



Upgrading your aging  
switchgear equipment is  
easier than you think.

Discover cost-effective modernization and upgrade solutions.

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# Get the facts: Switchgear upgrade guide

With maintenance costs rising and older breakers becoming obsolete, it's not a matter of IF a malfunction will occur ... it's a matter of WHEN. Follow the steps below to help you **compare** options to find the best solution for your facility needs.

Switchgear upgrade	Switchgear replacement
<p>Step 1: Know your options</p> <p>Modernize existing switchgear components to the latest technology and capabilities</p>	<p>Step 1: Know your options</p> <p>Replace entire switchgear structure with new equipment</p>
<p>Step 2: Assess the situation</p> <p><b>Workplace safety</b> Upgrades are in compliance with NFPA 70E standards</p> <p><b>Desire to upgrade to current technology</b> Can be done at a lower cost by modernizing equipment</p> <p><b>Cost savings</b> Modernizing existing circuit breakers can help you save over 40% of the total cost of a project **</p> <p><b>Operating environment</b> Equipment that is hard to access can be easily upgraded within the existing footprint</p>	<p>Step 2: Assess the situation</p> <p><b>Environmental impact</b> More waste materials to be processed</p> <p><b>Site preparation</b> More involved and time consuming</p> <p><b>Risk</b> New switchgear can require new or spliced cabling, increasing risk</p>
<p>Step 3: Weigh downtime</p> <p><b>Minimal to no downtime</b> required due to keeping existing structure intact</p>	<p>Step 3: Weigh downtime</p> <p><b>Increased downtime</b> required for installation</p>
<p>Step 4: Consider cost</p> <p><b>Lower cost now</b> by maintaining the existing footprint and reducing downtime</p> <p><b>Improved cash flow now</b> since retrofits can be spread out over time</p> <p><b>OpEx spend</b> — Upgrading is classified as an operating expense and typically easier to fund</p>	<p>Step 4: Consider cost</p> <p><b>Higher cost now</b> due to new equipment prices, conduit movement, structure reconfiguration, and testing</p> <p><b>More upfront costs now</b> since replacement is usually done all at once</p> <p><b>CapEx spend</b> — New equipment requires capital funds, which are often limited</p>



\$65 billion

worth of obsolete legacy systems are accounted for in electrical systems worldwide.\*



2 hours

of downtime per month costs the average plant \$2.4 million per year.\*

\*ARC Strategies – <http://iom.invensys.com/EN/pdfLibrary/ManagingObsoleteTechnologies-StrategiesandPractices.pdf>

\*\* “A Closer Look into the True Cost of Replacing Electrical Switchgear”  
<https://blog.schneider-electric.com/services/2017/08/11/closer-look-true-cost-replacing-electrical-switchgear/>



# Any brand. Any industry. Anytime.

Here are some of the reasons why our customers chose upgrade solutions:

- Reduced costs
- Less downtime
- Enhanced reliability
- Updated technology
- Digitization and connectivity

Here are some of our customers that chose upgrading solutions:

- Kimberly Clark
- VA Medical Center
- Public Services of New Mexico
- NSTAR
- Honda Motor Co.
- Astra Zeneca
- Ameren
- Miller Coors
- U.S. Steel
- Nestlé
- Oak Ridge National Laboratory
- And many more ...

# Two different modernization solutions provide the same end result

## Direct replacement

Circuit breakers are designed to fit into the existing cubicle with little to no modification to the switchgear cell. Direct replacement solutions reduce downtime since there is minimal outage on the equipment bus. Designs are available for any manufacturer's switchgear.

- **Low voltage** — A standard MasterPact™ cradle is installed into an adapter cradle to form one assembly, which is then installed into the switchgear cubicle. (This cradle-in-cradle assembly locks into place). The new MasterPact circuit breaker racks in and out of the adapter cradle. A new door is installed, however, cell interlocks, the racking mechanism, the primary/ secondary disconnects and the switchgear structure are not modified. Solutions are available for legacy circuit breakers and contactors.
- **Medium voltage** — The Magnum direct replacement circuit breaker will rack into the switchgear line-up and correctly interface with the existing compartment cell. The original racking mechanism, safety interlocks, and the primary/secondary disconnects inherent in the original equipment design are maintained and the switchgear structure is not modified.

Both the MasterPact NT/NW/MTZ and the Magnum circuit breakers are installed, tested, and commissioned by qualified field service personnel and are backed by a one-year warranty. Both the Low Voltage and Medium Voltage Direct Replacement breakers are design tested to ANSI C37.59.

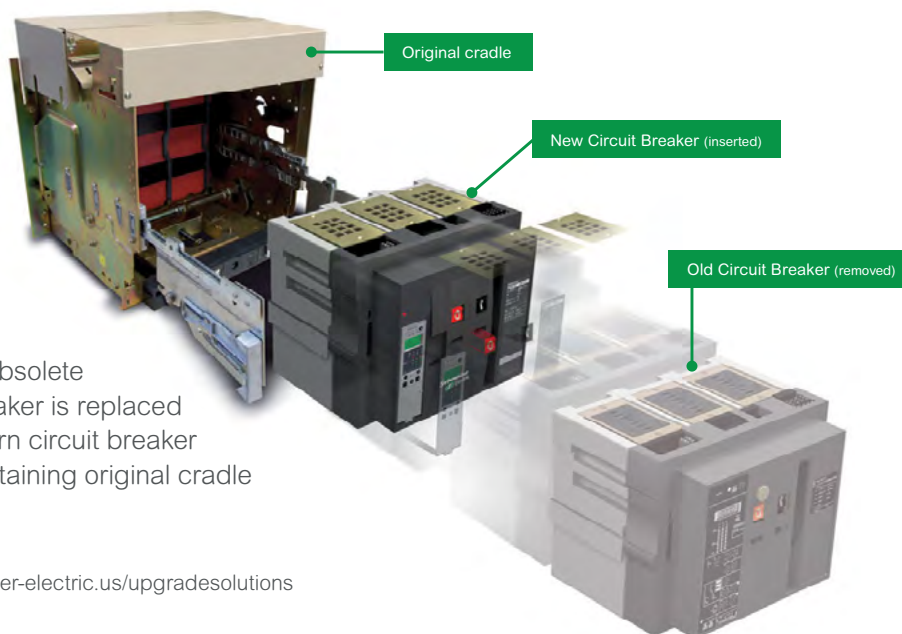
## Check out these additional LV resources:

Visit our [Schneider Electric YouTube Channel](#) and search "Upgrade Solutions."

  
**12 month**

extended warranty with the purchase of start-up and commissioning.\*

\*Additional 30 month warranty extension for drive start-up.



**Figure 6**

Aging or obsolete circuit breaker is replaced with modern circuit breaker while maintaining original cradle

## Retrofill

The existing switchgear cell and bus are modified to accept the new circuit breaker. This option requires a longer bus outage (compared to the direct replacement option), during which time the internal circuit breaker cell is modified to accept the new circuit breaker. A retrofill solution is often used in lieu of the direct replacement option for larger devices, such as main circuit breakers and tie circuit breakers.

- **Low voltage** — Features a MasterPact cradle and circuit breaker, along with a new racking mechanism and primary and secondary connections in each switchgear cell. Existing cells are modified to accept the new cradle and circuit breaker, including a custom-engineered connection between the cradle and the switchgear line and load side bus. Custom designs are available for any manufacturer's low-voltage switchgear.
- **Medium voltage** — This solution upgrades switchgear by installing a new medium-voltage circuit breaker and cell into an existing line-up. Necessary modifications — including an all-new racking mechanism, primary and secondary disconnects, and customized connections — are made to the existing cell. Available designs include:
  - Air-magnetic to vacuum or SF<sub>6</sub>
  - Air-blast to vacuum or SF<sub>6</sub>
  - OCB switchgear to vacuum or SF<sub>6</sub> switchgear
  - Convert stationary circuit breaker to draw-out, or obsolete air circuit breaker to vacuum or SF<sub>6</sub>



Equipment is de-energized

### New cubicle doors

Both the direct replacement and retrofill solutions feature new cubicle doors to match the existing equipment and new circuit breaker face.



Equipment is de-energized

### Less downtime for installation

Downtime is minimized when compared with the demolition and replacement of existing equipment.

# MasterPact™ NT/NW/MTZ low-voltage circuit breakers

Providing the latest in circuit breaker technology, MasterPact NT/NW/MTZ circuit breakers feature high ampere interrupting and short-time current ratings, Modbus communication protocol, and field-installable devices such as sensor plugs and accessories.

In addition, MasterPact NT/NW/MTZ circuit breakers meet the requirements of UL489, UL1066, ANSI, IEC 60947-2, and CE Mark standards. Under normal operating conditions, MasterPact circuit breakers do not require maintenance. Completely modular in design, all replaceable parts can be installed with hand tools and require no critical adjustments.

Completely modular in design, all replaceable parts can be installed with hand tools and require no critical adjustments.

## Additional features include:

- Draw-out circuit breakers with three racking positions and status indicator on cradle
- Draw-out or fixed mount, 3- or 4-pole construction
- Integral ground-fault protection for equipment
- Protective relaying functions
- Zone-selective interlocking, which can reduce damage in the event of a detected fault

Trip unit features	MasterPact NT/NT Trip Unit Types				MasterPact MTZ
	Basic	A	P	H	Nx
Open and close the circuit breaker	–	✓	✓	✓	✓
Circuit breaker position and status (Open/Tripped/ Closed/ Connected/Test/Disconnected)	–	✓	✓	✓	✓
Display measurements at all settings	–	✓	✓	✓	✓
View current and voltage waveforms	–	–	–	✓	✓
Fine settings	–	–	✓	✓	✓
Read all logged data	–	–	✓	✓	✓
Maintenance record	–	–	–	✓	✓
Protective relaying	–	–	–	✓	DM
ERMS	–	–	–	✓	DM

\*DM=Digital Module



MasterPact Circuit Breakers, MicroLogic Trip Units and MasterPact MTZ

## Modernizing your aging switchgear is the smart thing to do!

The Internet of Things (IoT) is changing the way we receive and consume data. Everything seems to be connected, even switchgear! Make your switchgear smarter in order to help you make better decisions and gain greater control of your facility.

**EcoStruxure™ Asset Advisor:** This cloud-based service provides actionable recommendation. It helps to detect potential issues inside your electrical distribution equipment and to mitigate the risk of electrical failure by harnessing the emergence of IoT with breakthroughs in connectivity, sensor technology, and analytics.

**Smart Systems asset management:** For low-voltage installations, its simple, plug-and-play design connects your computer to circuit breakers to identify opportunities to help you reduce downtime and improve operational efficiency.

**Asset Connect:** Upgrade your installation with smart sensors, to transform non-communicating equipment into connected assets for continuous monitoring.

**MicroLogic™ trip units:** MicroLogic trip units are available for use with MasterPact circuit breakers. These trip units provide advanced functionality, such as a communications interface, bluetooth technology, power metering, and monitoring capabilities, which allow for integration and coordination of your electrical system. Functions include load protection, power measurement, power monitoring, and maintenance monitoring.

# Magnum medium-voltage circuit breakers

Magnum direct replacement circuit breakers are a family of products that upgrade existing medium-voltage switchgear to current switching technologies.

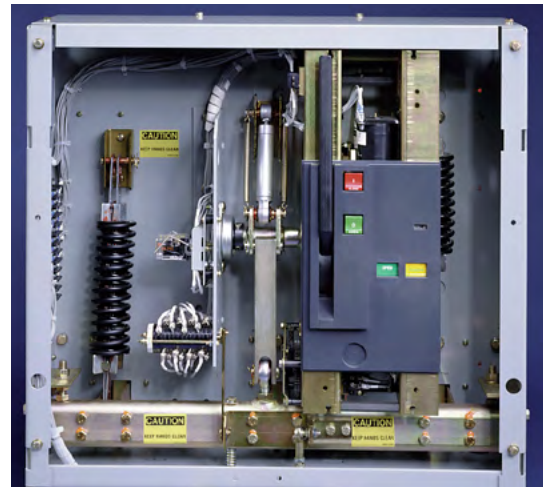
Built with new components and tested to ANSI standards, Magnum circuit breakers interface with the existing circuit breaker compartment components and maintain safety interlocks present in the original equipment design. To further simplify the modernization process, Magnum designs are available for any brand of medium-voltage switchgear.

## Features

- Available in 5 kV – 15 kV; upgraded MVA ratings available
- Low maintenance vacuum and SF<sub>6</sub> arc interruption technology
- Meets the requirements of ANSI/IEEE C37.59 standards
- High dielectric strength, moisture-resistant primary insulation
- Nuclear certification available
- No arc byproduct ventilated into the compartment
- Reduced power consumption of the control components
- Optional capabilities
  - Increased arc fault current interruption capacity
  - Arc flash reduction
  - Relay upgrade, improved accuracy and repeatability, and shorter interrupting time
  - Power monitoring and communication
  - Ground and test devices available
  - Remote racking solutions available

## Have a smaller cell size and footprint?

We now offer a 26" retrofill solution for 5 kV vacuum switchgear applications.



The operating mechanism on Magnum medium-voltage circuit breakers is simple to inspect and maintain.

Check out these additional MV resources:

**Medium-voltage direct replacement designs**  
Visit [schneider-electric.us/upgradesolutions](https://schneider-electric.us/upgradesolutions)

**Medium-voltage upgrade solutions demo videos!**

Visit [Schneider Electric YouTube Channel](https://www.youtube.com/channel/UC...) and search "Upgrade Solutions."



# Your single-source service provider

And when we say “single source,” we mean it! Our national team of qualified professionals has the expertise to service ANY brand of equipment. To see just how much we stand out from other providers, take a moment to review our qualifications.

## Mission

To enable you to operate at peak performance by delivering expert care throughout the life cycle of your electrical distribution system.

## Location



## Experience

- Over 200 professional engineers collectively registered in every state
- Over 20,000 power system studies, assessments, and designs
- Over 50 years of field services experience

## Expertise

- Maintenance and testing services
- Switchgear modernization solutions
- Power system engineering services
- Custom and turnkey solutions
- New installation services
- Emergency services 24/7
- Available 24/7 monitoring through EcoStruxure Asset Advisor

Committed to safety

8x

lower incident rating than national average

300+

operational safety awards by the National Safety Council in the past two years



National network

of qualified field service representatives, as defined by OSHA/ NFPA 70E



1 in 3 companies in the world

of qualified field service representatives, as defined by OSHA/ NFPA 70E

Committed to customers

81%

customer net promoter score, proving our best-in-class customer satisfaction

## How can we help you?

Our professional engineers and qualified field service personnel are ready and available to help you keep your facility safe, reliable, productive and efficient.

Emergency services available 24/7: **888-778-2733.**

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Discover upgrades solutions for all LV and MV applications, including switchgear, motor control centers, relays, and much more.

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Schneider Electric USA  
800 Federal Street  
Andover, MA 01810  
Phone: 978-794-0800



# Start-Up

Reduce risk and time to deploy your new installations

Who can commission your Schneider Electric equipment better than our Schneider Electric experts? An efficient control system begins with a successful start-up, so no business can afford installation start-up delays. That is why Schneider Electric provides you the tool you need to complete this key step with minimum time and effort.

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## Why choose start-up support?

The Schneider Electric service teams are expertly prepared to provide assistance in the installation and start-up of your new drive, ensuring your new equipment is setup correctly and fully tested before power-on. Our certified technicians use our proprietary tools to ensure that your equipment is properly commissioning and programmed. Furthermore, you will receive a detailed commissioning report, signed off by a Schneider Electric engineer, giving you peace of mind that your equipment is set up correctly and fully covered by our warranty.

## Benefits for your plant:

- Reduce start-up time to the minimum
- Minimize risk of equipment failure
- Ensure equipment performs to design
- Cut life cycle costs with installation that complies with Schneider Electric requirements and prevents warranty issues

## Start-Up service

Our dedicated Start-Up service enables you to achieve the full value of your automation investment. We can help you choose the right technologies for your project, aid in design, as well as train your staff on programming, maintenance, and user procedures. Cut your time to market and have your automation systems up and running in the shortest period of time possible.

## What is typically covered by the service?

- Power-up and diagnostic checks on all Schneider Electric system components with more than 100 checkpoints
- Validated system mounting, routing and connection of wiring, cabinet space, and airflow
- Maintenance booklet outlining the service schedule for the life of the drive
- Complete start-up report with details of drive configuration, topology, and recommendations
- Training in operation of the drive

## Minimize risk of warranty issues

with correct equipment start-up



# A cost-effective approach to modernizing aging switchgear.

Medium- and low-voltage direct replacement and retrofill modernization solutions selector guide



This equipment in this image is de-energized

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# Upgrading your aging switchgear is easier than you think...

For existing switchgear line-ups, we offer custom-engineered direct replacement circuit breakers which are designed to fit into the existing switchgear cell with minimal modification and down-time.

Our direct replacement and retrofill solutions utilize the upgraded technology of the Masterpact™ NT/NW insulated case circuit breaker for low voltage systems or the Magnum™ circuit breaker for medium voltage systems.

## Benefits:

- **Reduced costs for switchgear upgrades**
  - » New circuit breakers are installed in existing switchgear
  - » Original footprint is left intact, saving time and money
  - » Upgrades can be performed on an incremental basis
- **Less downtime for installation**
  - » Downtime is minimized when compared with the demolition and replacement of existing equipment
- **Enhanced equipment reliability**
  - » New circuit breakers undergo complete factory testing and are backed by our standard equipment warranty
- **Reduced maintenance and operating costs**
  - » New, easy-to-maintain operating mechanism
  - » Reduced need for difficult to obtain spare parts

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Designs available for ANY brand.



# Extended Warranty

Long-term protection for your assets

Schneider Electric covers its hardware with repair or replacement of products for a period of 24 months from the date of manufacture.\* If your buying procedures are complicated, you are in a remote location, or have business critical applications, you may require more than the standard exchange or repair procedure for your automation products such as variable speed drives, motion, HMI, and PLCs. To help you address this need, Schneider Electric can extend your standard factory warranty to provide up to five years of protection, letting you focus on running your business.

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### Extended warranty:

This service allows you to extend your factory warranty for an additional one or three years, giving you more flexibility, peace of mind and improved control of your maintenance budget.

Included:

- Replacement or repair of product
- Ship first — return later

### On-site support option

This warranty option takes you one step further. In addition to the extended warranty scope, you will have the possibility to have an expert on-site to perform a scheduled maintenance action or help resolve a technical event related to the warranted equipment. This extra-charge option can also include a specific response time commitment for on-site interventions, subject to applicable terms and conditions.

### Why do you need extended warranty?

After your original product warranty expires, you face the risk of additional maintenance expenses that are difficult to plan and budget. Our extended warranty service gives you protection against escalating repair costs.

### Benefits for your plant:

- Protect your budget from unscheduled expenses
- Reduce your administrative costs by processing only one purchase order per warranty period
- Protect your investment
- Benefit from high-quality repair performed by Schneider Electric experts

\* Subject to our local terms and conditions.

### Do you want to:

- Protect your budget from escalating repair costs?
- Reduce maintenance cost of new products?
- Have more time to focus on your core business?

Extended warranty means  
**more control**  
of your maintenance budget.

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# Drives services

Preventive maintenance – the key to continuous operations

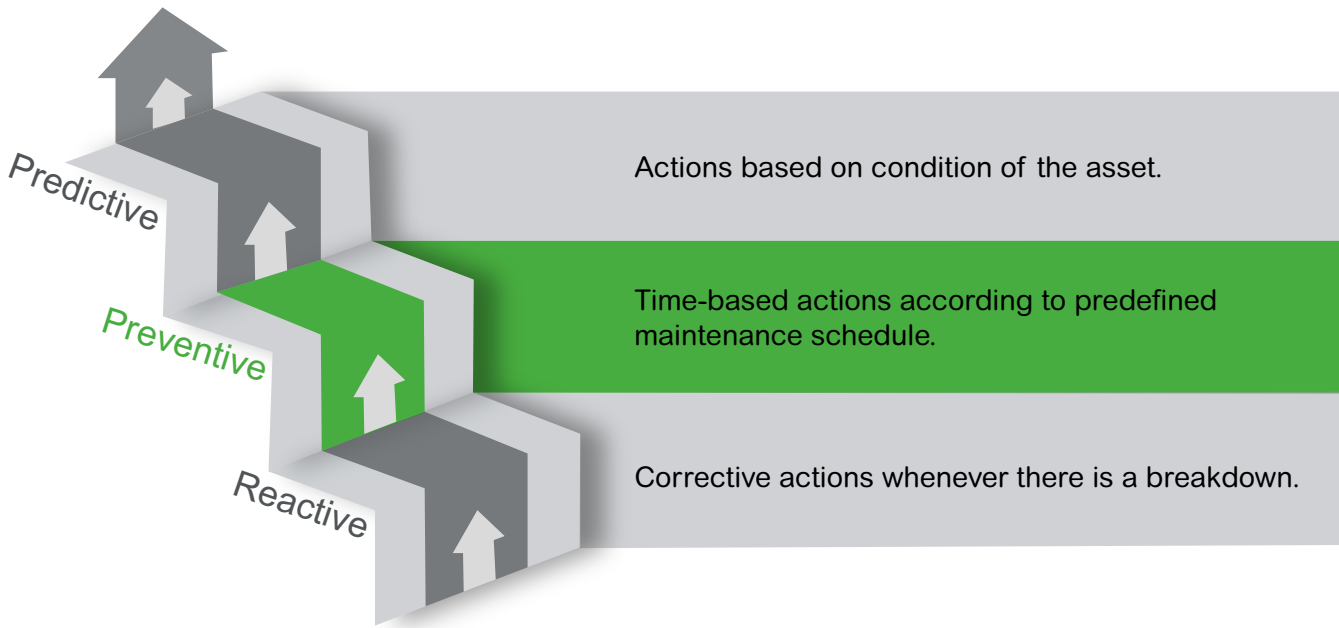
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# Preventive maintenance – key to continuous operations

Your plant's productivity depends largely on the condition and performance of your equipment. You choose your maintenance approach – reactive, preventive or predictive – depending on your availability targets. Need for more advanced maintenance increases when reliability and availability requirements grow.



Schneider Electric™ offers preventive maintenance services that help you reduce unexpected process interruptions by creating and executing a customized maintenance plan for your drives.

## Downtime is expensive

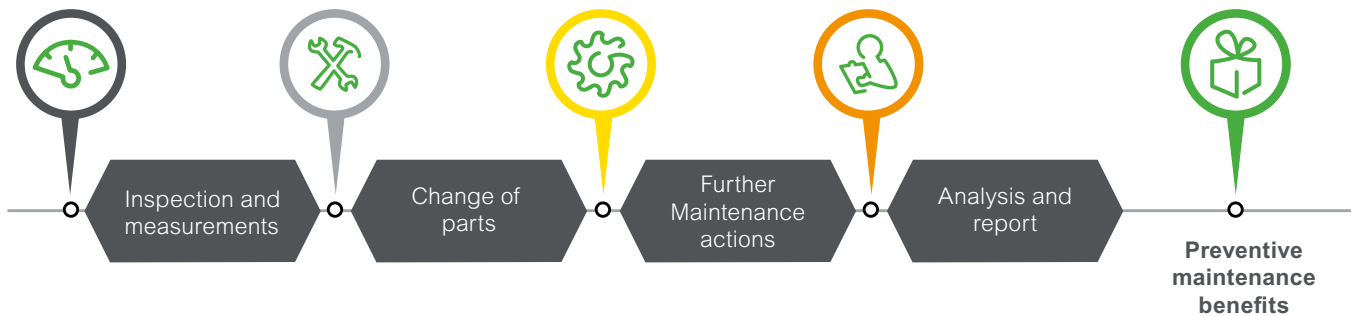
What does an hour of downtime cost your plant?

- Estimates vary based on the industry and size of the facility but have ranged from \$50K to over \$1M per hour of downtime per incident.
- Effectively, almost every factory loses at least 5% of its productive capacity due to downtime and many lose as much as 20%.
- Analysts report that 4 in every 5 industrial facilities are unable to evaluate their downtime accurately, with many underestimating the Total Downtime Cost (TDC) by 200 to 300%.

# Preventive maintenance helps avoid unplanned downtime

Our preventive maintenance service uses a time-based methodology where actions are performed on a yearly basis. The preset schedule is followed regardless of the equipment condition at the time, similar to changing a car's oil every 20000 miles.\*

- Parts replacement for aging and worn components
- Comprehensive testing to help ensure proper operation
- Minor corrections and repairs can be performed as needed



## Actions to be performed

### Inspection and Measurement

- Input/Output terminals
- Contacts
- Oxidation/Corrosion/Dust
- Cooling system
- Heat exchanger

### Change of parts

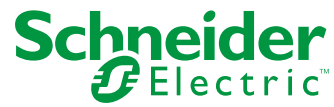
- Filters
- Fans
- Cooling fluid
- Capacitors

## Benefits for your plant

- Anticipate breakdowns and extend life of system and components
- Reduce risk of unscheduled downtime
- Maximize uptime and production revenue
- Keep your system running at peak performance
- Improve reliability of operations

\*Asset and environment conditions to be analyzed by Schneider Electric specialist.

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# Spare parts for drive products

## High quality original parts safeguard your process

Operational performance depends on your critical assets functioning at all times. Failure of critical parts can cause disruption and financial loss. The risk of production interruption can be reduced by proactive maintenance and by the fast replacement of broken or faulty parts. In both cases, high quality spare parts are needed to safeguard your process.

Schneider Electric™ provides you with original spare parts as the ideal base for your preventive maintenance and – if needed – repair work. In addition to that, Schneider Electric uses its expert product knowledge to provide recommendations for the optimal set of spare parts taking into account your installed base.

### Schneider Electric spare parts

Schneider Electric spare part service offers you parts which are:

- Original – As manufacturer Schneider Electric knows exactly the spare parts for its products.
- High quality – The parts are authentic and the same as used in the actual product. There is no fear for counterfeit parts when sourcing from the manufacturer.
- Available - Spare parts are available from our local, regional and global stocks. Fast delivery options can further accelerate the delivery of parts to you.

### Key benefits - the right parts at the right time

**Lower risk** of downtime and performance degradation owing to the unavailability of the right spare parts.

**Budget control** comes from planning the availability of key parts and avoiding emergency purchases or excess inventory.

**Flexibility** with different options to manage spares, ensuring your needs are met.

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## Parts for maintenance and other purposes

Schneider Electric offers wear parts which are needed to be changed on regular intervals as part of a preventive maintenance program. These parts include fans and filter pads and can be changed by your maintenance personnel or your service provider. Naturally, Schneider Electric also provides the workforce needed to do the change.

In addition to the wear parts, Schneider Electric provides parts for more complex repair, revitalization and maintenance actions. Those parts can only be changed with specially certified Schneider experts to help to ensure that no harm is done to the product in question.

## Optimized set of spare parts

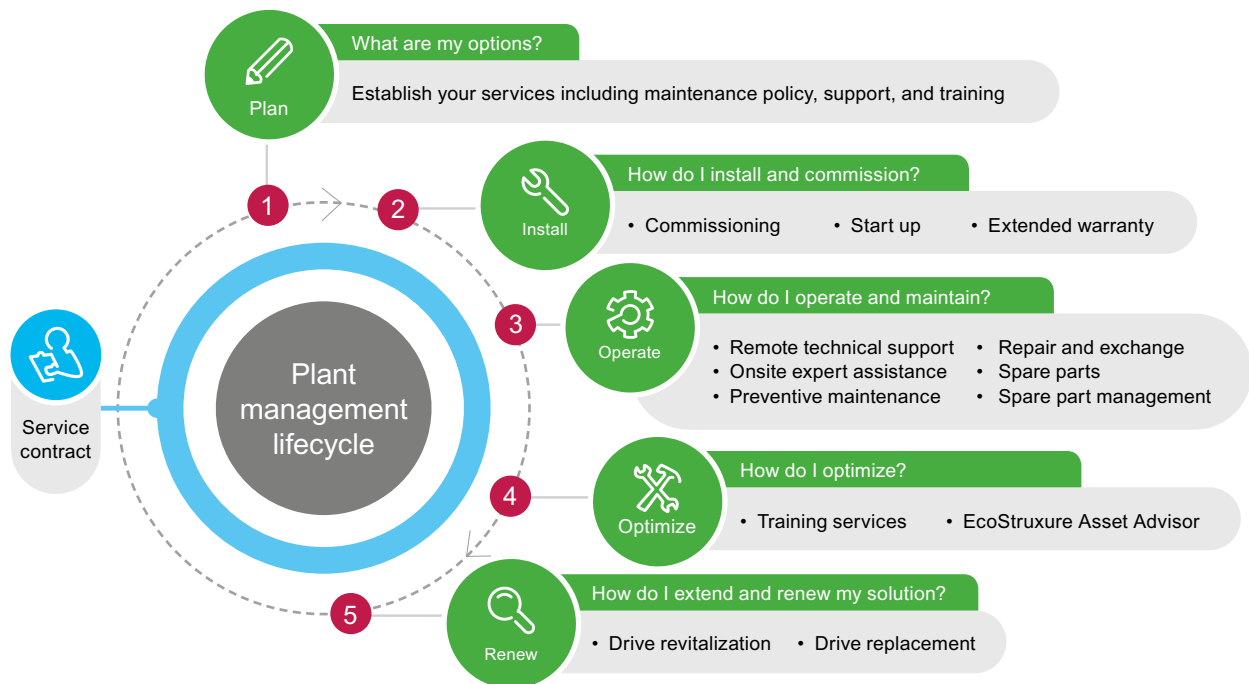
Based on your installed drives Schneider Electric is able to recommend an optimized set of spare parts for drive products to match the needs of your operation. Optimized set means minimizing the amount of various spares while still taking into account all the drive products included in your installed base. The target is to achieve optimal process availability and reduce cost.

## Additional service – spare part management

To be prepared for any sudden interruptions it is often the best to keep a stock of parts at your site for immediate availability. As that might mean a burden for your networking capital costs, Schneider Electric offers Spare Part Management service. With this service you can select between onsite or off-site stock of spares optimized to your needs and just pay for the service instead of owning the stock.

## Drive lifecycle services

Schneider Electric can provide a range of services throughout the lifecycle of your drive and plant operation. Contact your local representative to learn more.



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# Know and Weigh Your Options:

Five Key Questions to Help in Developing  
an Arc Flash Mitigation Strategy

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## Introduction

The best way to reduce arc flash hazards is by establishing a holistic strategy that accounts for enhanced safety and operation requirements as well as system reliability and continuity of service. To assist engineers trying to implement safety-by-design principles our experts have created this document to help assemble the knowledge needed to formulate an effective strategy. In this document we present five key questions that will help you with the challenges of developing an effective protection strategy for your application.

### 1. What are the goals for arc flash for each level of distribution equipment?

The secret to success is establishing clear goals. We have defined four categories that break down the different types of technologies based on how they aid in limiting arc flash impact. Your strategy could include one, or any combination for the different levels of distribution equipment.

An example of goal setting can be reducing arc incident energy levels in locations where there is a high frequency of exposure and a need for lower PPE levels without compromising personnel safety.

The four arc flash mitigation categories can be a good reference point when establishing overall goals for your application. It all starts with asking yourself “What do I want to achieve?”

**Do I want to AVOID? PREVENT? CONTAIN? REDUCE?”**



**Avoidance:**  
Help isolate personnel from the vicinity of the hazard but the arc flash hazard remains unaffected.



**Prevention:**  
Reduces the likelihood of an arc event without necessarily altering the arc flash severity levels.



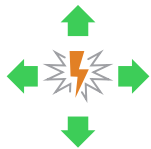
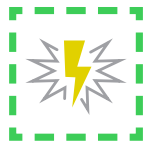
**Containment:**  
Effectively contains and redirects the arc flash fault and its by-products away from personnel.



**Reduction:**  
Lower the incident energy level by clearing the arc fault more quickly.

*The categories prove effective regardless of the application (medium voltage vs. low voltage, industrial vs. commercial, etc.).*



**AVOID****PREVENT****CONTAIN****REDUCE**

## 2. Which operations and maintenance procedures require protection?

It is important to identify procedures and tasks that may require protection, for example, during normal operations where there could be unintentional exposure due to proximity to the electrical equipment. It is recommended that a proper arc flash risk assessment is completed (as outlined in the NFPA Standard 70E) to help evaluate the potential for exposure based on given tasks.

## 3. What is the prevention and avoidance strategy for mitigating risk?

Prevention and Avoidance arc flash solutions should be considered the primary strategies for mitigating risk and be part of the risk assessment. It is important to remember that while these types of solutions are effective in helping reduce the risk, they do not reduce the potential hazard exposure. The reduction of risk is certainly a benefit, but if the goal is to reduce the level of incident energy at a location, other measures may need to be considered in lieu of, or in addition to these solutions.

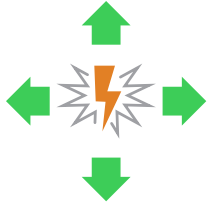
## 4. Is there a specific requirement for equipment survivability to minimize downtime?

It is difficult to quantify the effect of mitigation technology on equipment damage; nevertheless, there is a logical connection between the two. We recommend that critical equipment be evaluated to determine the potential need for greater degrees of mitigation.

## 5. What are the other limiting factors?

It is important to consider other factors, such as equipment footprint, capital expenditure (installed costs) versus operational expenditure (ongoing costs, including maintenance), sustainability of complex equipment or relaying schemes and reliability, including selective coordination.

*Please refer to the application notes that dig deeper into the details, benefits and limitations of the different arc flash mitigation types when deployed in specific environments.*



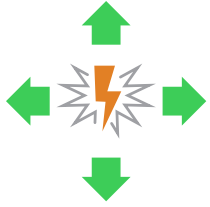
# AVOIDANCE

SOLUTIONS THAT HELP PERSONNEL AVOID THE HAZARD OR ADD DISTANCE

One way to reduce the likelihood of electrical incidents is to introduce measures that make it less necessary for personnel to be near locations with a high level of arc flash hazard. Avoidance measures can be effective in removing the worker from, or increasing the distance to, the exposed energized parts. Avoidance solutions reduce both the likelihood and severity to personnel but arc flash hazard levels remain unaffected.

Arc Flash Mitigation Types	Protection During Operation	Protection During Maintenance / Abnormal Operation	Reduced Incident Energy (cal/cm <sup>2</sup> ) <sup>1-2-3</sup>	Recovery Time	Impact on Footprint	Impact on Commissioning	Modifying Existing Equipment	CapEx <sup>5</sup>	OpEx <sup>5</sup>
Remote Operation	Yes	No	Yes <sup>4</sup>	NA	Low	None	Easily	\$\$	\$
Time Delay Switch (TDS) Operation	Limited	No	Yes <sup>4</sup>	NA	None	None	Easily	\$\$	\$
Absence of Voltage Tester	Limited	No	Yes <sup>4</sup>	NA	None	None	Possible	\$\$	\$
InfraRed (IR) Windows	Limited	No	Yes <sup>4</sup>	NA	None	None	Easily	\$\$	\$
Close Door Racking	Limited	No	No	NA	None	None	Possible	\$\$	\$
Remote Racking System	Yes	No	Yes <sup>4</sup>	NA	None	None	Easily	\$\$	\$
Partial De-Energization / Load Redundancy Multiple Sources (Main-Tie-Main)	Limited	Limited	Limited	Partial Operation Hours/Days	High	Medium	Difficult	\$\$\$	\$

**Notes:** 1. Based on clearing time and typical range of fault currents. / 2. At the operator (18 inches). / 3. Incident energy is reduced by adding distance between the operator and the hazard, the hazard level remains unchanged.  
 4. Costs are ranked for typical application but may vary based on actual application implemented. / 5. Capital Expenditures, Operating Expenditures



# AVOIDANCE

SOLUTIONS THAT HELP PERSONNEL AVOID THE HAZARD OR ADD DISTANCE

Arc Flash Mitigation Types	Application Notes
Remote Operation	<p>Remote operation of electrically operated circuit breakers, switches, etc. using motor operated tool or remote control station.</p> <ul style="list-style-type: none"> <li>• Only applies to actuation of device.</li> </ul>
Absence of Voltage Tester	<p>Allows confirmation of absence-of-voltage without having to access potentially live components of equipment.</p> <ul style="list-style-type: none"> <li>• Typically, lower PPE requirements per NFPA 70E for testing with door closed</li> <li>• Only applies to de-energized work.</li> </ul>
InfraRed (IR) Windows	<p>May prevent the need to open doors for IR thermography inspection, reducing the potential for exposure to energized parts.</p> <ul style="list-style-type: none"> <li>• Typically, lower PPE requirements per IEEE 70E for testing with door closed.</li> <li>• Only provides snapshot of the current operating conditions at the time of inspection.</li> <li>• Obstructions may prevent viewing of potential hot spots from window location.</li> <li>• Also see Continuous Thermal Monitoring as an alternative to help Avoid and Prevent</li> </ul>
Partial De-Energization / Load Redundancy / Multiple Sources (Main-Tie-Main)	<p>Equipment line-up(s) (SWGR, SWBD, MCC) configuration that if properly designed allows partial shutdown and limited operation so that work can be performed on de-energized sections of equipment. Commonly done with Main-Tie-Main, load redundancy on separate equipment line-ups, source switching, etc.</p> <ul style="list-style-type: none"> <li>• Main-Tie-Main has limited redundancy with dual mains and a tie segregating n+1 (or greater) equipment of similar function. Other configurations may allow for partial shutdown or transfer of loads to a separate or temporary source.</li> <li>• Reduces the likelihood of arc flash when work can be performed de-energized vs. energized on critical power.</li> <li>• Must be interlocked or locked out/tagged out to prevent human errors.</li> <li>• May still allow for possibility of arc flash propagation to neighboring sections of common equipment line-up.</li> <li>• Main-Tie-Main may have optional reduced sizing of main circuit breakers which may reduce incident energy of an event but not allow for full loading with only one main supplying full load of line-up.</li> </ul>
Time Delay Switch (TDS) Operation	<p>Operator initiate action of electrically operated circuit breakers, switch, etc. Actual operation of device does not occur for the prescribed time delay, giving time for the operator to remove themselves from hazard boundary before actuation.</p> <ul style="list-style-type: none"> <li>• No assurance that operator has left the hazard boundary in time.</li> <li>• Only applies to actuation of device.</li> </ul>
Closed Door Racking	<p>MCC bucket/compartament design that allows connection / disconnection to buss with door closed.</p> <ul style="list-style-type: none"> <li>• Only applies to racking of units.</li> <li>• Can be used in conjunction with remote racking tool to possibly work outside of hazard boundary during racking operations.</li> <li>• No tested confirmed benefits, just possible distancing from source of hazard.</li> </ul>
Remote Racking System	<p>Remote racking operations using a tool to work outside of arc flash boundary during racking operations.</p> <ul style="list-style-type: none"> <li>• Only applies to racking of with-drawable compartments.</li> </ul>



# PREVENTION

## SOLUTIONS THAT HELP REDUCE RISK

One of the best ways to prevent and control risk of hazard is to “design out.” Multiple technologies exist that help prevent or reduce the likelihood of an arc event. This is done by including prevention considerations in designs and are particularly important for critical applications.

Prevention by Design Arc Flash Mitigation Types	Protection During Operation	Protection During Maintenance / Abnormal Operation	Reduced Incident Energy (cal/cm <sup>2</sup> ) <sup>1-2-3</sup>	Recovery Time	Impact on Footprint	Impact on Commissioning	Modifying Existing Equipment	CapEx <sup>5</sup>	OpEx <sup>5</sup>
Barriers / ANSI Compartmentalization	Yes	Limited	No	NA	None	Low	Application Dependent	\$\$	\$\$
High Resistance Grounding	Limited	Limited	No	NA	Low	High	Possible	\$\$\$	\$\$
Gas Insulated Switchgear	Yes	Limited	No	NA	Improves	Medium	No	\$	\$
Shielded Solid Insulated Switchgear	Yes	Limited	No	NA	Improves	Medium	No	\$	\$
IR Thermographic Study	Increases exposure	Increases exposure	No	Predictive	None	None	NA	\$	\$\$\$
Continuous Thermal Monitoring	Alert Only	Alert Only	No	Predictive	Low	Low	Possible	\$\$\$	\$
Continuous Humidity Monitoring	Alert Only	Alert Only	No	Predictive	None	Low	Easily	\$\$	\$

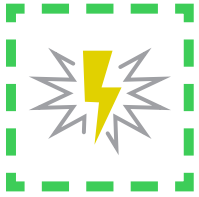
**Notes:** 1. Based on clearing time and typical range of fault currents. / 2. At the operator (18 inches). / 3. Incident energy is reduced by adding distance between the operator and the hazard, the hazard level remains unchanged.  
4. Costs are ranked for typical application but may vary based on actual application implemented. / 5. Capital Expenditures, Operating Expenditures



# PREVENTION

SOLUTIONS THAT HELP REDUCE RISK

Arc Flash Mitigation Types	Application Notes
Continuous Thermal Monitoring	<p>Thermal monitoring sensors at key measuring locations in lieu of thermographic inspection. Opening of doors or removal of covers is not required to access equipment for inspection, reducing the need for exposure to energized parts.</p> <ul style="list-style-type: none"> <li>• Continuous monitoring catches events not seen during inspections.</li> <li>• May predict events prior to occurrence for corrective actions.</li> <li>• Available on a limited number of equipment types and locations within equipment.</li> </ul>
Continuous Humidity Monitoring	<p>Humidity monitoring sensors for calculation of equipment degradation and hazards. Opening of doors or removal of covers is not required to access equipment for inspection, reducing the need for exposure to energized parts.</p> <ul style="list-style-type: none"> <li>• Continuous monitoring records values not seen during inspections.</li> <li>• May predict events prior to occurrence for corrective actions.</li> <li>• Requires some kind of asset / condition monitoring system with proper functionality.</li> </ul>
Barriers and ANSI Compartmentalization	<p>Various barriers to deter incidental exposure to a hazard or to provide additional protection from a hazardous event (e.g. insulation, terminal barriers, ANSI compartmentalization, section barriers, bus shutters, etc.)</p> <ul style="list-style-type: none"> <li>• May not be tested to confirm all types of benefits offered.</li> <li>• Reduces the likelihood of arc flash.</li> <li>• May lower risk of touch hazards that could initiate an event.</li> <li>• May reduce the likelihood of arc flash propagation to neighboring areas of equipment.</li> <li>• May contain some of incident energy to an area or section.</li> </ul>
High Resistance Grounding	<p>Lowers the phase-to-ground current to 10 amps or less for phase-to-ground faults.</p> <ul style="list-style-type: none"> <li>• Reduces the likelihood of arc flash by preventing phase-to-ground faults from initiating arc flash events.</li> <li>• Does not protect against line-line or three-phase faults.</li> <li>• Does not affect incident energy levels when arc-flash occurs as the result of a line-line or three-phase fault.</li> </ul>
Gas Insulated Switchgear	<p>Reduces the likelihood of arc flash by providing an insulating dielectric gas between conduction.</p> <ul style="list-style-type: none"> <li>• No exposed live components once installed.</li> <li>• Reduce likelihood of a phase to phase fault.</li> <li>• Only applies to Medium Voltage applications.</li> </ul>
Shielded Solid Insulated Switchgear	<p>Reduces the likelihood of arc flash by providing an epoxy insulation between phase conduction.</p> <ul style="list-style-type: none"> <li>• No exposed live components once installed.</li> <li>• Reduce likelihood of a phase to phase fault.</li> <li>• Only applies to Medium Voltage applications.</li> </ul>
IR Thermographic Study	<p>IR imaging locates hot spots where there may be issues such as overloading, loose connections, etc.</p> <ul style="list-style-type: none"> <li>• May predict events prior to occurrence for corrective actions.</li> <li>• Need to open doors and expose personnel to increased hazards and increased likelihood of causing an unintentional fault.</li> <li>• Only provides snapshot of the current operating conditions at the time of inspection.</li> </ul>



# CONTAINMENT

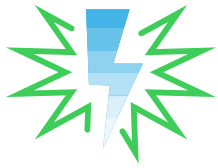
SOLUTIONS THAT HELP ENCLOSE THE HAZARD

These solutions typically feature an enclosure that is reinforced enough to contain and redirect the high pressure and heat produced during an arc flash event.

Containment Arc Flash Mitigation Types	Protection During Operation	Protection During Maintenance / Abnormal Operation	Reduced Incident Energy (cal/cm <sup>2</sup> ) <sup>1-2-3</sup>	Recovery Time	Impact on Footprint	Impact on Commissioning	Modifying Existing Equipment	CapEx <sup>5</sup>	OpEx <sup>5</sup>
Arc Resistant	Yes	No	No	Weeks/Months	Medium	Low	No	\$\$\$\$\$	\$

**Notes:** 1. Based on clearing time and typical range of fault currents. / 2. At the operator (18 inches). / 3. Incident energy is reduced by adding distance between the operator and the hazard, the hazard level remains unchanged.  
4. Costs are ranked for typical application but may vary based on actual application implemented. / 5. Capital Expenditures, Operating Expenditures

Arc Flash Mitigation Types	Application Notes
Arc Resistant	<p>Enclosures designed to contain or safely vent of an arc flash event. Tested per IEEE C37.20.7</p> <ul style="list-style-type: none"> <li>• Available on a limited number of equipment types.</li> <li>• Equipment must be installed within its ratings for maximum arcing current and arcing duration.</li> <li>• Impact to footprint due to ducting and venting into "secure areas."</li> <li>• Vent ducts obstruct space and need clearance. New hazardous regions introduced in venting areas.</li> </ul>



# REDUCTION

## SOLUTIONS THAT LOWER INCIDENT ENERGY

The most effective way to reduce incident-energy levels in an electrical system is to reduce the duration of the arc, by clearing the arcing fault from the system in the shortest amount of time possible.

Reduction Arc Flash Mitigation Types	Protection During Operation	Protection During Maintenance / Abnormal Operation	Reduced Incident Energy (cal/cm <sup>2</sup> ) <sup>1-2-3</sup>	Recovery Time	Impact on Footprint	Impact on Commissioning	Modifying Existing Equipment	CapEx <sup>5</sup>	OpEx <sup>5</sup>
Energy Reducing Maintenance Switch	Limited	Limited	Less than 8/12	Hours/Days* depending on ERMS switch been turn on	None	Low	Possible	\$\$	\$
Circuit breaker with Instantaneous or Override below arcing level	Limited	Limited	Less than 8/12	Hours/Days	None	Medium	Limited	\$\$	\$
Adaptive Settings	Limited	No	Less than 40	Weeks/Months	None	Low	Possible	\$	\$
Current-Limiting Circuit Breakers/Fuses	Limited	Limited	Less than 8/12	Hours/Days	Medium	Low	Limited	\$\$	\$
Digital Multi- Function Relay	Yes	Yes	Less than 40	Weeks/Months	Low	High	Possible	\$	\$
Zone Selective Interlocking	Yes	Yes	Less than 12	Hours/Days* depending on calorie availability	None	Medium	Possible	\$\$	\$
Differential Protection	Limited	Limited	Less than 8/12	Hours/Days	Low	High	Possible	\$\$\$	\$
Transfer Trip Scheme (Virtual Main)	Yes	Yes	Less than 8/12	Hours/Days	Low	Medium	Possible	\$\$	\$
Arc Flash Detection Device (Optical Sensors)	Yes	Yes	Less than 8/12	Hours/Days	Medium	Medium	Application Dependent	\$\$	\$
High Speed Shorting Switch (Quenchers)	Yes	Yes	Less than 1.2	Hours/Days	High	High	Possible	\$	\$
Line Side Isolation with Passive Reduction	Yes	Yes	Less than 1.2	Hours/Days	Low	Low	Possible	\$	\$

**Notes:** 1. Based on clearing time and typical range of fault currents. / 2. At the operator (18 inches). / 3. Incident energy is reduced by adding distance between the operator and the hazard, the hazard level remains unchanged.  
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# REDUCTION

SOLUTIONS THAT LOWER INCIDENT ENERGY

Arc Flash Mitigation Types	Application Notes
Zone Selective Interlocking (ZSI)	<p>Upstream instantaneous with no intentional trip delay when downstream feeder does not communicate trip event to upstream device, otherwise will trip on configured instantaneous trip settings. No intentional delay = 80ms. Instantaneous = 50ms.</p> <ul style="list-style-type: none"><li>• Can reduce trip time depending on fault location.</li></ul>
Energy Reducing Maintenance Switch (ERMS)	<p>Reduces trip time by changing protective device settings during maintenance operations.</p> <ul style="list-style-type: none"><li>• Negatively impacts coordination when enabled for maintenance.</li><li>• Typically, manual operation is required to enter and exit maintenance mode at appropriate times.</li><li>• Arc Flash study required.</li></ul>
Adaptive Settings	<p>Protective device has multiple sets of trip curves that can be selected for faster tripping and/or coordination.</p> <ul style="list-style-type: none"><li>• May be used on feeder protection that can be fed by multiple sources where different trip curves could provide better protection and/or coordination based on selected source characteristics.</li><li>• Arc Flash study required.</li></ul>
Differential Protection	<p>Summation of current in and out of a zone of protective devices to trip all devices on current mismatch.</p> <ul style="list-style-type: none"><li>• Available for some LV equipment, but more typically used at MV.</li><li>• Protection only provided inside the differential zone. Careful review is required to make sure that the protected zone is adequate to meet safety goals.</li><li>• Arc Flash study required.</li></ul>
High Speed Shorting (Quenchers)	<p>Creates a lower impedance 3 phase fault when an arc flash or arc current is detected directing energy to a sacrificial device and allowing protective devices to clear the fault.</p> <ul style="list-style-type: none"><li>• Bolted switch type devices may cause high upstream currents that could damage devices. Air gap type devices may prevent damage of upstream devices but must ensure lower impedance than the initiating fault to redirect incident energy.</li><li>• Available on a limited number of equipment types.</li><li>• Requires arc flash detection system.</li></ul>
Line Side Isolation with Passive Reduction	<p>Line side conductors are fully enclosed inside a cable vault, which has been tested for the ANSI/IEEE C37.20.7 requirements for arc containment.</p> <ul style="list-style-type: none"><li>• May reduce the likelihood of arc flash.</li><li>• Reduces and contains the arc energy of a fault.</li><li>• Available on a limited number of equipment types.</li></ul>





# REDUCTION

SOLUTIONS THAT LOWER INCIDENT ENERGY

Arc Flash Mitigation Types	Application Notes
Transfer Trip Scheme (Virtual Main)	<p>Tripping of transformer primary side circuit breaker using secondary side current (optional arc flash sensors) to increase zone of protection to include transformer secondary side equipment.</p> <ul style="list-style-type: none"><li>• Incident energy reduction using secondary short time fault current trip verses primary current.</li><li>• Can be used in conjunction with Energy Reduction Maintenance Switch.</li><li>• Arc Flash study required.</li></ul>
Current-Limiting Circuit Breakers/Fuses	<p>Incident energy reduction from faster clearing of fault</p> <ul style="list-style-type: none"><li>• Relatively high fault current to actuate.</li><li>• Coordination Study required to ensure coordination is possible.</li><li>• Arc Flash study required.</li></ul>
Breaker w/ Instantaneous or Override below arcing level	<p>Incident energy reduction from faster clearing of fault using protective device trip functions during maintenance operations.</p> <ul style="list-style-type: none"><li>• Less costly but more complicated than ERMS switch. Must be manually changed before and after maintenance activities.</li><li>• Arc Flash study required.</li><li>• May negatively impact selective coordination when enabled.</li></ul>