SIEMENS

Lorem est dolor sunt 2013

SENTRON

AFDD – Arcing Fault Protection

Agenda

- Arcing faults –
  History, causes and effects
- Origins of an arcing fault
- Protection concepts
- The challenge: arcing fault detection without false tripping
- 5SM6 AFD units
- Outlook:
  standardization activities
- Summary

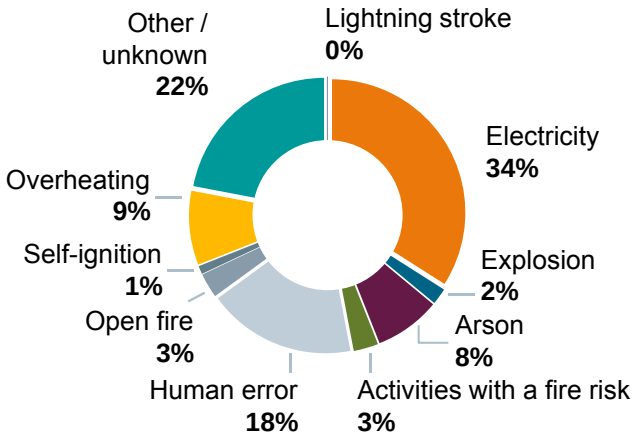
Agenda

- **Arcing faults –**
  History, causes and effects
- Origins of an arcing fault
- Protection concepts
- The challenge: arcing fault detection without false tripping
- 5SM6 AFD units
- Outlook:
  standardization activities
- Summary

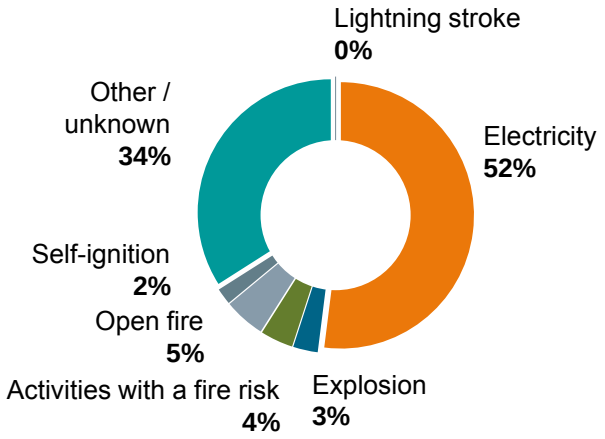
Causes of fire in Germany
Statistical background in Germany

SIEMENS

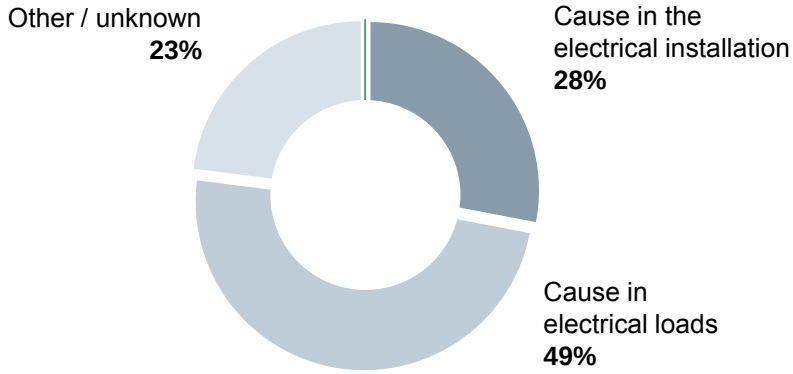
Causes of fire



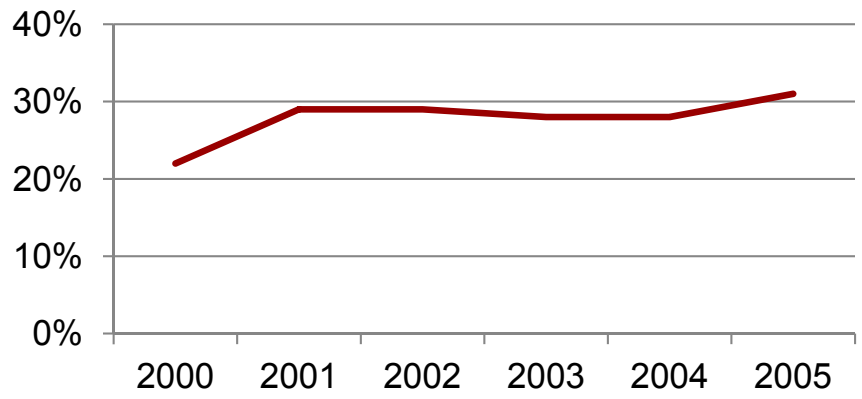
Preventable causes of fire (2010)



Causes of electrically caused fire



Electrically caused fire



Annual fire-related damage in Germany

Number of fire-related damage incidents	approx. **515.000**[1]
Volume of damage	approx. **6 Milliarden**[2]
Deaths[2]	**600** (of which 75% in private dwellings)
Injured persons[3]	approx. **60,000**
Seriously injured persons[3]	approx. **6.000**

1: GDV(Gesamtverband der deutschen Versicherungswirtschaft e.V.): www.gdv.de/Downloads/Schwerpunkte/GDV_Adventsbraende_in_Zahlen_2008-2009.pdf

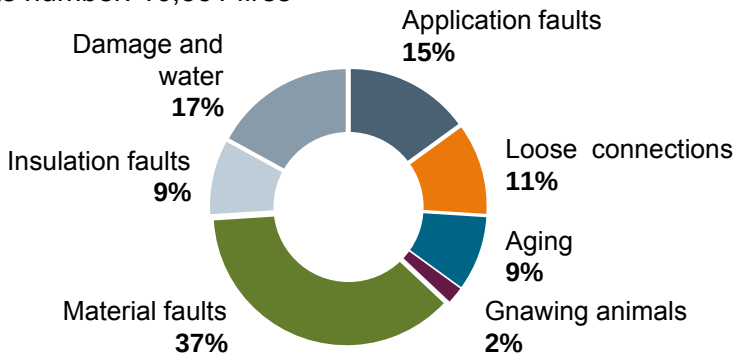
2: vfdb Technisch-Wissenschaftlicher Beirat (Arbeitsgruppe Brandschutzforschung) www.sachsen-anhalt.de/fileadmin/Elementbibliothek/Bibliothek_Feuerwehr/idf_dokumente/Kontexmen%c3%bc/Denkschrift_BS-Forschung.pdf

3: GDV: www.gdv.de/Presse/Archiv_der_Presseveranstaltungen/Presseveranstaltungen_2001/Presseforum_Schaden_und_Unfall_2001/inhaltsseite12184.html

Fire statistics from other European countries

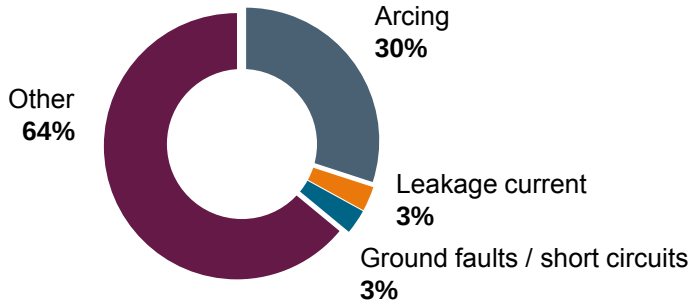
Denmark

Based on Fire Statistics 2005
Absolute number: 16,551 fires



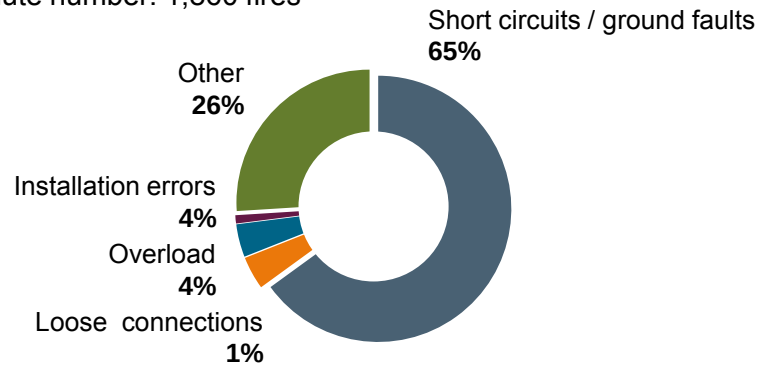
Norway

Based on Fire Statistics 2002 - 2006
Absolute number: 9,200 fires



Finland

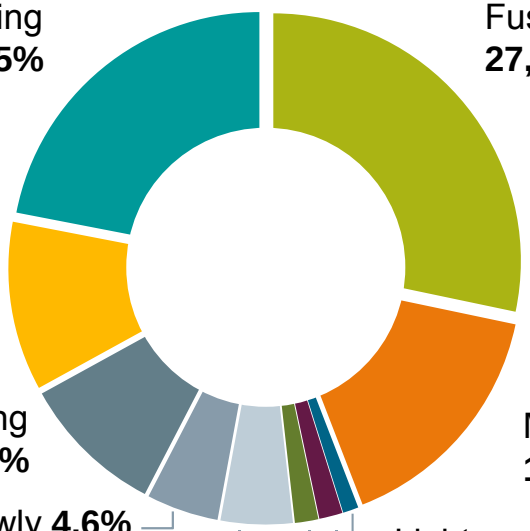
Based on Fire Statistics 2006
Absolute number: 1,860 fires



Electrical causes of fire – USA

USA - 10 cities (1980-81) with detailed investigations

Observations before the occurrence of a fire caused by electricity



Serial arcing fault and / or glowing

Lights flickering **21,5%**

Fuses bowling **27,7%**

Parallel arcing fault and / or short circuit

Serial arcing fault and / or glowing

Lights dimming **10,8%**

Parallel arcing fault and / or short circuit

Breaker tripping **9,2%**

Miscellaneues **15,5%**

Faulty connection ➡ arcing / glowing

Appliances operating slowly **4,6%**

Lights going out **1%**

Serial arcing fault and / or glowing

Bulbs burning out **4,6%**

Sparking, arcing at outlet **1,5%**

Arcing

Arcing or interference

Radio sounding scratchy **1,5%**

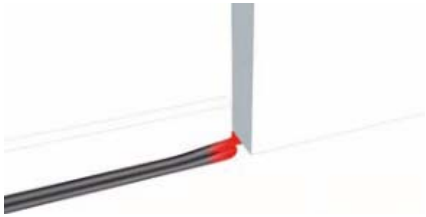
The fraction of fires caused by arcing faults is unknown but is likely to be significant.

Fire risk due to arcing faults in branch circuits

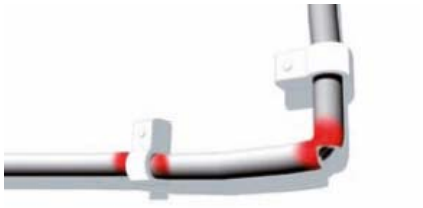
Parallel arcing fault between phase & conductor / ground

Nails or screws

Crushed cables



Overtight clips



High temperature of the arc

+

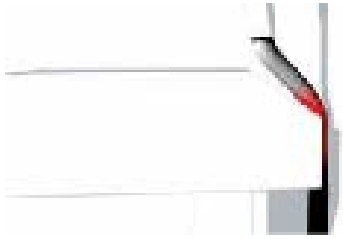
Ignitable material

Serial arcing fault in phase or neutral conductor

Loose contacts and terminals

UV radiation / gnawing animals

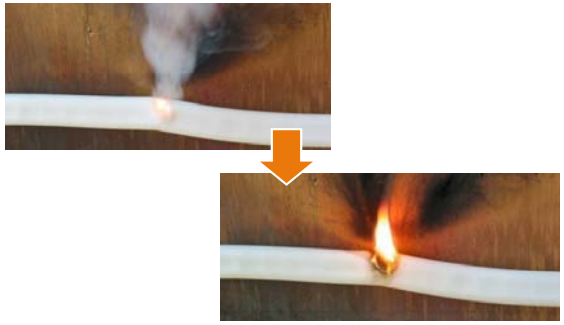
Kinks in connectors / cables



History of arcing fault detection in the USA

- **1983: first patents** for AFCI1 technology
- 1992: the Consumer Products Safety Commission (CPSC) initiates the Home Electrical System Fires Project
- CPSC arranges for UL to investigate and examine the causes of fire. The most promising solution: a new arc detection technology
- With effect from January 2008: National Electrical Code 2005 specifies **AFCI Class A** for the protection of all 15 / 20 A circuits **in living spaces**

Arcing and sparking in home installations caused approx. **40,000 fires** per year with **350 deaths** and **1,400 injured persons.**



Consumer Product Safety Review, Volume 4, Summer 1999

1: AFCI: Arc Fault Circuit Interruption

AFCIs from Siemens in the USA

AFCIs of the first generation: class B

- Protection against parallel arcing faults
- Tripping threshold ≥ 75 A according to UL1699
- Slight increase in fire protection

AFCIs of the new generation: class A

- Protection against parallel and serial arcing faults
- Tripping threshold ≥ 5 A according to UL1699
- Significant increase in fire protection plus high resistance to false tripping
- Residual current protection or overcurrent protection can be combined

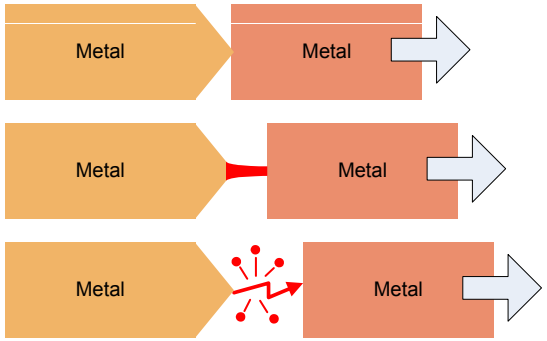
Agenda

- Arcing faults –
  History, causes and effects
- **Origins of an arcing fault**
- Protection concepts
- The challenge: arcing fault detection without false tripping
- 5SM6 AFD units
- Outlook:
  standardization activities
- Summary

Serial arcing faults

Direct contact between the electrodes:
Ignition of the arc by a very high current density and the explosive melting of a fused link in conjunction with a relative movement of the contacts.

Serial



Parallel

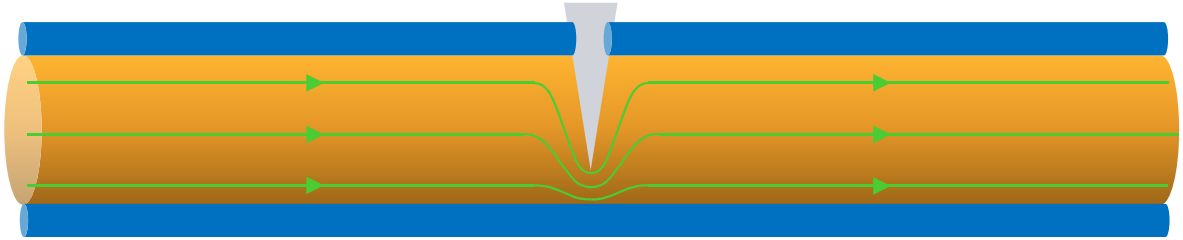
Causes:
vibrations, thermal expansion or contraction, mechanical loading of the electrical conductors,…

Hazard potential:
- Can cause glowing as well as stable serial arcing faults
- Direct damage in case of parallel arcing faults

Arc as the result of a fault in the cable

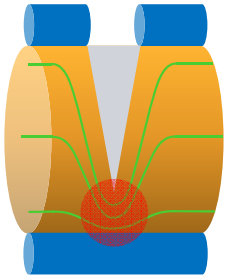
Phase 1

Electricity flows through a damaged cable



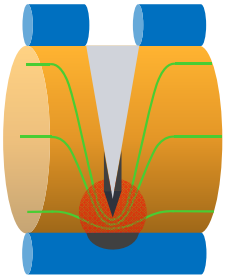
Phase 2

Bottleneck in cable and insulation becomes hot



Phase 3

hot copper oxidizes to copper oxide and the insulation carbonizes

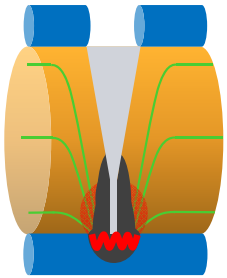


Up to approx. 1,250 ºC

Phase 4

The copper melts & gasifies brie-fly (e.g. at the sine-wave peak)

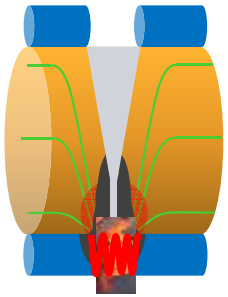
- air gap
- sporadic arcing fault across insulation



Up to approx. 6,000 ºC

Phase 5

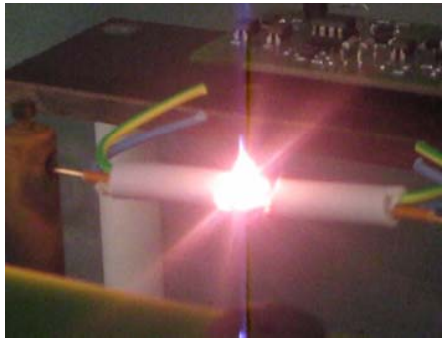
Stable arcing fault across carbonized insulation

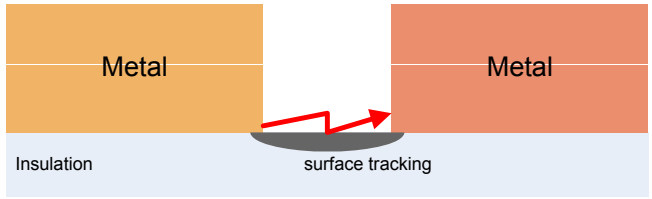


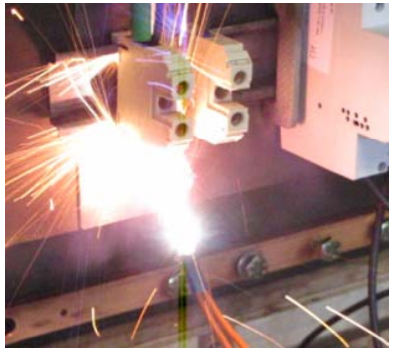
Approx. 6.000 ºC

Breakdown in case of damaged insulation

Initiator: surface damage to the insulation after exposure to high leakage currents







Causes: damage to insulation, deposits of impurities, ...

Characteristics:

- Long arcing duration, high stability
- Low breakdown voltage
- Large distances possible, high arcing voltages (up to 70 V)
- Power loss > 50 W for serial and > 2000 W for parallel arcing faults

Hazard potential:

- High energy release rates possible
- Considerable damage through parallel arcing faults

Breakdown in case of normal insulation

Possible causes of such breakdowns

- Overvoltages
- Surface roughness
- Surface soiling (carbon ➡ thermal emissions)
- Water vapor in the air etc.
- Ionized gases in the air due to fire or temporary arcs

Characteristics

- Short arcing duration, unstable ➡ quick interruption
- High breakdown voltages
- Arcing voltage depends greatly on the distance

Hazard potential

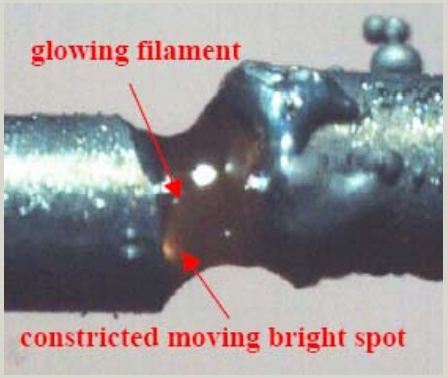
- Little probability of occurrence
- Short arcing duration and little thermal energy
- Risk of damage to insulation and initiation of leakage and charring processes

Cause of fire
glowing

Causes

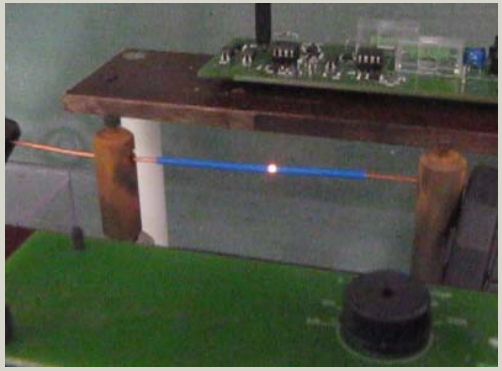
poor contacts, arcs

- Melting of the metal, formation of fused links
- Expansion of the fused link, increase in resistance and power losses



Characteristics

- Very stable with small currents < 10 A
- Can take a long time, starts again after a rise in current
- Power losses from a few watts to up to 50 W
- Temperature of the fused link from 800 ºC to up to 1800 ºC
- Considerable interaction with arcs:
  - can be caused by the arc
  - produces e. g. the conditions for a steadily burning arc



Example
glowing (2 A / 240 V)

Charring

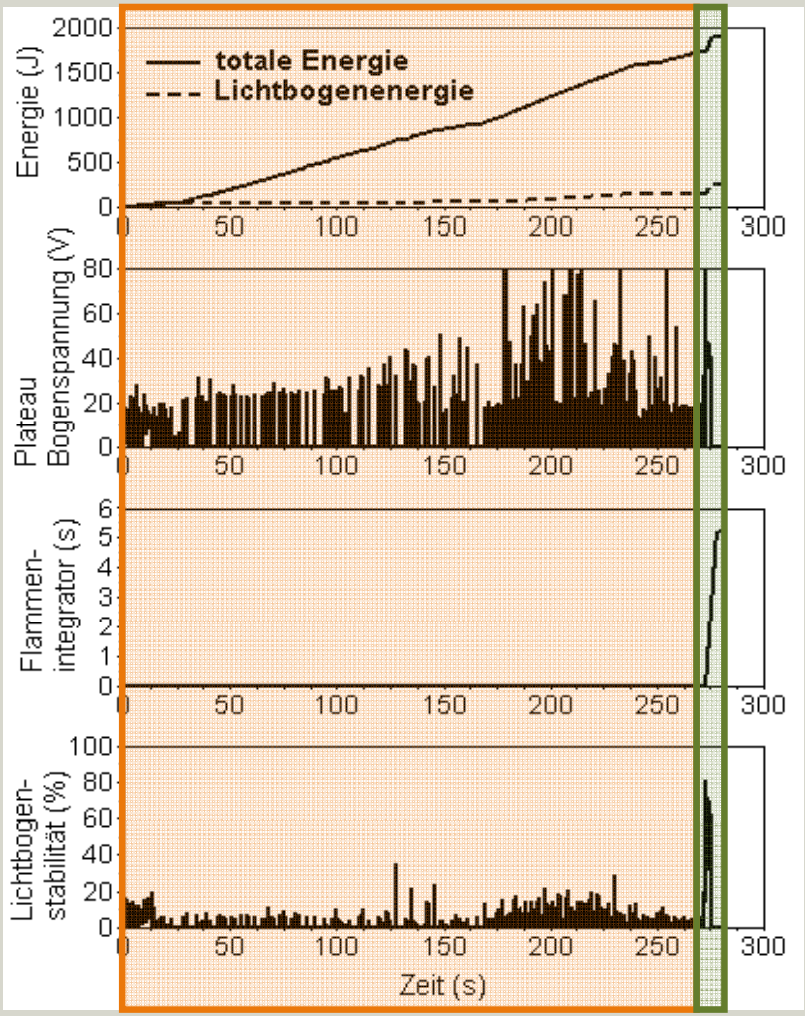
The charring phase is much longer with low currents. Glowing predominates during charring.

Ignition

The ignition phase is very short and the flame occurs almost simultaneously with the stable arc.

Fraction of arc energy

- Glowing predominates at 2 A



Example: arcing fault (5 A / 240 V)

Time-related development of a serial arc simulation divided into two phases

SIEMENS

Charring

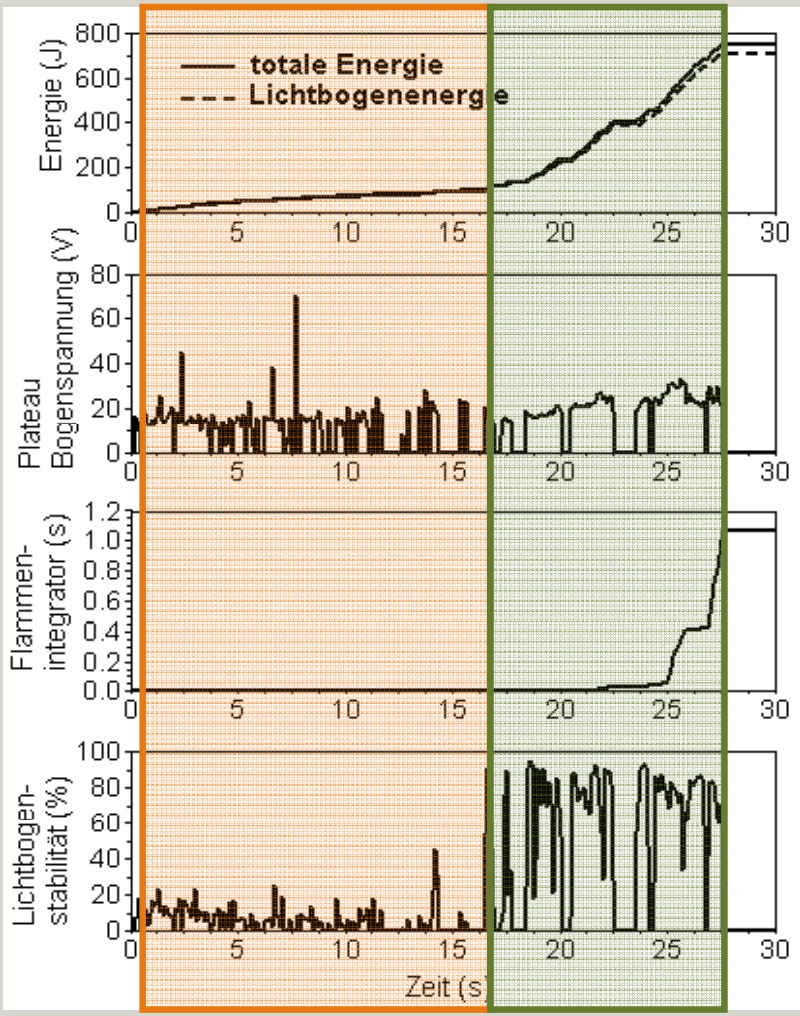
- Low arc stability
- Slow increase in energy
- No ignition of the cable possible

Ignition

- High arc stability
- Quick increase in energy
- Ignition of the cable in a few seconds

Fraction of arc energy

- Arc energy predominates at 5 A



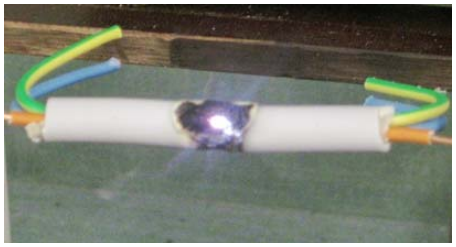
Agenda

- Arcing faults –
  History, causes and effects
- Origins of an arcing fault
- **Protection concepts**
- The challenge: arcing fault detection without false tripping
- 5SM6 AFD units
- Outlook:
  standardization activities
- Summary

Serial and parallel arcing faults

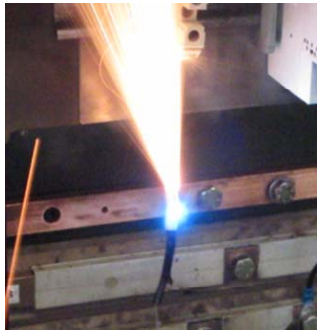
Serial arcing faults

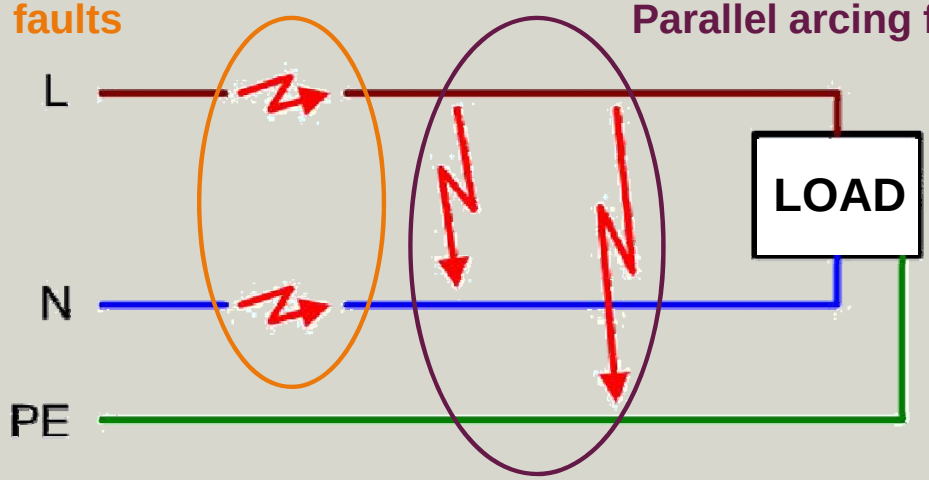
- The serial load limits the current
- The fault cannot be detected with conventional protection devices



Parallel arcing faults

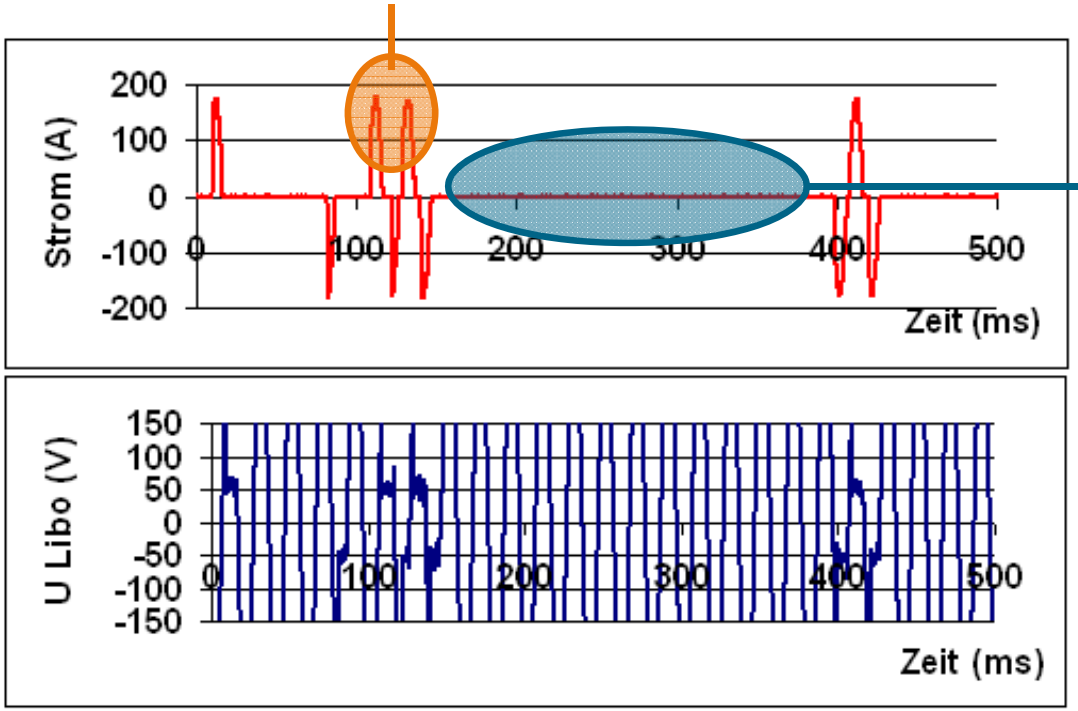
- The system impedance and the arc voltage limit the current
- L-N: protection with overcurrent protection
- L-PE: protection with overcurrent protection or residual current protection





Limits of the overcurrent protection

At a high arc voltage and system impedance, the value of the arc current may lie below the magnetic tripping current of the overcurrent circuit breaker.



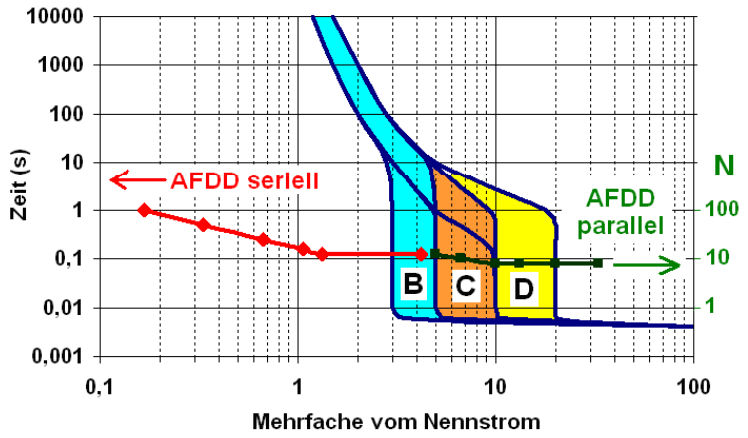
The arcing fault does not always reignite after the zero crossing:

- Gaps without current flow
- Thermal tripping of the MCB is not certain
- Fuse melts later

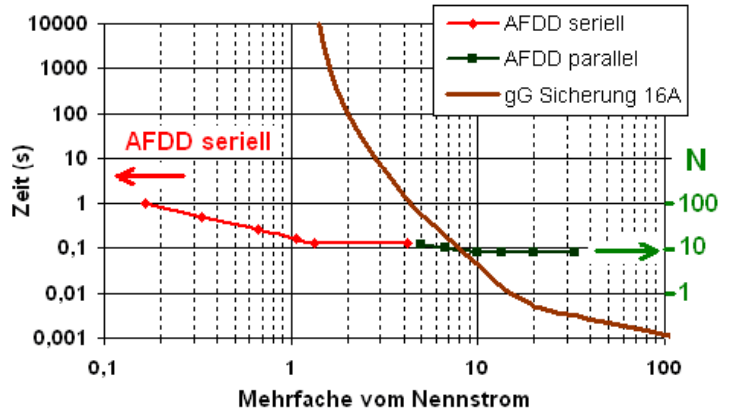
Parallel arcing fault in a two-wire cable; ignition by point contact with shears: “Guillotine Test”

Overcurrent protection in the electrical installation

Protection by MCB

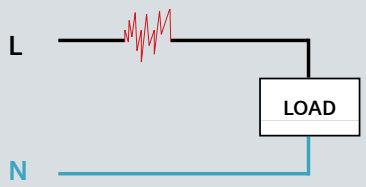
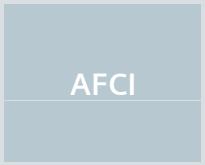
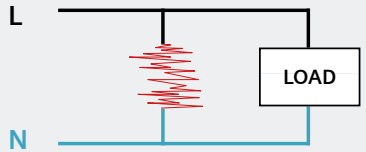
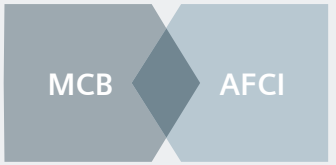
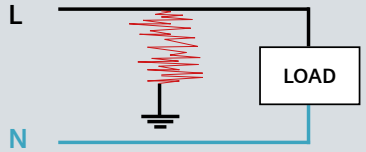
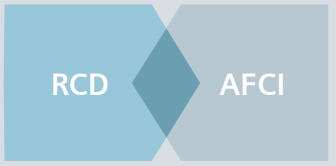


Protection by melting fuse



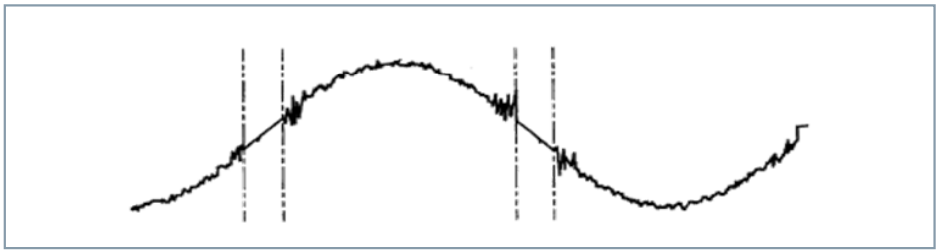
- The conventional overcurrent protection devices are effective only when the current / time characteristic of the fault lies above the tripping characteristic of the protection device.
- The electrical designer must make sure that the tripping characteristic of the protection device is suitable for the circuit.

Closing the safety gap for serial arcing faults

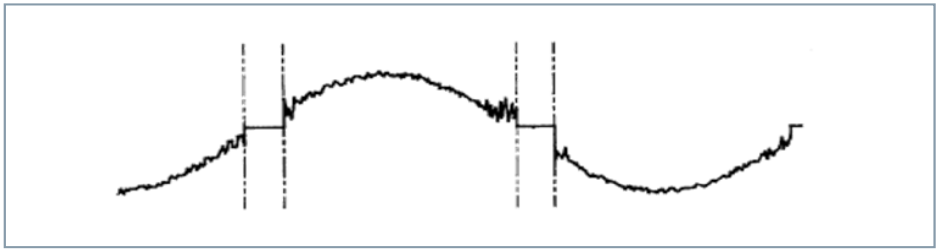
Type of fault	Protection according to IEC standard	Protection according to UL standard
Serial 		
Parallel Phase-Neutral / Phase-Phase 		
Parallel Phase-Protective conductor 		

AFDD	Arc fault detection device	**AFCI**	Arc fault circuit interruptor
MCB	Miniature circuit breaker	**MCB**	Miniature circuit breaker
RCD	Residual current protective device	**RCD**	Residual current protective device

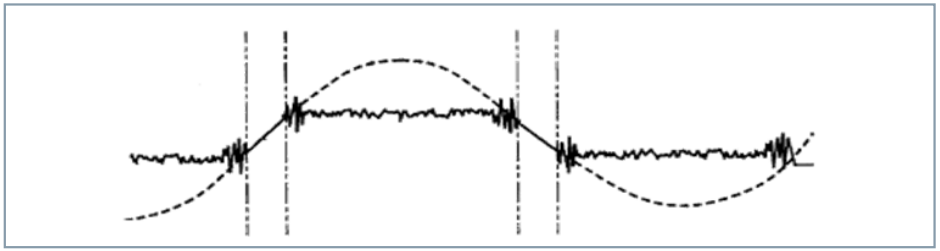
Arc detection by analysis of the HF noise



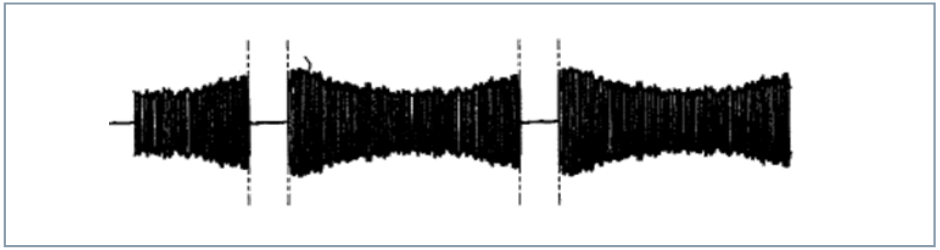
Mains voltage



Load current
(Interruptions at zero crossing and steep edges)

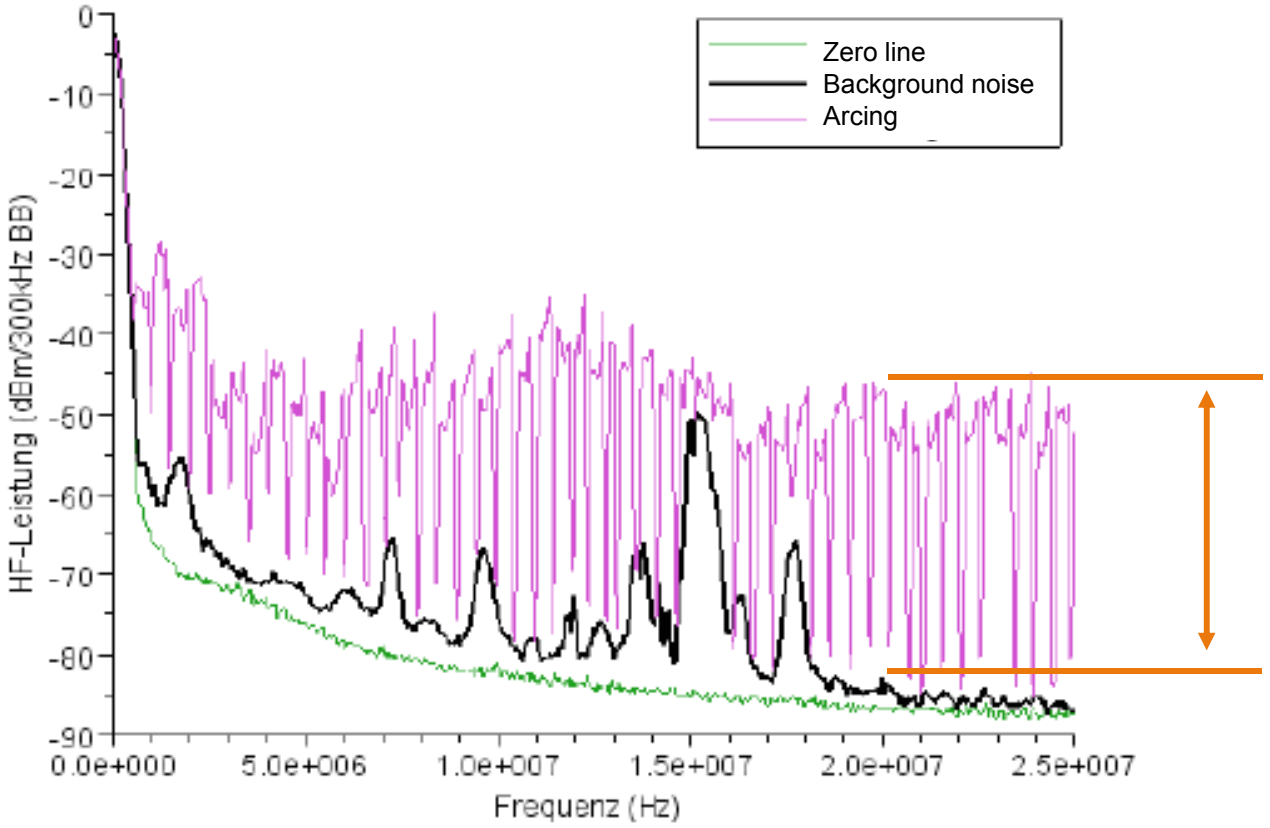


Arc voltage



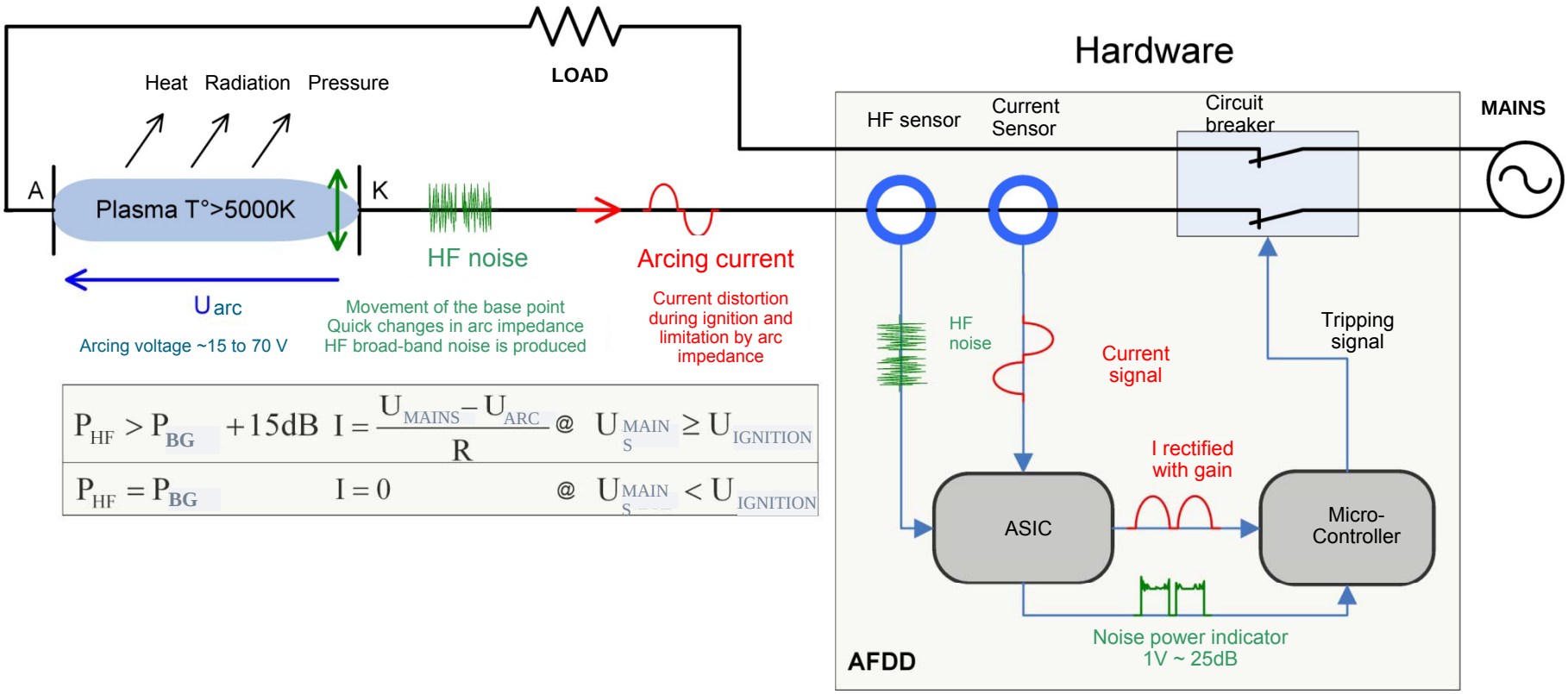
HF noise of the arc

Example
spectrum in the household

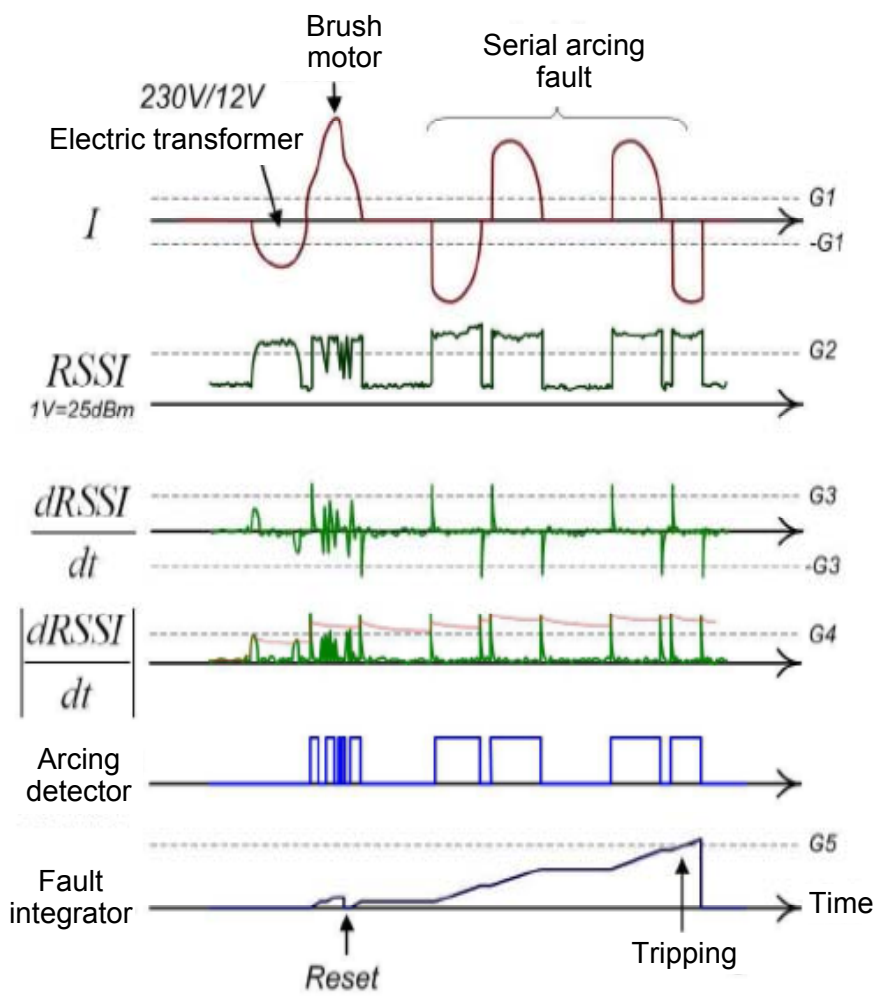


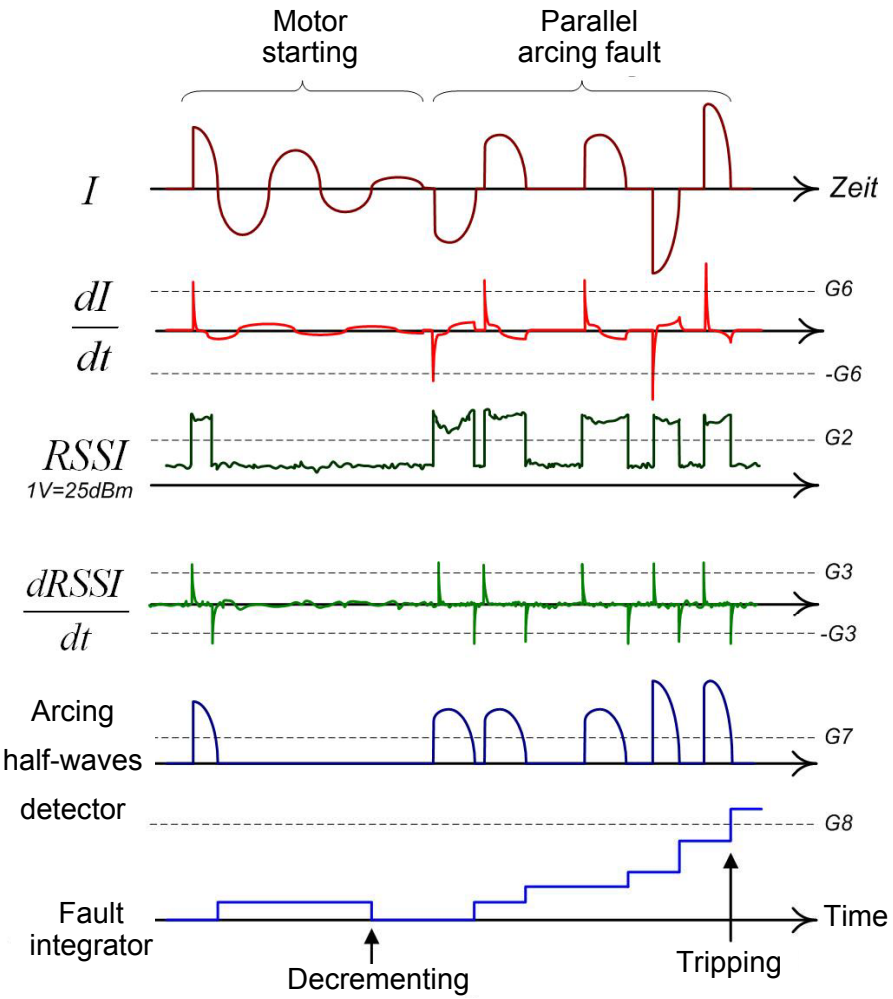
AFD units
Detection

Arc characteristics



5SM6 AFD units
evaluation principles





Agenda

- Arcing faults –
  History, causes and effects
- Origins of an arcing fault
- Protection concepts
- **The challenge: arcing fault detection without false tripping**
- 5SM6 AFD units
- Outlook:
  standardization activities
- Summary

Operational faults
prevention of unwanted tripping

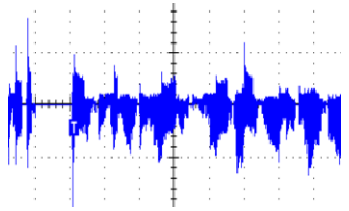
SIEMENS

Goal:
Differentiation between operational faults and unwanted or faulty conditions

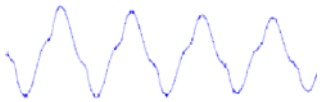
Operational faults
- **Inrush current**
  Fluorescent lamps and capacitors
- **Normal arcing**
  Electric motors, thermostat contacts, light switches, plug connectors
- **Non-sinusoidal vibrations**
  Electronic lamp dimmers, switch mode power supplies, fluorescent lamps

Crosstalking
- Prevention of tripping when an arc occurs in a neighboring circuit

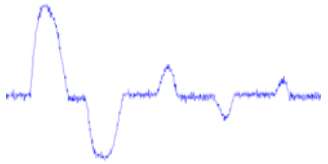
Bohr-maschine



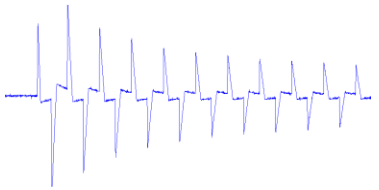
Staubsauger



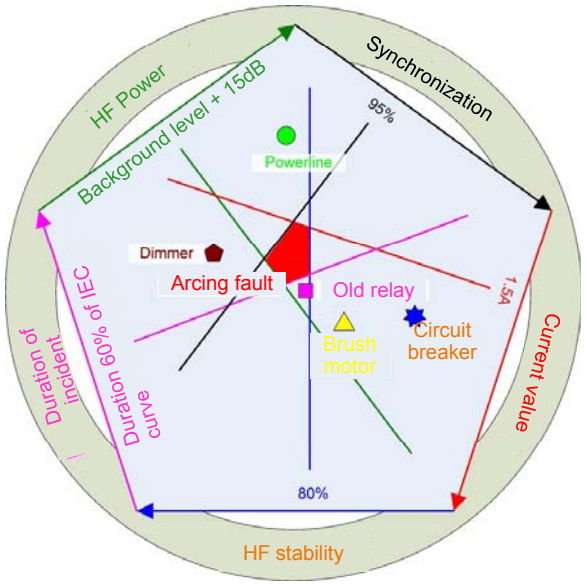
Schaltnetzteil

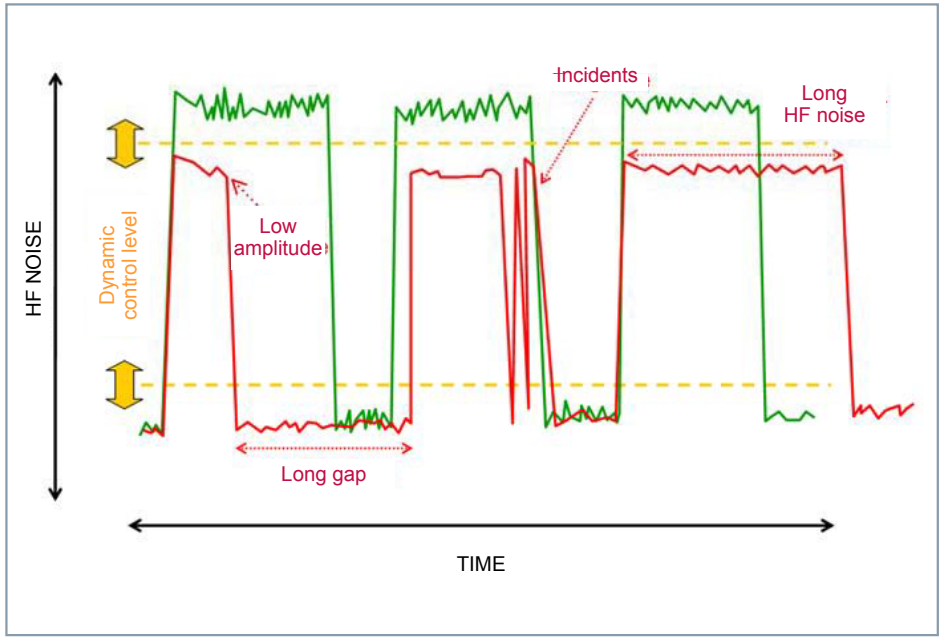


Dimmer



Arc detection
differentiation between faults





Arc detection

Microprocessor and / or ASIC

- Five main criteria for differentiating between arcing fault and arcs under normal operating conditions
- Various filters and hystereses for increasing the false tripping resistance

Agenda

- Arcing faults –
  History, causes and effects
- Origins of an arcing fault
- Protection concepts
- The challenge: arcing fault detection without false tripping
- **5SM6 AFD units**
- Outlook:
  standardization activities
- Summary

5SM6 AFD units
product variants (1/2)

5SM6 011-1

For Miniature Circuit Breakers 1 MW:
1+N (5SY60) – (max. 16 A)

5SM6 021-1

For circuit breakers 2 MW:

- RCBO 1+N (5SU1)
- MCB 1+N (5SY),

each max. 16 A

5SM6 AFD units
product variants (2/2)

SIEMENS

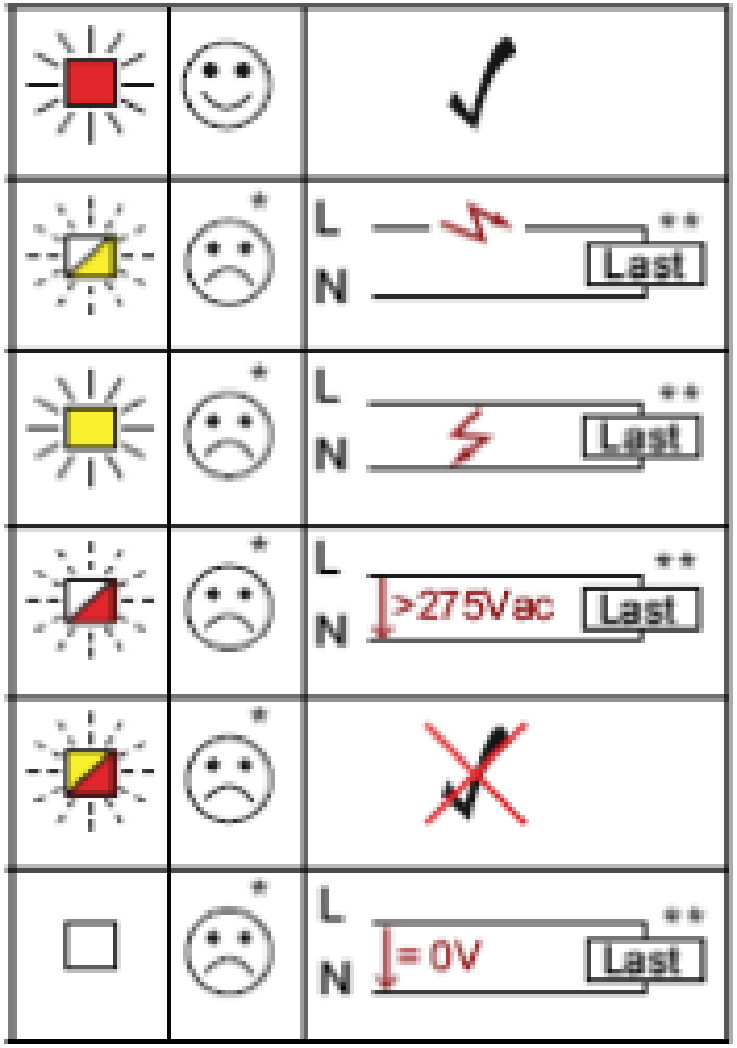
Special features

- Regular functional self-test
- Overvoltage protection: disconnection at voltages above 275 V between phase and neutral conductor
- Identical accessories as 5SY MCB (AS, FC, UR, ST)

Launch

October 2012

5SM6 AFD units
indication of the functional status



AFD unit ready, in operation

Tripped: serial arcing fault

Tripped: parallel arcing fault

Tripped: overvoltage > 275 V

AFD unit not ready

No voltage supply

Applications for branch circuits up to 16 A (1/2)

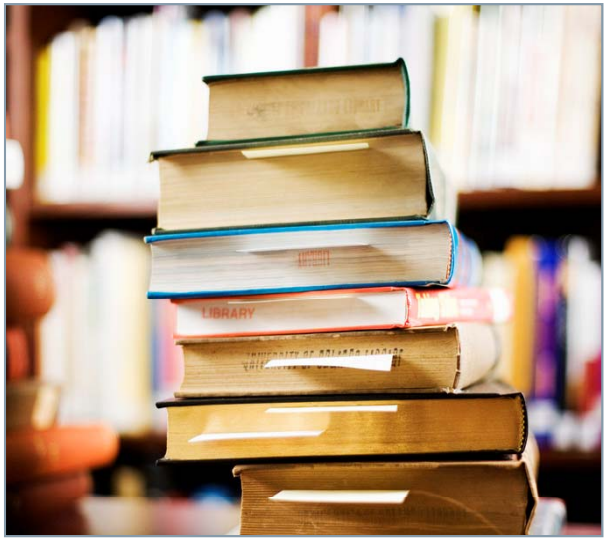
SIEMENS

Rooms in which a fire would not be immediately detected (persons at risk)

- Residential buildings
  - Bedrooms, children's rooms
  - Operation of unsupervised loads with a high level of power (e. g. night-time operation of washing machines, dish-washers)
- Old people's homes
- Hospitals

Rooms containing valuable items, objects of art

- Libraries
- Museums
- Galleries



Applications for branch circuits up to 16 A (2/2)

SIEMENS

Rooms with readily flammable materials

- Wooden structures and paneling, ecological building materials, loft conversions

Rooms in which readily flammable materials are processed

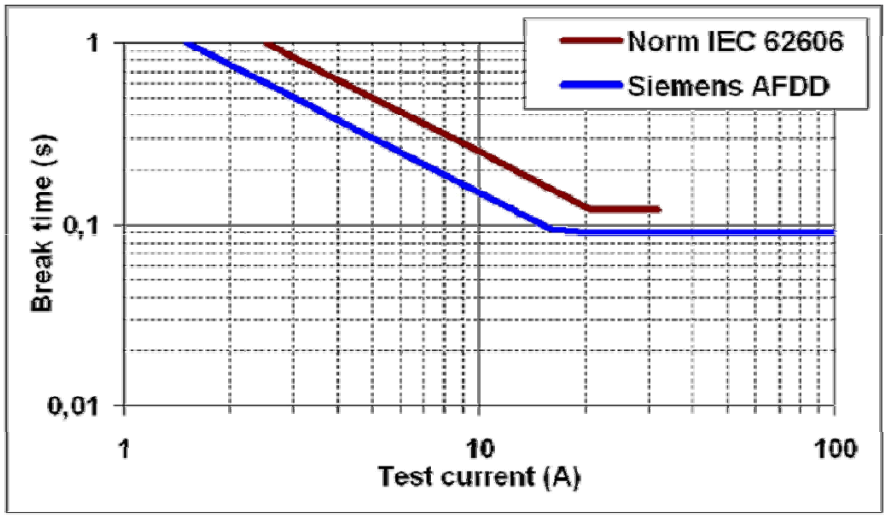
- Joiners' workshops
- Bakeries
- Cowsheds
- Barns

Agenda

- Arcing faults –
  History, causes and effects
- Origins of an arcing fault
- Protection concepts
- The challenge: arcing fault detection without false tripping
- 5SM6 AFD units
- **Outlook: standardization activities**
- Summary

Standard IEC 62606 (23E/742/CDV)

- Tripping characteristic with serial arcing
- Tripping characteristic with parallel arcing



- Resistance to false tripping with fault loads:




- EMC, endurance, insulation resistance, reliability

Draft standard IEC 62606
Tripping times for serial arc faults

SIEMENS

Table 1a – Limit values of break time for U_n 230V AFDDs						
Test arc current (rms values)	2,5A	5A	10A	16A	32A	63A
Maximum break time	1s	0,5s	0,25s	0,15s	0,12s	1)

Table 1b – Limit values of break time for U_n 120V AFDDs					
Test arc current (rms values)	5A	10A	16A	32A	63A
Maximum break time	1s	0,4s	0,28s	0,14s	1)

1: Break time value for 63A is under consideration
Low arc currents may occur due to insulation faults phase to earthor series arcing.

Draft standard IEC 62606
Tripping times for parallel arc faults

SIEMENS

Table 1c – Maximum allowed number of half-cycles within 0,5s for U_n 230V AFDDs and U_n 120V AFDDS						
Test arc current [1)] (rms values)	75A	100A	150A	200A	300A	500A
N [2)]	12	10	8	8	8	8

1: This test current is the prospective current is the current before arcing in the testing circuit
2: N is the number of half cycles at the rated frequency
High are currents may occur due to isolation faults phase to earth or parallel arcing

Agenda

- Arcing faults –
  History, causes and effects
- Origins of an arcing fault
- Protection concepts
- The challenge: arcing fault detection without false tripping
- 5SM6 AFD units
- Outlook:
  standardization activities
- **Summary**

Summary

- Arcing faults in the home can cause fatal fires.
- There are gaps in the classic safety concepts.
- An AFD unit can detect hazardous arcing faults reliably and shut them down safely.

The 5SM6 AFD unit supplements the service-proven RCCBs and MCBs, reducing the probability of fires caused by electricity.

List of references

Part of the content and some pictures of this slides where published in

JM. Martel, “Serielle Störlichtbögen in Elektroinstallationen im Niederspannungsbereich”, Siemens AG, VDE AKK-Seminar 2009

JM. Martel, M. Anheuser, A. Hueber, F. Berger, F. Erhard, "Schutz gegen parallele Störlichtbögen in der Hauselektroinstallation", Siemens AG, TU Ilmenau, VDE AKK-Seminar 2011

JM. Martel, "Characterization of arc faults and thermal effects", Siemens AG, ACE-Seminar Nancy 2012

M. Anheuser, JM. Martel, "Störlichtbogenschutz in Wechsel- und Gleichspannungsnetzen", HDT-Seminar Störlichtbogen, München 12/2011

Thank you for your attention!

Frank Bojko
Productmanager
IC LMV LP DI P 2

Siemensstr. 10
93055 Regensburg

Phone : +49 (941) 790-2568
Mobile: +49 (173) 7073494

E-Mail:
frank.bojko@siemens.com

siemens.com/lowvoltage