EUROPEAN HIGH VOLTAGE FUSES
AS PER IEC 60282
EduPack Training Module

2012
MEDIUM OR HIGH VOLTAGE FUSE?

High Voltage is the official definition provided by the standard. High Voltage starts just when Low Voltage ends.

Medium Voltage is the current and popular naming for utilities and users

Maximum voltage range :  72 500V

Our fuses: up to 40 500 volts
PROTECTION REQUIREMENTS FOR SAFETY - QUALITY - ECONOMY

• **Safety**: short-circuits can be dangerous for people and can destroy equipments

• **Quality**: of the power supply and quality of the equipments

• **Economy**: the protection can help to reduce the cost of the equipments and the cost of the maintenance.
SAFETY – QUALITY - ECONOMY

Medium voltage fuses can provide:

• Reliability
• Enclosed operation
• Speed
• High breaking capacity
• No maintenance before a short-circuit
• Small maintenance after a short-circuit
• Selectivity (or discrimination)
• Improved power quality
• Future system growth without problems
• Universal
• Low power consumption
• Price
TWO MAIN DIFFERENT CLASSES

2 main classes in the international publication IEC 60282-1:

- **Associated fuses** also known as “back up current limiting fuse” are capable of interrupting all currents from maximum interrupting rating (“breaking capacity”) down to minimum interrupting rating.

- **General purpose fuses** can interrupt all currents from maximum interrupting rating (“breaking capacity”) down to the current that causes the fuse element to melt in no less than 1 hour.
INTERRUPTING TESTS

Current $I_1$: maximum interrupting rating (breaking capacity)
Test voltage is 87% of fuse rated voltage

Current $I_2$: maximum energy test
Test voltage is 87% of fuse rated voltage

Current $I_3$: minimum interrupting current
Test voltage is 100% of fuse rated voltage

Associated fuse (Backup protection fuse): $I_3$ is the rated minimum interrupting current.

General Purpose: $I_3$ is the current that causes melting of the fuse in no less than 1h.

General purpose fuses may experience damage due to overheating if subjected to currents that cause them to interrupt at times significantly more than 1 hour.
The fuse current rating is defined for 40°C ambient temperature.

Typical limits are:
- Body: 115 K temperature rise i.e. 155°C maximum temperature
- Contacts: 65 K temperature rise i.e. 105°C maximum temperature
Tests conducted in the following time ranges:

Associated fuse (Back-up fuses): from 0.01s to 600s
General Purpose fuses: from 0.01s to 1h
FUSES CLASSIFIED AS « PARTIAL RANGE »
OR BACK-UP PROTECTION FUSES

Associated fuses are therefore recommended when they must not interrupt low values of fault currents.

They are working in association with a circuit breaker and are generally used for:

• The protection of circuits with motors
• The protection of capacitors
• The protection of transformers
FUSES CLASSIFIED AS « PARTIAL RANGE »
OR BACK-UP PROTECTION FUSES

As for low voltage fuses, the main components are:

• One or several fuse elements in parallel

• Body made of ceramic or fibre glass

• Terminals

• Filler: the filling material is sand
FULL-RANGE FUSES DESIGN FOR APPLICATIONS WITH LOW OVERLOADS

There are mainly two kinds of design:

Design 1: The use of alloys or eutectics with low melting temperature.

Design 2: The use of two systems in series in the same casing like low voltage « Dual Element »:
  • The 1st system contains classic fuse elements for short circuit currents
  • The 2nd system contains a spring loaded element designed to interrupt low overloads

Design 2 is more often used
TRANSFORMER PROTECTION FUSES
THREE MAIN TYPES

Indoor type fuses
Installed in the primary of the transformer

Outdoor type fuses
Protecting overhead transformers

Oil-immersed Fuses
Protecting oil immersed transformers
INDOOR FUSES FOR HIGH VOLTAGE PANELS AND SWITCHBOARDS

Dimensions to the standards:
UTE 64 210
DIN 43 625

When fitted with a striker pin controlling the operation of a circuit breaker, the striker pin must prove it has enough energy.
OUTDOOR FUSES

The fuses are Associated type and refer to DIN 43 625 or HM 24.94.035 C.

Outdoor applications require watertight equipment as well as the capacity to withstand UV and sand storms.
Oil-Tight Fuses

Oil Tight Fuses are immersed in the dielectric liquid:

- They have a total imperviousness to oil
- They must operate at temperatures generally close to 100°C
- They are fitted inside of high-voltage/low-voltage transformers above the coils
- General purpose or back up type fuses can be used
SELECTION OF RATED VOLTAGE $U_N$ OF THE FUSE
IEC 60282-1

When used on a three-phase earthed system

$U_N = $ largest line to line voltage

When used on a single-phase system

$U_N = 115\%$ of the largest single-phase circuit voltage

When used on a three-phase unearthed system, discussion about:

- Double earthed faults
- Capacitive currents in the case of phase to earth fault
Altitude

CEI 60282-1 §2.1 b)

“Rated voltages and insulations level in this recommendation apply to fuses intended for use at altitudes not exceeding 1000 m”
Values given by the IEC belongs more particularly to the fuse holders and isolators.

IEC specifies 5\% voltage derating at 1500 m and 20\% at 3000 m.

Our fuse rated 40.5 KV with epoxy body can certainly operates under 32 KV at 3000 m and is only 300 mm long.

Therefore all our fuses rated up to 36 KV in our catalogue do not need to be derated for altitudes lower than 3500 m.
Influence of the Environment on the Fuse Current Rating $I_N$

Ambient air temperature

CEI 60282-1 : Conditions in normal service

- Maximum: 40°C
- Average : 35°C
- Minimum : - 25°C
Influence of the environment on the fuse current rating $I_N$

Ambient air temperature

$$A_1 = \sqrt{\frac{120 - \theta_a}{80}}$$

$$K_\theta = \frac{1}{A_1}$$

$$I_N = I_B \times K_\theta$$

<table>
<thead>
<tr>
<th>$\theta_a$</th>
<th>$K_\theta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>45</td>
<td>1.03</td>
</tr>
<tr>
<td>50</td>
<td>1.07</td>
</tr>
<tr>
<td>55</td>
<td>1.11</td>
</tr>
<tr>
<td>60</td>
<td>1.16</td>
</tr>
<tr>
<td>65</td>
<td>1.21</td>
</tr>
<tr>
<td>70</td>
<td>1.27</td>
</tr>
</tbody>
</table>
## Influence of the Environment on the Fuse Current Rating $I_N$

### Altitude

<table>
<thead>
<tr>
<th>Altitude (m)</th>
<th>Correction factor for rated current</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1</td>
</tr>
<tr>
<td>1500</td>
<td>0.99</td>
</tr>
<tr>
<td>2000</td>
<td>0.98</td>
</tr>
<tr>
<td>2500</td>
<td>0.97</td>
</tr>
<tr>
<td>3000</td>
<td>0.96</td>
</tr>
</tbody>
</table>
PROTECTION OF POWER TRANSFORMERS

• The short-circuit between lines generates large currents. Fuses interrupt such currents very well within milliseconds, limiting the peak current down to low values.

• In case of fault inside the transformer, the value of the current increases generally progressively. It can reach high values together with production of gas in many cases. The absence of protection can be catastrophic with a real danger of explosion as the short-circuit is reaching high magnitudes. In this case, the current is limited and well interrupted by the fuses.
PROTECTION OF POWER TRANSFORMERS

The selection of fuses must be made taking into account:

• High transient currents occurring in the primary when the transformer power is switched on

• Overload currents linked to the transformer which are likely to make them prematurely age

• The use of a fuse in an oil bath requires a particular selection as the various parts of the equipment intervene in the heating process. A downgrading co-efficient is to be applied to the rating
PROTECTION OF POWER TRANSFORMERS

Transformer inrush current

\[ I_{\text{INR}} \]

\[ 12 I_{\text{N TRANS}} \text{ à } 25 I_{\text{N TRANS}} \text{ peak} \]

\[ 0.1s \]
As a rule of the thumb

The fuse current rating $I_n$ is at least equal to:

$$I_n = 1.7 \times I_B$$

When considering a 133% overloads:

$$I_n = 2.3 \times I_B$$

$I_B = \text{transformer rated current}$

Coefficient for temperature must be added:

$$I_n = 1.7 \times I_B \times K_\theta$$

Or $$I_n = 2.3 \times I_B \times K_\theta$$
PROTECTION OF POWER TRANSFORMERS

The table, opposite, may also be used. It has been computed using peak transient currents from 8 to 15 times the transformer current rating and a 130% overload rate.

Using this table also means applying the temperature derating factor A1 to the selected rating when ambient exceeds 40°C in the fuse environment.
# PROTECTION OF POWER TRANSFORMERS

## Selection from UTE Guide on fuses

<table>
<thead>
<tr>
<th>Network Rated Voltage (kV)</th>
<th>EDF Selection Transformer Rated Power</th>
<th>C13100 Recommendation Transformer Rated Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 100 160 250 400 630 1000</td>
<td>25 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1000 1250</td>
</tr>
<tr>
<td>10</td>
<td>6,3 16 32 32 63 63</td>
<td>6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3</td>
</tr>
<tr>
<td>15</td>
<td>6,3 16 16 43 43 63</td>
<td>6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3</td>
</tr>
<tr>
<td>20</td>
<td>6,3 6,3 16 43 43 43*</td>
<td>6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3 6,3</td>
</tr>
</tbody>
</table>

**Tension Nominale du réseau (kV)**

<table>
<thead>
<tr>
<th>25 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1000 1250</th>
</tr>
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<tbody>
<tr>
<td>10 6,3 6,3 6,3 6,3 16 16 16 32 32 32 63 63 63 63 63 63</td>
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<tr>
<td>15 6,3 6,3 6,3 6,3 6,3 16 16 16 16 43 43 43 43 43 43 63</td>
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</tbody>
</table>
RECOMMENDATIONS FOR MOTOR PROTECTION

\[ I_{FLA} = \frac{P_{KW}}{V_{AC} \times \sqrt{3} \times \eta \times \cos \Phi} \]

- \( P_{KW} \): Rated power of the motor (generally in Kilowatt)
- \( V_{AC} \): Rated line to line voltage
- \( \eta \): Efficiency of the motor
- \( \cos \Phi \): Power factor

The starting current can reach 3 to 8 times the rated current \( I_{FLA} \) of the motor.
## Recommendations for Motor Protection

<table>
<thead>
<tr>
<th>N</th>
<th>I_F</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1.8 x I_{start}</td>
</tr>
<tr>
<td>10 000</td>
<td>2.2 x I_{start}</td>
</tr>
<tr>
<td>100 000</td>
<td>2.85 x I_{start}</td>
</tr>
</tbody>
</table>

The average prearc curve of the fuse is shown in the diagram. The formula for the average prearc time, \( T_{START} \), is given by:

\[
T_{START} = \frac{d_1}{I_{F}}
\]

where \( d_1 \) is the distance on the curve and \( I_F \) is the fuse current.
RECOMMENDATIONS FOR MOTOR PROTECTION

Carrying the motor $I_{FLA}$ and environment conditions

As a general rule the fuse rating is at least $I_N = 1.25 \times I_{FLA}$
RECOMMENDATIONS FOR CAPACITOR PROTECTION

The fuse selection must take into:

• The inrush current occurring when the capacitor is switched on

• Harmonic currents during the normal operation of the network

• The recovery voltage across the fuse terminals after a fault interruption
RECOMMENDATIONS FOR CAPACITOR PROTECTION

Fuse type selection

• When a « g » type fuse is used for capacitor protection another protection system is necessary because the fuse rating is generally 2 times the capacitor rated current

• « a » type fuse can be used providing another protection system interrupt low overloads (minimum breaking capacity of the selected fuse)

Selection fo the fuse voltage rating

Service voltage may increase up to 20% during overloads

\[ U_{\text{FUSE}} > 1.2 \text{ times the circuit rated voltage} \]
RECOMMENDATIONS FOR CAPACITOR PROTECTION

Fuse current rating selection

General rule for the continuous load:

\[ I_{N\text{ FUSE}} = 2 \times \text{rated capacitor current} \]
RECOMMENDATIONS FOR CAPACITOR PROTECTION

Withstanding of the capacitor inrush current

<table>
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<tr>
<th>N</th>
<th>$I_F$</th>
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<tbody>
<tr>
<td>2000</td>
<td>$1.7 \times I_{\text{start}}$</td>
</tr>
<tr>
<td>10 000</td>
<td>$1.8 \times I_{\text{start}}$</td>
</tr>
<tr>
<td>100 000</td>
<td>$2 \times I_{\text{start}}$</td>
</tr>
</tbody>
</table>

Average prearc curve of fuse

![Graph showing inrush current and prearc curve of fuse]