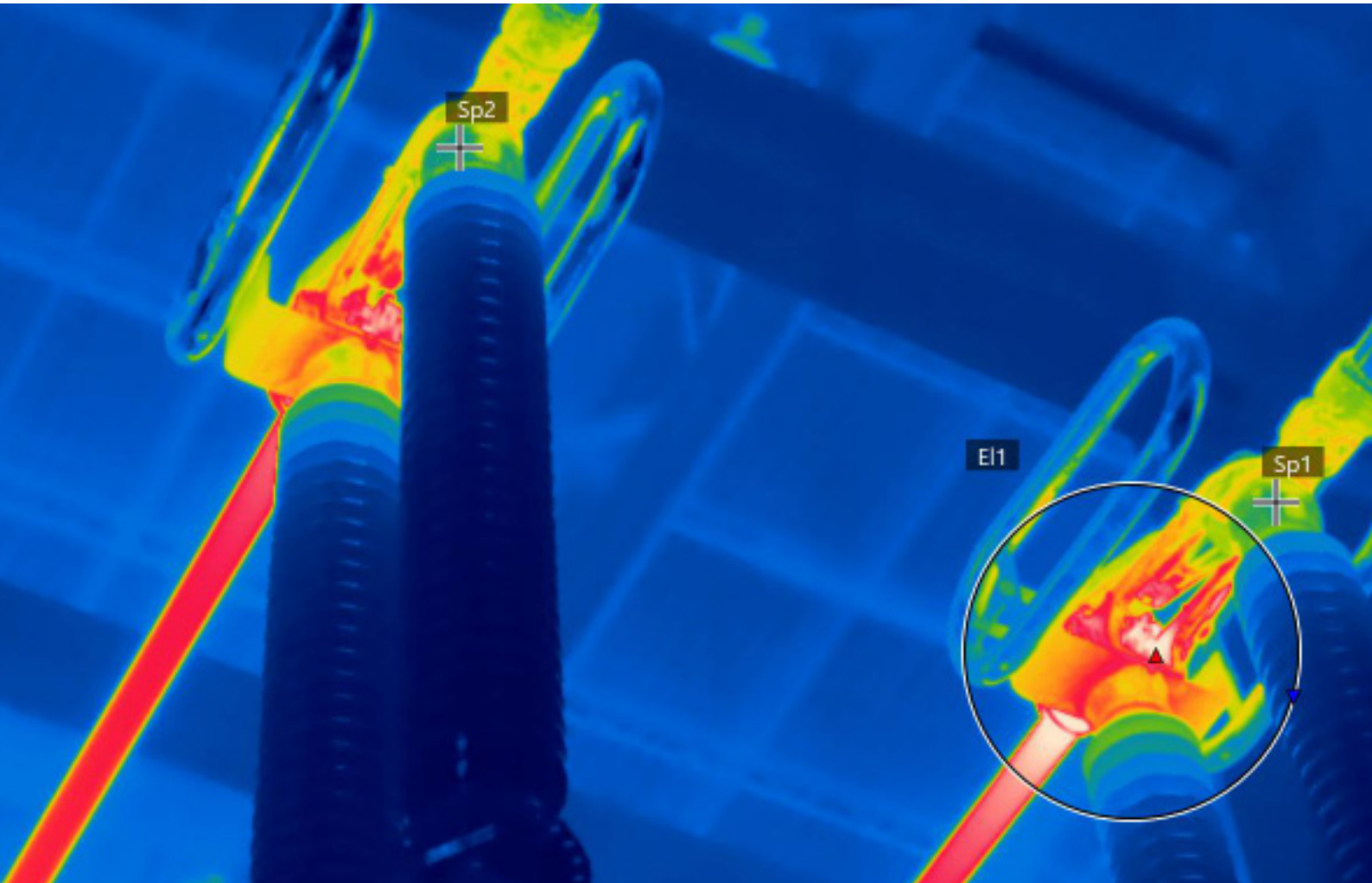
Global Risk Consultants

Guide

Reducing Risk Exposure with Electrical Protection:

A Comprehensive Guide for Risk Managers and Facilities Leaders





Mitigating Electrical Failures: The Key to Safer, More Insurable Facilities

Electrical hazards are among the top causes of industrial fires, costing businesses millions in property damage, lost productivity, and insurance claims. A 2023 report from the National Fire Protection Association found that U.S. fire departments responded to an average of 8,077 structure fires at industrial or manufacturing properties annually between 2017 and 2021, resulting in $988 million in direct property damage.[1] Meanwhile, the U.S. Fire Administration also reported an 8% increase in financial losses from electrical malfunctions between 2013 and 2022.[2]

For risk management leaders and property insurance professionals, these statistics reinforce a pressing concern: Proactively managing electrical risks before they escalate into costly failures is critical.

The solution lies in a comprehensive electrical protection strategy that includes predictive maintenance, infrared thermography, proactive chemistry protection, arc flash analysis, and electrical safety training. Read on to explore the latest best practices in electrical protection services, drawn from industry expertise and real-world case studies to demonstrate how proactive strategies safeguard facilities, reduce business interruption, and improve insurance outcomes.

+8% increase

in financial losses from electrical malfunctions between 2013 and 2022

Top Issues Guiding Electrical Protection Strategies

Companies, especially those with large portfolios of properties, may have the following issues affecting their electrical systems:

- Aging electrical infrastructure.
- Lack of adequate maintenance on electrical devices and distribution systems.
- Equipment wear-and-tear.
- Reliability of electrical protective (overcurrent and other) devices.
- Improper or compromised grounding systems, which can cause electrical shocks, flickering power, poor connections, potential fire, damage to electronics, voltage surges or fluctuations.
- Environmental factors (dust, internal process airborne, emission or chemical contaminants, salt-laden coastal airborne contaminants, etc.).
- Overloaded or imbalanced load conditions, resulting in potential overheating, arc-flash, fires, poor performance, failure and energy consumption.
- Harmonic distortion (the presence of additional frequencies in the power supply, caused by non-linear loads (power electronics, variable speed drives, switch-mode power supplies), which can cause overheating, vibrations and abnormal torque pulsations, power quality and increased energy costs.
- Varying levels of risk across a portfolio due to plants spread across the world or acquired in acquisition deals.





Importance of Electrical Preventative and Predictive Maintenance Programs

- **Code compliance with NFPA 70E** and other standards.
- **Ensure electrical systems** and protective devices are not overloaded.
- **Identify risks of arc flash hazards** and high or any abnormal temperature situations.
- **Develop plans** for appropriate personal protective equipment (PPE) required for employees and contractors to ensure they have the right safety measures in place.
- **Minimize the impact of downtime** so companies can continue to meet customer commitments.

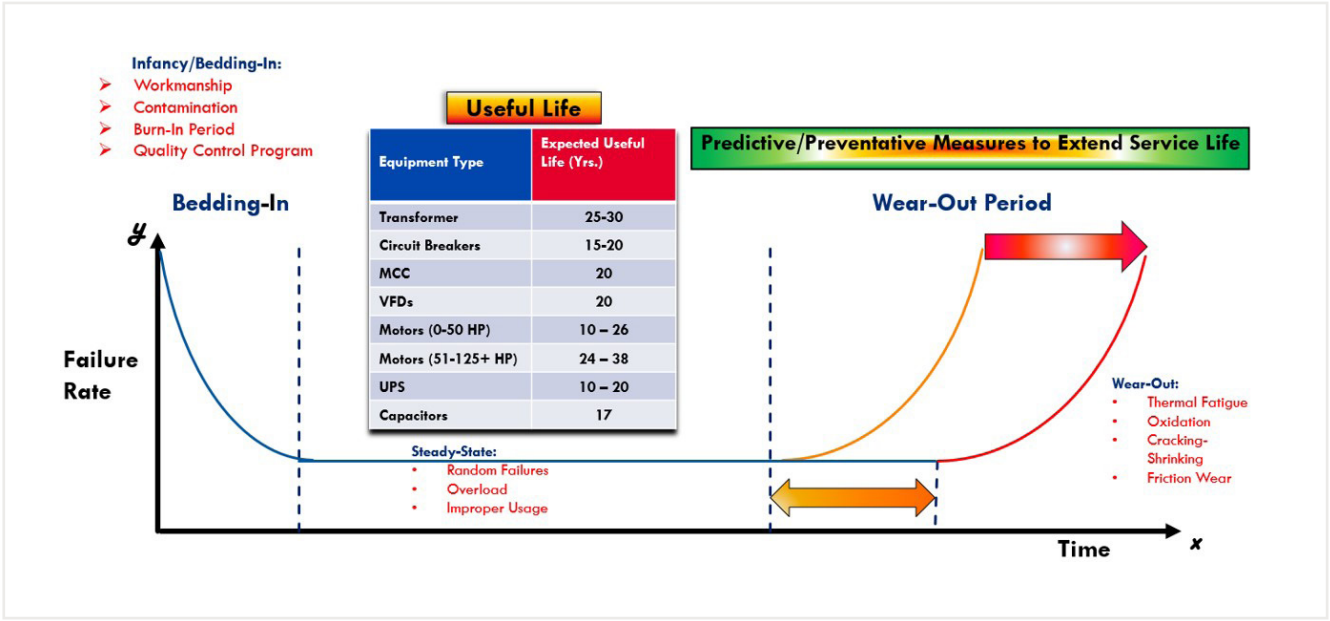


Insurance Impact: How Electrical Predictive and Preventative Maintenance Affects Underwriting

or insurance professionals, risk engineering and electrical protection services provide key advantages in assessing and pricing risk:

- **Demonstrate a commitment to protecting against electrical risks:** A robust program reduces the risk of catastrophic incidents while showcasing protection against a common and dangerous set of risks.
- **Better expense allocation:** Risk leaders can better allocate expenses for insurance programs down to the facility level, so facilities that take more proactive measures see a better allocation.
- **Data-driven risk insights:** Insurers gain valuable risk data from predictive maintenance reports, enabling more accurate underwriting.
- **Lower claim probability:** Facilities with regular thermography inspections and arc flash assessments present a lower risk of loss.
- **Stronger justification for premium discounts:** Facilities that invest in highly protected risk (HPR)-standard risk mitigation demonstrate proactive loss prevention, improving their negotiation position.

The Bathtub Curve: Understanding Service Life



The **bathtub curve** is a fundamental concept in reliability engineering describing the typical failure rate of electrical and mechanical equipment over time. Shaped like a bathtub, it shows high failure rates at the beginning (infant mortality phase) and end (wear-out phase) of an asset's lifecycle, and a relatively low, stable failure rate in the middle (useful life phase). Understanding this curve is essential for risk managers, facilities managers, maintenance professionals, engineers and safety professionals seeking to optimize equipment reliability and reduce unplanned failures through predictive maintenance strategies.

The Three Phases of the Bathtub Curve

1. Early Life Failures (Infant Mortality Phase)

- This phase occurs immediately after installation and is characterized by a high rate of failures due to manufacturing defects, poor workmanship, contamination, and installation errors.
- Issues like loose connections, improper torque settings, misaligned components, and defects in insulation materials are common.
- Facilities mitigate these risks through quality control measures, burn-in testing, and commissioning inspections before equipment becomes fully operational.



2. Random Failures (Useful Life Phase)

- Once equipment stabilizes, failure rates drop significantly and remain relatively low. This is the period where the asset operates under normal conditions with random failures occurring intermittently due to operational stresses.
- Failures in this stage are often caused by overloaded circuits, voltage imbalances, power fluctuations, improper maintenance, and unforeseen external factors like environmental contaminants.
- Regular predictive maintenance techniques such as infrared thermography, vibration analysis, and oil analysis help detect and address hidden issues before they escalate into major failures.

3. Wear-Out Failures (Aging and End-of-Life Phase)

- As equipment ages, failure rates rise again due to natural degradation of materials, mechanical fatigue, and electrical stress.
- Common failure modes include thermal fatigue, oxidation of electrical contacts, insulation breakdown, cracking, shrinkage, and corrosion.
- Without proper planning, this phase can lead to unexpected downtime and costly repairs. Proactive asset management involves planned replacements, scheduled refurbishments, and lifecycle assessments to determine when aging equipment should be retired or upgraded.

Electrical Equipment Type	Expected Useful Life (Years)
Transformer	25-30
Circuit breakers	15-20
Motor Control Centers	20
Variable Frequency Drives	20
Motors (0-50 hp)	10-26
Motors (51-125+ hp)	24-38
Uninterruptible Power Supplies	10-20
Capacitors	17

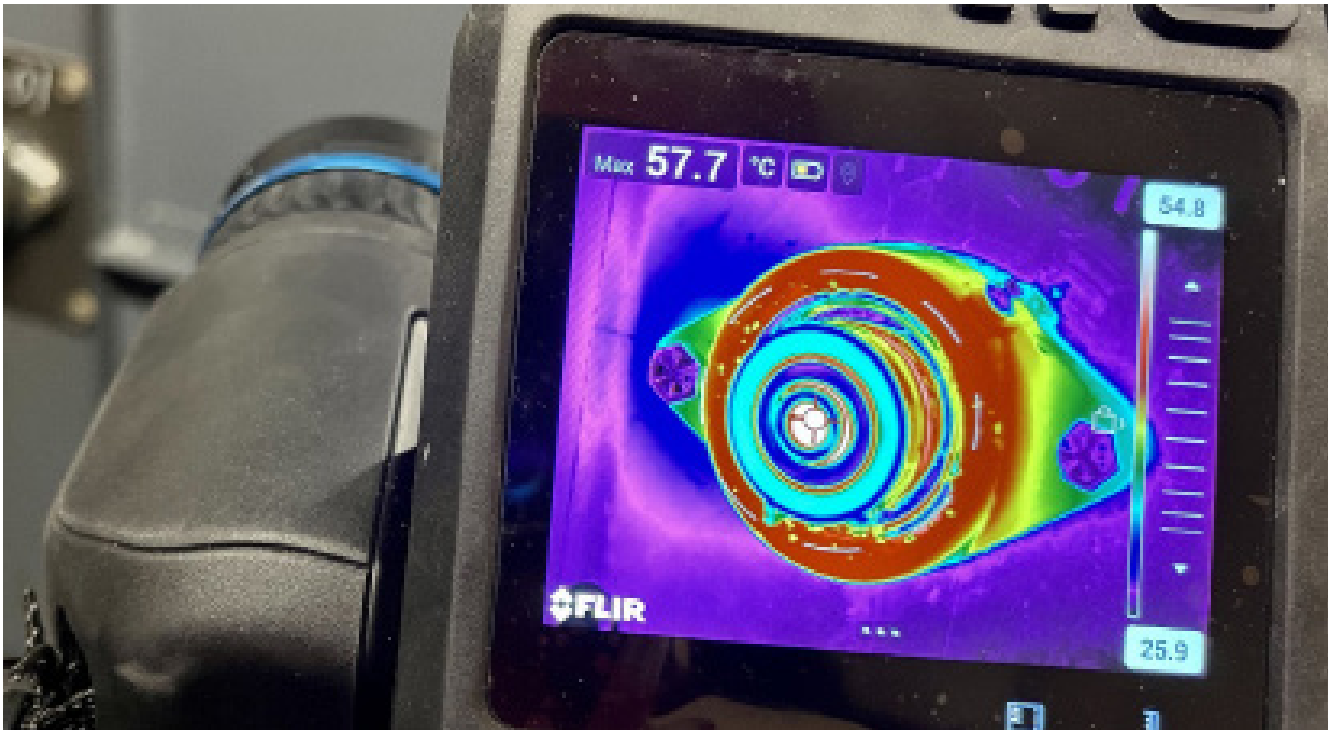
Infrared Thermography: Identifying Hidden Risks

Infrared thermography is the science of capturing and analyzing thermal information from machinery using infrared cameras. Every object with a temperature above absolute zero emits infrared radiation that is invisible to the human eye but can be detected by specialized sensors and cameras. Infrared thermography cameras capture this emitted radiation and convert it into a thermogram, or visual image, representing the temperature distribution across the object's surface. The amount of infrared radiation emitted by an object increases as its temperature increases. Infrared thermographic scanning can measure these emissions across a surface making it possible to form a thermal map of that surface and identify any areas of concern.

Infrared scanning is a predictive maintenance and engineering tool that is fast, accurate, and non-destructive. It helps risk managers, plant managers, facilities managers, facilities maintenance, environmental, health & safety managers and company leaders better understand fire and many potential failure risks in electrical, mechanical equipment, production machinery, and within many other applications. Infrared thermography inspections and infrared thermographic scanning/testing are best carried out by a certified Thermographic Consultant with a state-of-the-art camera and other predictive instrumentation (i.e. airborne ultrasound) to show a piece of equipment's progression toward failure, along with utilizing expertise in visual examination techniques for identifying potential failure points, hazards and risks in electromechanical systems which may not be yielding abnormal thermal or acoustic emission signatures at the time of any given inspection.

Key Benefits of Infrared Thermography:

- Prevents equipment failure by detecting loose connections, overloaded circuits, and deteriorating insulation.
- Minimizes downtime by identifying issues before they cause shutdowns.
- Reduces fire risks.
- Improves risk profile.
- Identifies abnormal thermal signatures (i.e. hot spots) and potentially hazardous anomalies before they become serious issues.



CASE STUDY: INFRARED THERMOGRAPHY

Preventing Catastrophic Failure at a Manufacturing Substation

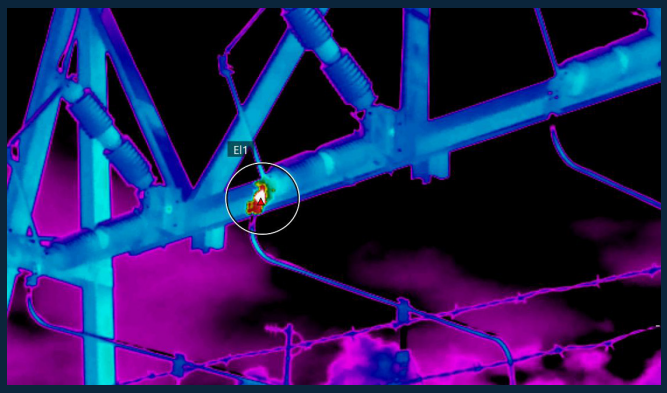
FACILITY BACKGROUND

Location: Main Substation at a large woodworking facility.

Total Insurable Value (TIV): $525 million

Equipment: High-Voltage 115-kV Switch/Bushing





The Challenge

The substation was a critical component of the facility's operations, responsible for regulating and distributing electrical power. Environmental conditions, including a coastal location with salt-laden air, compounded the risks to the electrical system. A routine infrared thermography inspection identified an alarming anomaly:

- **Fault Type:** B-phase load side lug connection
- **Temperature Rise:** +85.5°C above normal
- **Severity:** Critical (4-star rating)

Impact Assessment

If undetected, this fault could have led to:

- Equipment failure, triggering a complete substation outage.
- Estimated property damage exceeding $1 million.
- Business interruption potentially lasted between 1 to 4 months.

Solution

Infrared thermography, a non-destructive testing technique, was used to detect abnormal heat signatures in the substation equipment. After identifying the fault, immediate corrective actions were implemented:

- Proper cleaning maintenance.
- Utilization of specialized insulation, larger conductors etc.

Results

- Fault mitigated without any unplanned downtime.
- Significant cost savings by avoiding catastrophic equipment failure.
- Demonstrated the value of predictive maintenance to insurers and stakeholders.

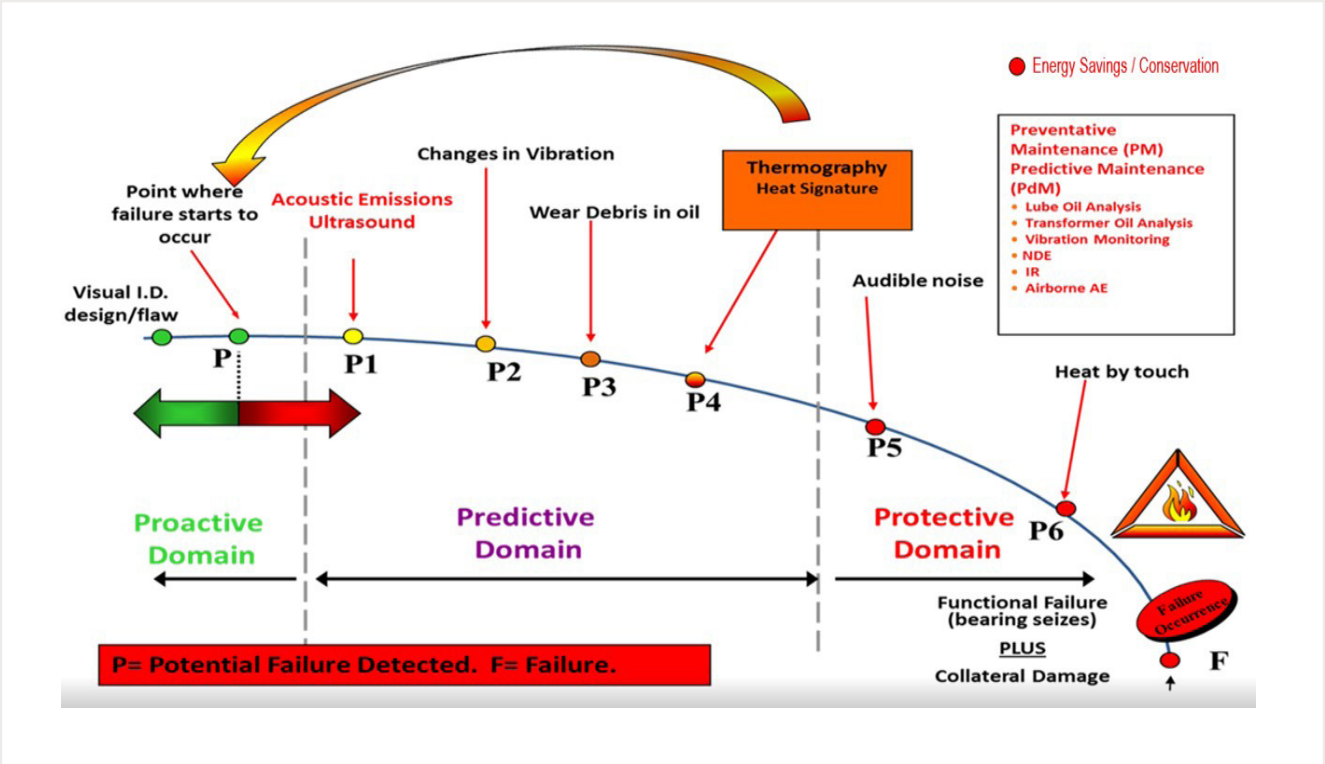
Key Takeaways

1. Proactive Risk Management: Routine infrared thermography inspections are essential for identifying and addressing critical anomalies.

2. Environmental Awareness: Facilities in challenging environments, such as coastal areas, face unique risks that require tailored maintenance strategies.

3. ROI of Infrared Thermography: A relatively small investment in thermography resulted in cost avoidance exceeding $1 million.

Understanding the Potential Failure (P-F) Curve and Electrical Equipment Lifespan



The Potential Failure Curve (P-F Curve) is a critical concept in predictive maintenance, illustrating how electrical and mechanical assets degrade over time and how early detection strategies can prevent catastrophic failures. By understanding this curve, risk managers, facilities managers, and maintenance teams can develop strategic maintenance programs that extend equipment lifespan, reduce costly downtime, and improve safety.

1. Proactive Phase: Early Detection and Prevention

- In this initial stage, the equipment is newly installed and operating efficiently.
- If a design flaw, installation issue, or component defect is present, it can sometimes be visually identified during commissioning or early inspections.
- This phase represents the best opportunity to prevent future failures through quality control, commissioning inspections, and proactive maintenance protocols.

2. Predictive Phase: Identifying Degradation Before Critical Failure

As the asset continues to operate, small anomalies begin to develop. These issues often go unnoticed without predictive maintenance technologies, but if left unaddressed, they escalate toward failure. Some common detection methods in this phase include:

- **Airborne Ultrasound:** Detects early electrical discharge or loose connections before they generate heat.
- **Vibration Analysis:** Identifies misalignments or wear in rotating equipment.
- **Oil Analysis:** Detects the condition of the lubricating oil (symptoms of oxidation, acid formation, chemical changing due to aging or high temperatures), including viscosity (oil's thickness), contaminants (water, fuel, coolant, dirt, foreign particulates which can negatively impact oil performance), levels of wear metals from engine components, additive levels (concentrations designed to protect against wear/oxidation) and potential signs of degradation. It can also detect molecular disturbances or debris in transformers and lubricated components.
- **Infrared Thermography:** Identifies abnormal heat signatures (i.e. hotspots) caused by loose connections, overloaded circuits, phase imbalances or unbalanced loads, faulty components, harmonic distortion or deteriorating insulation.

At this stage, early intervention can prevent major breakdowns and extend equipment life, providing a high return on investment.

3. Protective Phase: Warning Signs and Imminent Failure

If predictive maintenance is not performed, the asset moves into the protective domain, where failure is imminent. The warning signs become more apparent:

- **Audible noises** from electrical components or rotating machinery.
- **Physical heat** (hot to the touch) indicating excessive electrical resistance or overheating.
- **Irregular equipment performance**, such as fluctuating voltage, arcing, or sudden shutdowns.

At this point, failure is likely within hours to weeks, depending on operating conditions. If unaddressed, the result may be:

- **Arc Flash Incident:** High-energy electrical faults leading to explosions, fires, and/or, severe injuries.
- **Mechanical Failure:** Bearings or motor components seize up, causing an abrupt stop in operations.

The protective phase represents the last opportunity to intervene before catastrophic failure occurs.

Why the P-F Curve Matters for Risk Managers and Insurers

Early intervention saves costs:

Predictive strategies can prevent failures that lead to business interruption, expensive equipment replacements, and insurance claims.

Reduces fire and electrical hazards, maintain compliance with standards, improving up-time and unforeseen high-cost outages:

Identifying faults before they cause overheating or arc flash improves worker safety and compliance with NFPA 70E and IEEE 1584. Utilizing these electrical program maintenance strategies helps to ensure proper maintenance and performance of electrical systems. They also are critical to maintaining compliance with Internationally and Nationally recognized standards like IEEE, NFPA 70B, and others, for required maintenance types and frequencies under the Electrical Maintenance Program (EMP) provisions of NFPA standards.

Strengthens insurance profiles:

Facilities with strong predictive maintenance programs are seen as lower risk, leading to better terms from underwriters.

By leveraging electrical predictive/preventive maintenance studies and programs like infrared thermography, airborne ultrasound, transformer oil analysis, motor circuit analysis, vibration monitoring, solid insulation resistance (megger), arc flash analysis studies, and other partially predictive types like ground testing, etc., companies can shift from reactive maintenance to a proactive risk engineering approach, ensuring their electrical infrastructure remains safe, compliant, and efficient.

CASE STUDY: INFRARED THERMOGRAPHY

Critical Failure Detected in Primary Switchgear

FACILITY BACKGROUND

Location: Main Switchgear, Industrial Manufacturing Plant

Total Insurable Value (TIV): $1 billion

Equipment: 480-Volt, 1,600-Amp Switchgear





The Challenge

The switchgear, a vital component of the plant's electrical distribution system, exhibited a critical fault during a routine thermography inspection:

- **Fault Type:** B-phase line side bus bar to bushing connection.
- **Temperature Rise:** +582°C above baseline.
- **Maximum Temperature:** 688°C.
- **Severity:** Critical (4-star rating).

The fault may have been caused by loose connections or improper assembly during installation, compounded by dissimilar metals in the connectors.

• Impact Assessment

If left unresolved, this fault could have resulted in:

- Extensive damage to the primary switchgear, or total loss.
- Property damage exceeding $1 million.
- Business interruption lasted over 120 days.

Solution

The infrared thermography survey identified the abnormal heat signature, prompting immediate action:

- Emergency shutdown then de-energizing the switchgear to allow safe access.
- Replacing faulty components and ensuring all connections were tightened to the correct torque specifications.

Results

- Immediate correction of the fault, avoiding equipment failure.
- Reinforced the facility's commitment to safety and proactive maintenance.
- Minimized risk exposure and ensured operational continuity.

Key Takeaways

1. Precision Matters: Proper installation and maintenance, including torque specifications, are critical to the longevity of electrical systems.

2. Early Detection Saves Millions: Identifying faults before failure prevents significant financial and operational losses.

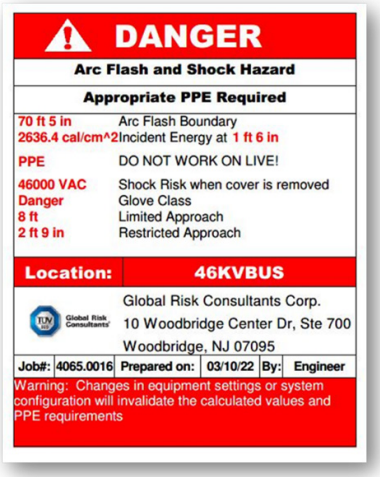
3. Predictive Maintenance in Action: Infrared thermography continues to prove its value as a cornerstone of electrical risk management.

Arc Flash Analysis: Identifying Electrical Explosion Risks

An arc flash hazard is a dangerous condition associated with the release of energy caused by an electric arc – the explosive release of energy caused by an electrical current flowing through the air between conductors. The energy discharge can result from a fault in electrical equipment, creating intense heat and a potentially explosive atmosphere. Arc flash hazards include thermal radiation, high temperatures, and pressure waves that can have devastating effects on personnel and equipment.

The dangers of an arc flash are multifaceted. Arc flash temperatures can reach upwards of 35,000°C, which is sufficient to vaporize metal and cause severe burns. The pressure wave can propel debris and molten metal at high speeds, resulting in physical trauma. Additionally, the intense light can cause temporary or permanent blindness, and the sound blast can damage hearing.

The most common cause of an arc flash is human error, such as accidentally dropping tools or contacting energized components during maintenance. Equipment failure, such as insulation breakdown, corrosion, or faulty installation, also contributes to the occurrence of arc flashes. Damage can be exacerbated with improper labelling and insufficient personal protective gear.





CASE STUDY: ARC FLASH

Preventing Catastrophic Failure from Mismatched Circuit Breakers

FACILITY BACKGROUND

Location: Industrial Manufacturing Plant

Equipment: 480-Volt Circuit Breaker

Manufacturer: Eaton

Model: EHD

The Challenge

During the arc flash assessment, engineers identified a significant hazard:

- **Fault Current:** 27 kA (kiloampere)
- **Breaker Interrupt Rating:** 14 kA
- **Cause:** An older power panel contained circuit breakers that were physically compatible but lacked the appropriate electrical interrupting rating to handle the fault current.

The mismatch could result in the breaker failing to clear a fault, potentially escalating the issue and causing catastrophic damage further upstream or downstream in the system.

Impact Assessment

If left unresolved, this issue could have led to:

- Extensive damage to the electrical system, including upstream components.
- Increased likelihood of an arc flash incident with severe consequences for worker safety.
- Prolonged downtime and costly repairs.

Solution

The arc flash analysis provided critical data that informed corrective actions:

- Replacing the mismatched breaker with a properly rated one.
- Ensuring all breakers in the panel met the required interrupt rating for the fault current.

Results

- Hazard mitigated without incident or downtime.
- The facility achieved compliance with NFPA 70E and IEEE 1584 standards.
- Workers were safeguarded from potential arc flash hazards.



Key Takeaways

1. Precision in Equipment Selection: Breakers must match fault current ratings to ensure they function as intended.

2. The Value of Arc Flash Analysis: Regular assessments are critical for identifying hidden hazards and maintaining system integrity.

3. Worker Safety is Paramount: Properly rated equipment prevents failures that could endanger lives.

5 Phases of Arc Flash Assessments

01 Data collection

Collect a wide range of data on electrical system necessary for studies and computer modeling. Information collected includes voltage, fault currents, wire sizes, components like breakers and fuses, over current protective devices, and more.

02 Short-circuit study

Verify protective devices and electrical equipment components have adequate interrupting capability. Engineers will examine equipment parameters like voltage, impedance, and power rating. They'll examine all the fault scenarios and run calculations with short circuit currents for different fault types.

03 Coordination study

Verify adequate protective device settings and proper coordination to isolate faults. Engineers examine overcurrent protected devices and make sure they will operate in the specified time limits to clear the fault. They're going to look at relay coordination, design assessments, check the settings on these overcurrent protective devices, looking at fault clearing time. They also examine transformer protection such as fuses or breakers to protect the transformers and cables from faults.

04 Arc flash study

Determine PPE requirements to operate and maintain energized equipment. It also includes one-line electrical diagram schematics. The arc fault, current and your incident energy are measured so you can determine proper arc flash boundaries.

05 Label installation

Provides the information necessary for workers to protect themselves and to lower the risk of shock, arc flash and arc blast to an acceptable level.



Key Benefits of Arc Flash Analysis

Worker Safety

Improved Risk Assessment

Proper PPE Selection

Compliance with Standards / Regulations

Facilities Electrical Systems Overcurrent Protective Devices (OPD's)

Preventive Maintenance Guidance

System Optimization

Emergency Preparedness

Training & Awareness

Cost Savings

CASE STUDY: ARC FLASH

Coordination Issues in Circuit Breakers

FACILITY BACKGROUND

Location: Industrial Manufacturing Plant

Equipment: Circuit Breakers

Manufacturer: Square D FA and Siemens JJ

Voltage: 480-Volt

The Challenge

The arc flash analysis revealed overlapping coordination settings between two molded-case circuit breakers:

- The primary breaker's settings were adjusted from "Low" to "High" to avoid interference with the secondary breaker's tripping curve.
- This adjustment compromised the system's ability to isolate faults at the downstream breaker, increasing the risk of a larger fault escalating upstream.

Impact Assessment

Without intervention, the coordination issue could have resulted in:

- A failure to isolate faults effectively, leading to broader system damage.
- Increased risk of worker injuries during an arc flash event.
- Higher repair costs and operational downtime due to a cascading fault.

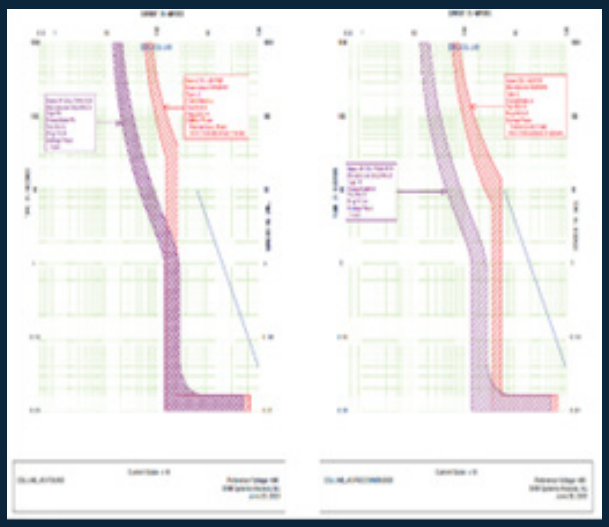
Solution

The coordination study provided actionable recommendations:

- Adjusting the primary breaker's settings to ensure proper fault isolation.
- Revising system design to eliminate overlapping tripping curves.
- Conducting additional training for maintenance teams on proper breaker settings.

Results

- The facility restored proper fault isolation, reducing the risk of widespread damage.
- Compliance with NFPA and IEEE standards was reinforced.
- Workers and equipment were safeguarded from potential arc flash incidents.



Key Takeaways

1. Importance of Coordination Studies: Proper breaker coordination ensures faults are isolated at the source, minimizing system-wide damage.

2. Regular System Audits are Essential: Over time, system changes can create hidden risks that must be identified and addressed.

3. Training Improves Outcomes: Ensuring teams understand proper breaker settings helps prevent coordination issues from recurring.

Electrical Safety Training: The Human Factor in Risk Prevention

Even with the best technology, human error remains one of the greatest contributors to electrical failures. Comprehensive electrical safety training ensures that employees:

- Understand arc flash hazards and follow proper procedures.
- Use the correct PPE to reduce injury risks.
- Follow lockout/tagout (LOTO) protocols to prevent accidental energization.



Benefits of Electrical Safety Training for Insurance Underwriters:

Reduces the likelihood of claims by minimizing human-related incidents.

Improves HPR status, leading to better insurability and underwriting terms.

Showcases compliance with standards (NFPA 70E, OSHA, Int'l Safety Standards).

Highlights worker protection when employees work on energized electrical equipment.

Showcases safe work practices and PPE selection.

Bundling Electrical Protection Services together provides ROI:

Reduced risk of employee injury.

Protection against potentially millions in expense from catastrophic loss.

Reduced insurance claims lead to continued solid relationships and negotiations with carriers.

Protection against costly business interruption due to electrical system failures and hazards.

Cost of downtime at facilities would far exceed risk engineering spend.

High ROI in comparison to an employee injury, disruption to operation or physical damage.



Why Risk Managers Must Prioritize Electrical Protection Services

Risk managers can protect against electrical failures and the right strategies make all the difference.

- Predictive maintenance technologies like infrared thermography detect risks early.
- Arc flash studies ensure compliance and worker safety.
- Electrical safety training reduces human error and enhances workplace safety.

Global Risk Consultants specializes in electrical protection services that help companies protect against failures, meet compliance standards, and strengthen their insurance positioning. By combining arc flash, infrared thermography, and electrical safety training, GRC can help companies catch anomalies quickly and better protect their facilities.

Want to learn more about GRC's Electrical Protection Services? Visit our website at www.tuvsud.com/grc.

Endnotes

1. NFPA: Fire in Industrial or Manufacturing Properties

2. U.S. Fire Administration: Nonresidential Building Electrical Malfunction Fire Trends (2013-2022)

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