-flash incident energy, creating shock hazards for maintenance personnel and increasing the risk of catastrophic failures from partial discharge.

Financial burden
Shortened equipment lifespan often requires premature replacement, increased emergency maintenance costs, and lost revenue during extended outages.

Regulatory exposure
Regulatory non-compliance can result in violations and fines, voided insurance coverage, and potential liability for preventable outages.

Peak demand risk
Weather-related failures during high-load periods make restoration more difficult and amplify the consequences.

Proper enclosure protection is essential to grid reliability, safety and long-term operational resilience.
As aging infrastructure faces unprecedented stress from extreme weather, utilities must prioritize environmental protection to maintain service continuity and reduce risk exposure.

PROTECTION STANDARDS FOR EXTREME ENVIRONMENTS

U.S. utilities largely rely on NEMA enclosure ratings for outdoor electrical equipment, and for good reason. These standards define:

- Construction and structural integrity requirements
- Corrosion resistance verified through extended salt-spray testing
- Performance under ice loading and when ice-laden
- Gasket aging and thermal criteria
- Long-term performance validation

For outdoor circuit breakers, NEMA 3R and NEMA 4 are the industry-standard ratings utilities depend on to protect critical infrastructure from the environmental stresses facing today's grids.

NEMA 3R enclosure

Rain, sleet, and snow protection

R-MAG with NEMA 3R housing provides essential protection for typical outdoor installations through a gravity-based water-shedding design that keeps precipitation away from internal components. The rating ensures resistance to ice formation, with enclosures that tolerate external ice loading while mechanisms remain operable when ice-laden. NEMA 3R enclosures also protect equipment from falling dirt, debris, and airborne particulates.

This level of protection is well suited for standard outdoor substations, fenced equipment yards, locations where dust-tight sealing is unnecessary, and applications that benefit from natural ventilation. In most utility environments, NEMA 3R serves as the baseline rating for outdoor medium voltage equipment.

NEMA 4 enclosure

Maximum environmental protection

R-MAG with NEMA 4 housing delivers a higher level of outdoor protection with watertight sealing that withstands hose-directed water at 65 gallons per minute from a 1-inch nozzle at 10 feet, a critical capability for storm cleanup and industrial washdown. The rating requires dust-tight construction with continuous gaskets that block windblown dust; full weather protection against rain, sleet, snow, and splashing water; and robust, welded or precision-sealed enclosures with gaskets on all openings.

This level of protection is best suited for coastal substations exposed to salt spray, industrial sites with frequent washdowns, locations with severe dust, and critical infrastructure that demands maximum protection. As extreme weather grows more frequent and severe, NEMA 4 is increasingly specified for high-value assets where equipment failure would carry serious consequences.

ENCLOSURE PROTECTION STANDARDS

NEMA vs. IEC

U.S. utilities overwhelmingly specify NEMA 250 enclosure ratings rather than IEC IP codes for outdoor electrical equipment. NEMA 250 goes beyond IP basic ingress protection, adding construction and structural requirements, corrosion resistance verified through extended salt-spray testing, performance under ice loading and when ice-laden, and gasket aging, thermal, and long-term performance criteria.

Because of this broader scope, NEMA ratings are treated as the reference standard for North American utility applications, and NEC Section 110.28 makes clear that IP ratings are not acceptable substitutes for NEMA Type ratings.

R-MAG® NEXT GENERATION CIRCUIT BREAKER

ABB's R-MAG outdoor circuit breaker helps address the challenges of extreme weather and harsh environments, combining proven vacuum-interruption technology, maintenance-free magnetic actuation and industry-leading environmental protection through NEMA 3R and NEMA 4 enclosure ratings.

Field tested in more than 50,000 installations across 10+ countries, the R-MAG outdoor circuit breaker has an established track record of reliability under harsh environmental conditions. The magnetic actuation system features only one moving part, dramatically reducing potential points of failure compared to traditional spring-operated mechanisms.

This design simplicity translates to exceptional operational reliability:

- Magnetic actuator rated for 100,000 operations for 15-27 kV models and 50,000 operations for 38 kV models
- Vacuum interrupters rated for 30,000 full-load operations
- Tested for reliability in environmental conditions from -50°C to +70°C
- Electronic control board eliminates risk of coil burning and provides a wide input voltage range (77-280 V DC or 85-264 V AC)
- Interrupting time of 3 cycles helps ensure rapid fault clearing

ABB R-MAG outdoor circuit breaker is designed for reliable medium-voltage substation performance, with NEMA 3R and NEMA 4 enclosure options available.

The R-MAG outdoor circuit breaker can also be configured to address the needs of customers in high-wind (up to 200mph) and seismically active areas. Optional configurations are qualified to the moderate and high-performance levels of IEEE Std 693-2018, and are suitable for installations designed using ASCE 7-16 load and response criteria.

Built for rigorous utility and industrial applications, R-MAG breakers are designed and tested in accordance with IEEE Std C37.04, C37.06, C37.09, and IEC 62271-100. Available upgrades include a C2 Class rating for capacitor switching, an arc-resistant Type 2B enclosure for enhanced personnel safety, and stainless-steel housing options.

Available in 15.5/27/38 kV voltage classes, with continuous current ratings up to 3,700 A and interruption levels up to 40 kA, the R-MAG circuit breaker provides extensive customization in control and protection elements to meet specific utility requirements. This flexibility enables utilities to specify precisely the protection and functionality needed for each application while maintaining standardization on a proven platform.

The combination of maintenance-free operation, proven reliability, and enhanced environmental protection positions the R-MAG outdoor circuit breaker as a strategic solution for utilities building resilient grid infrastructure capable of withstanding the environmental challenges of the coming decades.

BUILDING RESILIENT INFRASTRUCTURE FOR TOMORROW'S GRID

As extreme weather intensifies and resiliency becomes a regulatory expectation, environmental protection for outdoor circuit breakers has shifted from a design preference to a fundamental requirement for grid reliability. Utilities can no longer rely on historical weather patterns or legacy equipment assumptions when planning, operating, and hardening their systems against disruption.

Rigorously defined enclosure standards play a central role in protecting critical assets and maintaining service continuity. By specifying field-proven solutions that align with these standards, utilities can better manage risk, extend asset life, and control long-term operating costs. As the grid continues to evolve, ABB remains committed to partnering with utilities to address the challenges ahead.

Sources

[1] Climate Central. "Surging Weather-related Power Outages." September 13, 2022. Accessed March, 2026.

[2] NOAA National Centers for Environmental Information. "U.S. Billion-Dollar Weather and Climate Disasters (1980–Present)." Accessed March, 2026.

ABB Inc.
305 Gregson Dr.
Cary, NC 27511
United States

electrification.us.abb.com

We reserve the right to make technical changes or modify the contents of this document without prior notice. With regard to purchase orders, the agreed particulars shall prevail. ABB Inc. does not accept any responsibility whatsoever for potential errors or possible lack of information in this document.

We reserve all rights in this document and in the subject matter and illustrations contained therein. Any reproduction, disclosure to third parties or utilization of its contents – in whole or in parts – is forbidden without prior written consent of ABB Inc. Copyright© 2026 ABB
All rights reserved

9AKK108472A7271, REV A JUNE 2026