Integration of arcing fault mitigation devices into power switchgear and control gear assemblies according to IEC61439-2
Welcome

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Welcome to LV Webinar, 16 April 2020

Agenda

• 09:45 – 10.00 Webinar introduction and CESI presentation (C.La Salvia)
• 10:00 – 10:40 LV Technical seminar (R.Borchert)
• 10:45 – 11.00 Q&A Session and conclusion

LIVE Registration and today presentation will be available for download in the CESI website, in the next days

www.cesi.it/webinars
CESI Group: the Making of a Global Company

- **1921**: Founded as Study Society for High Voltage Systems (SfH)
- **1951**: Started as a safety testing facility for hydraulic dams, quickly developed in other important sectors
- **1953**: Founded as part of Research Institute of Czech Technical University of Prague
- **1956**: Founded as national German High-Power test lab
- **1956**: Created as a testing company with first Italian large scale test facilities
- **1956**: CHALFONT, Test lab built as part of ITE Corporation Research Center in Chalfont
- **1972**: CHALFONT, Test lab built as part of ITE Corporation Research Center in Chalfont
- **1927**: Founded by Dutch power companies
- **1951**: Started as a safety testing facility for hydraulic dams, quickly developed in other important sectors
- **2003**: Funded to improve operation and reliability of power grids through advanced technology
- **2019**: Created as Joint Venture Company between CESI and GCC ETL
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Space Solar Cells

CESI
Production of Advanced Multi-junction Solar Cells for Space Applications
30,000 MVA, Next to Our Clients

**Arnhem, NL**
- 13,000 MVA
- Short Circuit HV up to 1200 kV, 100 kA
- High Power Trafo up to 800 kV
- Dielectric Test HV up to 550 kV
- Cable Prequalification up to 550 kV
- Temperature Rise up to 25 kA

**Milan, IT**
- 4,000 MVA
- Short Circuit HV up to 420 kV, 63 kA
- Direct Test up to 36kV/31.5kA
- Dielectric Test HV up to 1,600 kVac
- Cable Prequalification up to 800kV
- Temperature Rise up to 10kA

**Berlin, DE**
- 3,000 MVA
- Short Circuit LV to 250kAac/150kAAdc
- Direct Test up to 36kV/25kA
- Dielectric Test HV up to 550 kV
- Cable Prequalification up to 500 kV
- Temperature Rise up to 50kA

**Prague, CZ**
- 2,500 MVA
- Short Circuit MV up to 36 kV, 25 kA
- Power arc insulators up to 63 kA
- Power Trafo up to 230 kV, 63 MVA
- Short-time current up to 280 kA/2.5s

**Mannheim, DE**
- 800 MVA
- HVDC cable up to 600 kV
- Direct Test short-circuit up to 800 MVA
- Dielectric Test HV up to 800 kV
- Cable Prequalification up to 400 kV
- Pollution test up to 600 kV

**Chalfont, USA**
- 3,200 MVA
- Short Circuit MV up to 36 kV, 25 kA
- Short Circuit LV up to 300 kA
- Short Circuit LV up to 300 kA
- Dielectric Test HV up to 245 kV
- Temperature Rise up to 30 kA

**Dammam, KSA**
- 2,500 MVA
- Short Circuit HV up to 550 kV/63 kA
- Direct Test up to 40kV/80kA
- 500 kVac
- Cable Prequalification up to 800 kV
- Short Circuit LV up to 250kAac/150kAAdc

Under Construction
Low voltage Expertise

DC Switchgear and assemblies for railways application

**Berlin**
- Power tests up to 200MVA
- Voltage up to 8kV DC
- According to EN50123-IEC61992
- EN50526 IEC60310 (EN60310)
- IEC60077 (EN60077)IEC 61287-1 and many others

AC/DC Switchgear assemblies

**Berlin, Prague, Chalfont**
- All Type Test up to 6300 A
- According to IEC61439-1, IEC61921, IEC60146 and many other IEC standard
- UL508/UL845/UL98/UL891/UL681/CSA C22

AC/DC Circuit breakers and fuses

**Berlin, Chalfont**
- Complete type test sequence according to IEC60947, IEC60898 and many others
- Overload tests up to 10kA
- AC 1ph and 3ph
- UL248/UL1077/UL1066/UL489

AC/DC Power tests

**Berlin, Chalfont**
- Making and Breaking capacity test up to 180kA
- Short-circuit withstand current up to 200kA
- Internal arc test
- According to IEC61439-1IEC61641,IEEE and many others
Cristian La Salvia, Ronald Borchert

LIVE Webinar April 16, 2020

A brand new Low Voltage standard
Ronald Borchert – LV Senior test engineer

Member of committees
IEC/SC121B Low Voltage Switchgear and controlgear assemblies
PT63107: Integration of arc fault mitigation system
DKE UK 431.1 Low Voltage switchgear and controlgear assemblies
DKE UK 431.1.4

IEC TS 63107 ED1: Integration of arcing fault mitigation devices into power switchgear and control-gear assemblies (PSC-ASSEMBLIES) according to IEC61439-2
Summary

1. Integration in the international standard system
2. Scope
3. Components and basic structure
4. Protected and non-protected areas
5. Design verification
Integration in the international standard system

Product standards

- **IEC 61439-1**: Low-voltage switchgear and controlgear assemblies – General rules
- **IEC 61439-2**: Low-voltage switchgear and controlgear assemblies – Power switchgear and controlgear assemblies
- **IEC TR 61641**: Enclosed low-voltage switchgear and controlgear assemblies – Guide for testing under conditions of arcing due to internal fault
- **IEC 60947-9-1**: Arc quenching devices
- **IEC 60947-9-2**: Active arc-fault combined mitigation systems - Optical-based internal arc-detection and combined mitigation devices

IEC TS 63107
Integration in the international standard system

Standards for protective measures and erection of electrical equipment

IEC 61482-1-1
Live working – Protective clothing against the thermal hazards of an electric arc – Test method 1: Determination of the arc rating of flame resistant materials for clothing

IEC 61482-1-2
Live working – Protective clothing against the thermal hazards of an electric arc – Test method 2: Determination of arc protection class of material and closing by using a constrained and directed arc (box test)

IEC 60364-4-42
Protection for safety – Protection against thermal effects

IEC 60364-5-53
Selection and erection of electrical equipment – switchgear and controlgear

IEC TS 63107
Summary

1. Integration in the international standard system
2. Scope
3. Components and basic structure
4. Protected and non-protected areas
5. Design verification
Scope

• The TS states requirements for integration and testing of IAMS in Low-voltage PSC-assemblies according to IEC 61439-2 to demonstrate their correct operation.

• It does not address personnel safety or damage to the PSC-assembly. These requirements are dealt with IEC TR 61641.

• IAMS consist of control devices (IACD) and arc-fault reduction devices (IARD) complying with their relevant product standards.

• Requirements with respect to construction and performance as well as to testing for the reliable function of an IAMS under built-in conditions are addressed.
Summary

1. Integration in the international standard system
2. Scope
3. Components and basic structure
4. Protected and non-protected areas
5. Design verification
Components and basic structure

IAMS (Internal Arc-fault Mitigation System)

IACD (Internal Arc-fault Control Device)
- Sensors
- Interfaces
- Control unit

IARD (Internal Arc-fault Reduction Device)
- AQD (Arc Quenching Device) in connection with a SCPD
- IALD (Internal Arc-fault Limitation Device), but no SCPD
- SCPD

Note: IACD and IARD can be one combined device.
And now it’s time for fun......

Scan with your Mobile the QR Code and answer the questions live within 2 minutes!
And now it’s time for fun......

Scan with your Mobile the QR Code and answer the questions live within 90 seconds!
Summary

1. Integration in the international standard system
2. Scope
3. Components and basic structure
4. Protected and non-protected areas
5. Design verification
An IAMS-protected area has to meet the following behavioral requirements:

- The detection of an arcing fault is guaranteed.
- Unintentional tripping (e.g. caused by a switching arc) is prevented.
- The detected arcing fault is limited and ultimately extinguished.
The declaration of each IAMS-protected area includes the following parameters:

- Range of the prospective short-circuit current that is present at the input terminals of the PSC-assembly.
- The range of rated operational voltages correlating to the range of the prospective short-circuit current.
- The highest arc energy that has been determined as electrical energy in the design verification tests.
## Protected and non-protected areas

**Example for an optical based IAMS and an AQD as IARD**

<table>
<thead>
<tr>
<th>AQD section</th>
<th>Incoming section</th>
<th>NH-Outgoing section</th>
<th>MCCB-Outgoing section</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image_1.png" alt="Diagram" /></td>
<td><img src="image_2.png" alt="Diagram" /></td>
<td><img src="image_3.png" alt="Diagram" /></td>
<td><img src="image_4.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

### IAMS-protected area
- **a)** No sensor
- **b)** Sensor is installed but unintended operation by switching arc is possible
- **c)** Sensor is installed but the correct functioning depends on the location of the fault, the switching status of the incoming switch and the effect of any back-up protection that may be present.

### Non IAMS-protected area
- **a)** SC
- **F1, F2** Fault locations

### Conditionally IAMS-protected area
- **SC** Short-circuit

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KEMA Labs
1. Integration in the international standard system
2. Scope
3. Components and basic structure
4. Protected and non-protected areas
5. Design verification
Design Verification

The complete design verification acc. to IEC 61439-2 includes the following:

a) Construction

10.2 Strength of materials and parts
10.3 Degree of protection of enclosures
10.4 Clearances and creepage distances
10.5 Protection against electric shock and integrity of protective circuits
10.6 Incorporation of switching devices and components
10.7 Internal electrical circuits and connections
10.8 Terminals for external conductors

b) Performance

10.9 Dielectric properties
10.10 Verification of temperature rise
10.11 Short-circuit withstand strength
10.12 Electromagnetic compatibility
10.13 Mechanical operation

The technical standard specifies some additional tests to demonstrate the correct functioning of the entire arc protection system under built-in conditions.
Design verification-Additional tests

10.10.1 Additional tests to verify the temperature-rise

10.11.1 Additional tests to verify the short-circuit withstand strength of the AQD-circuit (wanted, internal, metallic short-circuit)

10.101.2 Verification of arc-fault detection by test

10.101.3 Verification by test that unintended operation will not occur

10.101.4 Verification of an IAMS in PSC-assemblies by test

10.101.5 Performance after powering or repowering
Design verification-Temperature-rise test

Temperature measuring points on the optical sensors and on the AQD

By courtesy of Siemens AG and DEHN SE+Co KG
10.11.1 General

Addition:
If present, the AQD main circuit including the incoming circuit and the connection to the connection point of the AQD have to be tested.

10.11.5.5 Evaluation

Addition:
In applications with an IAMS using an AQD, no crack(s) within the busbar system are allowed.

**Note:** The use of resettable (Reusable) AQD can draw additional requirements.
Design verification-Arc fault detection

For the lowest rated operational voltage, this test has to be carried out with the lowest, single-phase short-circuit current declared by the manufacturer. The ignition of the arc should take place at the point of an IAMS-protected area at which the occurrence of an arcing fault is most likely.

If the manufacturer does not specify a minimum short-circuit current value, the test should be carried out with 10 kA.

In addition, unfavorable conditions such as shading of the sensor have to be taken into account. This is particularly the case with internal separations and in cable outlets.
## Ignition points

<table>
<thead>
<tr>
<th>Network</th>
<th>Number of phases</th>
<th>Number of active conductors</th>
<th>Ignition between</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN-C</td>
<td>1</td>
<td>2</td>
<td>L and PEN</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
<td>LX and PEN</td>
</tr>
<tr>
<td>TN-S</td>
<td>1</td>
<td>2</td>
<td>L and PE or N</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
<td>LX and PE or N</td>
</tr>
<tr>
<td>TT</td>
<td>1</td>
<td>2</td>
<td>L and N</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td>LX and LY</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
<td>LX and N</td>
</tr>
<tr>
<td>IT</td>
<td>1</td>
<td>2</td>
<td>L1 and L2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td>LX and LY</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
<td>LX and N</td>
</tr>
</tbody>
</table>

Design verification-Arc fault detection
Design verification-Arc fault detection

Test and measuring circuits

Ignition point

Status indication

Oscillogram

By courtesy of Siemens AG and DEHN SE+Co KG
Switching arcs emit e.g. light and heat with an accompanying increase in pressure, which, depending on the sensor system, can cause an unwanted activation of the arc protection system.

Air-insulated switches have to be considered for the operating conditions short circuit, overload and normal load.

If circuit breakers are installed as SCPD, the test has to be carried out with the highest let-through energies, i.e.:

- with the highest prospective short-circuit current and the corresponding rated operational voltage as well as
- at the highest setting of the overcurrent releases as specified by the manufacturer.
Design verification- Verification that unintended operation will not occur

The test has to be carried out with the intended switchgear that delivers the greatest emissions. The safety distances to earthed metal parts can provide an indication of this.
Design verification - Verification that unintended operation will not occur

Circuit-breaker section

Oscillogram

Status indication

By courtesy of Siemens AG and DEHN SE+Co KG
The intend of this test is to demonstrate that the entire IAMS is functioning correctly. In addition, the arcing energy released within the switchgear (purely electrical) has to be determined.

If circuit breakers are installed as SCPD, the test must be carried out with the highest let-through energies, i.e.:

- with the rated short-circuit current and the rated short-time current at the corresponding rated operational voltage as well as
- at the highest release settings as specified by the manufacturer.

Note: The test can be carried out in conjunction with IEC TR 61641.
The arc has to be ignited three pole in three-phase systems. In single phase systems as follows:

<table>
<thead>
<tr>
<th>Network</th>
<th>Ignition between</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN-C</td>
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<tr>
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<td>L and PE or N</td>
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<tr>
<td>TT</td>
<td>L and N</td>
</tr>
<tr>
<td>IT</td>
<td>L1 and L2</td>
</tr>
</tbody>
</table>

The test (ignition) has to be carried out in the IAMS-protected area that is closest to the incoming terminals.
Description of the extinction of an internal arc-fault by an IAMS using an AQD as IARD (Annex JJ)

Design verification - Verification of an IAMS in PSC assemblies by test
The following sequence of events will occur:

a) Test switch (making switch of the test laboratory) is closed.

b) The arc-ignition wire is melting.

c) The arc is ignited (time $t_o$ in accordance to IEC 60947-9-2).

d) The arc is recognized by the IACD.

e) Only AQD or both, AQD and incoming SCPD are triggered by the IACD.

f) The low-impedance state of the AQD is established.

g) The current is almost completely commutated into the AQD circuit.

h) The incoming SCPD has cleared all line currents.

Note: Due to the definition of $t_o$, the event d) can occur before c).
a) Test switch (making switch of the test laboratory) is closed.

c) The arc is ignited (time $t_o$ in accordance to IEC 60947-9-2).

f) The low-impedance state of the AQD is established.

g) The current is almost completely commutated into the AQD circuit.
a) Test switch (making switch of the test laboratory) is closed.

b) The arc is ignited (time $t_o$ in accordance to IEC 60947-9-2).

c) The low-impedance state of the AQD is established.

d) The current is almost completely commutated into the AQD circuit.
Design verification - Verification of an IAMS in PSC assemblies by test

Currents in the arc-fault circuit (magnified scale)

a) Test switch (making switch of the test laboratory) is closed.

c) The arc is ignited (time $t_0$ in accordance to IEC 60947-9-2).

f) The low-impedance state of the AQD is established.

g) The current is almost completely commutated into the AQD circuit.
Design verification- Verification of an IAMS in PSC assemblies by test

Currents in the AQD circuit

a) Test switch (making switch of the test laboratory) is closed.

c) The arc is ignited (time $t_0$ in accordance to IEC 60947-9-2).

f) The low-impedance state of the AQD is established.

g) The current is almost completely commutated into the AQD circuit.
Design verification- Verification of an IAMS in PSC assemblies by test

Voltages at the incoming terminals

a) Test switch (making switch of the test laboratory) is closed.

b) The arc-ignition wire is melting.

c) The arc is ignited (time $t_o$ in accordance to IEC 60947-9-2).

d) The low-impedance state of the AQD is established.

g) The current is almost completely commutated into the AQD circuit.
Design verification - Verification of an IAMS in PSC assemblies by test

Voltages at the incoming terminals (dotted curves) and incoming currents at the end of sequence

h) The incoming SCPD has cleared all line currents.
Design verification - Verification of an IAMS in PSC assemblies by test

Effective limitation of the increase in arc-energy

a) Test switch (making switch of the test laboratory) is closed.

c) The arc is ignited (time $t_o$ in accordance to IEC 60947-9-2).

f) The low-impedance state of the AQD is established.

g) The current is almost completely commutated into the AQD circuit.

h) The incoming SCPD has cleared all line currents.

$$E_{arc,w}(t) = \int_{t_c}^{t_h} (u_w(t) \cdot i_w(t)) \, dt \quad \text{mit}$$

$$E_{arc}(t) = \sum_{w=1}^{N} E_{arc,w}(t_h)$$

$w$ - phase-index;

$t_c$, point c);

$t_h$, point h);

$u_w(t) =$ measured phase to earth voltage at the incoming terminals;

$i_w(t) =$ measured or calculated arc-fault line current of the relevant phase;

$N =$ number of phase(s)
Ronald Borchert

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Many thanks for your attention
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Thank you

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