



LV Switchgear Assemblies

How to increase the safety of LV switchgear assemblies -
“Avoid serious injuries of persons and blackouts of power”

Lutz Graumann
November 2016



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Safety Above Standard

Your conversation partner today

- Lutz Graumann
 - Eaton Industries Germany
 - Business Development Manager EMEA
 - Safety Specialist – personal and assembly protection @LV switchgear assemblies
 - Consulting IEC 61439, TR61641
 - 25 years engineer with „passion“ and expertise in LV switchgear assemblies upto 6300A, busways, electronic arc flash protection, long term stays in US, Poland, Lower Gulf

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Content

- Why is safety important ?
- Causes & Types of faults
- Risk Mitigation
- Eaton's view of switchboard safety
 - Verification by test to the standard
 - Passive safety measures
 - Active safety measures
- Discussion

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Why do we meet today?

The protection of personnel and systems is increasingly important

- Injury and or death of individuals
- Cost of lost production
- Continuation of supply
 - Continuous processes
 - Life saving power requirements
 - Secure power supplies
- Cost or repair
- Safety First culture



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Safety Management

- Eaton
- assen
- We a
- assen
- Eaton
- a saf
- We w
- again

The screenshot shows the Eaton website page for 'Safety Management for Low Voltage Assemblies'. The page includes the Eaton logo, a navigation menu with 'Products & Services', 'Market Solutions', 'Customer Support', and 'Our Company'. A sidebar on the left lists categories like 'Electrical', 'Application Solutions', and 'Safety Management', with 'Safety Management for Low Voltage Assemblies' selected. The main content area features a large image of an electrical cabinet with a fire, a 'STOP' sign, and a list of products: 'Arc fault Reduction Maintenance System', 'Seismic Compliance', 'IEC814841 Arc fault mitigation', 'ARCON Active Arc fault protection', and 'Diagnose System'. Below the list, there is a paragraph about Eaton's focus on safety management and a link to a video titled 'Safety and risk in electrical low-voltage installations'.

switchgear

for LV switchgear

and is launching

endcustomer

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Incident from the media



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Fault causes and consequences

- Event caused by
 - Technical defect
 - External influences "non-human"
 - Human error
- Consequences
 - Seriously injured people or even death
 - Damage to the assembly, buildings or parts of buildings
 - „Black-out" - inactivity of process - inability to supply



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Faults in a LV switchgear assembly are not 100% predictable or can be completely eliminated

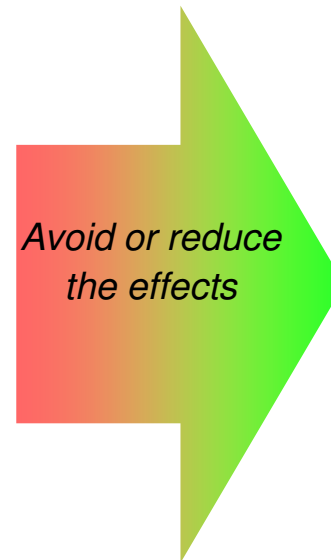
Some of the more common faults are caused by:

- Arc faults, phase to phase, phase to ground, low level arcing faults
- Malfunction within the switchgear assembly, e.g. main busbar / connections, etc.
- Direct short circuits
 - Phase to phase are less common
 - Phase to earth more common
- Hot-Spots, overheating, fire
- Contact with live parts
- Overloading

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Influences on the safety and operation of switchboard

- Design / latest standard
- Work instructions
- Staff knowledge
- PPE
- Monitoring of the system
- Accessibility
- Maintenance
- ...



Measures, to...

- reduce the possibility of a case of damage
- limit the extent of the damage effect

Need for...

- higher standards
- solutions above standards

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Standards / solutions above standard...



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Standards / solutions above standard...

- "Damage prevention" measures
 - IEC / EN 61439
 - Internal separation
 - Fully withdrawable technology instead of fixed installation
 - Passive arc fault protection according to TR 61641
 - Continuous temperature monitoring
 - Seismic tested assembly
- Measures to "Limit the damage"
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 - "Maintenance settings" for circuit breaker
 - Active electronic arc fault protection system

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LV switchgear assembly according to IEC / EN 61439



Minimum requirement of safety for people and systems by assembly according to **IEC / EN 61439**

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Basics about IEC / EN 61439

- Assemblies according to IEC / EN 61439 part 2 **not to use by ordinary persons** – usually $I_{nA} > 250A$
- **Responsibility and documentation** are now more clearly regulated - "original manufacturer" - panel builder
- **Documentation** is required in detail for all systems – design verification and routine test
- **Design verification** by testing, deriving or assessments/calculation
- **Evidence** of temperature rise for assembly $I_{nA} > 1600A$ through testing
- **Exchange of a tested devices** by non tested brands 'almost' impossible (if necessary test and design verification again required)

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Typical design of an assembly ...

- Selection ...



Section: high current circuit breaker

- Air circuit or molded case circuit breakers
- Fixed or withdrawable
- Form 2-4
- Typical for incomer or feeder $\geq 630A$

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Typical design of an assembly

- Selection ...



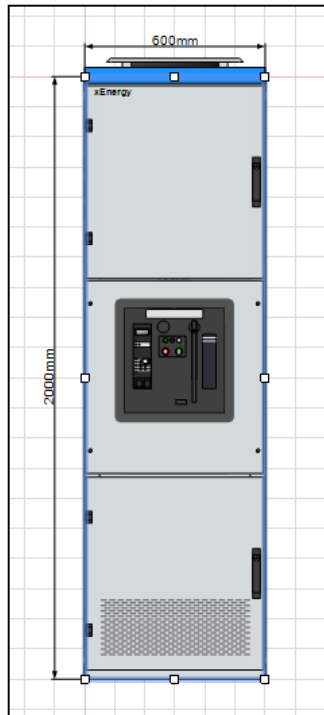
Section: feeder/motor starter

- Motor starter / feeder in fully withdrawable technology
- Form 2-4
- Typical for motor starters up to 250kW and feeder up to 630A
- Ideal for rapid exchange

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Proof of conformity by design verification

- Ensuring clear labelling and traceability of evidence



Eaton Industries (Austria) GmbH
Scheydlgasse 42
1215 Wien
Austria

Design verification
Baurnachweis
xEnergy

No. DV-EA-XE-0000049

**Design verification
Baurnachweis**

according to IEC 61439-2 (VDE 0690-600-2) in its up-to-date valid version
for Low-voltage switchgear and controlgear assemblies
gemäß IEC 61439-2 (VDE 0690-600-2) in seiner am Ausstellungsstag gültigen Ausfertigung
für Niederspannungsschaltgeräteeinheiten

Original manufacturer
Ursprünglicher Hersteller
Trade mark
Warenzeichen
EATON
xEnergy

Verified Unit
Zugelassene Einheit
Type Reference
IP2X: 1x2MK40-250kV...XE section w. 600 (L: 600-0-1) h: 2000

The referred Type/Unit has been verified in accordance with the requirements of IEC 61439-2 (VDE 0690-600-2)
Der genannte Type/Einheit wurde gemäß den Anforderungen aus IEC 61439-2 (VDE 0690-600-2) nachgewiesen

1) Construction / Konstruktion		
Necessity Anforderung Bedürfnis	Class Abstrakt	Verification document Nachweisdokument
<input checked="" type="checkbox"/>	10.1 Strength of materials and parts / Festigkeit von Werkstoffen und Teilen	2147134-05-NC; 2.03.00429.1.0 n.a.; 2.03.02200.1.0_xEnergy_Feuer Spez. CD_Fire n.a.; 2.03.02200.1.0_xEnergy_Feuer Spez. CD_Fire 2.03.02200.1.0_xEnergy_Feuer Spez. CD_Fire 2147134-05-NC
<input checked="" type="checkbox"/>	10.3 Degree of protection of enclosures / Schutzart von Umhüllungen	1101205
<input checked="" type="checkbox"/>	10.4 Clearances and creepage distances / Luft- und Kriechstrecken	2147953-01-NC; F8-4810-176-009
<input checked="" type="checkbox"/>	10.5 Protection against electric shock and integrity of protective circuits / Schutz gegen elektr. Schlag u. Durchgängigkeit von Schutzleitkreisen	F8-6A-18-0000004
<input checked="" type="checkbox"/>	10.6 Incorporation of switching devices and components / Einbau von Schaltgeräten	F8-6A-18-0000003
<input checked="" type="checkbox"/>	10.7 Internal electrical circuits and connections / Interne Stromkreise und Verbindungen	F8-6A-18-0000006
<input checked="" type="checkbox"/>	10.8 Terminals for external conductors / Anschluss für von außen eingehende Leiter	F8-6A-18-0000006
2) Performance / Verhalten		
Necessity Anforderung Bedürfnis	Class Abstrakt	Verification document Nachweisdokument
<input checked="" type="checkbox"/>	10.9 Dielectric properties / Isolationseigenschaften	2147953-01-NC; 2147953-01-NC n.a.
<input checked="" type="checkbox"/>	10.10 Temperature rise / Erwärmung	2147953-01-NC
<input checked="" type="checkbox"/>	10.11 Short-circuit withstand strength / Kurzschlussfestigkeit	2147953-01-NC
<input checked="" type="checkbox"/>	10.12 Electromagnetic compatibility / Elektromagnetische Verträglichkeit	VA 0402889
<input checked="" type="checkbox"/>	10.13 Mechanical operation / Mechanische Funktion	2.03.02200.1.0_xEnergy_Feuer Spez. CD_Fire

Friedrich Seibert
Power Distribution Components Division

15-Sep-2014
Systems

Bernhard Seibtbauer
Power Distribution Components Division

DV-EA-102 / Form 1

Design verification :

- all documents as package per field or project
- Latest documents

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Switchgear assembly according to IEC / EN 61439

- F.e: Eaton xEnergy



Characteristics:

- U_n up to 690V 50Hz
- I_{nA} up to 6300A - rear/top busbar design
- Fixed installation, plug-in, fully withdrawable technology
- IP 30/31/42/55
- Form 1 - 4
- Design verification according to IEC 61439 "tested"
- Network licensed and trained Panel Builder

Everything from one source - Eaton enclosure system and Eaton devices as a LV switchgear assembly according to IEC / EN 61439 - deposited by several thousand tests in laboratories only (documented in approximately 5000 design verifications)

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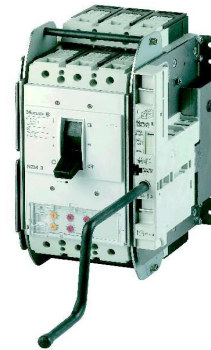
Standards / solutions above standard...

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Withdrawable unit instead of fixed installation

- Power Circuit Breaker section



Power Circuit Breaker field 630A ...

- Withdrawable open circuit breaker
- Withdrawable compact circuit breaker
- Easy replacement

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Withdrawable unit instead of fixed installation

- MCC fully withdrawable unit



Fully withdrawable unit...

- Motorstarter & Energy outflow
- Easy to replace
- No tools necessary

Safety Above Standard

Withdrawable unit instead of fixed installation

- MCC fully withdrawable unit



Characteristics

- Motorstarter conventionell MPCB, eMPCB, MCCB
- Soft starters and frequency converters
- Energy feeder MCCB
- iMCC = communication-capable slot by protection devices with electronic shutter (SmartWire)

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Withdrawable unit instead of fixed installation

- MCC fully withdrawable unit



Lockable

- Prevents access by unauthorized persons
- Safety for operating personnel



Positions

- 3 Positions
- connected, test, disconnected



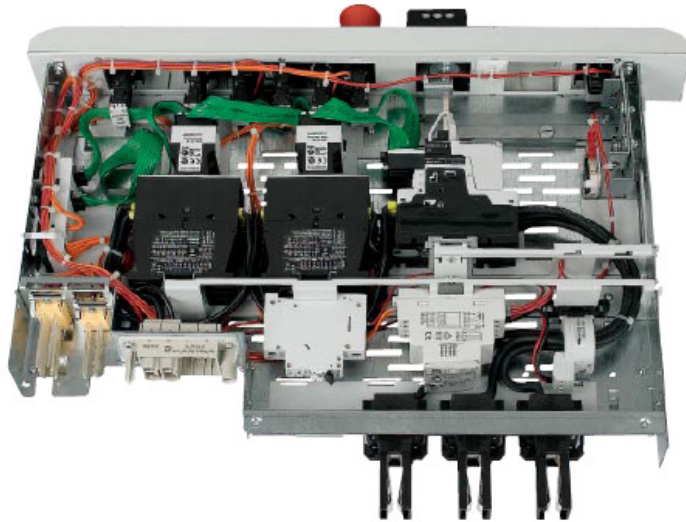
IP2X or Shutter

- Finger safety cover or
- Completely covered by automatic shutter

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Withdrawable unit instead of fixed installation

- iMCC fully withdrawable unit



Characteristics

- Motorstarter eMPCB, MCCB
- Internal communication via SmartWire (green cable)
- Status messages of the electronic protection devices

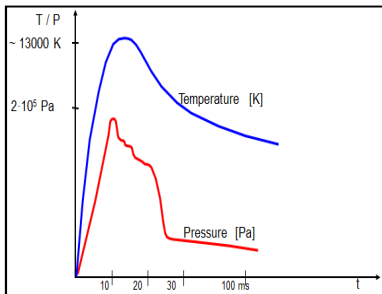
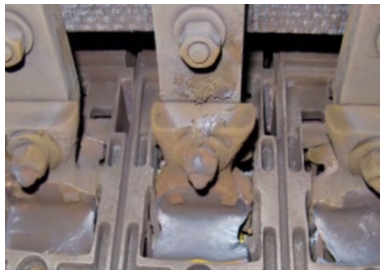
Safety Above Standard

Standards / solutions above standard...

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Basics of an arc fault within a switchboard



- An arc fault can be caused by the following circumstances...
 - Human error
 - Technical defect
 - Change of environmental conditions
 - Animals in the assembly ...
- An arc is formed 3 pole, runs away with $v = 100$ m/s from the line side (transformer supply e.g.)
- Strong pressure and temperature development
- Doors flying on and flying away, massive parts
- Steam and gas expansion
- Fire hazard
- ...

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Basics about passive arc fault protection acc. TR 61641

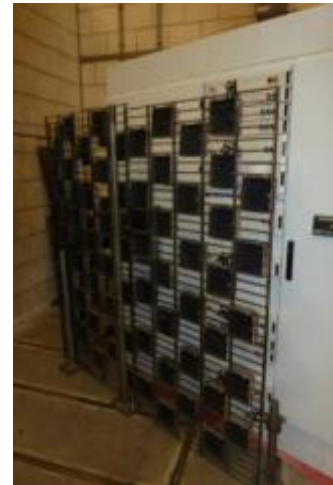
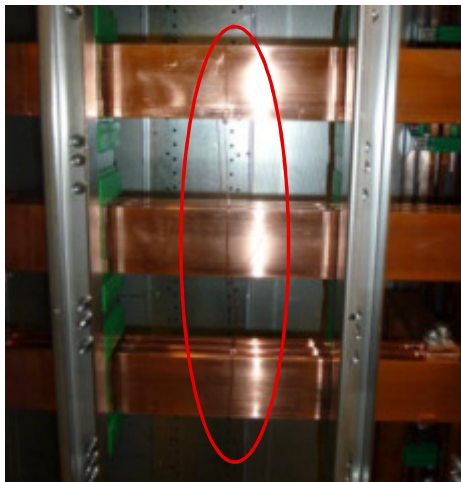
- Is **not part** of the **design verification** IEC / EN 61439
- User – manufacturer agreement
- Results **valid only** for **closed** panels
- Dedicated **more for personal protection** and limited for system protection
- **Wording** : „arc tested“ und „arc ignition protected“
- Arc fault classes A*, B*, C* (personal resp. personal and system protection), class I (arc ignition protected = „insulation“)
- NEW: Access limited, access unlimited ... Test with 150g/m² cretone or 40 g/m² in 300mm distance

*) consist of arc tested and when available arc ignition zones

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Test lab procedures

- Pre-defined ignition wires are assembled into the panel to get the arc started at the defined locations

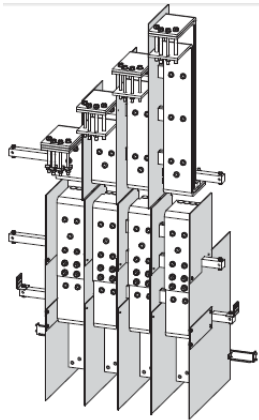


- Pre-defined cotton indicators, simulate operators and are not allowed to ignite or burn, during or after the test.

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Passive arc fault protection according to TR 61641

- Measures for the passive arc fault protection



Separation/Covers

- Separation between live parts - in particular in the terminal box
- Prevent a discharge



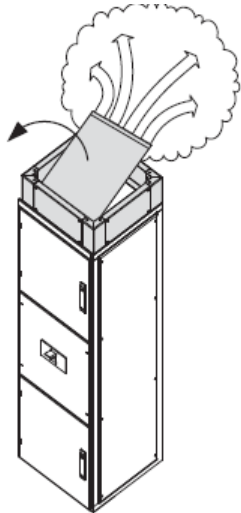
Strengthened lock/mounting and hinges

- Strengthened lock on the doors / hinges
- Prevents opening of the doors during an arc

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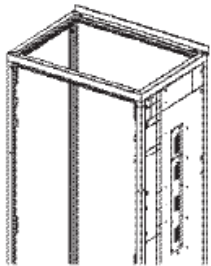
Passive arc fault protection according to TR 61641

- Measures for the mechanical arc fault protection



Depressuring/ flaps

- predetermined breaking cover for depressuring the internal in a defined range
- De-dangering of the front (area where the personnel stays in common)



Arc barriers within MBB area

- Continue of the arc prevented by arc barriers section-section in MBB room
- Limiting the arc on defined area

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Passive arc fault protection according to TR 61641

- F.e.: Eaton xEnergy with passive arc fault protection



Characteristics:

- Personnel and system protection
- Criteria 1 to 6
- $U_e = 400V$ 50Hz
- $I_{\text{parc}} = 65kA$
- $t_{\text{arc}} = 300ms$

Safety from a single source - Eaton xEnergy tested according to TR 61641

Increased Safety for persons and systems

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Standards / solutions above standard...

- "Damage prevention" measures
 - IEC / EN 61439
 - Internal separation
 - Fully withdrawable technology instead of fixed installation
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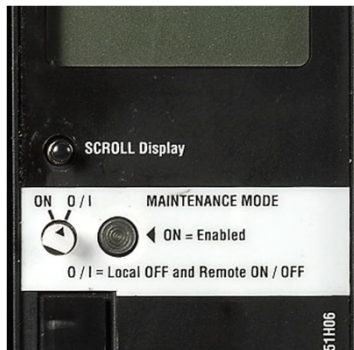
"Maintenance settings" for circuit breaker with electronic release

- Air circuit breaker with ARMS System ...



Characteristics ARMS

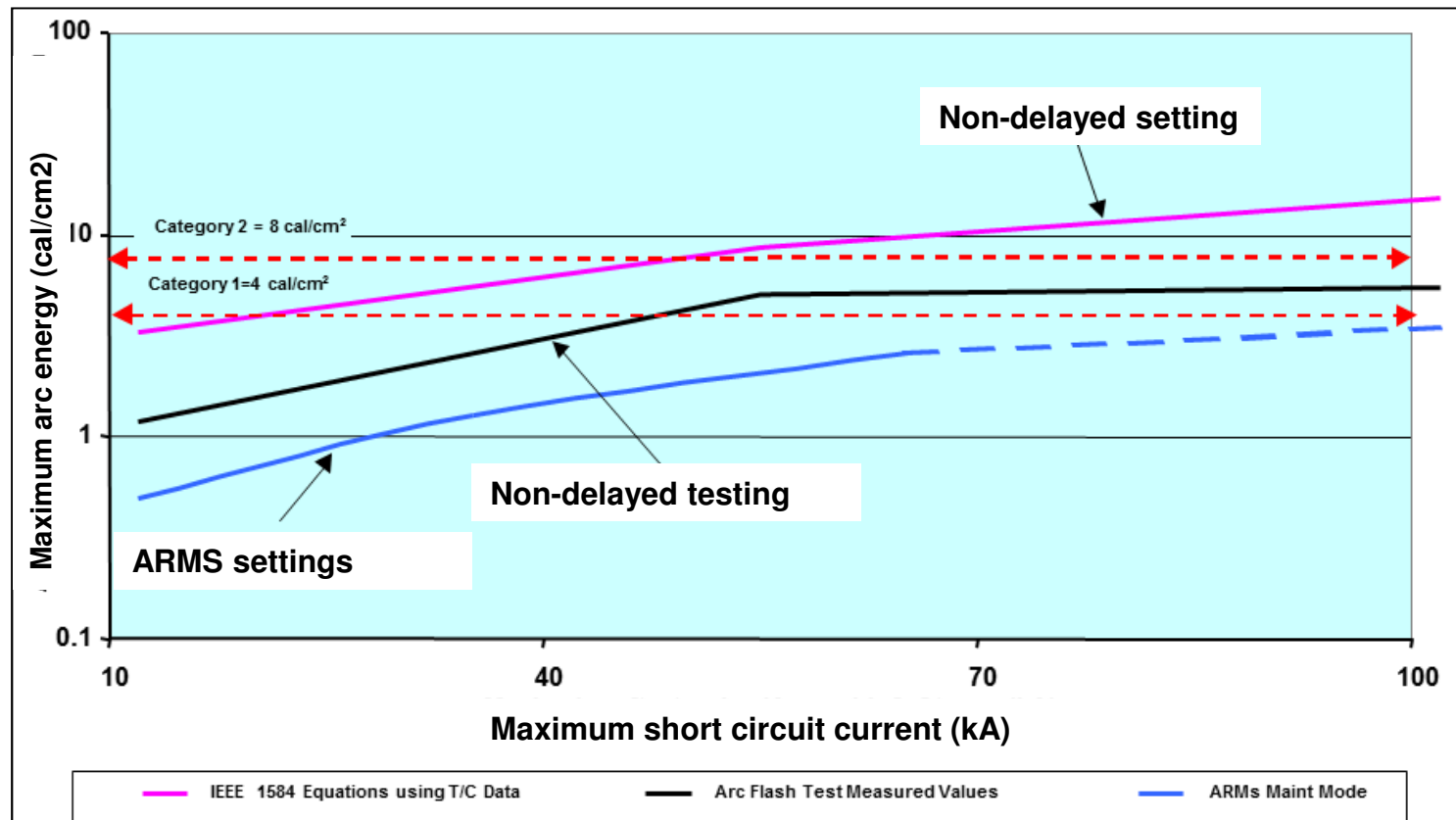
- Reduce the arc energy to approximately $\frac{1}{4}$ of the energy at a "non-delayed" ACB
- Protection of persons during maintenance
- Remote activation e.g. door contact of the switchgear



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"Maintenance settings" for circuit breaker with electronic release

- Air circuit breaker with ARMS System ...

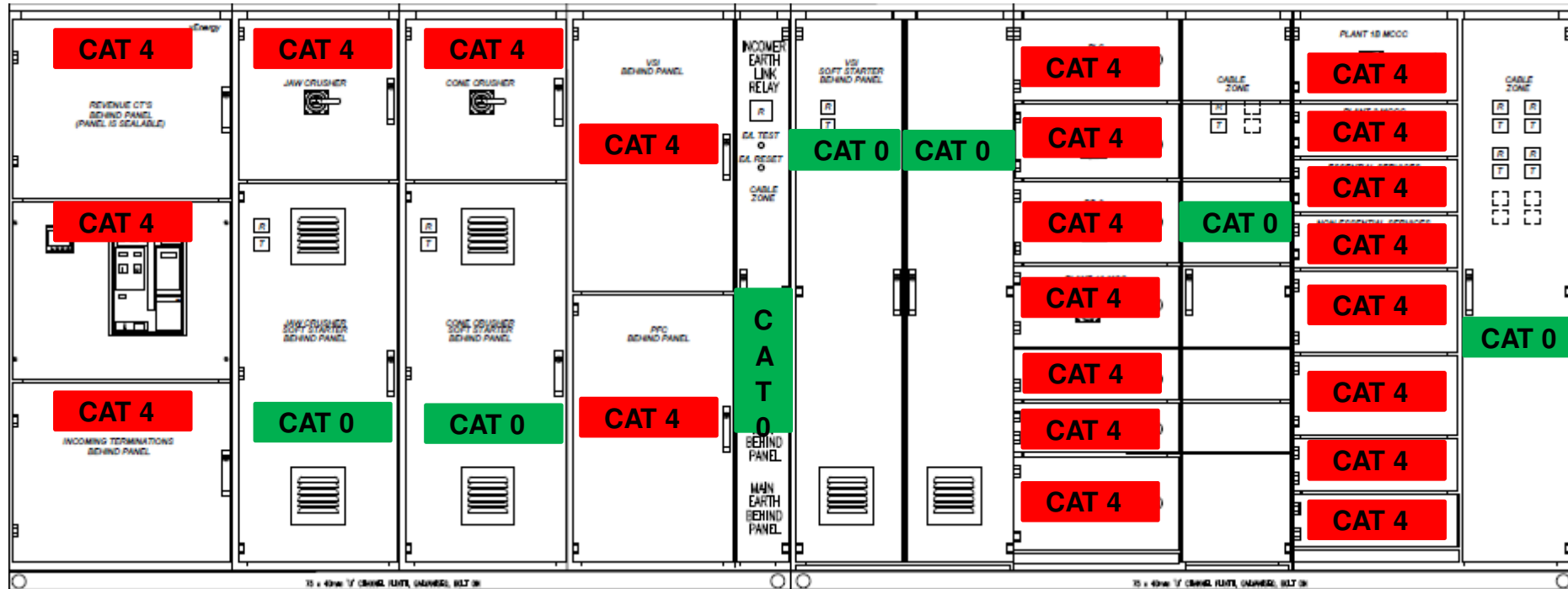


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Layout of a Main Switchgear Assembly

Switchboard **WITHOUT** ARMS

Cabinet Category levels

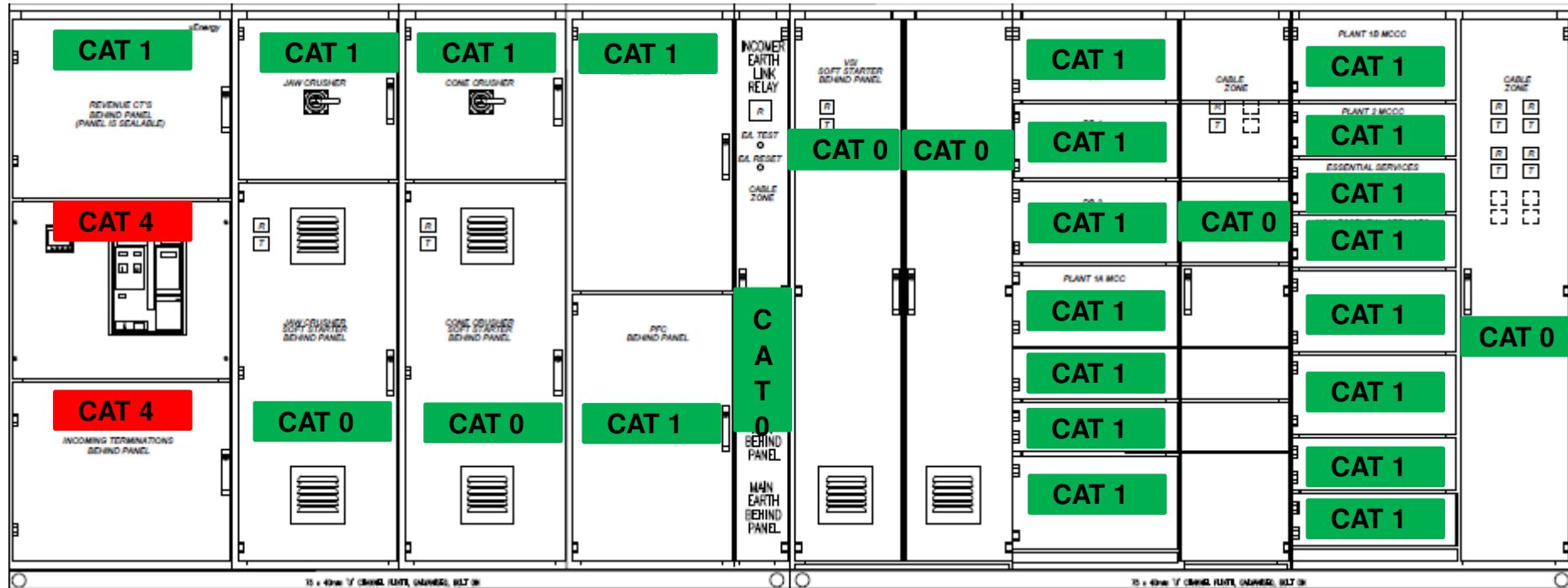


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Layout of a Main Switchgear Assembly

Switchboard **WITH** ARMS

Cabinet Category levels



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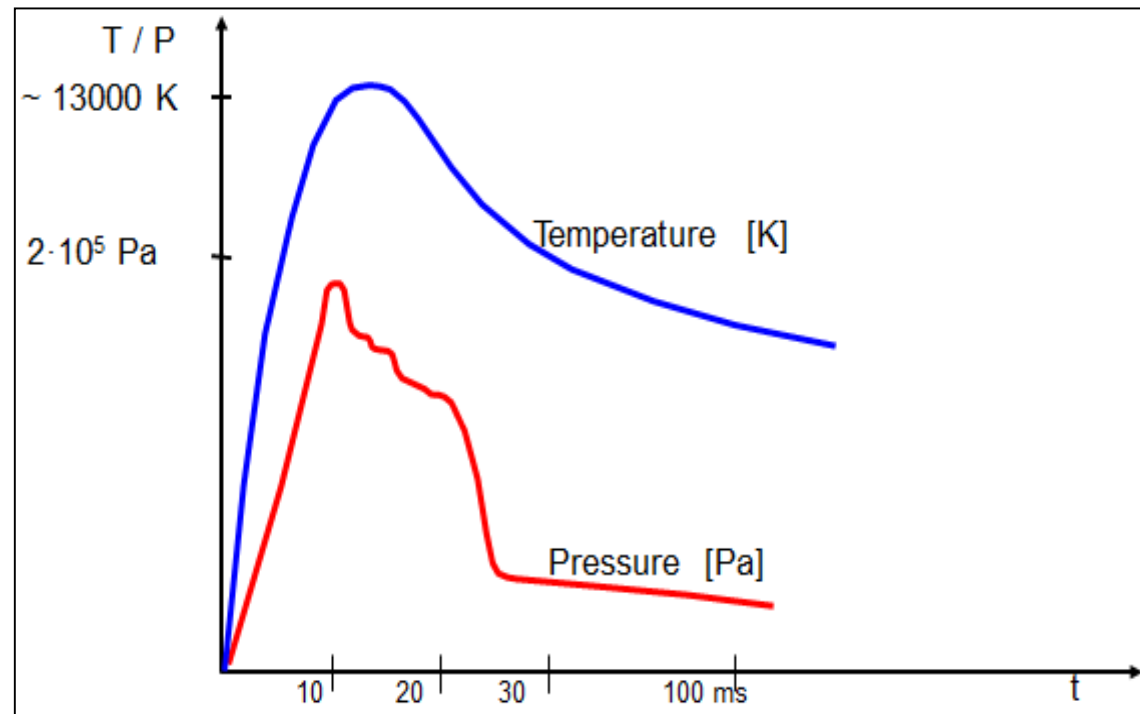
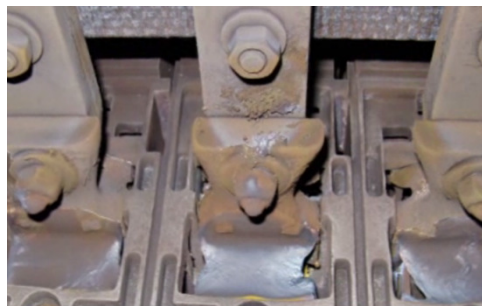
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Basics of an arc fault within a switchboard

- Effects of arc faults...

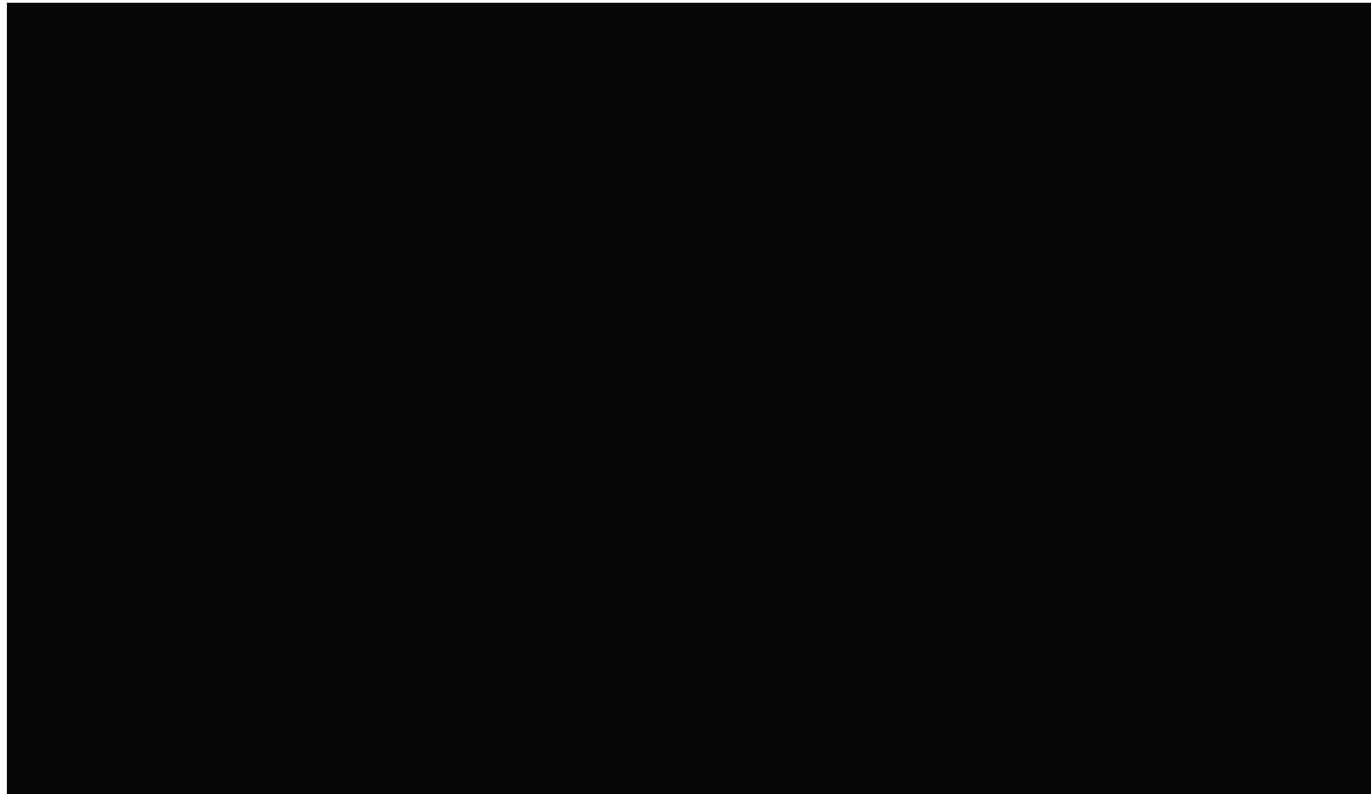


*) Klöckner-Moeller / Eaton / Universität Ilmenau

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Active electronic arc fault protection system with quenching device

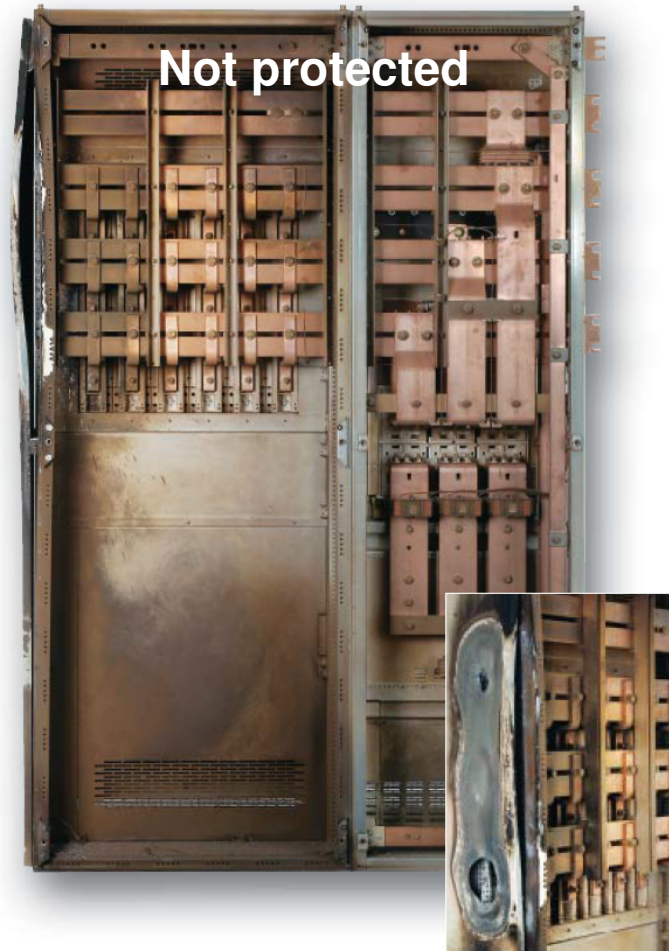
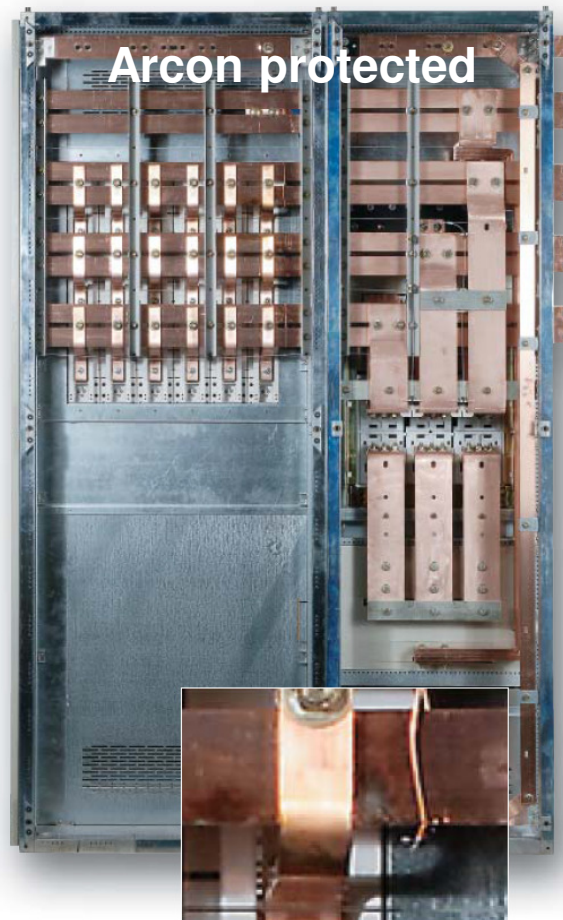
- Quenching device – Fast tripping time by gas pressure generator drive



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Active electronic arc fault protection system with quenching device

- Consequences with or without usage of ARCON



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Active electronic arc fault protection system with quenching device

- Not protected vs. protected



Not protected



protected

Do you see the difference... ?

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Active electronic arc fault protection system with quenching device – advantages for the user

- Examples for PPE



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Standards / Solutions

- "Damage preventing" measures"
 - Assemblies as xEnergy/Modan from Eaton tested according to IEC 61439
 - Internal separation in form of ... in Eaton ... gears
 - Fully withdrawable unit instead of fixed installation in xEnergy/Modan available
 - **Passive arc fault protection** acc.g to TR 61641 in xEnergy/Modan available
 - **Continuous temperature monitoring diagnose** in xEnergy/Modan for predictive maintenance
 - seismic-test ... xEnergy/Modan
- Measures to "Limit the damage"
 - **Passive arc fault protection** acc. to TR 61641 in xEnergy/Modan available
 - **"Maintenance settings"** for switches with electronic release with **IZMX and ARMS** (arc fault reduction maintenance system)
 - **Active electronic arc protection system ARCON with quenching device**

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xSpider V3.0 Software Tool ...

The screenshot displays the xSpider V3.0 software interface for a power network diagram titled "DEMO-Network_2MVATF_IJHX40". The main workspace shows a detailed network layout on a grid background. At the top, a main network (NET1) is connected to a transformer (TR1). Below this is a busbar (NODE1) which branches into four feeders (FA1, FA2, FA3, FA4). Each feeder is connected to a specific piece of equipment: FA1 to a transformer (FA1), FA2 to a transformer (FA2), FA3 to a transformer (FA3), and FA4 to a transformer (FA4). These feeders then connect to various cables (W1-W4) and finally to equipment: Tech1, Tech2, and M1. The software interface includes a menu bar (File, Home, View), a toolbar with drawing tools (Line, Circle, Rectangle, Text, Erase, Move, Copy, Stretch), a tool box on the left with favorites and power groups, and an error list at the bottom. The error list is currently empty, showing columns for Category, Component, Tag, and Problem description.

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xSpider V3.0 Software Tool ...

Working distance

Arc-Flash Boundary

DEM0-Network_2HVATF_IJHX40 - xSpider 3.0.14

NET1
Un=22KV, Sk=500MVA

Arc Risk - Arc Flash Hazard Analysis - Calculation Results

Calculation inputs:

Network node: NODE1

Short circuit at: Busbar side ARMS / ARCON: ARMS is not applicable

Calculation results:

Incident Energy: E 288.72 J/cm²

Arc Flash Boundary: DB 5388.20 mm

Risk Matrix | PPE Level

	Slight	Minor	Medium	Critical	Catastrophic
Unlikely	1	2	3	4	5
Seldom	2	4	6	8	10
Occasional	3	6	9	12	15
Likely	4	8	12	16	20
Definite	5	10	15	20	25

Error List [DEM0-Network_2HVATF_IJHX40]

Category	Component	Tag	Problem description

X=70,0, Y=215,0 Snap Grid Osnap Ortho

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xSpider V3.0 Software Tool ...

Working

DEM0-Network_2HVATF_IJHX40 - xSpider 3.0.14

Calculation

Tripping Characteristics

Database

Property Grid

Nothing has been selected ...

Calculation inputs:

Network node: NODE1

Short circuit at: Busbar side

ARMS / ARCON: ARCON applied

Calculation results:

Incident Energy: E 0.10 J/cm²

Arc Flash Boundary: DB 455.00 mm

Risk Matrix | PPE Level

	Slight	Minor	Medium	Critical	Catastrophic
Unlikely	1	2	3	4	5
Seldom	2	4	6	8	10
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Definite	5	10	15	20	25

	Critical	Catastrophic
Unlikely	4	5
Seldom	8	10
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Print Export Help Close

Error List [DEM0-Network_2HVATF_IJHX40]

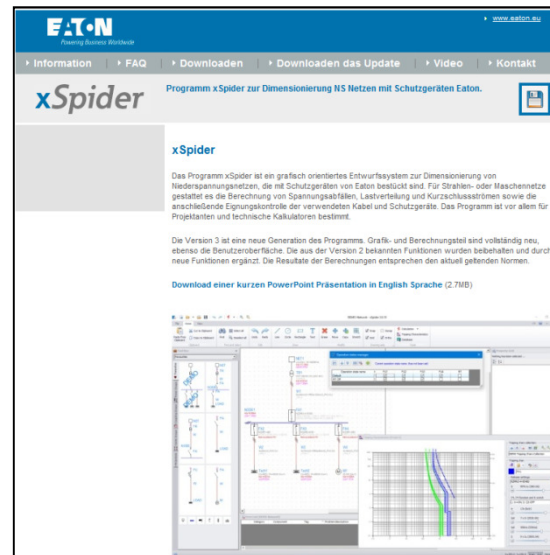
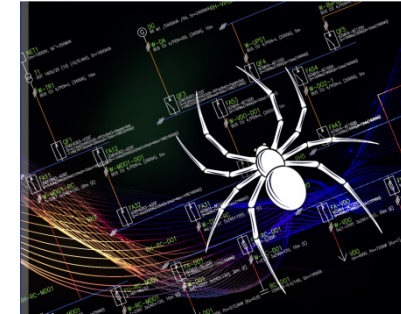
Category	Component	Tag	Problem description
----------	-----------	-----	---------------------

X=70,0, Y=215,0 Snap Grid Osnap Ortho

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xSpider V3.0 Software Tool ...

- Network calculation etc.
- Risk assessment / „Arc flash hazzard study“
- Acc. IEEE 1584™-2002 (EN 50110-1,-2)
- Integration of ARMS, ARCON etc.
- xSpider is free of charge
- Download and register: www.xspider.eaton.eu



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Standards / solutions above standard...

- "Damage prevention" measures
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 - Seismic-tested assembly
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Basics concerning temperature monitoring

- **Aging** of equipment or **loose connections** can cause problems
- Congested **ventilation**
- Thermal scening shows hot spots - but it also has limits
 - Thermal recognition gives only an "**idea of the moment**"
 - Scanning must be done under **normal load**
 - **Inaccessible places** can be not covered
- ...

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Basics concerning temperature monitoring

- Examples thermal screening



Procedure:

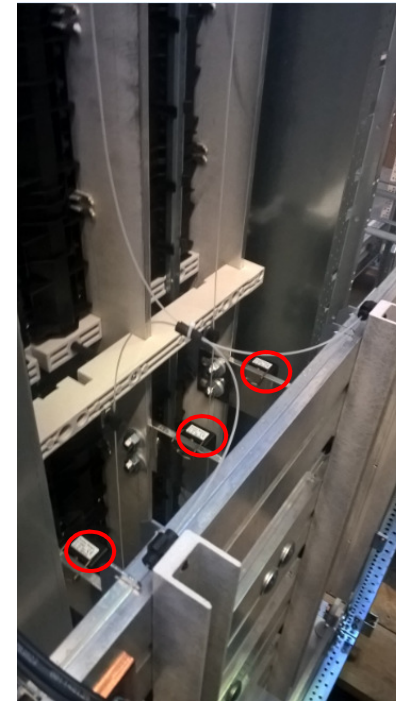
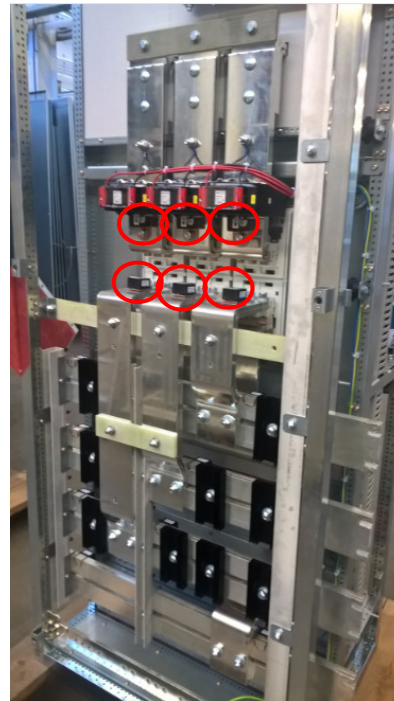
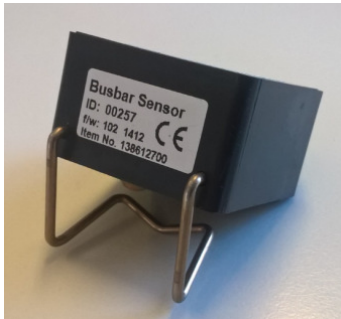
- Removing of insulation or install from so-called IR Windows
- Thermal camera to detect hot spots
- Below : 20 y.o. panel findings ... not visible by thermal screening due to position of connection



Safety Above Standard

Permanent temperature monitoring

- Positioning of sensors at critical points / measuring variations

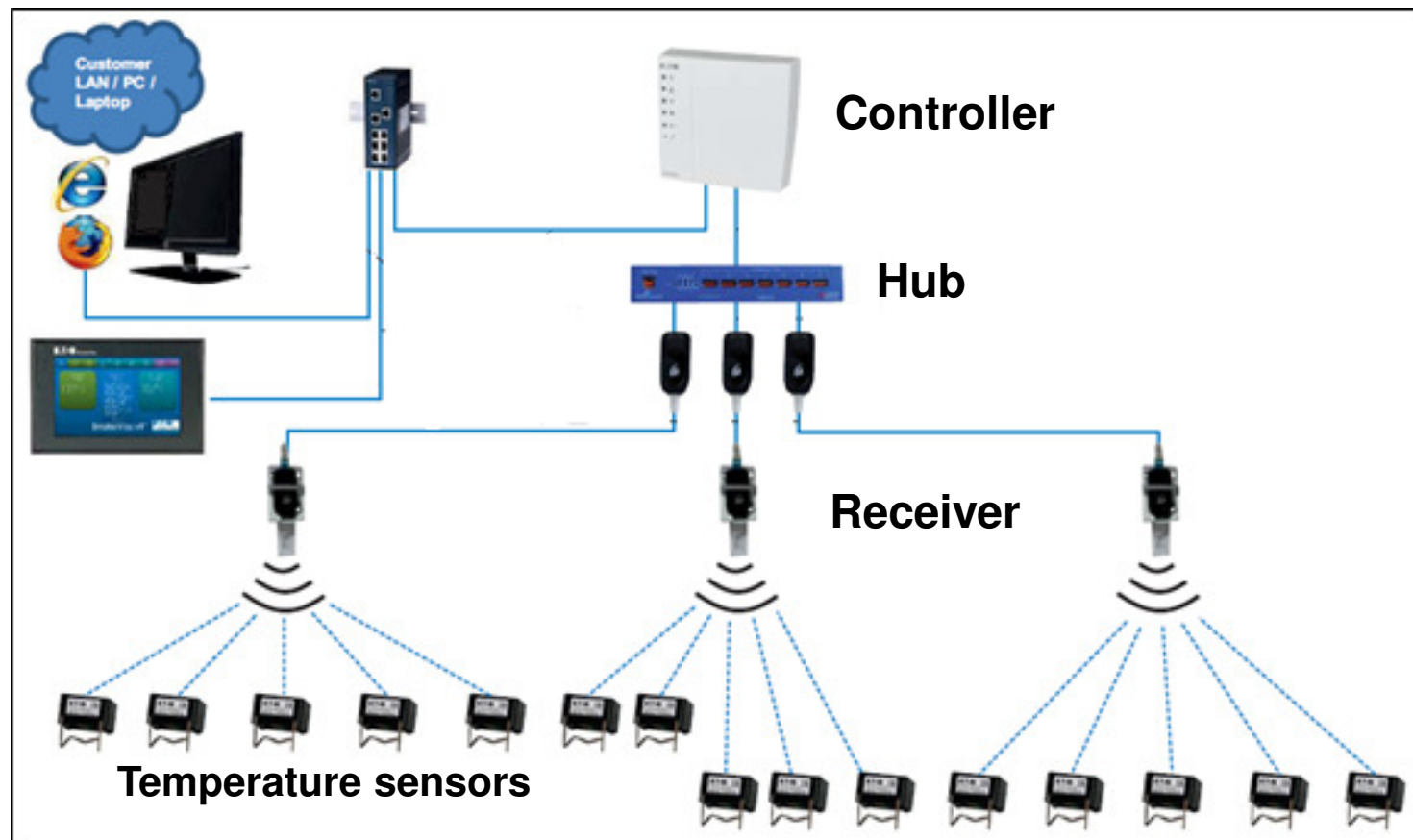


- Breaker, transport split, Link breaker

Safety Above Standard

Permanent temperature monitoring for predictive maintenance

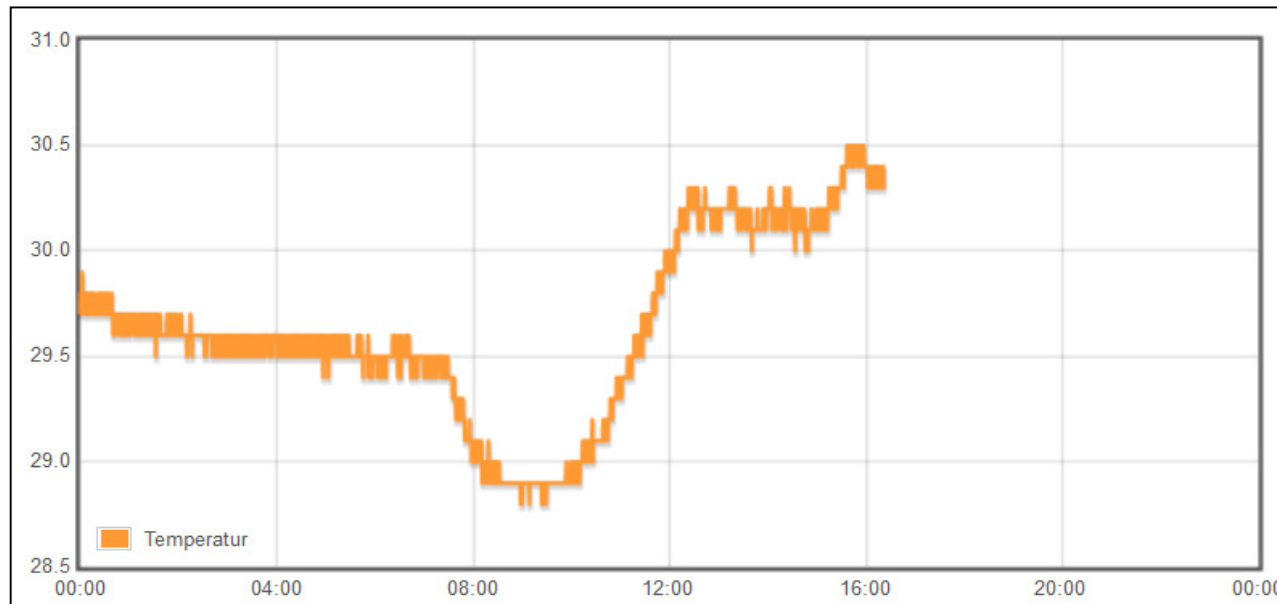
- Topology within the assembly



Safety Above Standard

Continuous temperature monitoring for predictive maintenance

- Trend (24h)

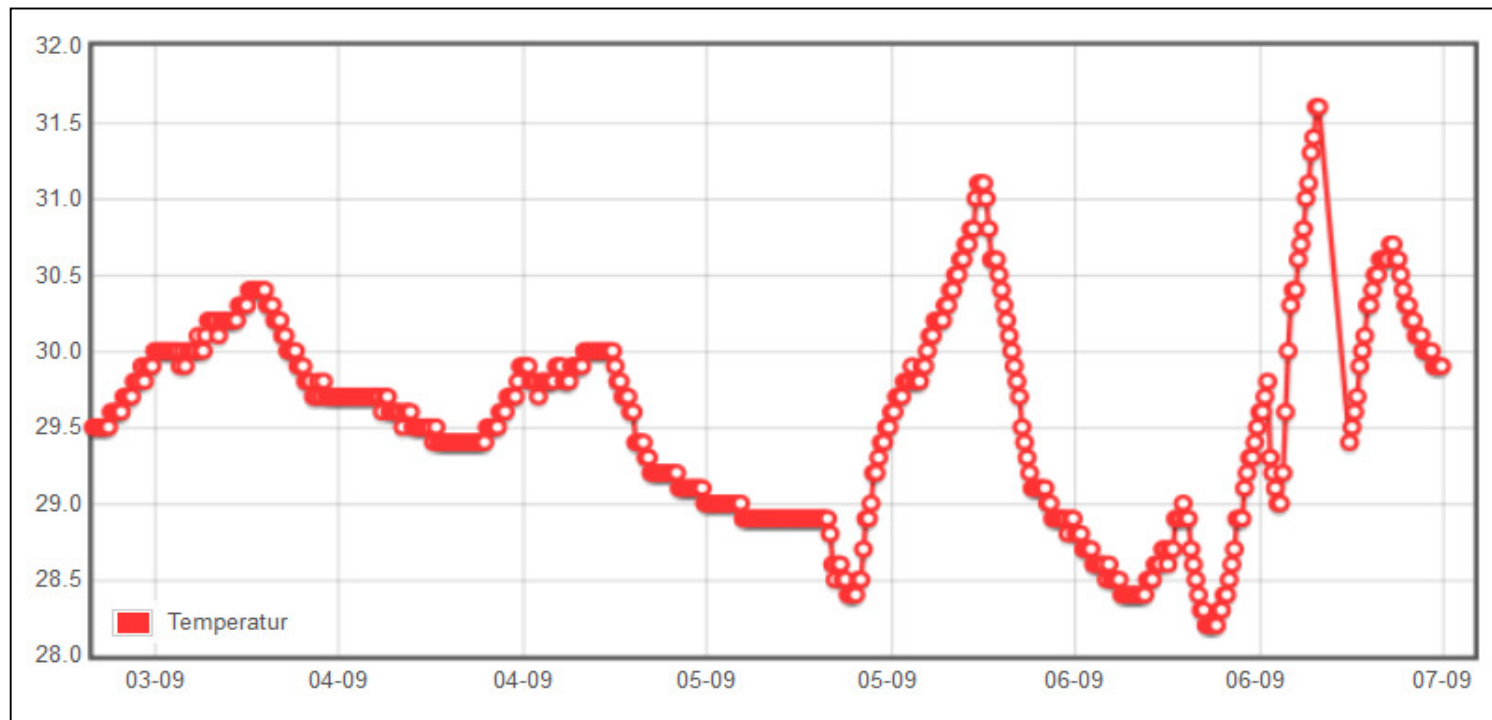


- Storage every 30s/sensor 24h

Safety Above Standard

Continuous temperature monitoring for predictive maintenance

- Trend (28d)



- Storage of 10min values / sensor

Safety Above Standard

Standards / Solutions

- "Damage preventing" measures"
 - Assemblies as xEnergy/Modan from Eaton tested according to IEC 61439
 - Internal separation in form 3 or 4 in Eaton switchgears
 - Fully withdrawable unit instead of fixed installation in xEnergy available
 - **Passive arc fault protection** acc.g to TR 61641 in xEnergy available
 - **Continuous temperature monitoring diagnose** in xEnergy for predictive maintenance
 - seismic-tested xEnergy
- Measures to "Limit the damage"
 - **Passive arc fault protection** acc. to TR 61641 in xEnergy available
 - **"Maintenance settings"** for switches with electronic release with **IZMX and ARMS** (arc fault reduction maintenance system)
 - **Active electronic arc protection system ARCON with quenching device**

Safety Above Standard

Standards / solutions above standard...

- New device to protect against electrical ignited fires ...



AFDD
Arc fault detection device (IEC 60364)

New technology in IEC

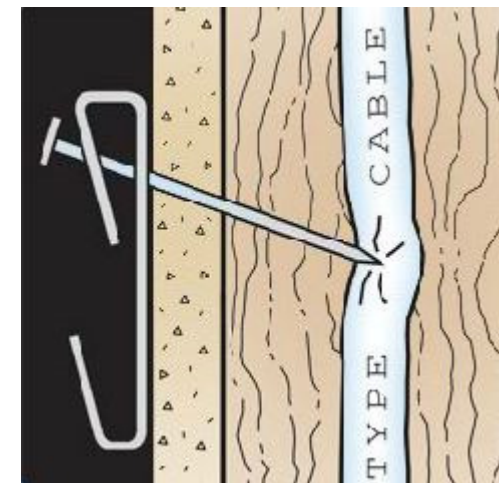
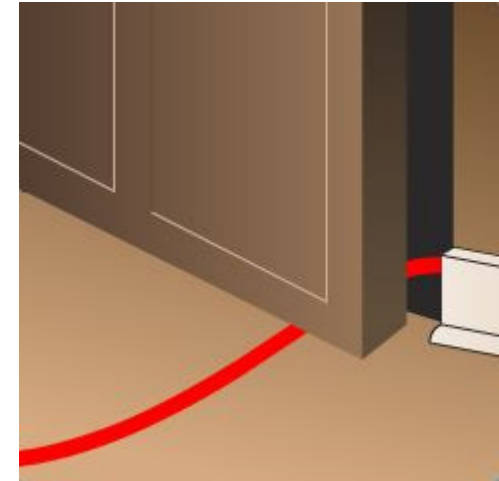


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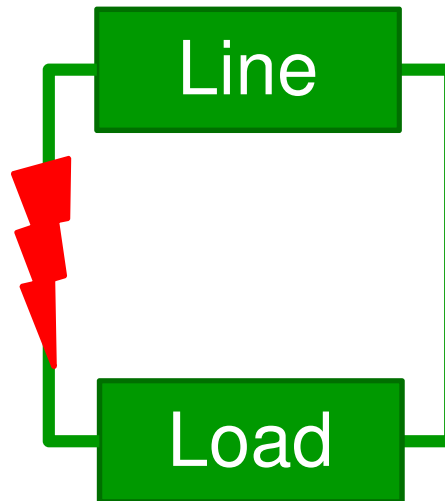
Triggered by...

- Damaged cables (power cords)
 - E.g. pinched under doors or furniture
- Damaged plugs
 - E.g. crippled and overstretched cables
- Defective (lose) terminals
 - Lose screws
- Aged/damaged Insulation
 - Pierced by nails or screws



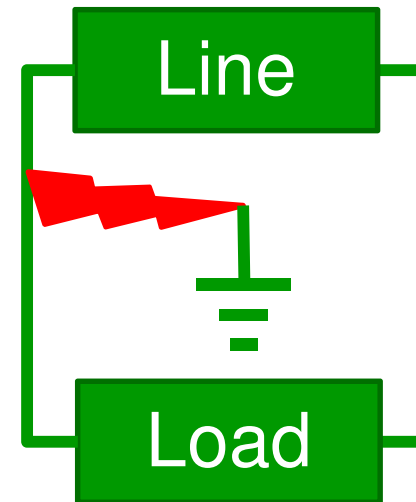
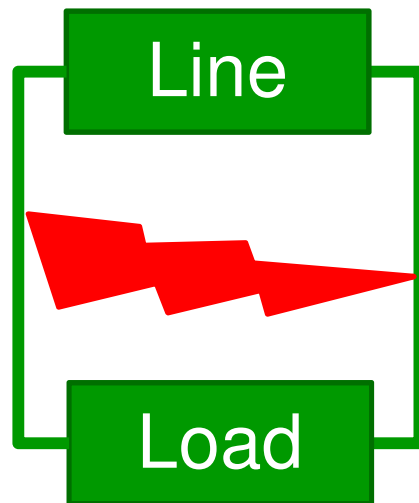
Serial arcs

- Serial arcs (over 90%)
 - Typically below nominal current of the MCB > No trip



Parallel Arcs

- Parallel Arcs (below 10%)
 - Between N und L: Typically below nominal current of the MCB > No trip
 - Between L und PE: Typically above 30mA > RCD will trip



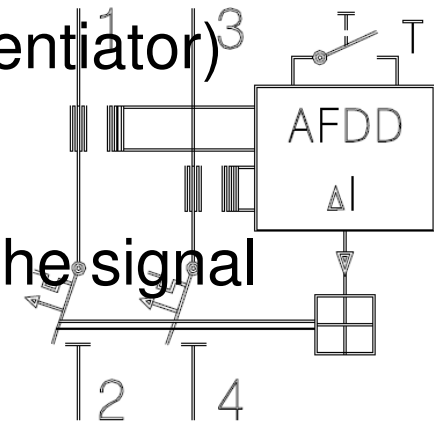
The Eaton solution

- + „All-in-one“ device
 - + Short-circuit and overload
 - + RCD
 - + AFDD
- + Safely detects arcs above 1A (2,5A)
- + 10 - 40A max.
- + Simple, easy and robust installation
- + Cost effective



AFDD: How does it work

- Electronic detection of the HF pattern
 - Safe and quick detection
 - Low nuisance tripping (quality differentiator)
- Only one device per outlet circuit
 - Too many different loads may mask the signal
- „Cross talk“ test
 - Only the right AFDD shall trip (not the neighbouring device)



FAQs

- Will it work with:
 - Old drilling machines ✓
 - Welding devices ✓
 - Electronic loads ✓
 - Dimmed loads ✓
 - Power line communication ✓



Safety Above Standard

Any questions?

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