IEC 60282 - EUROPEAN MEDIUM VOLTAGE FUSES

1. INTRODUCTION

Medium Voltage systems are now classified as HTA

The HTA maximum voltage range is: 72 000V
The FERRAZ SHAWMUT fuses are available up to : 40 500 volts

As for low voltage fuses the medium voltage fuse ensure people and equipment safety at the best cost due to a large group of qualities like:

- **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**

2. IEC 282 : MEDIUM VOLTAGE FUSES

2.1. Two main classes in the international publication IEC 282-1:

– ASSOCIATED FUSES also known as “back up current limiting fuse”: 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.

2.2. 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
As for low voltage fuses current I_2 will produce the maximum arc energy during interruption

- **Current I_3 : minimum interrupting current**

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, performed at fuse rated voltage. 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

2.3. Temperature rise test

The fuse current rating is defined for 40°C ambient temperature.

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2.4. Time current curve

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

No gates are specified.

3. FUSE DESIGNS

3.1. Fuses classified as back up protection fuses

They are working in association with a circuit breaker.

As for low voltage fuses, the main components are:

- one or several fuse elements in parallel.
- body made of ceramic or fibre glass.
- Two terminals
- filler: the filling material is sand.

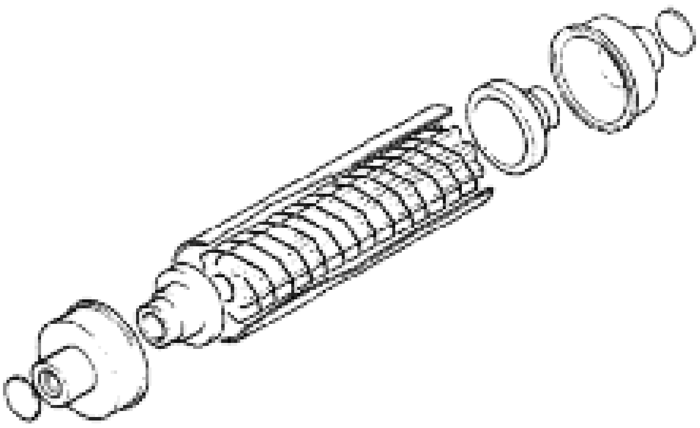

Figure 1

3.2. Fuses classified as general purpose fuse

Figure 2

For applications with low level fault currents

There are mainly 2 kind of design:

a. The use of alloy with a low melting temperature

b. The use of the « Dual Element » concept i.e. two systems in series in the same casing :

- The 1st system contains classic fuse for short circuit currents
- The 2nd system contains a spring loaded element designed to interrupt low overloads

The b. design is usually preferred, the complete system being housed in the same casing.

Together with the fuse elements systems the other main components are:

- Body
- Two terminals
- Filler = sand

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4. FUSE TECHNOLOGIES FOR TRANSFORMER PROTECTION

THREE MAIN TYPES

4.1. Indoor fuses

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.

Figure 3: indoor type fuses installed in the primary of the transformer

4.2. 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.

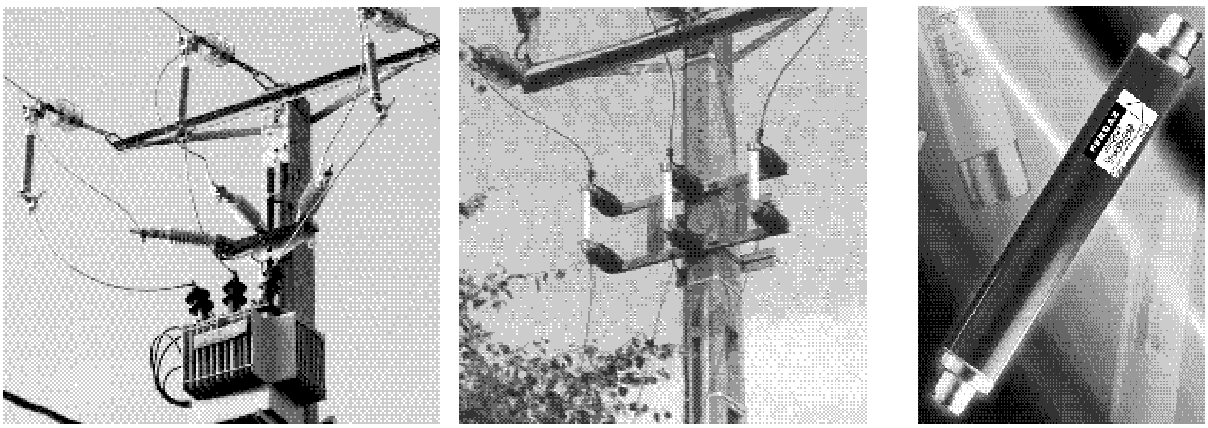

Figure 4 : outdoor type fuses protecting overhead transformers

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4.3. Oil immersed fuses

Figure 5: Oil tight fuse

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℃
- They are fitted inside of high-voltage/low-voltage transformers above the coils
- General purpose or back up type fuses can be used

5. SELECTION OF THE FUSE VOLTAGE RATING U_N

5.1. Three phase earthed system:

U_N = largest line to line voltage

5.2. Single - phase system:

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

5.3. Three phase unearthed system:

discussion about double earthed faults & discussion on capacitive currents in the case of phase to earth fault.

5.4. Influence of the altitude

IEC 282-1 §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 2005 catalogue do not need to be derated for altitudes lower than 3500 m.

6. INFLUENCE OF THE ENVIRONMENT ON THE FUSE CURRENT RATING I_N

6.1. Ambient air temperature

Normal service conditions are:

- Maximum: 40℃
- Average : 35℃
- Minimum : - 25℃

When the ambient temperature θ_a is above 40℃ the rated current I_N of the fuse is obtained with a corrective coefficient K_θ applied on the working current I_B of the circuit.

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

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

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

TABLE 1

θ_a	K_θ
40	1
45	1.03
50	1.07
55	1.11
60	1.16
65	1.21
70	1.27

6.2. Altitude

IEC 282-1 §2.1 b): " Rated voltages and insulations level in this recommendation apply to fuses intended for use at altitudes not exceeding 1000 m"

TABLE 2

ALTITUDE (m)	CORRECTION FACTOR FOR RATED CURRENT K_A
1000	1
1500	0.99
2000	0.98
2500	0.97
3000	0.96

Coefficients are combined, then :

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

7. PROTECTION OF POWER TRANSFORMERS

- the short-circuit between lines generates large currents. FUSES easily interrupt such currents 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 current is reaching high magnitudes. In this case, the current is limited and well interrupted by the FUSES

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7.1. Transformer inrush current

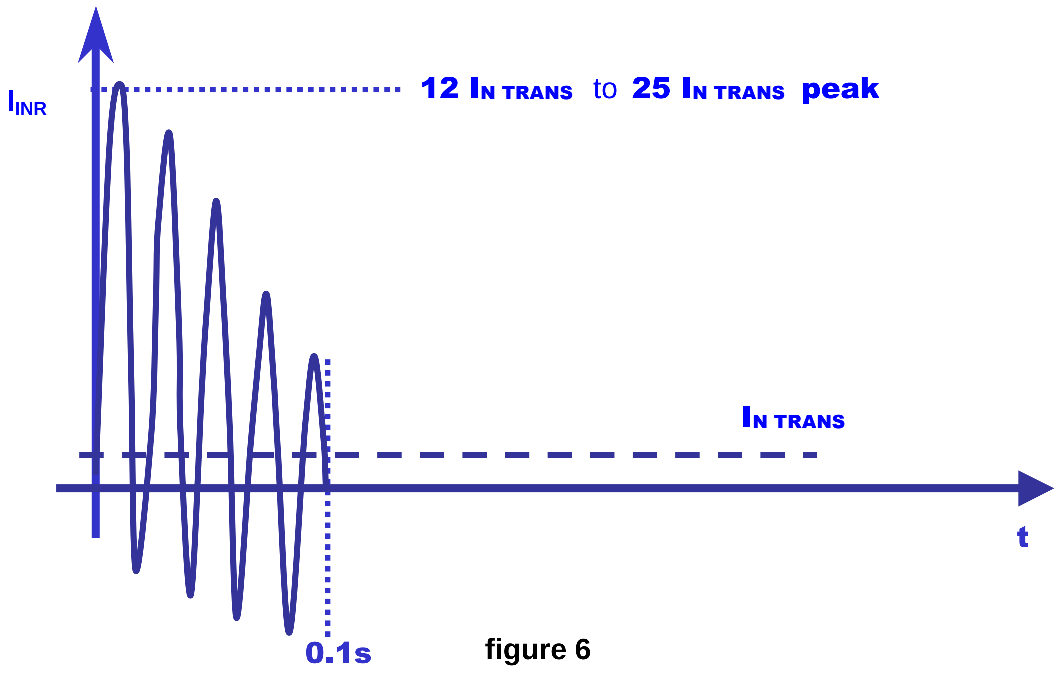

figure 6

the selection of fuses must be made taking into account :

- high transient peak currents occurring in the primary when the transformer power is switched on, typically up to 25 times the transformer rated current at 0.01 second
  10 to 15 times the transformer rated current at 0.10 second
- Overload currents linked to the transformer which are likely to make them prematurely age

The RMS value of the inrush current at 10 ms is: $\mathbf{I_{INRUSH}} = \dfrac{\mathbf{I_{PEAK}}}{\mathbf{1.6}}$

the fuse melting curve must be above the calculated prearc current I_F of the fuse at a given time T_{INRUSH} (in this case **T_{INRUSH} = 10 millisecondes) as shown in figure 7.**

N	I_F
2 000	1.7 x I_{INRUSH}
10 000	1.8 x I_{INRUSH}
100 000	2 x I_{INRUSH}

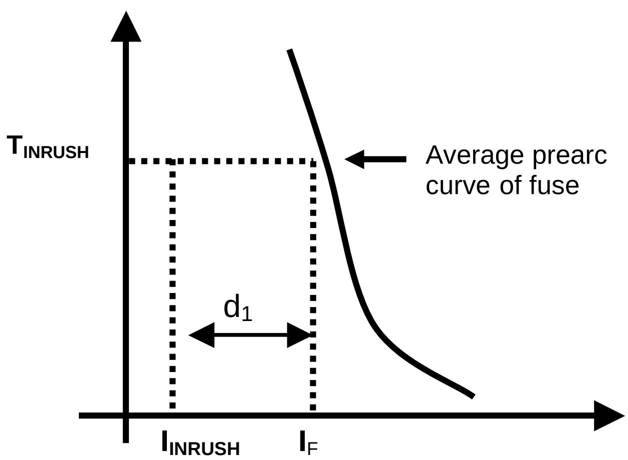

Figure 7

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7.2. Fuse selection tables

As a rule of the thumb the fuse current rating I_N is at least equal to:

I_N = 1.7 x transformer rated current

When considering a 133 % overload:

I_N = 2.3 x transformer rated current

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

Using this table also means applying the temperature derating factor A_1 to the selected rating when the ambient temperature exceeds 40℃ in the fuse environment.

TABLE 3

Transformer power (kVA)	Operating voltage (kV)							
	3.3	5/5.5	6/6.6	10/11	13.8	15	20/22	30/33
25	16	10	10	6.3	6.3	6.3	6.3	6.3
50	25	16	16	10	10	10	6.3	6.3
63	25	20	20	16	10	10	6.3	6.3
80	31.5	25	25	16	16	10	10	6.3
100	40	31.5	25	20	16	16	10	6.3
125	50	31.5	31.5	25	16	16	16	10
160	50	40	31.5	25	20	16	16	10
200	63	50	40	31.5	20	20	16	16
250	80	63	50	40	25	25	20	16
315	100	100	63	50	31.5	25	25	16
400	–	100	80	63	40	31.5	25	20
500	–	–	100	63	50	40	31.5	25
630	–	–	–	80	50	50	40	31.5
800	–	–	–	100	63	63	50	31.5
1000	–	–	–	–	80	80	50	40
1250	–	–	–	–	100	100	63	–
1600	–	–	–	–	–	–	80	–
2000	–	–	–	–	–	–	100	–

TABLE 4 : UTE FUSE SELECTION

NETWORK RATED VOLTAGE (kV)	EDF SELECTION TRANSFORMER RATED POWER						
	50	100	160	250	400	630	1000
10	6,3	16	32	32	63	63	
15	6,3	16	16	16	43	43	63
20	6,3	6,3	16	16	43	43	43*

NETWORK RATED VOLTAGE (kV)	C13100 RECOMMANDATION TRANSFORMER RATED POWER																
	25	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250
10	6,3	6,3	6,3	6,3	16	16	16	32	32	32	63	63	63	63			
15	6,3	6,3	6,3	6,3	6,3	16	16	16	16	16	43	43	43	43	43	63	
20	6,3	6,3	6,3	6,3	6,3	6,3	6,3	16	16	16	16	43	43	43	43	43	63

7.3. oil immersed fuse

The use of a fuse in the dielectric liquid of a transformer requires a particular selection as the various parts of the equipment intervene in the heating process. But since the fuse current carrying capacity is larger in the liquid than in ambient air a special coefficient must be applied to find the suitable fuse. In such a case consult FERRAZ SHAWMUT.

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8. GENERAL RECOMMENDATION FOR MOTOR PROTECTION

As for low voltage fuses the fuse must withstand the motor starting current

8.1. Calculation of the motor full load amp and the motor starting current

The rated current I_{FLA} (FLA = Full Load Amps) of a three phase asynchronous motor is given by:

$$I_{FLA} = \frac{P_{KW}}{V_{AC} * \sqrt{3} * \eta * \cos\Phi}$$

P_{KW}	rated power of the motor (generally given in Kilowatt)
V_{AC}	rated line to line voltage of the circuit
η	efficiency of the motor
$\cos\Phi$	Power factor

8.2. Fuse current rating selection: withstanding of the motors starting current

The fuse able to withstand N times the motor starting current must have a prearc curve well above the starting current R.M.S. value I_{START} for the same start time T_{START} (figure 8).

The starting current **I_{START} is generally around 6 times the I_{FLA}**
The average melting current I_F of the fuse is given in TABLE 5:

TABLEAU 5

N	I_F
2 000	1.8 x I_{START}
10 000	2.2 x I_{START}
100 000	2.85 x I_{START}

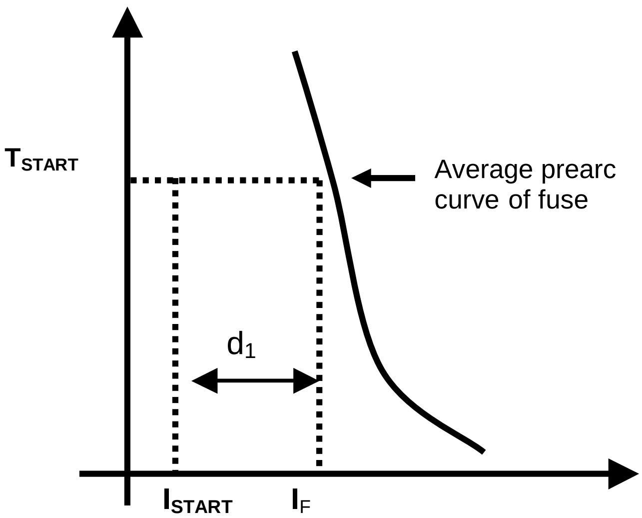

Figure 8

8.3. Fuse current rating selection: withstanding the motor I_{FLA} and environment conditions

The calculation of the fuse rating I_N able to carry continuously the I_{FLA} must be done as explained in §6. As a general rule the fuse rating is at least $I_N = 1.25 \times I_{FLA}$

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9. RECOMMENDATION FOR CAPACITOR PROTECTION

The fuse selection must take into account:

- the inrush current occurring when he the capacitor is switched on
- the harmonic currents during the normal operation of the network
- the recovery voltage across the fuse terminals after a fault interruption.

9.1. Fuse type selection

A « g » type fuse is generally used for capacitor protection.
However another protection system is necessary to protect against low overloads since the fuse rated current is often above 2 times the capacitor theoretical current rating (§ 9.3. et § 9.4.)
Then « a » type fuse can be used providing another protection system against low overloads taking into account the minimum breaking capacity of the selected fuse is installed.

9.2. Selection of the fuse voltage rating

Increasing service voltage up to 20 % for several minutes may occur during low overloads periods. It is then advisable to check this because when this phenomena must occur the rated voltage $\mathbf{U_{NFUSIBLE}}$ of the fuse must be equal or higher than 1.2 times the circuit rated voltage.

9.3. Fuse current rating selection: general rule for the continuous load

Standards indicate a capacitor may carry a R.M.S. current 30 % higher than the rated current calculated from the rated power in KVAR. Standards indicate as well possible 10 % variation. But bad current sharing between the fuse elements caused by the harmonics must be taken into account. The result is that the fuse will carry a current $\mathbf{I_B}$ equal to: **I_B = 1.7 x rated capacitor current**
Coefficients for environment conditions must be applied (§6)

The fuse rated current I_N is generally close to: **I_N = 2 x rated capacitor current**

9.4. Fuse current rating selection: withstanding of the capacitor inrush current

The inrush time $\mathbf{T_{INRUSH}}$ is usually shorter than 400 milliseconds. The fuse prearc curve must go above the gate defined by $\mathbf{I_F}$ / $\mathbf{T_{INRUSH}}$ (figure 9)

$\mathbf{I_F}$ is calculated with values given in Table 6.

TABLE 6

N	I_F
2 000	1.7 x I_{INRUSH}
10 000	1.8 x I_{INRUSH}
100 000	2 x I_{INRUSH}

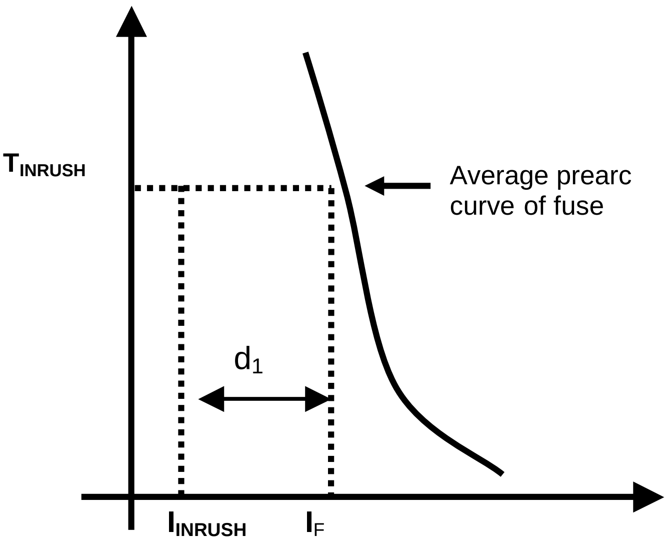

Figure 9

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10. GENERAL RECOMMENDATION FOR POTENTIEL TRANSFORMER FUSES

Must hold high inrush current
Size fuse at 200% minimum
Secondary fuse must be used for overload protection
Table 7 and figure 10 in the last page describe our fuse range for the protection of potential transformers.

FUSES FOR POTENTIAL TRANSFORMERS

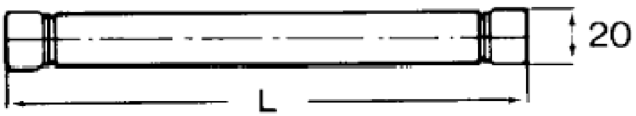

Figure 10

TABLE 7

Rated voltage (kV)	L (mm)	Rating I_N (A)	Catalog number [1]
5,5	127	0,63	5 500 CP gL 20x127 / 0,63
		1	5 500 CP gL 20x127 / 1
		2	5 500 CP gL 20x127 / 2
		3,15	5 500 CP gL 20x127 / 3,15
7,2	190	0,63	7 200 CP gL 20x190 / 0,63
		1	7 200 CP gL 20x190 / 1
		2	7 200 CP gL 20x190 / 2
		3,15	7 200 CP gL 20x190 / 3,15
8,25	190	0,63	8 250 CP gL 20x190 / 0,63
		1	8 250 CP gL 20x190 / 1
		2	8 250 CP gL 20x190 / 2
		3,15	8 250 CP gL 20x190 / 3,15
12	254	0,63	12 000 CP gL 20x254 / 0,63
		1	12 000 CP gL 20x254 / 1
		2	12 000 CP gL 20x254 / 2
		3,15	12 000 CP gL 20x254 / 3,15
15,5	254	0,63	15 500 CP gL 20x254 / 0,63
		1	15 500 CP gL 20x254 / 1
		2	15 500 CP gL 20x254 / 2
		3,15	15 500 CP gL 20x254 / 3,15
24	340	0,63	24 000 CP gL 20x340 / 0,63
25,5	340	0,5	25 500 CP gL 20x340 / 0,5
40.5 KV 6.3 A 55x300			

11. REPLACEMENT OF FUSES

- Circuit must be OFF-LOAD
- It is advisable to replace all three fuses unless it is definitively known that no overcurrent has passed through the unmelted fuses.

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