WEBINAR

Protección contra Sobretensiones

EXPOSITOR:

Ing. Msc. Kamal Arreaza

inel
Engineering Education

Kamal Arreaza

Gerente de Ingeniería y Construcción

Nacionalidad

Educación

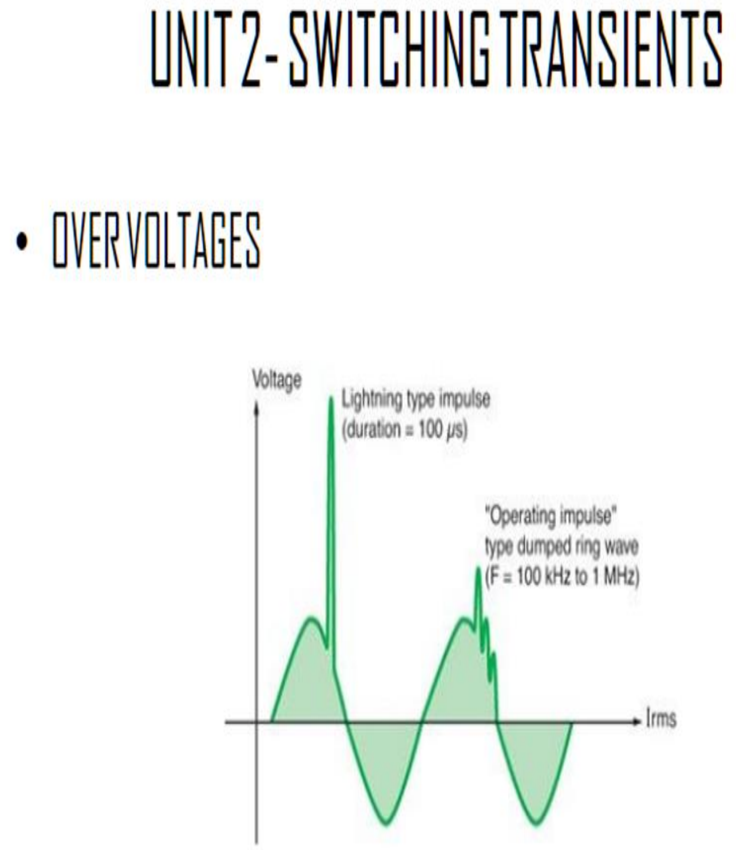
Egresado de Ingeniería Eléctrica de la Universidad de Oriente (UDO), Venezuela. Con una Maestría en Ingeniería Eléctrica en la UNEXPO, Venezuela.

Experiencia

Catorce (14) años de experiencia en el diseño y construcción de grandes proyectos de Ingeniería para clientes en varios países de Latinoamérica incluyendo: Venezuela, Chile, Perú, México, Colombia y Ecuador. Ha revisado Ingeniería de líneas y subestaciones eléctricas en calidad de interventor para empresas de Estados Unidos.

Medidas de control y protecciones

Medidas de control y protección contra sobretensiones



Medidas de control y protecciones

5 Types of overvoltages

Table 1, extracted from IEC 60071-1, and Figure 1, detail the characteristics of all types of overvoltages.

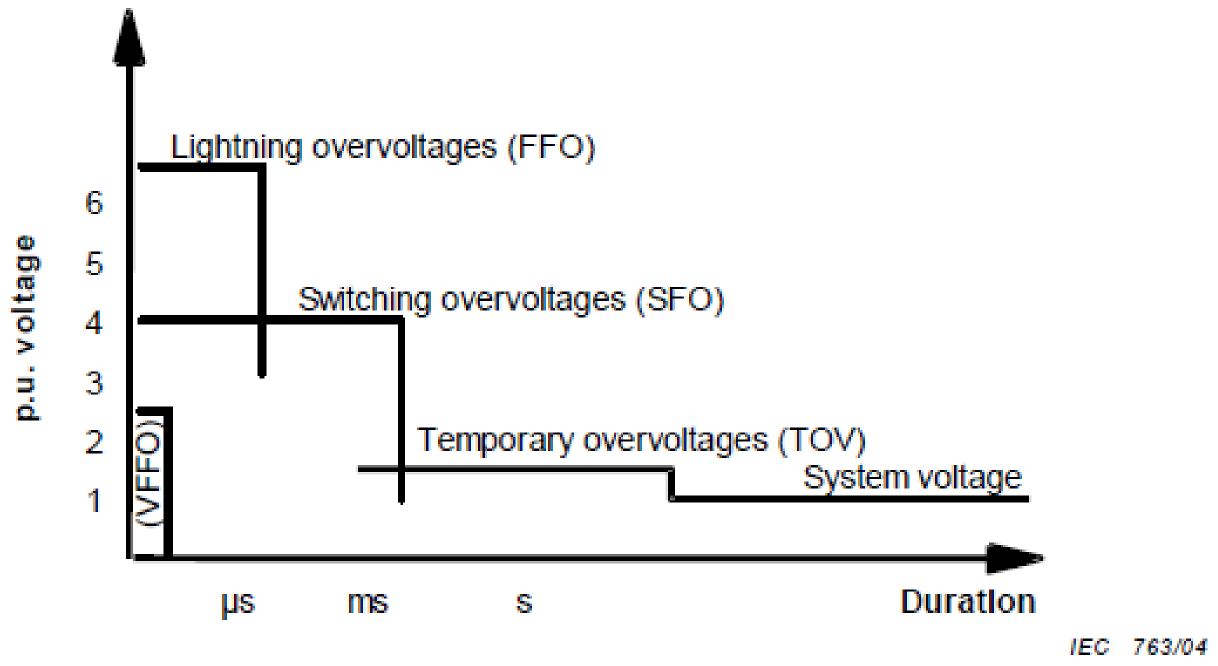
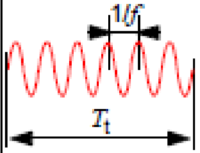
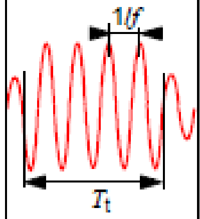
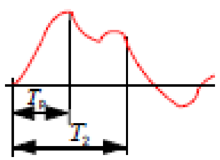
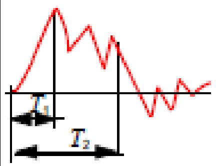
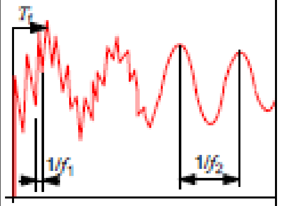
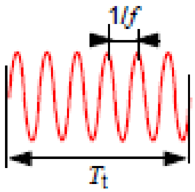
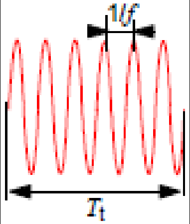
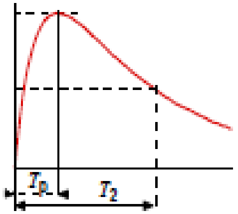
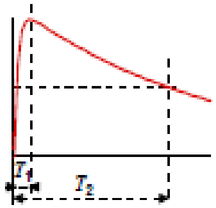


Figure 1 – Types of overvoltages (excepted very-fast-front overvoltages)

Table 1 – Classes and shapes of overvoltages – Standard voltage shapes and standard withstand tests

Class	Low frequency		Transient		
	Continuous	Temporary	Slow-front	Fast-front	Very-fast-front
Voltage or over-voltage shapes					
Range of voltage or over-voltage shapes	f = 50 Hz or 60 Hz $T_t \geq 3\,600$ s	10 Hz < f < 500 Hz 0,03 s ≤ T_t ≤ 3 600 s	20 µs < T_p ≤ 5 000 µs $T_2 \leq$ 20 ms	0,1 µs < T_1 ≤ 20 µs $T_2 \leq$ 300 µs	3 ns < T_f ≤ 100 ns 0,3 MHz < f_1 < 100 MHz 30 kHz < f_2 < 300 kHz
Standard voltage shapes	 f = 50 Hz or 60 Hz T_t [1]	 48 Hz ≤ f ≤ 62 Hz T_t = 60 s	 T_p = 250 µs T_2 = 2 500 µs	 T_1 = 1,2 µs T_2 = 50 µs	[1]
Standard withstand test	[1]	Short-duration power frequency test	Switching impulse test	Lightning mpulse test	[1]

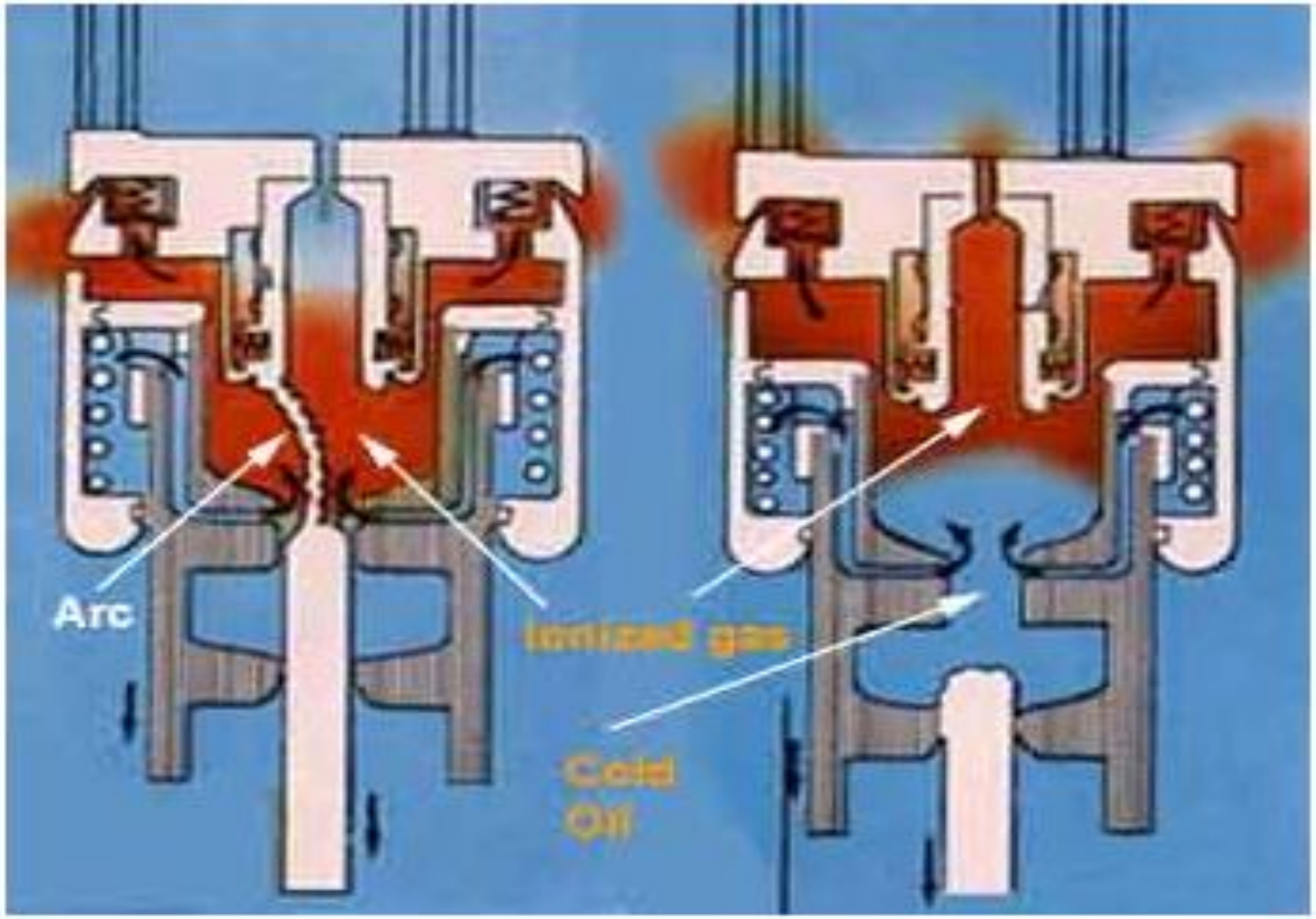
[1] To be specified by the relevant apparatus committees.

Engineering Education

Resistencias

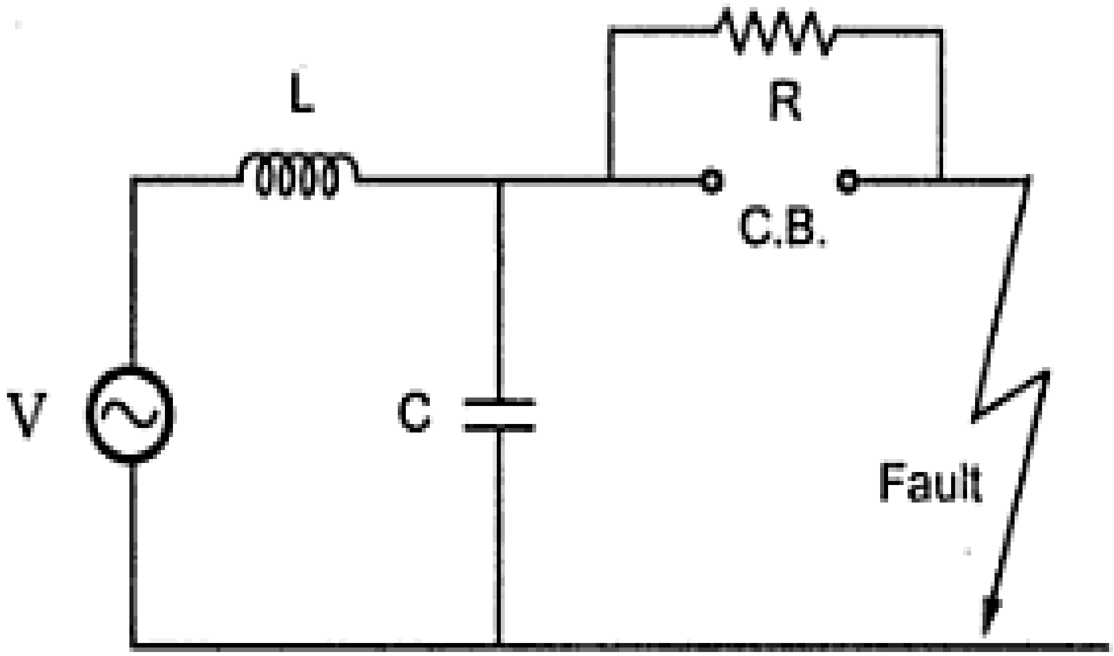
de pre-inserción

(proceso de cierre)



Medidas de control y protecciones

Resistencias de inserción



Medidas de control y protecciones

Resistencias de inserción

Medidas de control y protecciones

Resistencias de inserción

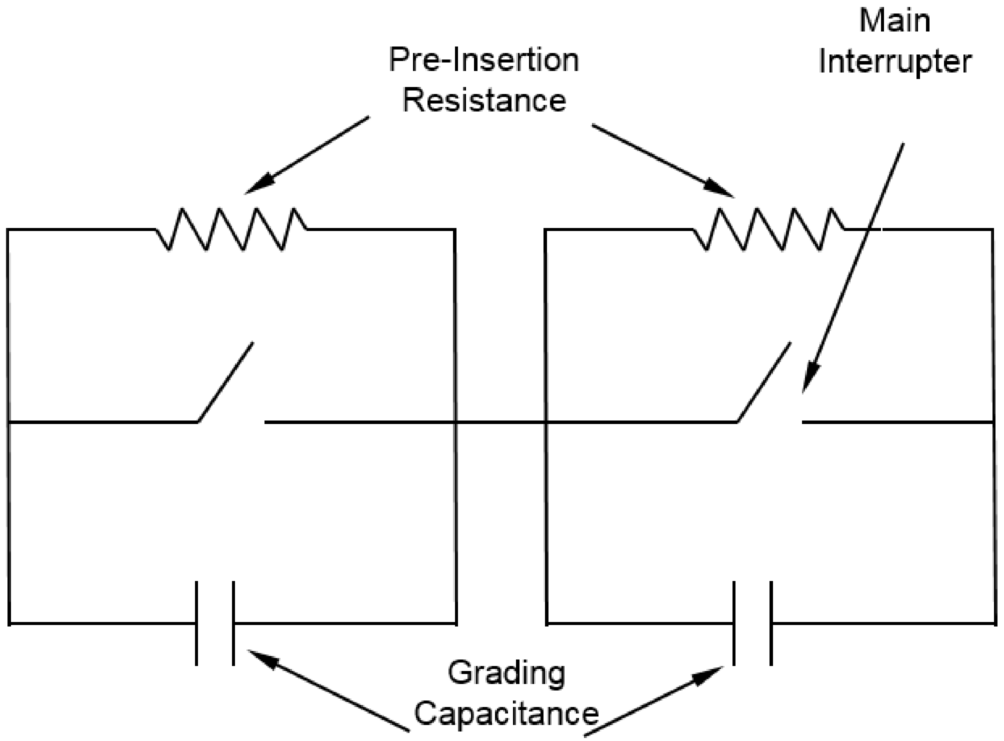


Fig: - Equivalent Circuit of CB

Medidas de control y protecciones

Resistencias
de pre-inserción y
Grading Capacitor

Medidas de control y protecciones

https://ieeexplore.ieee.org/abstract/document/7390307

Abstract:

Preinsertion resistors (PIR) are used in combination with circuit breakers to absorb switching transients and come into effect during the "closing" operation of the breaker. It is mainly used for rated voltages equal to or higher than 420 kV for line lengths above 200 km. Although it is an important component, power testing of complete PIR is very complicated and not well defined. Therefore, an attempt has been made in this paper to provide alternative test methods for power testing of PIR without compromising its important parameters. Due to high energy requirements and limitations of the test laboratory, a multipart testing of PIR is necessary to prove its thermal capability and dielectric behavior. Before proceeding with the complete PIR test, the critical parameters of PIR, such as mechanical insertion time, rate of decay of dielectric strength of the interrupter, and PIR switch, etc., should be verified with testing. These test procedures are also explained in detail along with a method to theoretically evaluate electrical insertion time for different network conditions. The series PIR configuration for the metal-enclosed SF_6 system has been considered in this paper.

Published in: IEEE Transactions on Power Delivery (Volume: 32 , Issue: 4 , Aug. 2017)

Page(s): 1688 - 1695

INSPEC Accession Number: 16898927

Date of Publication: 25 January 2016

DOI: 10.1109/TPWRD.2016.2519604

▸ **ISSN Information:**

Publisher: IEEE

Resistencia de Preinsercion

https://www.researchgate.net/publication/241162142_Use_of_a_Pre-Insertion_Resistor_to_Minimize_Zero-Missing_Phenomenon_and_Switching_Overvoltages

Use of a Pre-Insertion Resistor to Minimize Zero-Missing Phenomenon and Switching Overvoltages

F. Faria da Silva, C. L. Bak, U. S. Guðmundsdóttir, W. Wiechowski and M. R. Knardrupgård

***Abstract*--With the increasing use of High-Voltage Cables, which have different electric characteristics from Overhead Lines, phenomenon like current zero-missing start to appear more often on the transmission systems. Methods to prevent zero-missing phenomenon are still being studied and compared to see which countermeasure works the best. Technically the best way to avoid zero-missing phenomenon produces very high switching overvoltages, making the operator to choose to either avoid the zero-missing phenomenon or to minimize the switching transients. This paper presents a method of determining an optimal value of the resistance of the pre-insertion resistor that results in minimizing both the zero-missing phenomenon and switching overvoltages simultaneously.**

***Index Terms*--Cables, Circuit Breaker, Pre-Insertion Resistor, Shunt Reactor, Switching Transients, Level-crossing problems**

I. Introduction

The increase of public pressure regarding the devastation of areas of natural beauty by Overhead Lines (OHL), drove to increase demand for the substitution of the OHL by underground cables.

The Danish Transmission System Operator (Energinet.dk) is studying a possible expansion of the high-voltage system using AC underground cables instead of OHL. One of the problems that must be studied when using systems with underground cable is zero-missing phenomenon.

Electrically the main difference between an OHL and an Underground Cable is the much higher capacitance of the last ones, which can be dozens of times superior to the capacitance of OHL [2].

Because of this high capacitance, it is required to connect shunt reactor(s) in parallel to the cables, in order to compensate the reactive power generated by them.

If the shunt reactors are compensating all the reactive power generated by the cable, the AC component of the current in the cable has opposite phase angle to AC component of the current into the shunt reactors, and therefore they cancel out each other. As the transient of the shunt's reactor current contain both AC and DC components, during transient conditions (as for instance energization of a cable compensated with shunt reactors) under ideal conditions only DC component would remain.

During energizing, the cable has no load and it is open in the far end. As the resistance of the system (cables+shunt reactors) is very small, it may take several seconds for the DC component to be damped. As the current does not cross zero during those seconds, it is not possible to open the circuit breaker without risking damaging it, unless it is prepared to interrupt DC currents or currents with several amperes [3][4].

If in the meanwhile, a single-phase or two-phase fault occurs on the cable, the circuit breaker will be able to open the faulted phases but not the healthy phase(s) because of the lack of zero-crossings of the current. This can leads to a damage of the circuit breaker.

A method that can be used to damp the DC component in just half of cycle, is to use circuit breakers equipped with pre-insertion resistors.

II. Zero-Missing Phenomenon and Switching Overvoltages

An easy way to understand zero-missing phenomenon is to analyze the transient behaviour of an inductor in parallel with a capacitor of equal impedance.

In this situation the currents in each one of the elements have equal amplitude and are in phase opposition. But in transient conditions the current in the inductor also has a DC offset, whose value depends on the voltage value at the connection moment.

There is a 90º difference between the phases of the current and the voltage in an inductor, therefore if the inductor is connected in a voltage peak the current should be zero. If it is connected when the voltage is zero the current should have a peak value. As the current in the inductor must maintain its continuity, and it was zero before the connection of the

This work was supported in part by the Danish Transmission System Operator, Energinet.dk.

F. F. da Silva is a PhD student at the Institute of Energy Technology, Aalborg University, 9220 Aalborg, Denmark (e-mail:ffs@iet.aau.dk).

C. L. Bak is with the Institute of Energy Technology, Aalborg University, 9220 Aalborg, Demark (e-mail: clb@iet.aau.dk).

U. S. Gudmundsdottir is a PhD student at the Institute of Energy Technology, Aalborg University, 9220 Aalborg, Denmark (e-mail: usg@iet.aau.dk).

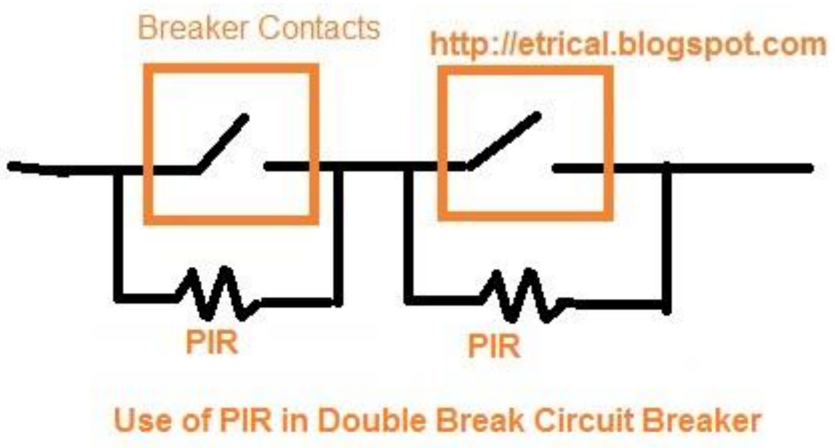
W. Wiechowski is a Senior System Analyst at the Planning Department of Energinet.dk (e-mail: wwi@energinet.dk)

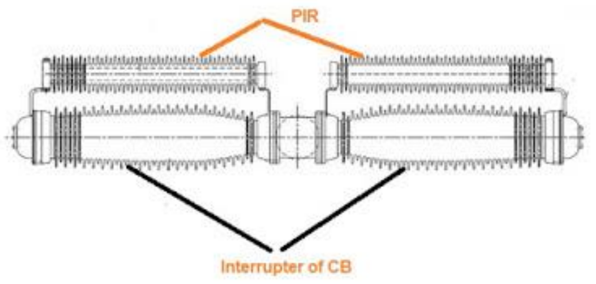
M. R. Knardrupgård is with the Planning Department of Energinet.dk (e-mail: mra@energinet.dk)

978-1-4244-4241-6/09/$25.00 ©2009 IEEE

Resistencia de Preinsercion

https://electricalbaba.com/pre-insertion-resistor-and-grading-capacitor-in-multi-break-circuit-breaker/





Propósito de PIR:

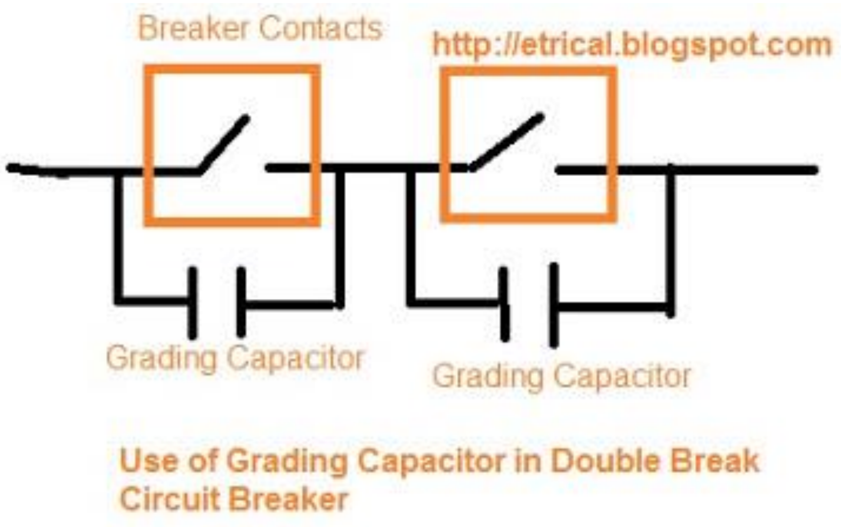
PIR es resistencia de preinserción. Esta es una resistencia de aproximadamente 200-400 ohmios que se cierra antes de cerrar el interruptor de circuito. La secuencia es (orden cerrado) -> cierre de PIR-> 10-12milliseconds-> cierre de ruptura principal.

Pero mientras se abre, PIR se desconecta primero por el mecanismo operativo del interruptor y luego, después de 10 ms, se abren los contactos principales del interruptor. El propósito principal de PIR es limitar la corriente de carga inicial de la línea. Como la corriente de carga de la línea larga será mucho mayor, es aconsejable usar un interruptor que tenga PIR en la línea de transmisión larga.

Cuando el circuito eléctrico tiene capacitancia o transformador que puede tener irrupción. También los transformadores pueden tener una gran corriente de entrada. La línea de transmisión (debido a su capacitancia) es otro de esos circuitos.

Grading Capacitor

https://electricalbaba.com/pre-insertion-resistor-and-grading-capacitor-in-multi-break-circuit-breaker/



Propósito del condensador de clasificación:

El propósito del Grading Capacitor es asegurar una distribución uniforme de voltaje en posición abierta. La presión del gas SF6 que se mantiene en el interruptor de 220 kV Switchyard es de 6 bar y la utilizada en 400 kV también es de 6 bar. ¿Cómo puede ser esto posible? Suponiendo que el espacio entre los contactos principales de los interruptores utilizados en el patio de maniobras de 220 kV y 400 kV es el mismo, cuando aumentamos el voltaje, la presión del SF6 también debe aumentarse, ya que la resistencia a la ruptura dieléctrica del SF6 es proporcional a su presión.

La cosa es que cuando usamos el Grading Capacitor, el voltaje a través de cada contacto se distribuye de manera uniforme. Por lo tanto, para el interruptor que tiene dos contactos, es decir, para el interruptor de circuito de doble interrupción, el voltaje en cada contacto será de 200 kV y, por lo tanto, 6 bar de SF6 funcionarán bien.

https://electricalbaba.com/calculation-grading-capacitor-voltage-distribution/

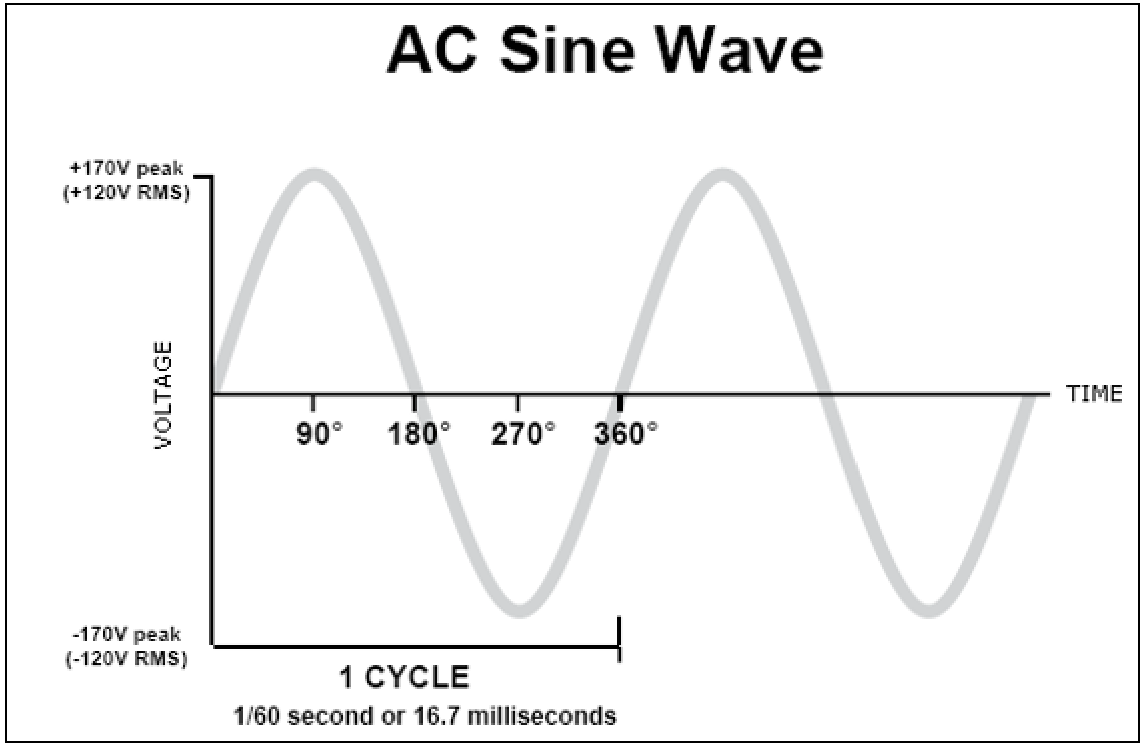
Medidas de control y protecciones

Dispositivos

de sincronización

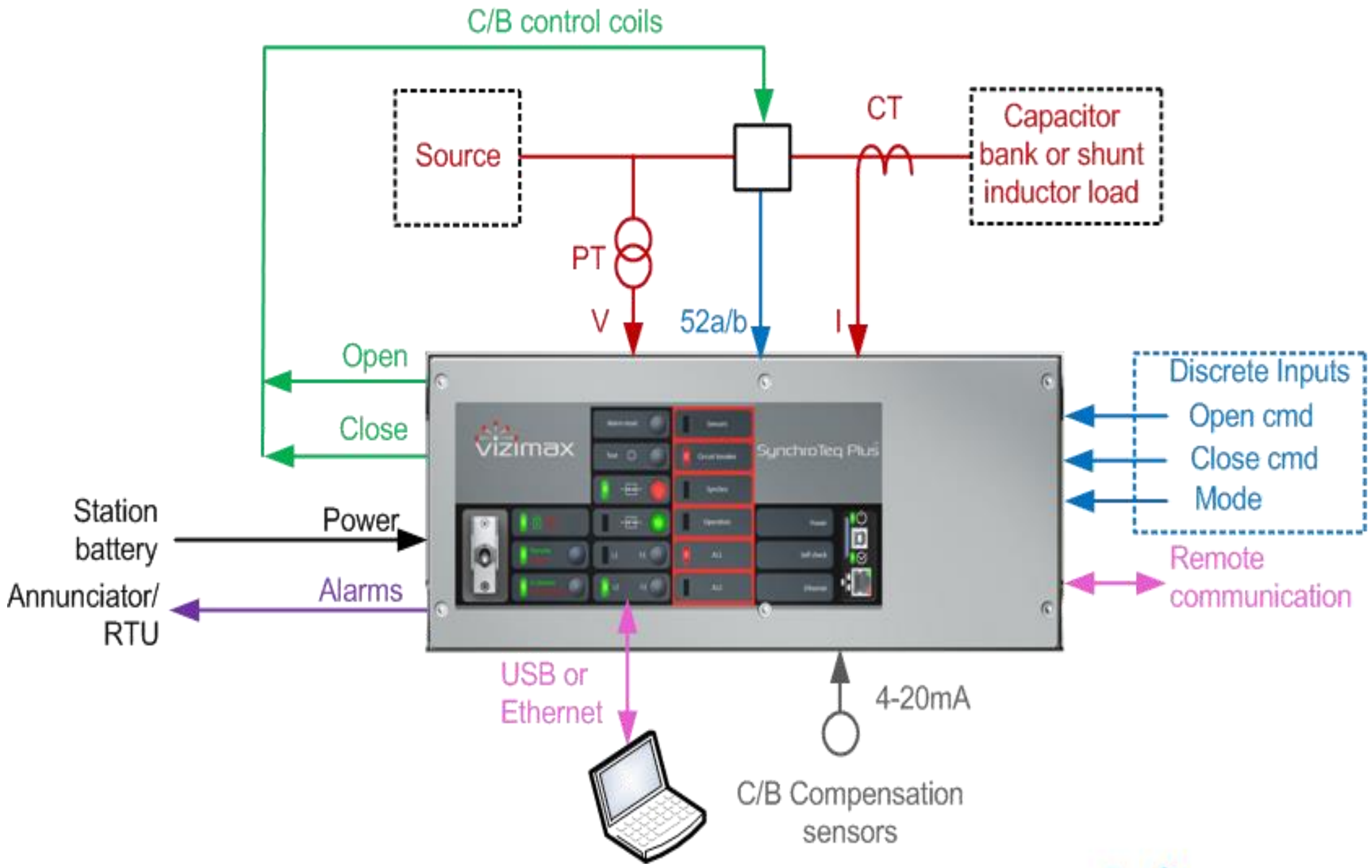
de apertura o cierre

Revista Electra N° 183 de Abril de 1999



Medidas de control y protecciones

Dispositivos
de sincronización
de apertura o cierre



Medidas de control y protecciones

Descargador de Sobretensión

Medidas de control y protecciones

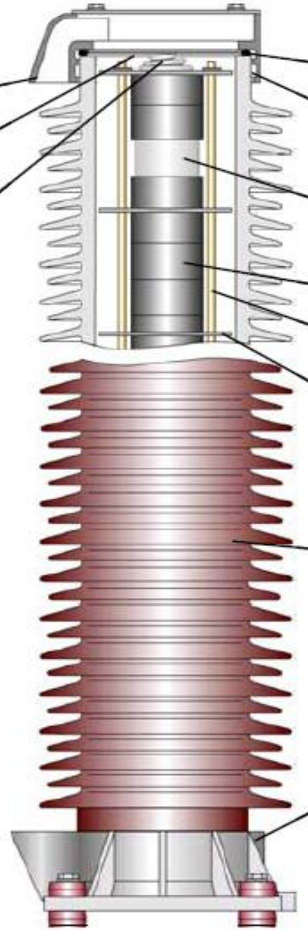
Listado de normas que aplican para descargadores de sobretensiones

Norma	Descripción
NTC 4389	Descargadores de sobretensiones (pararrayos) de óxido metálico sin espaciadores (gaps) para sistemas de corriente alterna.
IEC 60099-4	Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems
ANSI/IEEE C62.11	Standard for Metal-Oxide Surge Arresters for AC Power Circuits
IEC 60099-1	Non-linear resistor type gapped surge arresters for a.c. systems.
NTC 2076 (ASTM A-153)	Recubrimiento de Zinc por inmersión en caliente para elementos en hierro y acero.
ANSI/IEEE C62.22	Guide for the application of Metal-Oxide Surge Arresters for Alternating-Current Systems.
ASTM D-178	Standard Specification for Rubber Insulating Matting.
ASTM F711	Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Live Line Tools.
ASTM F712	Standard Test Methods and Specifications for Electrically Insulating Plastic Guard Equipment for Protection of Workers.
IEEE STD 1264	Guide for Animal Deterrents for Electric Power Supply Substations.
ASTM F 968	Standard Specification for Electrically Insulating Plastic Guard Equipment for Protection of workers.

Medidas de control y protecciones

Descargador

construcción



Medidas de control y protecciones

Descargador

discos individuales

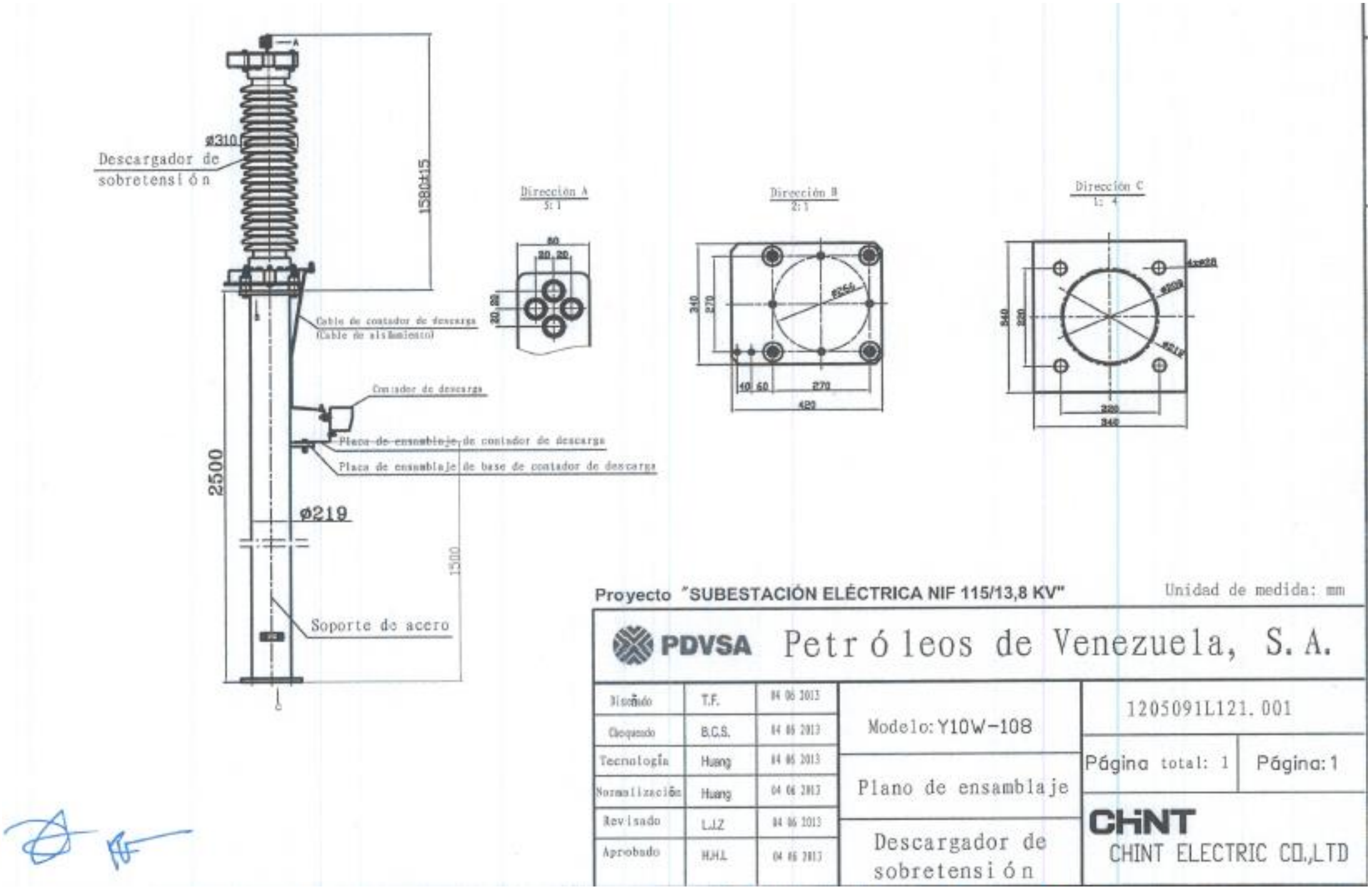
DESCARGADOR DE SOBRETENSIONES

DESCARGADOR DE SOBRETENSIONES

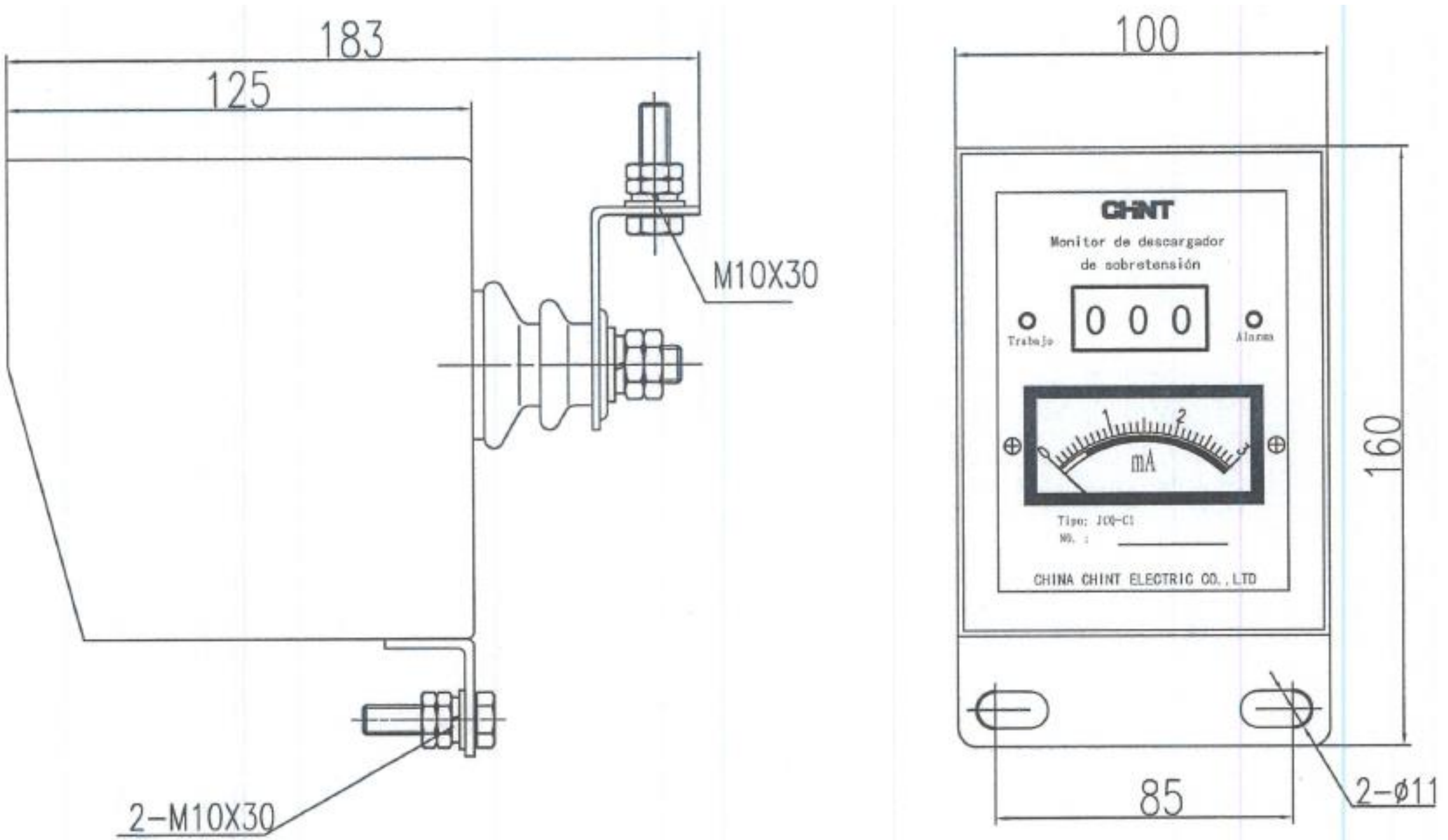
DESCARGADOR DE SOBRETENSIONES

DESCARGADOR DE SOBRETENSIONES

DESCARGADOR DE SOBRETENSIONES

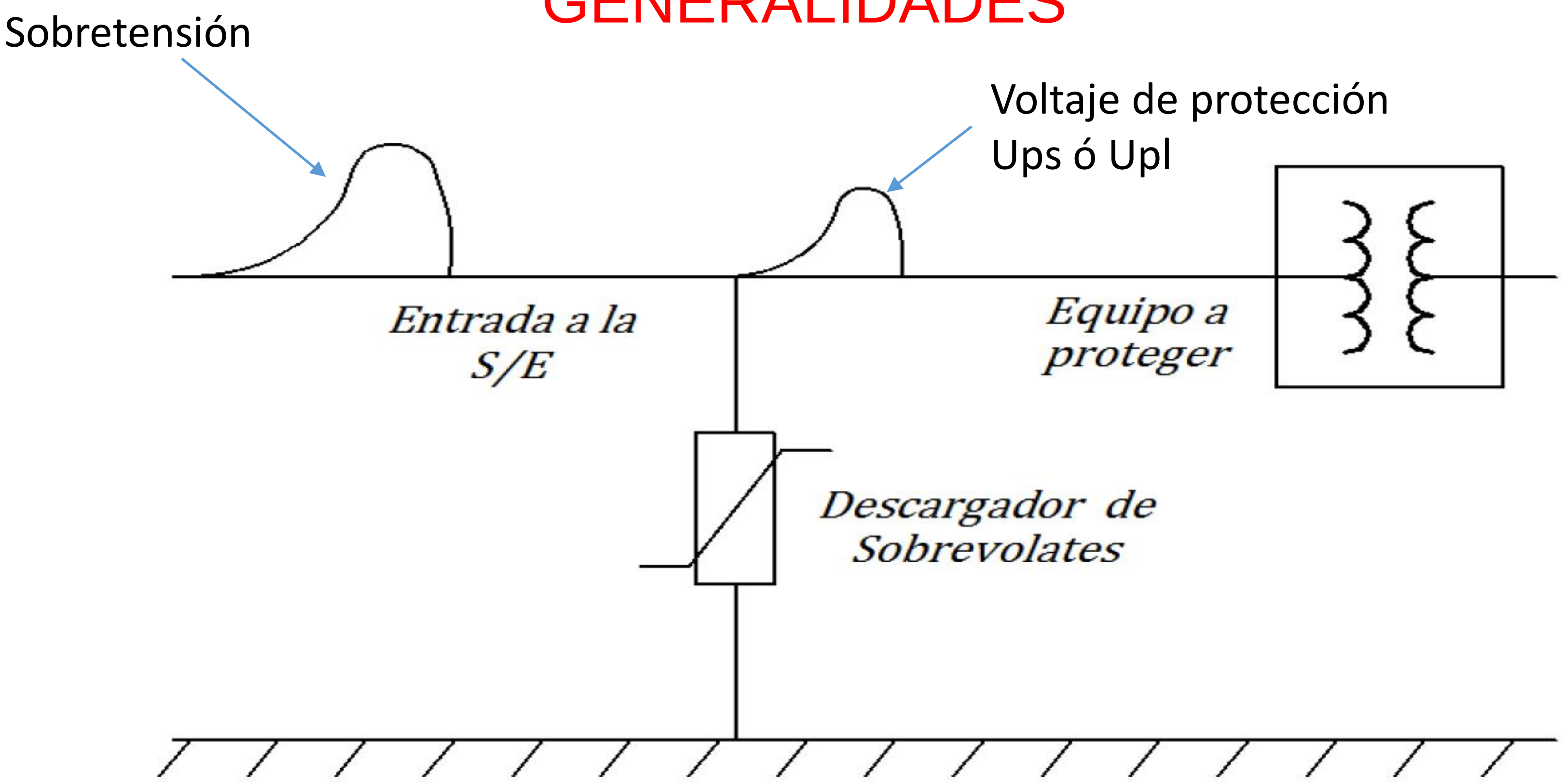


DESCARGADOR DE SOBRETENSIONES



DESCARGADOR DE SOBRETENSIONES

GENERALIDADES



NIVELES DE PROTECCION

Niveles de protección

Nivel de protección a impulsos tipo maniobra (SIPL, Switching impulse protection level)
Es el valor máximo de la tensión residual del pararrayos a las corrientes de impulso tipo maniobra especificadas

Ups
30/70us
30/60us

Nivel de protección a impulsos tipo rayo (LIPL, lightning impulse protection level)
Es la máxima tensión residual del pararrayos para la corriente nominal de descarga tipo rayo

Upl
8/20us

DESCARGADOR DE SOBRETENSIONES

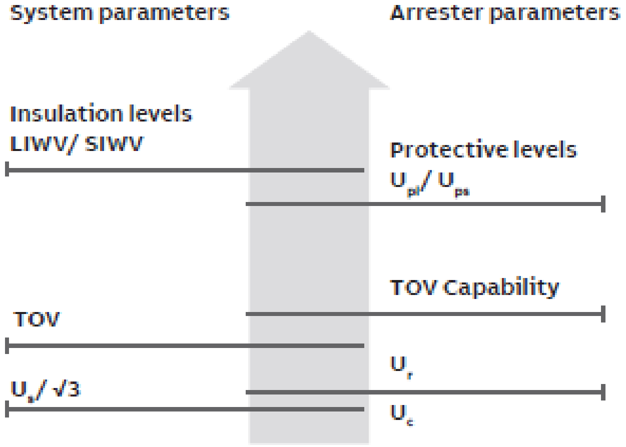
Simplified selection procedure

The selection is carried out in two major steps:

1. Matching the electrical characteristics of the arresters to the system's electrical demands
2. Matching the mechanical characteristics of the arresters to the system's mechanical and environmental requirements

The final selection is reflected in the arrester type designation.

System/ arrester parameters



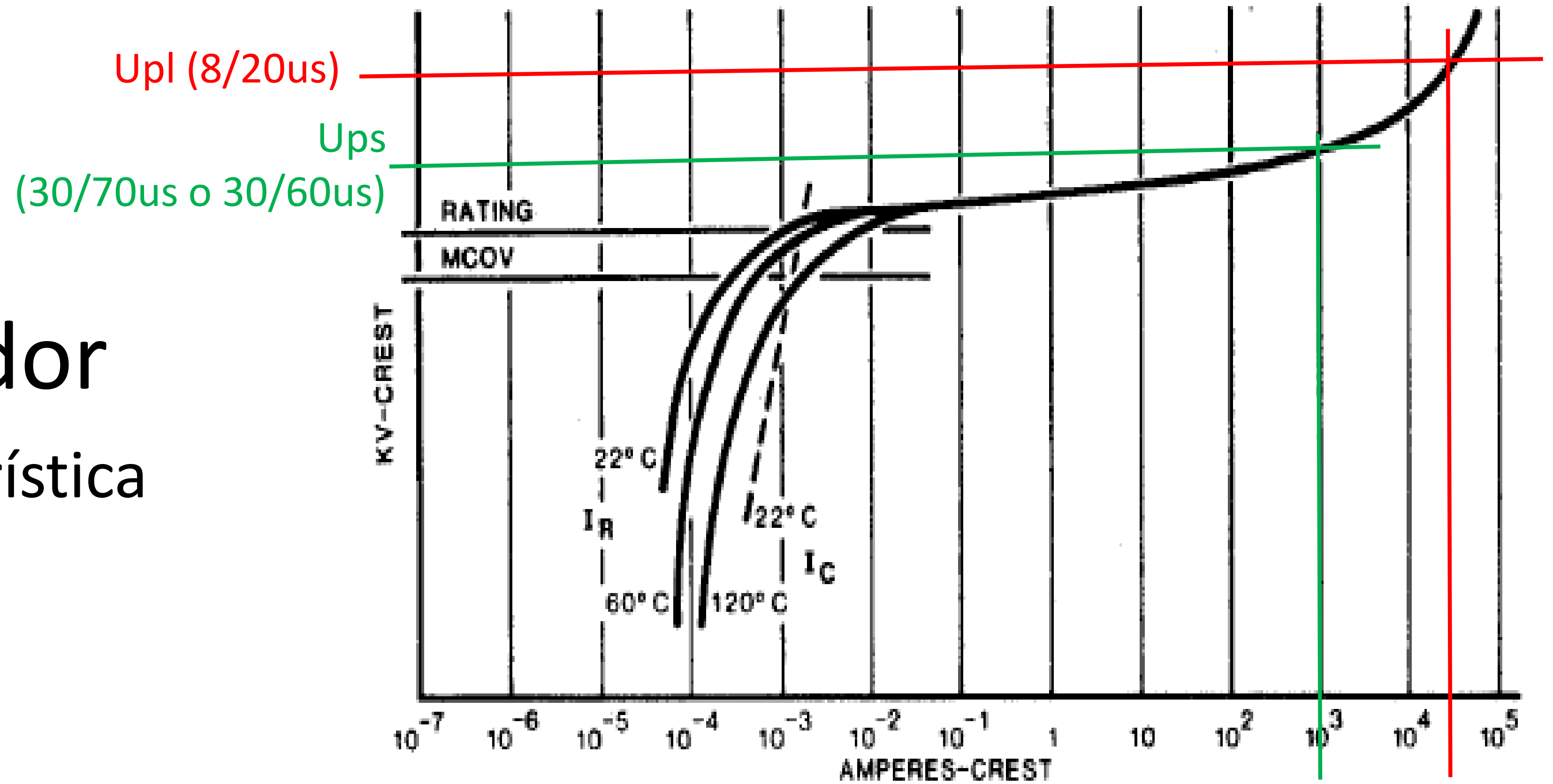
—
Vocabulary

U_s	Maximum system voltage
U_c	Continuous operating voltage
U_r	Rated voltage
TOV	Temporary overvoltage
T	TOV strength factor
k	Earth fault factor
U_{ps}	Switching impulse protective level
U_{pl}	Lightning impulse protective level
U_{ws}	Switching impulse withstand level
U_{wl}	Lightning impulse withstand level
SIWV	Switching impulse withstand voltage
LIWV	Lightning impulse withstand voltage

Medidas de control y protecciones

Descargador

curva característica

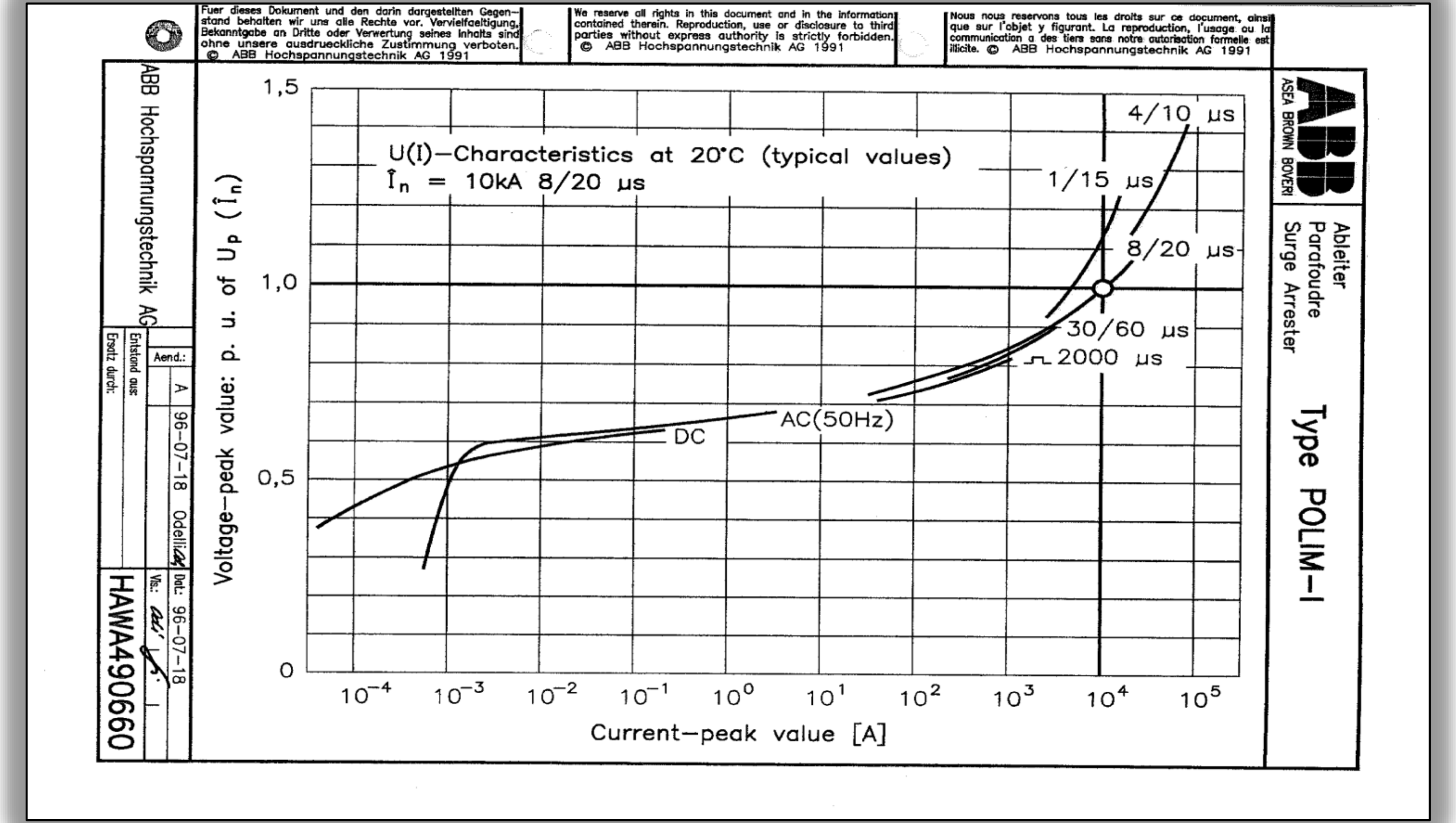


Temperature effects on the *V/I* curve of a metal oxide varistor (Courtesy of the Ohio Brass Co.)

DESCARGADOR DE SOBRETENSIONES

MODELO IEEE 3.4.11

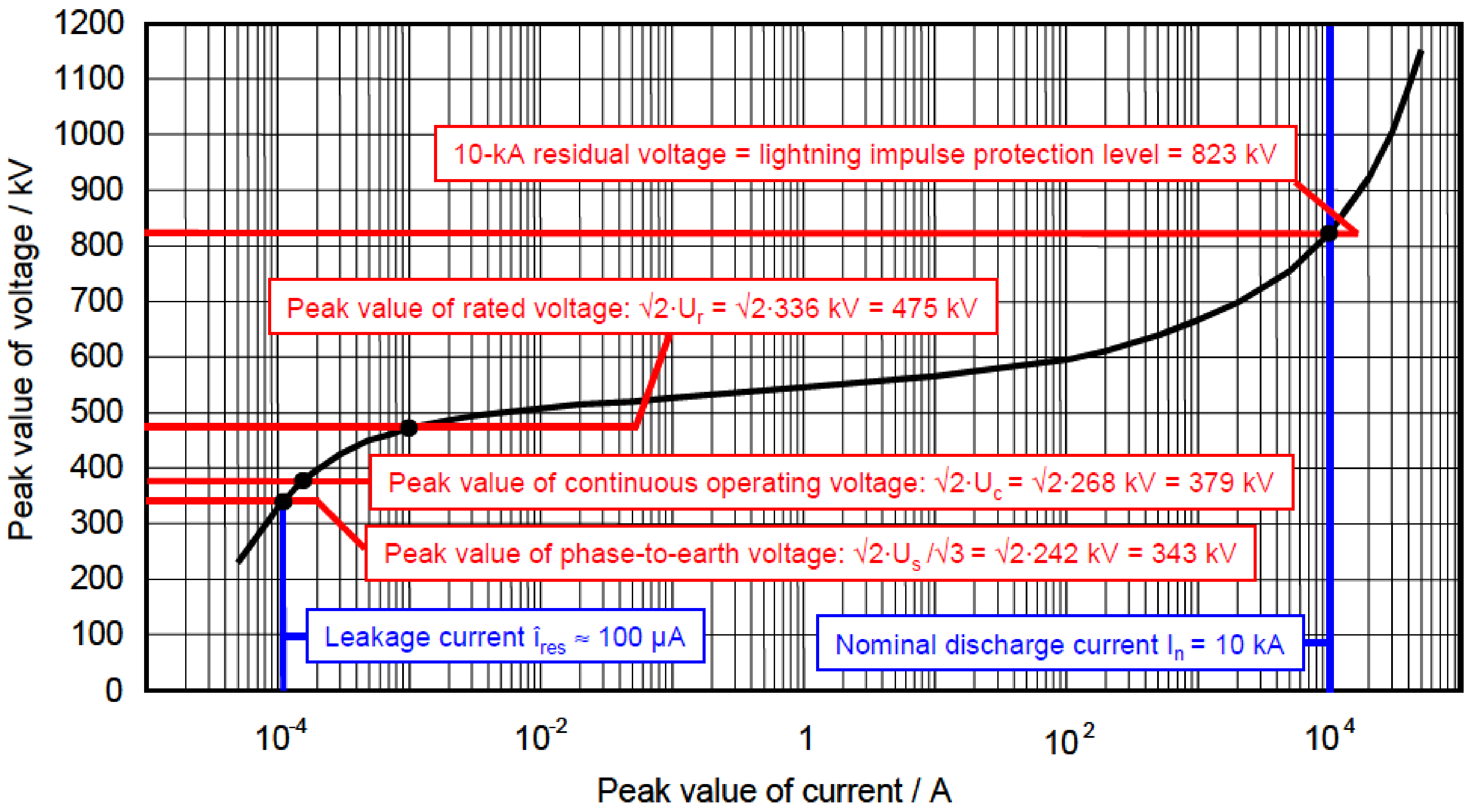
CURVA TENSIÓN VS CORRIENTE DESCARGADOR



Medidas de control y protecciones

Descargador

ejemplo



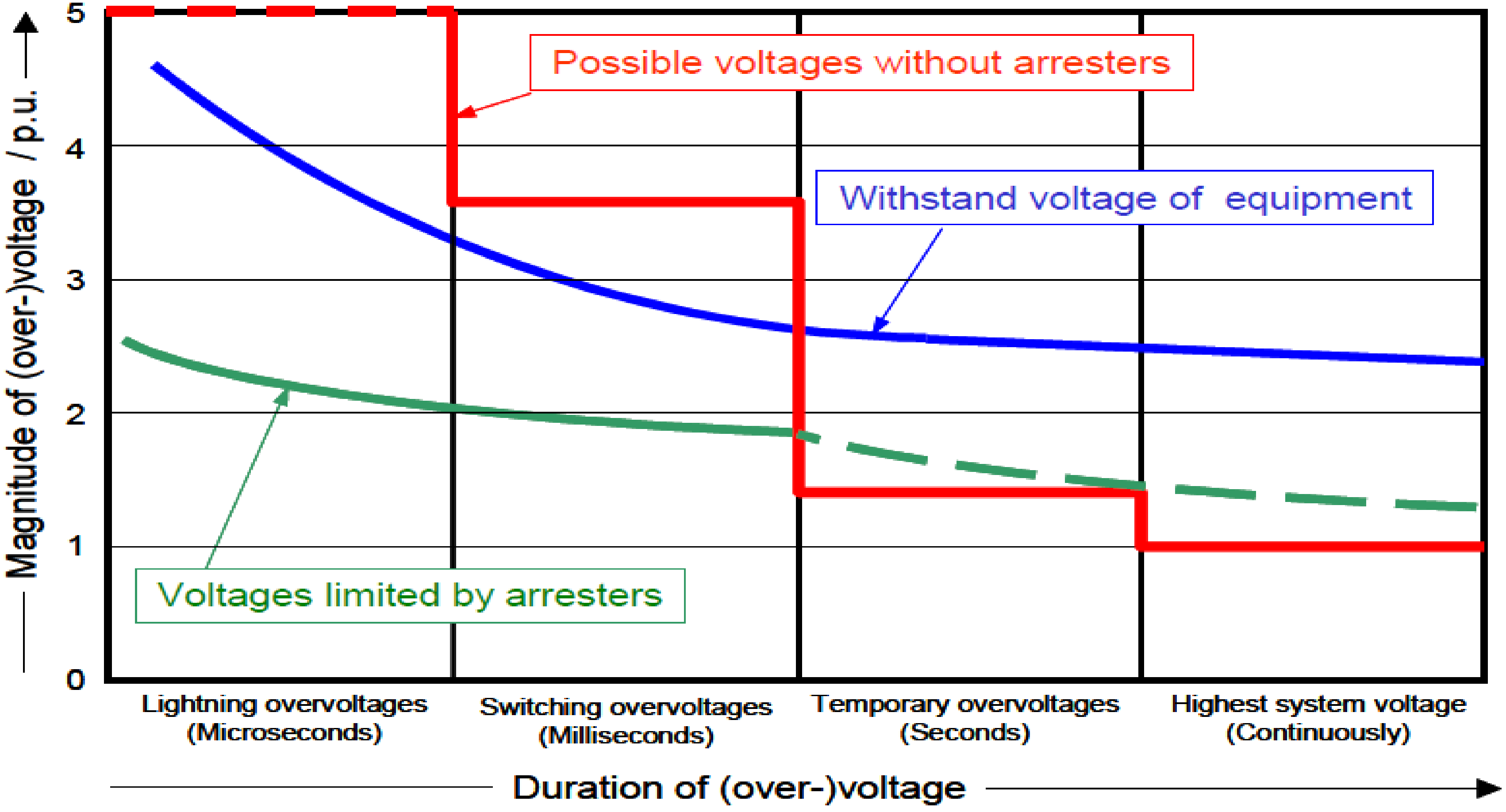
Medidas de control y protecciones

Pararrayos

Nivel de protección

Vs.

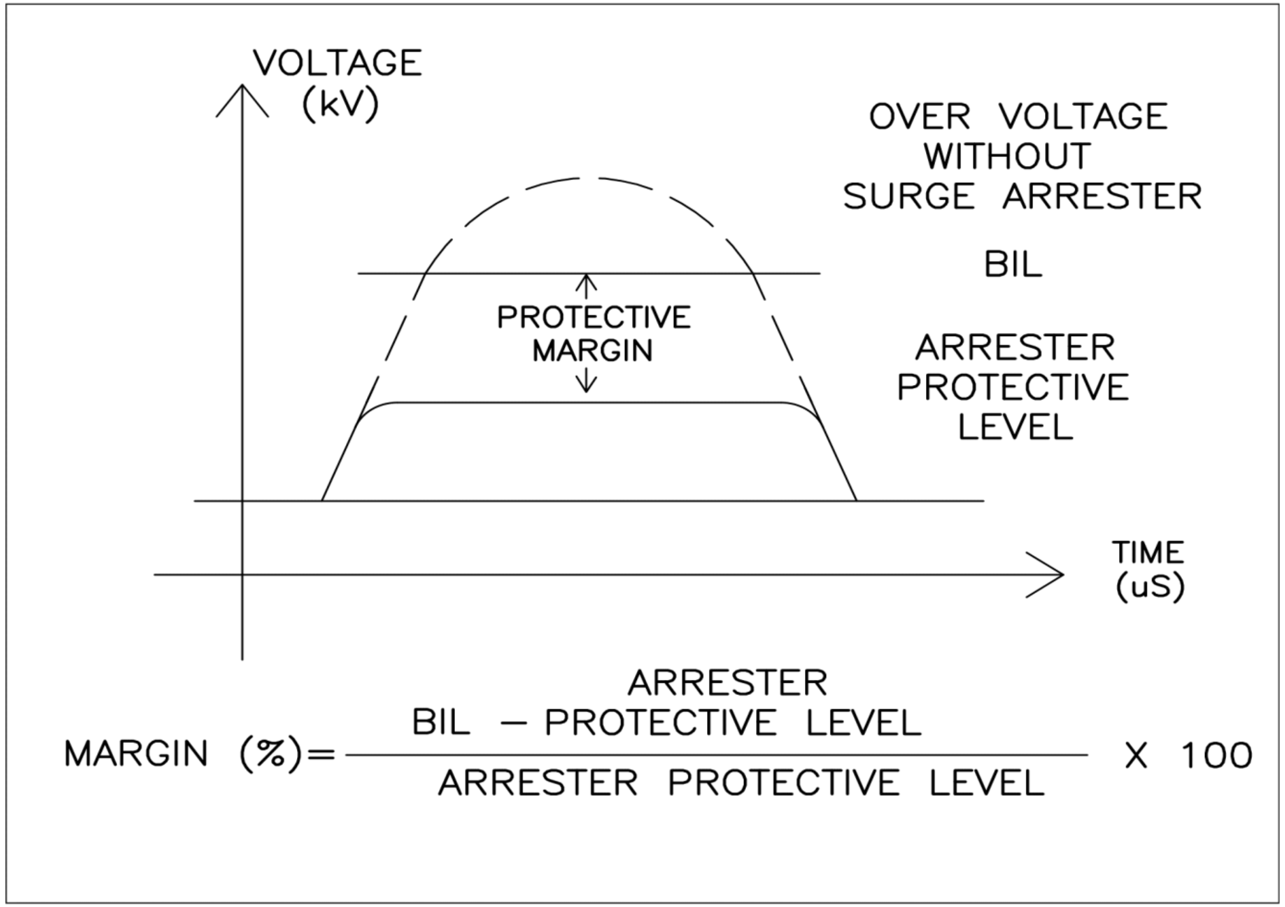
Nivel de aislamiento



Pararrayos

Margen

de Protección



Medidas de control y protecciones

Engineering Education

Descargador

Corriente

de coordinación

IEC 60099-4:2014 © IEC 2014 – 35 –

Table 3 – Arrester type tests

Arrester class	Station	Station	Distribution
Nominal discharge current	20 kA 10 kA	20 kA 10 kA	10 kA 5 kA 2,5 kA
Typical U_s (kV), rms value	> 245	≤ 245	≤ 52
1 Insulation withstand tests on the arrester housing			
a) Lightning impulse	8.2.6	8.2.6	8.2.6
b) Switching impulse	8.2.7	Not required	Not required
c) Power-frequency	Not required	8.2.8	8.2.8
2 Residual voltage test			
a) Steep current	8.3.2	8.3.2	8.3.2
b) Lightning impulse	8.3.3	8.3.3	8.3.3
c) Switching impulse	8.3.4	8.3.4	Not required
3 Test to verify long term stability under continuous operating voltage	8.4	8.4	8.4
4 Repetitive charge transfer withstand	8.5	8.5	8.5
5 Heat dissipation behaviour verification of test sample	8.6	8.6	8.6
6 Operating duty test	8.7	8.7	8.7
7 Power-frequency voltage versus time	8.8	8.8	8.8
8 Arrester disconnector/fault indicator (when fitted)	8.9	8.9	8.9
9 Short-circuit tests	8.10	8.10	8.10
10 Bending moment	8.11	8.11	8.11
11 Environmental tests	8.12	8.12	8.12
12 Seal leak rate	8.13	8.13	8.13
13 Radio interference voltage (RIV)	8.14	8.14	Not required
14 Test to verify the dielectric withstand of the internal components of an arrester	8.15	8.15	8.15
15 Test of internal grading components	8.16	8.16	8.16
16 Polluted housing test	Annex C	Annex C	Annex C

Numbers in rows 1-16 refer to clauses and subclauses in this standard.

NOTE Type tests for other types of arresters (polymer-housed, GIS, dead-front and separable, and liquid-immersed) are specified in 10.8, 11.8, 12.8 and 13.8.

Medidas de control y protecciones

Existen varios tipos de descargadores clasificados según su ciclo de trabajo, y la amplitud de la corriente de impulso tipo rayo empleada en el ensayo. Es importante aclarar que la clasificación mostrada a continuación es de la norma Americana **ANSI/ IEEE C62.11 (Tabla 6).**

Descargadores tipo distribución:
Poseen las mayores tensiones de descarga y usualmente se diferencian entre normal y liviano (5 kA) y pesado (10 kA), los descargadores tipo distribución son los más económicos y poseen la mayor demanda comercial. Como su nombre lo indica son diseñados para proteger sistemas de distribución.

Descargadores tipo intermedio: Presentan características de protección mejoradas, pueden manejar mayores cantidades de energía sin afectar su durabilidad (para servicio normal y liviano (5 kA) y pesado (10 kA), Son sustancialmente más costosos que los de distribución.

Descargadores tipo estación: Proveen los mayores índices de protección, poseen la mayor de las capacidades de absorción de energía trabajo pesado (10 kA y 20kA) y tienen mayor durabilidad, cumplen uno de los trabajos más importantes en un sistema, el de proteger los Transformadores, Autotransformadores de Potencia y equipos pertenecientes a una Subestación. Son los más robustos y costosos de los descargadores.

Medidas de control y protecciones

Clasificación según IEC 60099-4: La norma Europea IEC 60099-4 expone otra clasificación de los dispositivos de protección de sobretensiones, los clasifica en 5 clases (parámetro clases de descarga de línea (LDC) 1 a 5) y de acuerdo a la amplitud de la onda de impulso (1.5, 2.5, 5, 10, y 20 kA - 8/20µseg);, cada corriente nominal de descarga pertenece a diferentes gamas de tensiones nominales y la clase de descarga de línea corresponde a las corrientes con que se prueban dichos dispositivos para evaluar su capacidad de disipar energía kJ/kV de tensión nominal, en función de la relación entre Uresidual con impulso tipo maniobra y el valor eficaz de la tensión nominal Unominal del descargador. En resumen, la función real de esta clasificación es especificar las diferentes pruebas que debe cumplir cada descargador dependiendo de la clase de descarga de línea (LDC).

Medidas de control y protecciones

Engineering Education

Upl

Ups

Pararrayos

catálogo

Nivel

de protección

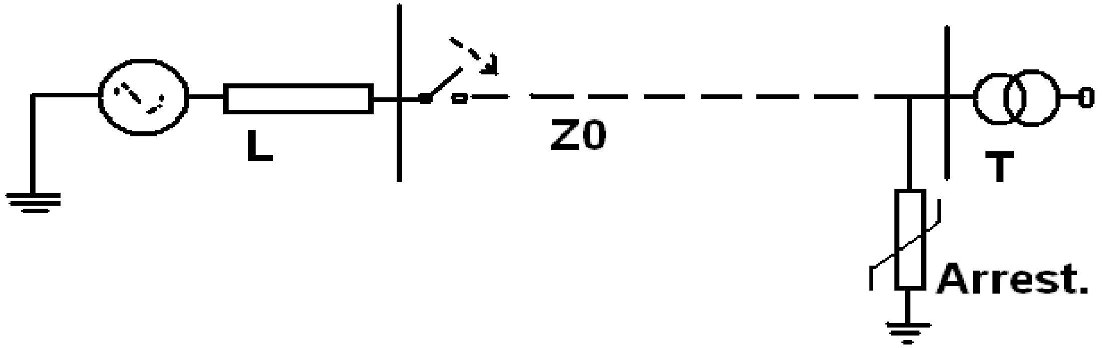
Concepto de Voltaje Residual

type / Typ	rated voltage / Bemessungsspannung	continuous operating voltage / Dauerspannung	temporary overvoltage TOV[1] / zeitweilige Spannungsüberhöhung[1]		residual voltage at steep, lightning and switching impulse current / Restspannung bei Steil-, Blitzstoßstrom und Schaltstoßstrom								
	U_r	U_c	U_{1s}	U_{10s}	10 kA (1/2 µs)	5 kA (8/20 µs)	10 kA (8/20 µs)	20 kA (8/20 µs)	40 kA (8/20 µs)	250 A (30/70µs)	500 A (30/70µs)	1000 A (30/70µs)	2000 A (30/70µs)
	kV	kV	kV	kV	kV	kV	kV	kV	kV	kV	kV	kV	kV
SBK-... 6/10.3	6	4,8	6,9	6,5	16,6	14,4	15,2	16,6	17,6	12,2	12,5	12,9	13,3
SBK-... 9/10.3	9	7,2	10,4	9,7	24,9	21,7	22,8	24,9	26,4	18,2	18,8	19,4	20,0
SBK-... 12/10.3	12	9,6	13,8	13,0	33,1	28,9	30,4	33,1	35,3	24,3	25,1	25,8	26,7
SBK-... 15/10.3	15	12,0	17,3	16,2	41,4	36,1	38,0	41,4	44,1	30,4	31,3	32,3	33,3
SBK-... 18/10.3	18	14,4	20,7	19,4	49,6	43,2	45,5	49,6	52,8	36,4	37,5	38,7	39,9
SBK-... 21/10.3	21	16,8	24,2	22,7	57,9	50,4	53,1	57,9	61,6	42,5	43,8	45,1	46,6
SBK-... 24/10.3	24	19,2	27,6	25,9	66,2	57,7	60,7	66,2	70,4	48,6	50,0	51,6	53,2
SBK-... 27/10.3	27	21,6	31,1	29,2	74,4	64,9	68,3	74,4	79,2	54,6	56,3	58,1	59,9
SBK-... 30/10.3	30	24,0	34,5	32,4	78,5	68,4	72,0	78,5	83,5	57,6	59,4	61,2	63,1
SBK-... 33/10.3	33	26,4	38,0	35,6	86,3	75,2	79,2	86,3	91,9	63,4	65,3	67,3	69,5
SBK-... 36/10.3	36	28,8	41,4	38,9	94,2	82,1	86,4	94,2	100,2	69,1	71,2	73,4	75,8
SBK-... 39/10.3	39	31,2	44,9	42,1	102,0	88,9	93,6	102,0	108,6	74,9	77,2	79,6	82,1
SBK-... 42/10.3	42	33,6	48,3	45,4	109,9	95,8	100,8	109,9	116,9	80,6	83,1	85,7	88,4
SBK-... 48/10.3	48	38,4	55,2	51,8	125,6	109,4	115,2	125,6	133,6	92,2	95,0	97,9	101,0
SBK-... 51/10.3	51	41	59	55	133	116	122	133	142	98	101	104	107
SBK-... 54/10.3	54	43	62	58	142	124	130	142	151	104	107	111	114
SBK-... 60/10.3	60	48	69	65	157	137	144	157	167	115	119	122	126
SBK-... 63/10.3	63	50	72	68	165	143	151	165	175	121	124	128	132
SBK-... 66/10.3	66	53	76	71	172	150	158	172	183	126	130	134	139
SBK-... 72/10.3	72	58	83	78	189	164	173	189	201	138	143	147	152
SBK-... 75/10.3	75	60	86	81	196	171	180	196	209	144	148	153	158

Medidas de control y protecciones

Descargador

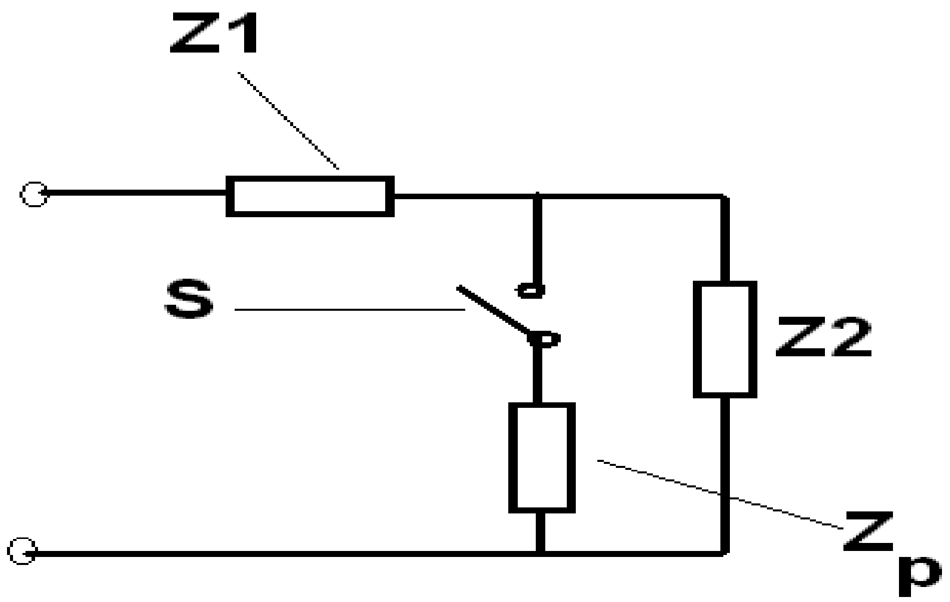
posición



Medidas de control y protecciones

Descargador

circuito equivalente



Medidas de control y protecciones

Descargador

implantación física

https://www.inmr.com/arrester-transformer-separation-distance-substations/

Separación del Descargador al Equipo

IEC 60099-5 2013 Pág. 43

The earthing effectiveness will affect the protection provided by the arrester. Therefore if the earth system is not solidly earthed, the margin offered for fast-front overvoltages needs to be considered through a study.

In high voltage systems, in particular, U_s > 245 kV, it is usually difficult to locate the arresters very close to the equipment. However, every effort shall be made to reduce the separation distance between the arrester and equipment. As a general rule, and for effective overvoltage protection, the separation distance should always be less than 10 m. Common practical separation distances are on average 3 to 5 m, which results in difficulties to establish a direct short connection between the arrester base and the earth terminal of the equipment to be protected. Under such circumstances the arrester is connected to the substation earth grid and effectively bonded to the equipment through the grid. However, without the provision of a low impedance earth connection at these locations, the overvoltage protection afforded by the arrester could be impaired, and high earth potentials could appear on the earthing connections close to the surge arrester itself and at the equipment following the passage of high magnitude, fast-front surge.

It is now well established that fast-front surges will rapidly attenuate in the earthing system, giving a sharp fall in surface earth potential, away from the point of injection. This may result in large voltage differences between close locations on the same earthing system. In order to minimise these potential differences, an earthing connection, as short and straight (free of bends) as possible, should be made between the earthing points of the plant and the arrester. To mitigate the rise of earth potential and help dissipate the surge current in an effective manner, the so-called high frequency rod is an alternative. These rods can be driven to depths of 5 m or deeper depending on the local soil resistivity. The rods allow contact with deeper, low resistivity soil layers, and hence, improve surge current dissipation and reduce the overall earth impedance. When rods are not practical, buried horizontal-conductor counterpoises can be used. If the separation distance is relatively long, the earthing connection should be routed directly underneath the high voltage connection between the arrester and the equipment, which reduces the loop inductance.

Medidas de control y protecciones

Descargador

capacidad de descarga de línea

Line discharge class	U_s (kV)
1	≤ 245
2	≤ 300
3	≤ 420
4	≤ 550
5	≤ 800

Medidas de control y protecciones

Descargador

capacidad de descarga de línea

TABLE Maximum energy capability Tranquell* XE MOV arresters (Courtesy of the General Electric Co.)

Arrester Class Rating (kV)	Energy Capability	
	kJ/kV of Rating	kJ/kV of MCOV
2.7–48	4.0	4.9
54–360	7.2	8.9

* Proprietary name of the General Electric Co.

PROCEDIMIENTO DE SELECCIÓN

DESCARGADOR DE SOBRETENSIONES

Engineering Education

- **Tipo de aislamiento**
- **Frecuencia asignada**
- **Línea de fuga**
- **Voltaje de operación continua: *Uc***
- **Capacidad del descargador frente a sobrevoltajes temporales: *TOVc***
- **Voltaje asignado o nominal (Rating): *Ur***
- **Corriente nominal de descarga: *In***

  - Clase de descarga de la línea
- **Voltaje residual o de descarga: *Ures***
- **Clase de alivio de presión**

DESCARGADOR DE SOBRETENSIONES

PARÁMETROS AMBIENTALES Y ELÉCTRICOS DEL SISTEMA

PARÁMETROS	UNIDAD	VALOR		
		S.E. NUEVA AZÁNGARO, S.E. NUEVA JULIACA, S.E. PUNO		
a. Tensión de operación del sistema.	kV	220	138	10,5
b. Tensión máxima del equipo	kV	245	145	12
c. Frecuencia asignada.	Hz	60	60	60
Nivel de aislamiento:				
• Tensión asignada soportada al impulso tipo rayo, f-f y f-t (U_p).	kVp	1050 (*)	550 (*)	75 (*)
• Tensión asignada soportada a frecuencia industrial, f-t (U_d).	kV	460 (*)	230 (*)	28 (*)
d. Puesta a tierra.		Sólido	Sólido	Sólido
e. Corriente de corta duración admisible asignada.	kA	40	31,5	25
f. Máxima duración admisible del cortocircuito.	s	0,5	0,5	0,5
g. Nivel de contaminación de la zona	mm/kV	20	20	20
h. Tiempo normal de aclaración de la falla.	ms	100	100	100
i. Tiempo de aclaración de la falla en respaldo.	ms	300	300	300
j. Identificación de fases.		R,S,T	R,S,T	R,S,T

NOTA:
(*): Estos valores serán corregidos de acuerdo a la altura de instalación del proyecto.

PARÁMETROS AMBIENTALES Y ELÉCTRICOS DEL SISTEMA

PARÁMETROS	UNIDAD	VALOR		
		S.E. AZÁNGARO NUEVA	S.E. JULIACA NUEVA	S.E. PUNO
a. Altura sobre el nivel del mar.	m	3863	3832	4150
b. Temperatura:				
• Máxima promedio anual.	°C	25	25	25
• Promedio anual.	°C	8	8	8
• Mínima promedio anual.	°C	- 15	- 15	- 15
c. Nivel ceráunico	días/año	40	40	40
d. Velocidad máxima del viento	km/h	104	104	113
e. Características sísmicas:				
• Aceleración horizontal	g	0,5	0,5	0,5
• Aceleración vertical	g	0,3	0,3	0,3
f. Radiación solar:				
• Intensidad de la radiación solar	W/m^2	1000	1000	1000

Voltajes normalizados

4 General principles for the application of surge arresters

IEC 60071 specifies withstand voltages for two ranges of highest voltages for equipment:

– range I: above 1 kV to 245 kV included
– range II: above 245 kV

In addition this guide uses:

– distribution voltage up to 52 kV
– UHV above and 800 kV included

NOTE Insulation coordination refers both to U_m (highest voltage for equipment) U_s (highest system voltage), whereas the dimensioning of arresters is usually based exclusively on U_s.

For range I systems containing overhead lines, the main risk to equipment arises from induced and direct lightning strikes to the connected overhead lines. In cable systems not connected to overhead lines, overvoltages due to faults or switching operations are most likely to occur. In rare cases, however, lightning induced overvoltages may also be generated. In systems of range II, in addition to range I factors, switching overvoltages become important, increasing with higher system voltages. Overvoltages may cause flashovers and serious damage to the equipment and thereby jeopardize the supply of power to users. It is essential to prevent this by proper coordination of surge arresters with the insulation. Therefore, it is recommended to use surge arresters if there are possibilities of lightning overvoltages or high switching overvoltages, which may be dangerous to the equipment.

Definiciones

IEC 60099-5 2013 Pág. 30

5.2.2.7.2 Continuous operating voltage, U_c

The continuous operating voltage U_c is the maximum permissible value of a sinusoidal power frequency voltage, which may be continuously applied between the arrester terminals. The continuous operating voltage of the complete arrester may be lower per section than that used in the operating duty test, for the ageing procedure, and for verifying thermal stability. The lower continuous operating voltage may be due to the pollution strength of the arrester housing or to large non-linearities in the voltage distribution along the MO resistor stack due to less effective grading caused by proximity effects of other objects. Smaller grading rings and proximity to earthed objects are other reasons.

5.2.2.7.3 Rated voltage, U_r

The rated voltage U_r is the maximum power frequency voltage that is applied in the operating duty test for ten seconds (see 8.5 of IEC 60099-4:2009). It is, furthermore, the reference parameter to establish the power frequency voltage versus time characteristic of the arrester, and for defining the test requirements for the line discharge test.

Standard rated voltages are defined in steps of 1 to 24 kV according to IEC 60099-4:2009, Table 2. Other values are acceptable, provided they are multiples of six.

5.2.2.7.4 Nominal discharge current, I_n

The nominal discharge current I_n is used for the surge arrester classification. Five standard nominal discharge currents exist according to IEC 60099-4:2009, Table 1, with an increasing number indicating increased duties and requirements (1 500 A, 2 500 A, 5 000 A, 10 000 A, 20 000 A). Though the IEC standard gives these values in A, it is common practice to specify the nominal discharge current in kA (i.e. 1,5 kA, 2,5 kA, 5 kA, 10 kA, 20 kA). The nominal discharge current is the main parameter for the protective characteristics and the energy absorption capability of the arrester. Its choice has also an impact on the whole procedure of insulation coordination.

Definiciones

IEC 60099-5 2013 Pág. 30

5.2.2.7.5 Protective (or protection) levels, U_{pl} and U_{ps}

The lightning impulse protective level, LIPL (according to IEC 60071-1) or U_{pl} (according to IEC 60099-4) of an arrester is the maximum residual voltage at nominal discharge current. It is applicable to the protection of equipment from fast-front overvoltages.

The switching impulse protective level, SIPL or U_{ps} is the maximum residual voltage at the specified switching impulse currents. It is applicable to the protection of equipment from slow-front overvoltages.

For the protection performance of metal-oxide surge arresters for very-fast-front overvoltages the residual voltage is tested in the steep current impulse test.

5.2.2.7.6 Line discharge (LD) class

A number related to the energy absorption capability of 10 kA and 20 kA arresters for the discharge of long transmission lines. Five classes exist according to IEC 60099-4:2009, Table 5, with an increasing number indicating increased energy absorption capability. Required energies for UHV arresters may not be covered by existing LD classes.

For arresters with LD class 2 and above, the resulting discharge current is used in the operating duty test to verify thermal stability after energy absorption. System events causing arrester currents with different shapes may be evaluated by comparison with energy and current of an equivalent line discharge. However, energy handling capability of an arrester is not a fixed value but depends on current density and time duration of the energy injection. In general, energy handling capability increases with higher current densities and shorter time durations. This matter is still under investigation [38] [41] [55].

Clase del Descargador

inel Engineering Education

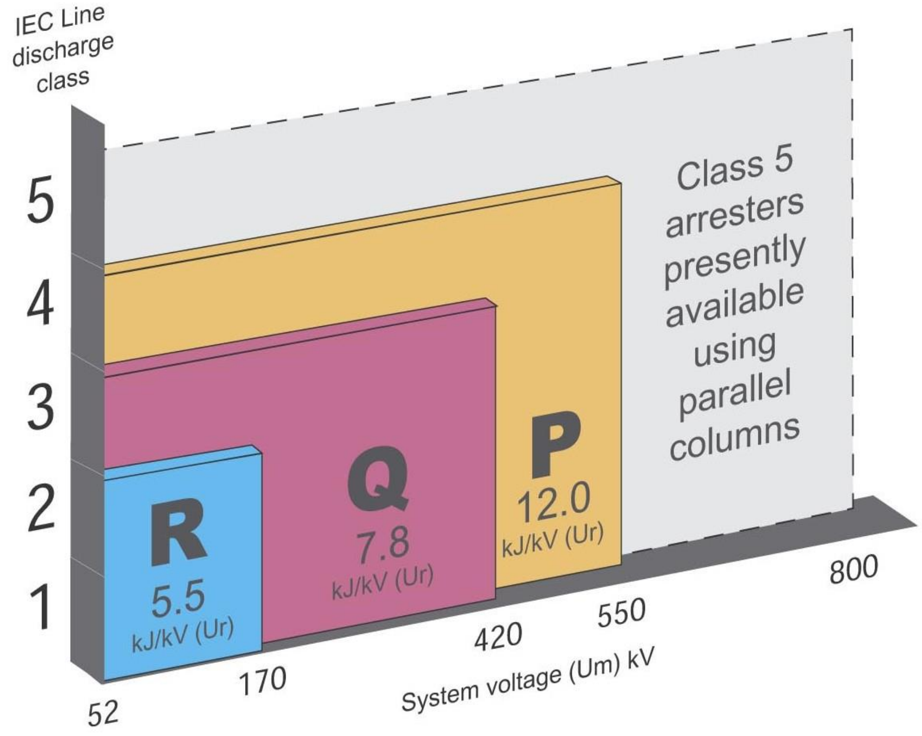
For arresters with the TOV capability expressed as factor of the rated voltage $T_r \times U_r$ shall be higher than or equal to the expected temporary overvoltage at the arrester terminals for the considered time duration.

For arresters with the TOV capability expressed as a factor of the continuous operating voltage $T_c \times U_c$ shall be higher than or equal to the expected temporary overvoltage at the arrester terminals for the considered time duration.

6.3.2.3 Selection of nominal discharge current and line discharge class

The nominal discharge current, I_n which provides the lightning impulse protection level, LIPL of a surge arrester is used as one of the metal oxide arrester classification. However the value of the nominal discharge current alone does not give enough information about the performance of the arrester. Additional information about the line discharge class or generally the required energy withstand capability is needed. Usually the IEC LD class is chosen first and then the user will automatically get a nominal discharge current (see Table 2). Particularly between IEC LD classes 3 and 4 it should be noted that I_n changes from 10 to 20 kA so that the LIPL for the LD class 4 arrester may look higher but is in reality lower for the same coordinating current. The co-ordinating current for the LIPL shall be selected to correspond to the actual risk of substation flashover due to lightning strikes on the connected OH lines. However, the user may still use another coordinated current than the nominal discharge current for determining of the LIPL of the arrester, such as 0,5 or 2 times I_n. In addition the nominal discharge current is combined with a specific high current impulse (see Table 2).

ABSORCIÓN DE ENERGÍA



For surge arresters protecting high-voltage substation equipment line discharge classes 2 to 5 are used. In medium voltage systems mainly 5 kA and 10 kA arresters with line discharge class 1 are used. For specific applications as protection of cables, rotating machines or capacitor banks higher line discharge classes may also be selected for medium voltage systems.

Table 2 – Arrester classification for surge arresters

LD class	-/-	1	2	3	4	5
I_n in kA	5	10	10	10	20	20
I_{hc} in kA	65	100	100	100	100	100
I_{sw} in A	-/-	125 and 500	125 and 500	250 and 1000	500 and 2000	500 and 2000

Selección de Descargadores

Para calcular los parámetros eléctricos de los descargadores de sobretensiones de ZnO, se considera el siguiente procedimiento:

– Tensión continúa de operación, *COV*. (conexión fase-tierra).

$$COV = 1{,}05 * \frac{Um}{\sqrt{3}}$$

Um corresponde a la máxima tensión del equipo.

– Sobretensión temporal, *TOV*

$$TOV = Ke \cdot \frac{Um}{\sqrt{3}}$$

Ke es el factor de tierra, el cual, en términos generales, es igual a 1,4 para sistemas sólidamente puestos a tierra, y 1,73 para sistemas con neutro aislado.

– La tensión nominal del descargador de sobretensiones, *R*, es el mayor valor entre *Ur1* y *Ur2*.

$$Ur1 = \frac{COV}{Ko}$$

Ko es el factor de diseño del descargador de sobretensiones, el cual varía según el fabricante. Un valor típico es 0.8.

$$Ur2 = \frac{TOV}{Ktov}$$

Ktov es la capacidad del descargador y depende del tiempo de duración de la sobretensión temporal. Así, para un segundo, *Ktov* = *1,15*; para 10 segundos, *Ktov* = *1,06* y para dos horas, *Ktov* = *0,95* (valores aproximados).

TENSION DE OPERACIÓN CONTINUA
Uc

Selección de Descargadores IEC 60071-2

Pararrayos

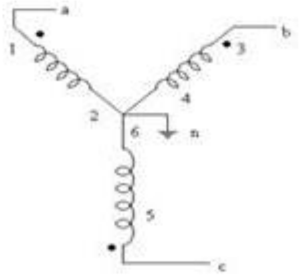
MCOV (mínimo)

$$U_{C,\min} \geq \begin{cases} \dfrac{1.05 \times U_m}{\sqrt{3}} & \text{effectively earthed} \\ 1.05 \times U_m & \text{non - effectively earthed} \end{cases}$$

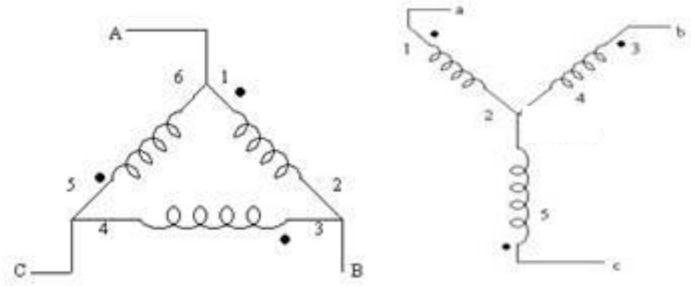
DESCARGADOR DE SOBRETENSIONES

TENSION DE OPERACIÓN CONTINUA DEL PARARRAYOS *Uc*

$$U_c = \frac{U_m}{\sqrt{3}} \times 1.05$$



$$U_c = U_m \times 1.05$$



CAPACIDAD PARA SOPORTAR SOBREVOLTAJES TEMPORALES TOV

SOBREVOLTAJES TEMPORALES TOV

IEC 60099-5 2013 Pág. 52

6.2.3.5 Temporary overvoltages

A temporary overvoltage (TOV) is an oscillatory phase-to-earth or phase-to-phase condition that is of relatively long duration and is undamped or only weakly damped. TOV magnitudes are determinable and the effect on insulation is considered in steady-state terms. The following causes of temporary overvoltages are typically considered:

Earth fault overvoltages occur over a large part of the system. Guidance for the determination of temporary overvoltage amplitudes is given in Annex A. The duration of the overvoltage corresponds to the period of the fault (until fault clearing). Within earthed neutral systems it is generally less than 1 s. For resonant earthed neutral systems, with fault clearing, it is generally less than 10 s and systems without earth fault clearing the duration may be several hours.

Load rejection, following disconnection of a load, the voltage can rise at the source side of the operating circuit breaker. The amplitude of the overvoltage depends on the disconnected load and the short-circuit power of the feeding substation. The temporary overvoltages have particularly high amplitudes after full load rejection at generator transformers depending on magnetizing and over-speed conditions. The amplitude of load rejection overvoltages is

SOBREVOLTAJES TEMPORALES TOV

IEC 60099-5 2013 Pág. 53

60099-5 © IEC:2013(E) – 53 –

usually not constant during its duration. Accurate calculations have to consider many parameters, the following typical values of such overvoltages may be considered

- In moderately extended systems, a full load rejection can give rise to phase-to-earth overvoltages with amplitude usually below 1,2 p.u. The overvoltage duration depends on the operation of voltage-control equipment and may be up to several minutes.
- In extended systems, after a full load rejection, the phase-to-earth overvoltages may reach 1,6 p.u. or even higher when Ferranti or resonance effects occur. Their duration may be in the order of some seconds.
- For load rejection of generator transformers, the temporary overvoltages may reach amplitudes up to 1,4 p.u. for turbo generators and up to 1,5 p.u. for hydro generators. The duration is approximately 3 s.

The following causes of temporary overvoltages may also require consideration depending on the nature of the network:

- resonance effects, e.g. when charging long unloaded lines or resonance between systems;
- voltage rise along long lines (Ferranti effect);
- harmonic overvoltages, e.g. when switching transformers;
- backfeed through interconnected transformer windings, e.g. dual transformer station with common secondary bus during fault clearing or single-phase switched three-phase transformer with an unbalanced secondary load.

Annex A
(informative)

Determination of temporary overvoltages due to earth faults

The earth fault factor k is the ratio of the highest r.m.s. phase-to-earth power frequency voltage on a sound phase at a particular location during a fault to earth (affecting one or more phases at any point) to the r.m.s. phase-to-earth power frequency voltage which should be obtained without the fault (see 3.17 of IEC 60071-1:2006).

The earth fault factor is calculated using the complex impedances Z_1, Z_2 and Z_0 of the positive, negative and zero sequence systems, taking into account the fault resistance R. The following applies:

$Z_1 = Z_2 = R_1 + jX_1$: resistance and reactance of positive and negative sequence system;

$Z_0 = R_0 + jX_0$: resistance and reactance of zero sequence system.

NOTE It should be observed that, in extended resonant earthed networks, the earth fault factor might be higher at other locations than at the fault.

The earth fault factors are calculated for the location of the fault. Figure A.1 shows the overall situation, when $R_1 << X_1$ and $R_1 = 0$. The range of high values for X_0/X_1, positive and/or negative, applies to resonant earthed or isolated neutral systems. The range of low values of positive X_0/X_1 is valid for earthed neutral systems. The range of low values of negative X_0/X_1, shown hatched, is not suitable for practical application due to resonant conditions. For earthed neutral systems, Figures A.2 through A.5 show the earth fault factors as families of curves applicable to particular values of R_1/X_1. The curves are valid for fault resistance values giving the highest earth fault factors.

SOBREVOLTAJES TEMPORALES TOV

– Sobretensión temporal, *TOV*

$$TOV = Ke \cdot COV$$

Ke es el factor de tierra, el cual, en términos generales, es igual a 1,4 para sistemas sólidamente puestos a tierra, y 1.73 para sistemas con neutro aislado. A partir de los equivalentes de secuencia positiva y secuencia cero en las subestaciones y con base en gráficas del Anexo B de la norma IEC 60071-2 fue posible estimar un valor aproximado para el factor de tierra. Así:

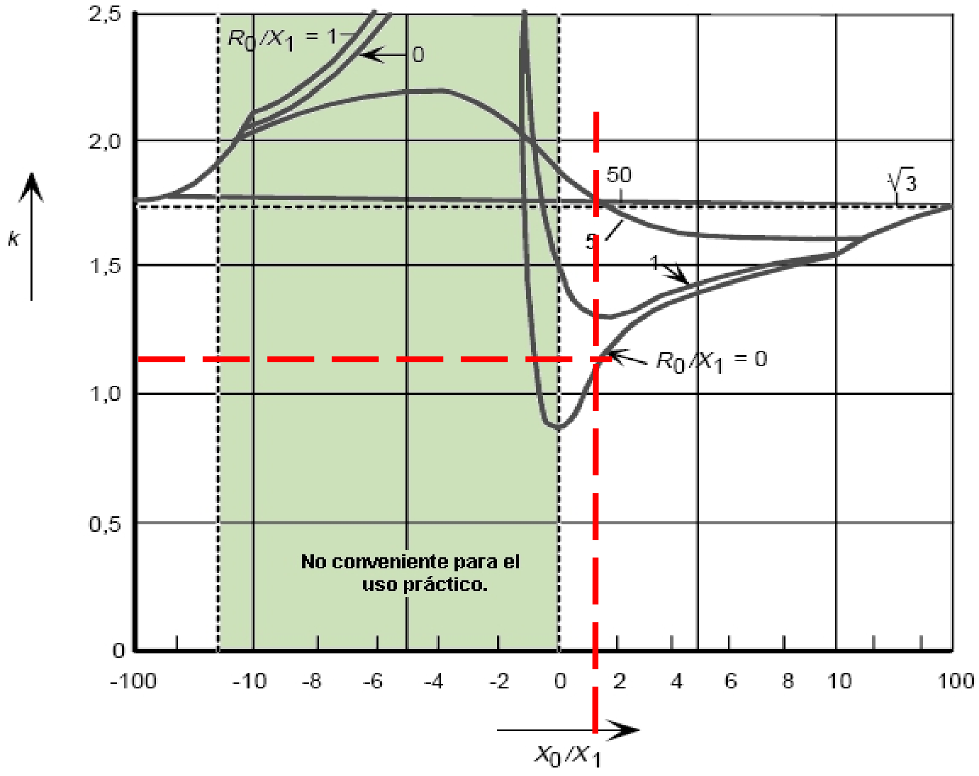
	LA NIÑA 220 kV	LA NIÑA 500 kV	TRUJILLO 500 kV
R0	3.81	36.63	5.67
X0	17.80	200.11	72.00
R1	3.23	15.07	8.71
X1	32.73	157.60	103.37
R1/X1	0.10	0.10	0.08
X0/X1	0.54	1.27	0.70
R0/X1	0.12	0.23	0.05
Ke	1.2	1.2	1.2

La norma IEC 60071-2 presenta 3 tipos de curvas para el cálculo del factor de tierra, las cuales varían en la relación entre R1 y X1. Con R1=0 (Figura B.2 de la referencia [4]) y se obtiene un Ke=1.2 para las dos subestaciones. Conservativamente, se toma un valor de Ke=1.4.

k = Factor de falla a tierra

125 – B.1/71-2

Situación general para R1 << X1 y R = 0



SOBREVOLTAJES TEMPORALES TOV

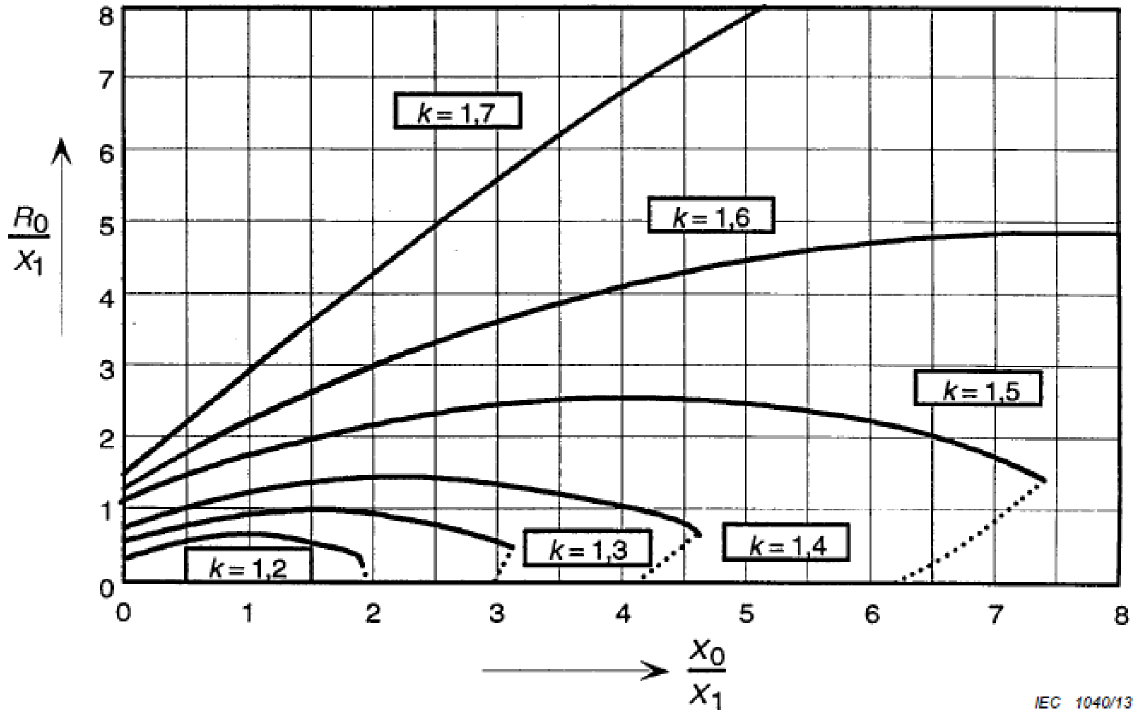


Figure A.2 – Relationship between R_0/X_1 and X_0/X_1 for constant values of earth fault factor k where $R_1 = 0$

SOBREVOLTAJES TEMPORALES TOV

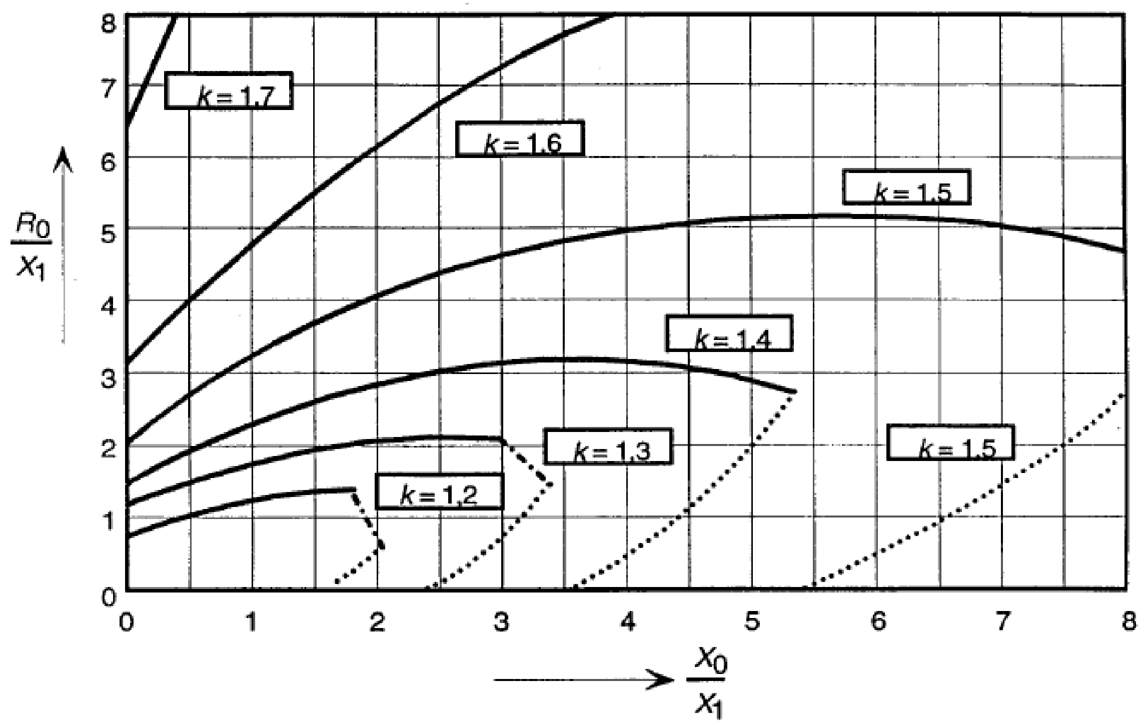


Figure A.3 – Relationship between R_0/X_1 and X_0/X_1 for constant values of earth fault factor k where $R_1 = 0,5\ X_1$

SOBREVOLTAJES TEMPORALES TOV

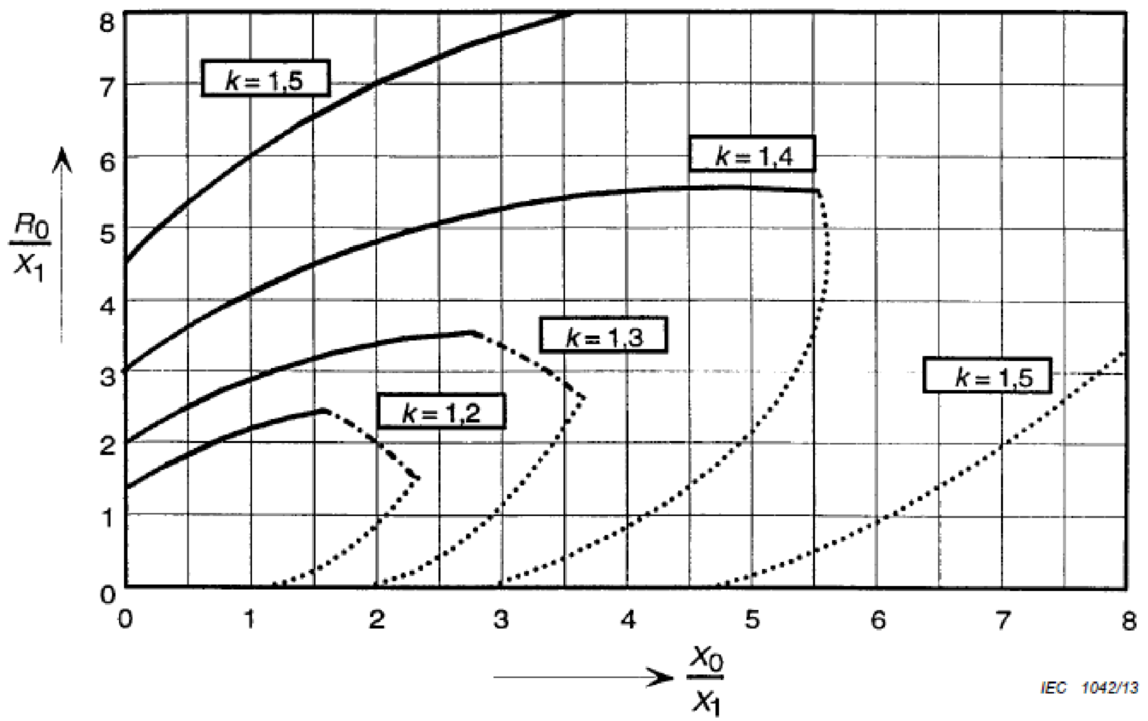


Figure A.4 – Relationship between R_0/X_1 and X_0/X_1 for constant values of earth fault factor k where $R_1 = X_1$

SOBREVOLTAJES TEMPORALES TOV

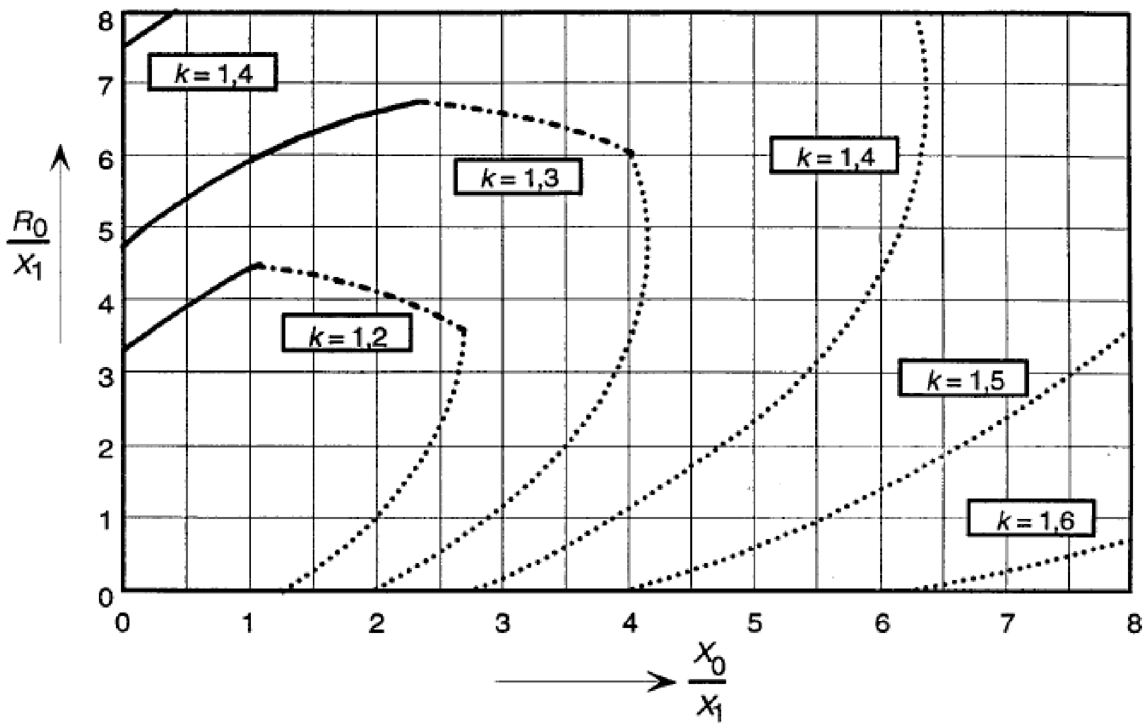


Figure A.5 – Relationship between R_0/X_1 and X_0/X_1 for constant values of earth fault factor k where $R_1 = 2X_1$

TENSION ASIGNADA O NOMINAL (RATING) Ur

Factor kTOV

Valor eficaz del máximo sobrevoltaje temporal a frecuencia industrial que es capaz de soportar entre sus terminales durante un tiempo determinado.

Suelen presentarse como referencia los valores de kTOV para 1s = 1,15 y 10s = 1,06.

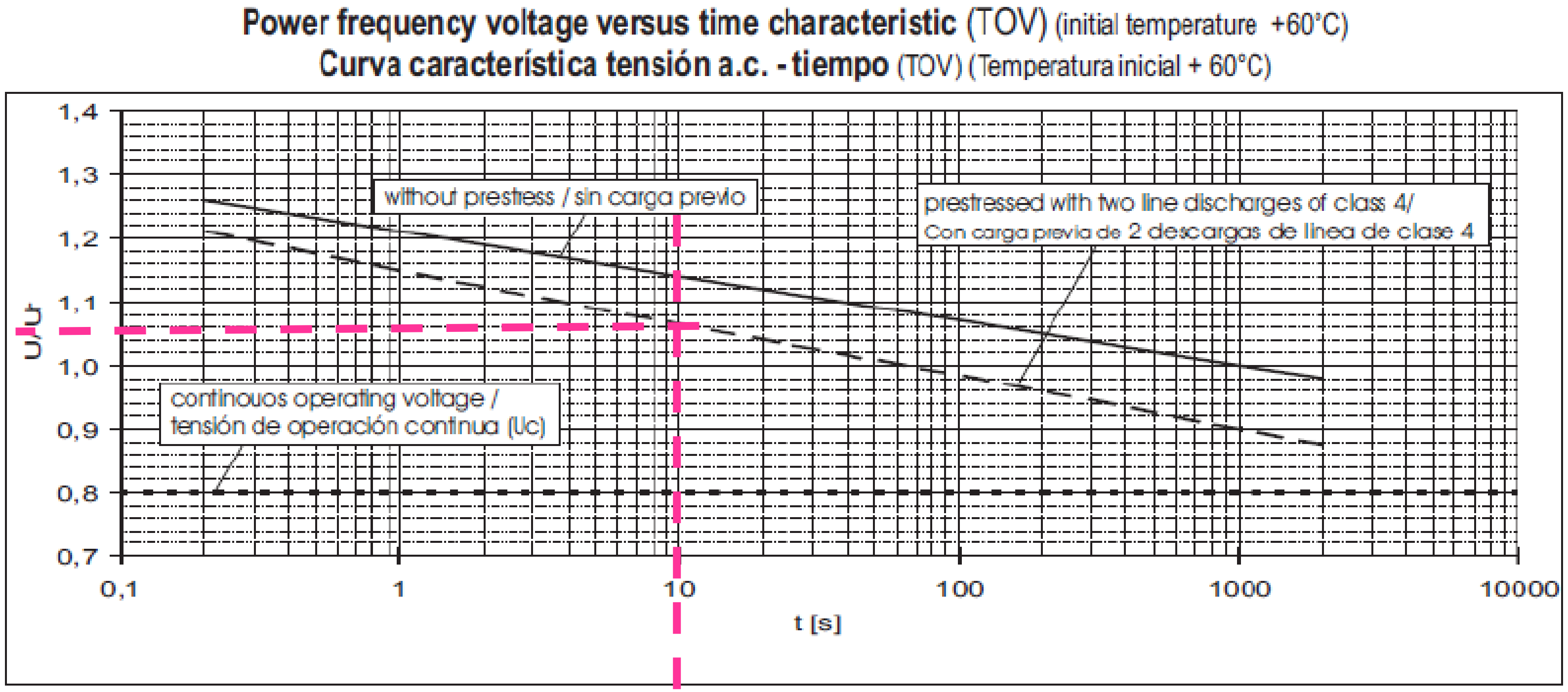


Figura 2. Curva típica de sobretensión de pararrayos

Coordinación de Aislamiento

Aplicando este procedimiento, se obtienen las tensiones nominales y de operación continua para los descargadores de sobretensiones en las subestaciones a 220 kV / 138 kV / 10,5 kV, las cuales serán el insumo para la selección de los parámetros típicos de los descargadores que se consideran en la coordinación de aislamiento.

– Descargadores de sobretensiones en subestaciones de 220 kV.

$COV = 1{,}05 \times 245\ \text{kV} / \sqrt{3} = 148{,}52\ \text{kV}$

$TOV = 1{,}40 \times 245\ \text{kV} / \sqrt{3} = 198{,}03\ \text{kV}$

$Ur1 = 148{,}52\ \text{kV} / 0{,}8 = 185{,}65\ \text{kV}$

$Ur2 = 198{,}03\ \text{kV} / 1{,}06 = 186{,}82\ \text{kV}$

$\mathbf{Ur = \text{máx.}\{Ur1,\ Ur2\} = 186{,}82\ kV}$

Se recomienda aumentar Ur en
5%= 186.82x1,05= 196.16kV

Selección de Descargadores

Descargador

Corriente

de coordinación

	Standard nominal discharge current [a]				
	20 000 A	10 000 A	5 000 A	2 500 A	1 500 A
Rated voltage U_r (kV_{rms})	$360 < U_r \leq 756$	$3 \leq U_r \leq 360$	$U_r \leq 132$	$U_r \leq 36$	[b]

[a] In some countries it is customary to classify arresters as follows:

- station for 10 000 A and 20 000 A arresters;
- intermediate or distribution for 5 000 A arresters;
- secondary for 1 500 A arresters.

[b] This low-voltage range is under consideration.

Tabla 1. IEC 60099-4 2004 Pág. 39. Nota: La norma se actualizo ver lamina siguiente

Selección de Descargadores

Engineering Education

4.2 Arrester classification

Station and distribution class arresters are classified as indicated in Table 1, and they shall meet at least the test requirements and performance characteristics specified in Table 3.

Depending on application, NGLA may take on the classification of any one of the arresters indicated in Table1.

Table 1 – Arrester classification

Arrester class	Station			Distribution		
Designation	SH	SM	SL	DH	DM	DL
Nominal discharge current[a]	20 kA	10 kA	10 kA	10 kA	5 kA	2,5 kA
Switching impulse discharge current[a]	2 kA	1 kA	0,5 kA	--	--	--
Q_{rs} (C)	≥ 2,4	≥ 1,6	≥ 1,0	≥ 0,4	≥ 0,2	≥ 0,1
W_{th} (kJ/kV)	≥10	≥ 7	≥ 4	--	--	--
Q_{th} (C)	--	--	--	≥ 1,1	≥ 0,7	≥ 0,45

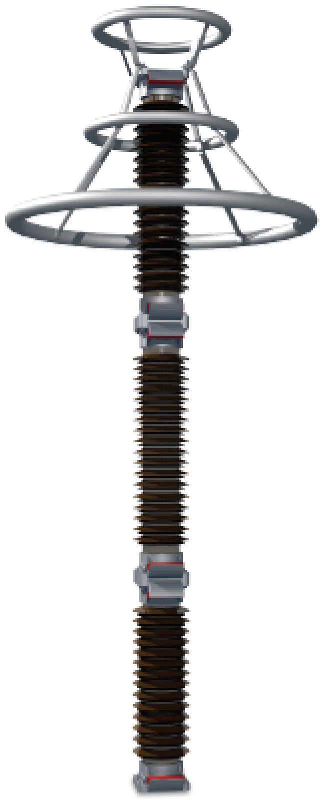
[a] Other currents may be specified upon agreement between manufacturer and user.

NOTE The letters "H", "M" and "L" in the designation stand for "high", "medium" and "low" duty, respectively.

IEC 60099-4 2014 Pág. 28

Pág. 99- Guía del Comprador ABB

Brief performance data



Arrester classification as per IEC 60099-4 Ed 3.0	Station; SH
Arrester classification as per IEEE Std C62.11-2012	Station
System voltages (U_s)	52 - 550 kV
Rated voltages (U_r)	42 - 444 kV
Nominal discharge current (IEC)	20 kA_{peak}
Lightning impulse classifying current (ANSI/ IEEE)	10/ 15 kA_{peak}
Charge, energy and current withstand:	
Repetitive charge transfer rating, Q_{rs} (IEC)	3.2 C
Thermal energy rating, W_{th} (IEC)	11 kJ/ kV (U_r)
Single impulse energy capability (2 ms to 4 ms impulse)	7 kJ/ kV (U_r)
Discharge current withstand strength:	
• High current 4/ 10 µs	100 kA_{peak}
• Low current 2000 µs, (based on Q_{rs})	1600 A_{peak}
Energy class as per IEEE standard (switching surge energy rating)	G
Single-impulse withstand rating as per IEEE standard	3.2 C
Repetitive charge transfer test value - sample tests on all	4.0 C
Short-circuit/ Pressure relief capability	**65 $kA_{rms(sym)}$**
Mechanical strength:	
Specified long-term load (SLL)	8000 Nm
Specified short-term load (SSL)	20000 Nm
Service conditions:	
Ambient temperature	-50°C to +45°C
Design altitude	max. 1000 m
Frequency	15 - 62 Hz
Line discharge class (as per IEC60099-4, Ed. 2.2	**Class 4**

—

NOTE: Further data according to the IEEE standard can be supplied on request

Engineering Education

Pág. 101- Guía del Comprador ABB

EXLIM P-G

Guaranteed protective data 245 - 550 kV

Ups

Upl

Max. system voltage U_s	Rated voltage U_r	Max. continuous operating voltage[1]		TOV capability[2]		Max. residual voltage with current wave						
		as per IEC	as per ANSI/ IEEE			30/ 60 µs					8/ 20 µs	
		U_c	MCOV	1 s	10 s	1 kA	2 kA	3 kA	5 kA	10 kA	20 kA	40 kA
kV_{rms}	kV_{rms}	kV_{rms}	kV_{rms}	kV_{rms}	kV_{rms}	kV_{peak}	kV_{peak}	kV_{peak}	kV_{peak}	kV_{peak}	kV_{peak}	kV_{peak}
245	180	144	144	196	186	351	364	373	390	410	449	492
	192	154	154	209	199	375	388	398	415	437	479	525
	198	156	160	216	205	387	400	410	428	451	494	541
	210	156	170	229	217	410	425	435	454	478	524	574
	216	156	174	236	223	422	437	448	467	492	539	590
	219	156	177	239	227	427	443	454	474	499	546	598
	228	156	180	249	236	445	461	473	493	519	568	623

Características de los Descargadores de Sobretensiones 220 kV

Para este sistema se toma como base las características de protección de descargadores de sobretensiones de la referencia [5], los cuales poseen las siguientes características:

Pararrayos en 220 kV:

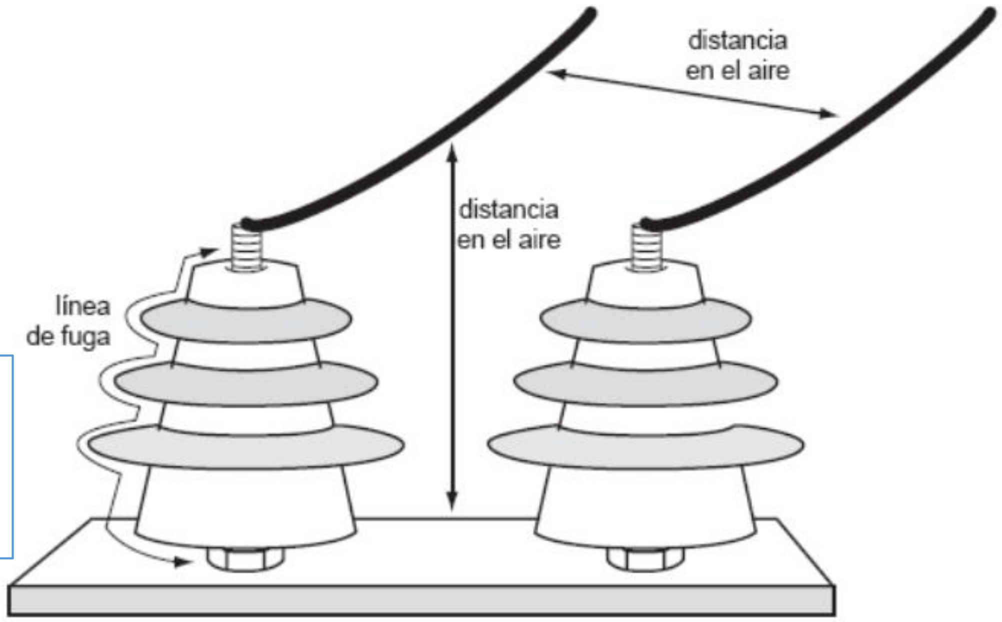
Tensión nominal asignada:	U_r = 198 kV
Tensión continua de operación:	U_c = 156 kV
Nivel de protección al impulso de maniobra:	U_{ps} = 400 kVp
Nivel de protección al impulso atmosférico:	U_{pl} = 494 kVp
Capacidad de absorción de energía:	7 kJ/kV_{Ur}

DESCARGADOR DE SOBRETENSIO

LONGITUD DE FUGA

$$\text{Linea de Fuga (mm)} = U_s(\text{kV}) \times L_e(\text{mm/kV})$$

$$\text{Linea de Fuga (mm)} = 245(\text{kV}) \times 20\ (\text{mm/kV}) = 4900\text{mm}$$



IEC 60815

DESCARGADOR DE SOBRETENSIONES

Engineering Education

IEC 60815

Pollution performance

IEC 60815 defines five levels of pollution (from very light to very heavy), with the traditional correspondingly required creepage for porcelain housings as indicated in the table below.

Site polltion severity class	Pollution level	Specific creepage in mm/ kV (U_s)	Unified specific creepage distance mm/ kV ($U_s/\sqrt{3}$)
a	Very light	12.7	22.0
b	Light (L)	16	27.8
c	Medium (M)	20	34.7
d	Heavy (H)	25	43.3
e	Very heavy (V)	31	53.7

IEC 60815

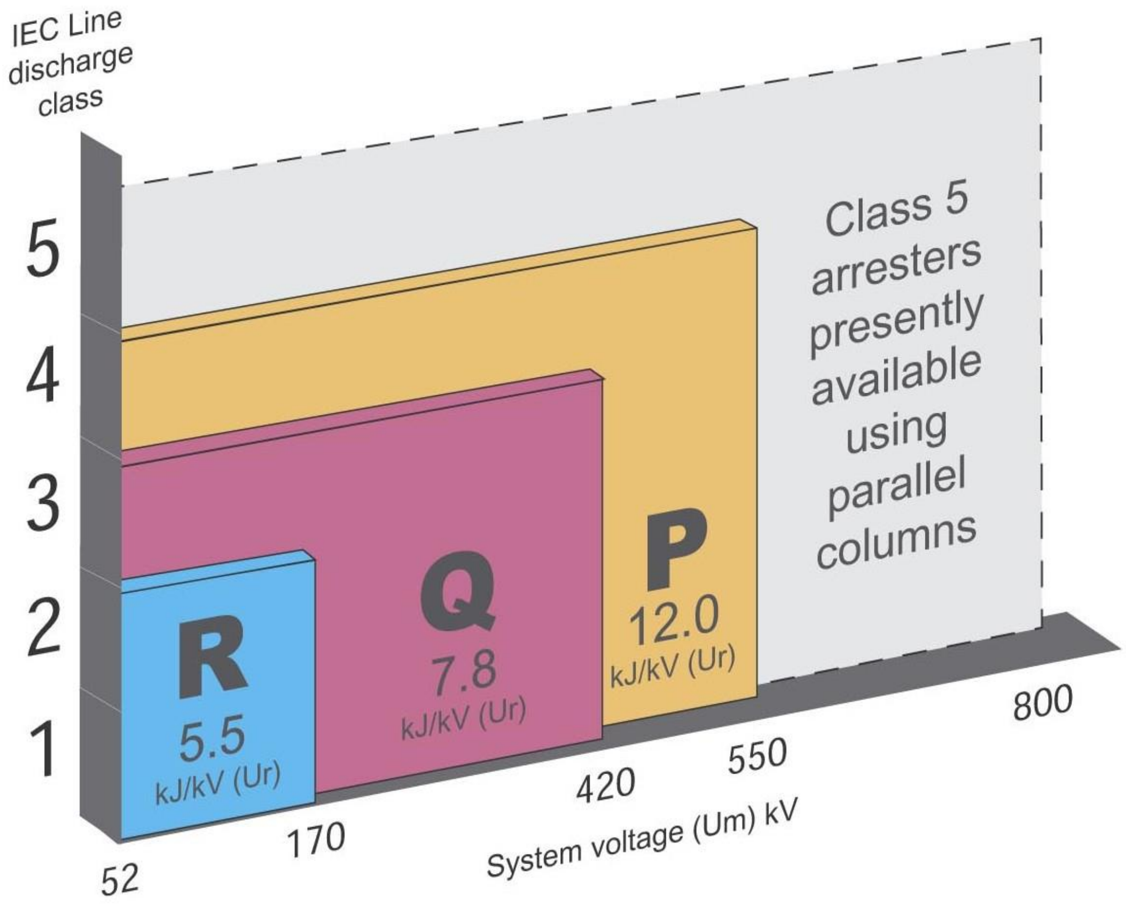
Table 4 – Requirements for high current impulses

Arrester classification	Peak current 4/10 kA
20 kA and 10 kA	100
5 kA	65
2,5 kA	25

– 50 – IEC 60099-4:2014 © IEC 2014

ABSORCIÓN DE ENERGÍA

ABSORCIÓN DE ENERGÍA



ABSORCIÓN DE ENERGÍA

Table L.3 – Comparison of the classification system according to IEC 60099-4:2009 (Ed.2.2) and to IEC 60099-4:2014 (Ed.3.0)

Old LDC	Required minimum test energy[a] kJ/kV	Corresponding *new* thermal energy rating as per 8.7.3 W_{th} kJ/kV	Estimated current at *old* LD test [b] A	Charge calculated with the same current and duration as for *old* LDC to give the required minimum energy C	Corresponding *new* repetitive charge transfer rating as per 8.5.4 Q_{rs} C	Repetitive charge transfer test value (= 1,1 × Q_{rs}) C
1	1,0	2	277	0,56	0,5	0,55
2	2,1	4	538	1,10	1	1,10
3	3,3	7	721	1,78	1,6	1,76
4	5,0	10	962	2,75	2,4	2,64
5	6,9	14	1118	3,75	3,6	3,96

a Calculated with U_{resmin} (I_{min}) = 1,8 × U_r (see Figure L.1).

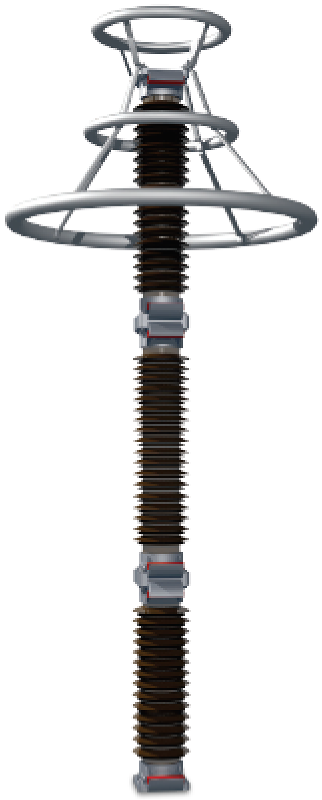
b Estimated from LD parameters and b) and c) above.

Coordinación de Aislamiento

Engineering Education

Pág. 99- Guía del Comprador ABB

Brief performance data



Arrester classification as per IEC 60099-4 Ed 3.0	Station; SH
Arrester classification as per IEEE Std C62.11-2012	Station
System voltages (U_s)	52 - 550 kV
Rated voltages (U_r)	42 - 444 kV
Nominal discharge current (IEC)	20 kA_{peak}
Lightning impulse classifying current (ANSI/ IEEE)	10/ 15 kA_{peak}
Charge, energy and current withstand:	
Repetitive charge transfer rating, Q_{rs} (IEC)	3.2 C
Thermal energy rating, W_{th} (IEC)	11 kJ/ kV (U_r)
Single impulse energy capability (2 ms to 4 ms impulse)	7 kJ/ kV (U_r)
Discharge current withstand strength:	
• High current 4/ 10 µs	100 kA_{peak}
• Low current 2000 µs, (based on Q_{rs})	1600 A_{peak}
Energy class as per IEEE standard (switching surge energy rating)	G
Single-impulse withstand rating as per IEEE standard	3.2 C
Repetitive charge transfer test value - sample tests on all	4.0 C
Short-circuit/ Pressure relief capability	**65 $kA_{rms(sym)}$**
Mechanical strength:	
Specified long-term load (SLL)	8000 Nm
Specified short-term load (SSL)	20000 Nm
Service conditions:	
Ambient temperature	-50°C to +45°C
Design altitude	max. 1000 m
Frequency	15 - 62 Hz
Line discharge class (as per IEC60099-4, Ed. 2.2	**Class 4**

—

NOTE: Further data according to the IEEE standard can be supplied on request

Clase del Descargador

6.3.2.4 Surge arrester energy dissipation during lightning current discharges

The energy from lightning strikes can be estimated from Formula (4) [3], [4]:

$$W = \left[2 \times U_f - N \times U_{pl}\left(1 + \ln\left(2 \times \frac{U_f}{U_{pl}}\right)\right)\right]\frac{U_{pl} \times T_l}{Z} \quad (4)$$

where

W is the energy. If the distances between stations in distribution systems are small, the energy can be divided because of current sharing.

ln is the natural logarithm;

U_{pl} is the lightning impulse protection level of the arrester;

U_f is the negative flashover voltage of the line insulation;

Z is the line surge impedance;

N is the number of lines connected to the arrester;

– 70 – 60099-5 © IEC:2013(E)

T_l is the equivalent duration of the current of a lightning flash including first and subsequent strikes. Typical value 3×10^{-4} s.

NOTE The formula is derived from an integration of an exponentially decreasing overvoltage.

Computer analysis according to IEC 60071-4 on lightning energy dissipation into surge arresters can give more accurate values.

Clase del Descargador

6.3.2.5 Surge arrester energy dissipation during line switching

The arrester switching energy is dependent on surge magnitude, wave shape, system impedance and configuration, arrester protective characteristics and frequency of switching operations within a short time period. Ultimately, the selected surge arrester shall have energy capacity greater than the accumulated energies over the severest operating duty. The required surge arrester energy duty is obtained during the insulation coordination step determining the representative overvoltages. In most practical cases, since nature of switching is statistical and generated waveforms are typically complex especially with highly non-linear characteristics of an arrester, it is desirable to perform computer simulation studies. When such studies are unavailable for line switching, a conservative estimate can be obtained from an equation similar to that used for defining arrester line discharge class (IEC 60099-4:2009, Table 5). The simplified arrester energy Formula (5) is derived based on the assumption that the entire line is charged to a prospective switching surge voltage and is discharged through the arrester at its protective level during twice the travel time of the line [7].

$$W = U_{ps} \times \frac{U_{rp} - U_{ps}}{Z_s} \times 2 \times \frac{L}{c} \quad \text{per switching} \qquad (5)$$

where

- W is the energy
- L is the line length;
- c is the speed of light;
- Z_s is the line surge impedance;
- U_{ps} is the arrester residual voltage at the lower of the two switching impulse currents;
- U_{rp} is the representative maximum switching voltage.

Clase del Descargador

Table L.2 – Parameters for the line discharge test on 20 000 A and 10 000 A arresters
(Reproduction of Table 5 of IEC 60099-4:2009)

Arrester classification	Line discharge class	Surge impedance of the line Z Ω	Virtual duration of peak T µs	Charging voltage U_L kV d.c.
10 000 A	1	4,9 U_r	2 000	3,2 U_r
10 000 A	2	2,4 U_r	2 000	3,2 U_r
10 000 A	3	1,3 U_r	2 400	2,8 U_r
20 000 A	4	0,8 U_r	2 800	2,6 U_r
20 000 A	5	0,5 U_r	3 200	2,4 U_r

U_r is the rated voltage of the test sample in kilovolts r.m.s.

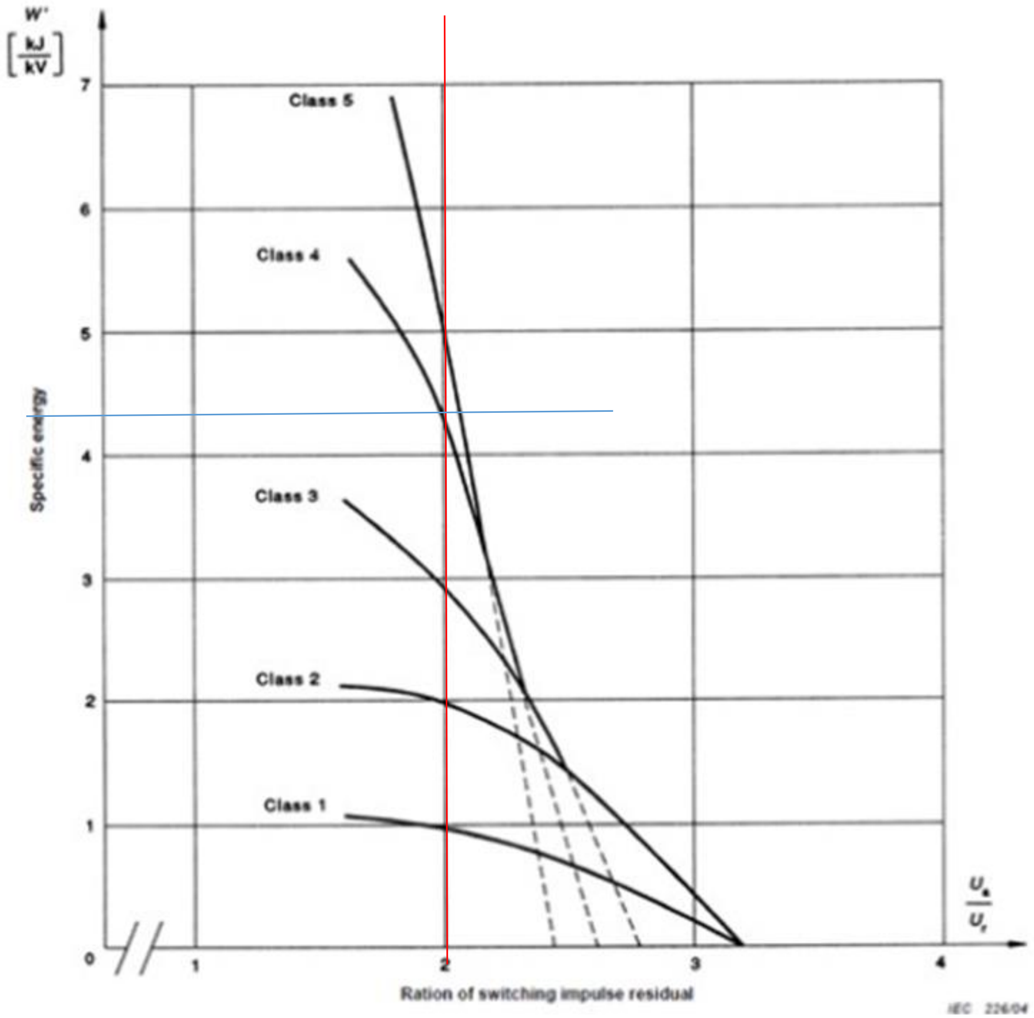
NOTE Classes 1 to 5 correspond to increasing discharge requirements. The selection of the appropriate discharge class is based on system requirements and is dealt with in Annex E.

Clase del Descargador

WTh(kJ/kV)= 4,35

Ups/Ur = 400/198= 2,02

Specific energy in kJ/kV of rated voltage dependent on the ratio of switching impulse residual voltage U_a to the r.m.s. value of the rated voltage U_r the arrester.
[Fig. E1 IEC 60099-4]



GUARANTEED TECHNICAL SPECIFICATIONS

ITEM	FEATURES	UNIT	REQUIRED	GUARANTEED	OBSERV.
1	Manufacturer	-	(1)	Chint Electric	
2	Model	-	(1)	Y10W-108	
3	Catalog	-	(1)		
4	IEEE Class	-	Station	Station	
5	Type	-	ZnO	ZnO	
6	Material	-	Porcelain	Porcelain	
7	Standard	-	IEEE Std.C 62.11, 62.22 IEC 60099-4	IEC60099-4	
8	Assembly	-	Exterior	Exterior	
9	Nominal system voltage	kV rms	115	115	
10	Maximum network voltage	kV rms	123	123	
11	Maximum design voltage	kV rms	145	145	
12	Insulation level at 1.2x50 μs wave	kV peak	(1)	According to design	
13	System Insulation Basic Level	kV peak	650	650	
14	Grounding type	-	Solidly grounded	Solidly grounded	
15	Frequency	Hz	60	60	
16	Nominal Voltage Discharger	kV rms	108	108	
17	Maximum continuous operation voltage (MCOV)	kV rms	84	84	
18	Minimum temporary voltage, after discharger operation at its energetic capacity (TOV) - 1 seconds - 10 seconds	 kV rms kV rms	 (1) (1)	 126 108	
19	Pressure relief capacity	kA rms	(1)	100 ✓	
20	Nominal discharge current	kA	10	10	
21	Impulse current 4/10μs	kA	65	65	
22	Maximum residual current 8/20μs 5 kA 10 kA 20 kA 40 kA	 kV peak kV peak kV peak kV peak	 (1) (1) (1) (1)	 262 ✓ 281 ✓ 323 ✓ 357	

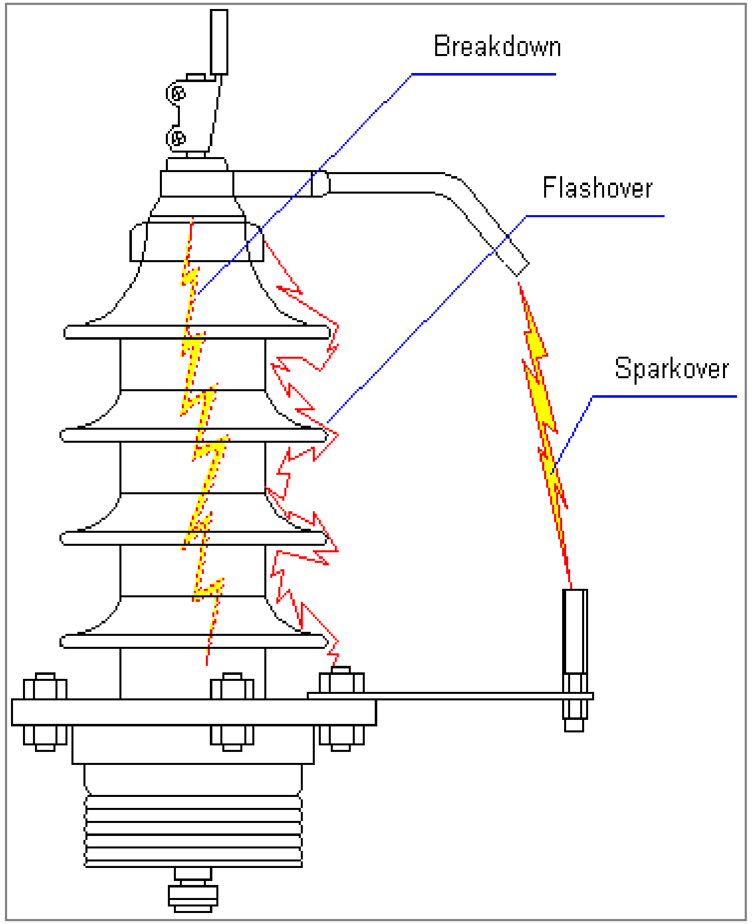
23	Maximum residual voltage 30/60 µs 1 kA 2 kA 3 kA	kV peak kV peak kV peak	(1) (1) (1)	239 261 284	
24	Specific leakage distance	mm/kV	25	>25	
25	Class of line discharge (according to IEC 60099-4)	----	3	3	
26	Weight	Kg	(1)	153	
27	Test voltage at low frequency dry 1 minute	kV rms	310	310	
28	Test voltage at low frequency Wet 10 seconds	kV rms	275	275	
29	Vending resistance (Cantilever)	Kgf	998	998	
30	Compression resistance	Kgf	34020	34020	
31	Voltage resistance	Kgf	11340	11340	
32	Torsion resistance	kgf.m	1037	1037	
33	Discharger counter Leakage current meter	----	Yes	Yes	
34	Insulation bases	----	Yes	Yes	
35	Assembly structure	----	Yes	Yes	
36	Porcelain color	----	Gray	Gray	
37	Line connection terminals	----	500 – 1.024 kcmil	500 – 1.024 kcmil	
38	Grounding Terminals	----	2/0-250 kcmil	2/0-250 kcmil	
39	Pressure relief capacity	kA rms	40	40	

(1) Information to be supplied by the manufacturer

Medidas de control y protecciones

Herrajes

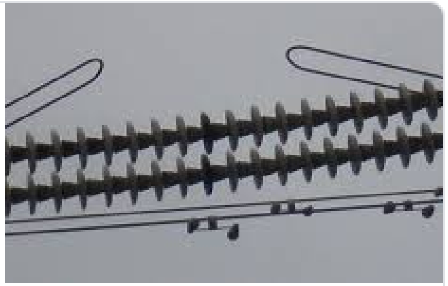
en equipos



Herrajes

tipo cuerno

Arcing horns (sometimes **arc-horns**) are projecting conductors **used** to protect insulators or switch hardware on high voltage electric power transmission systems from damage during flashover. ... They are frequently to be seen on insulator strings on overhead lines, or protecting transformer bushings.



en.wikipedia.org › wiki › Arcing_horns

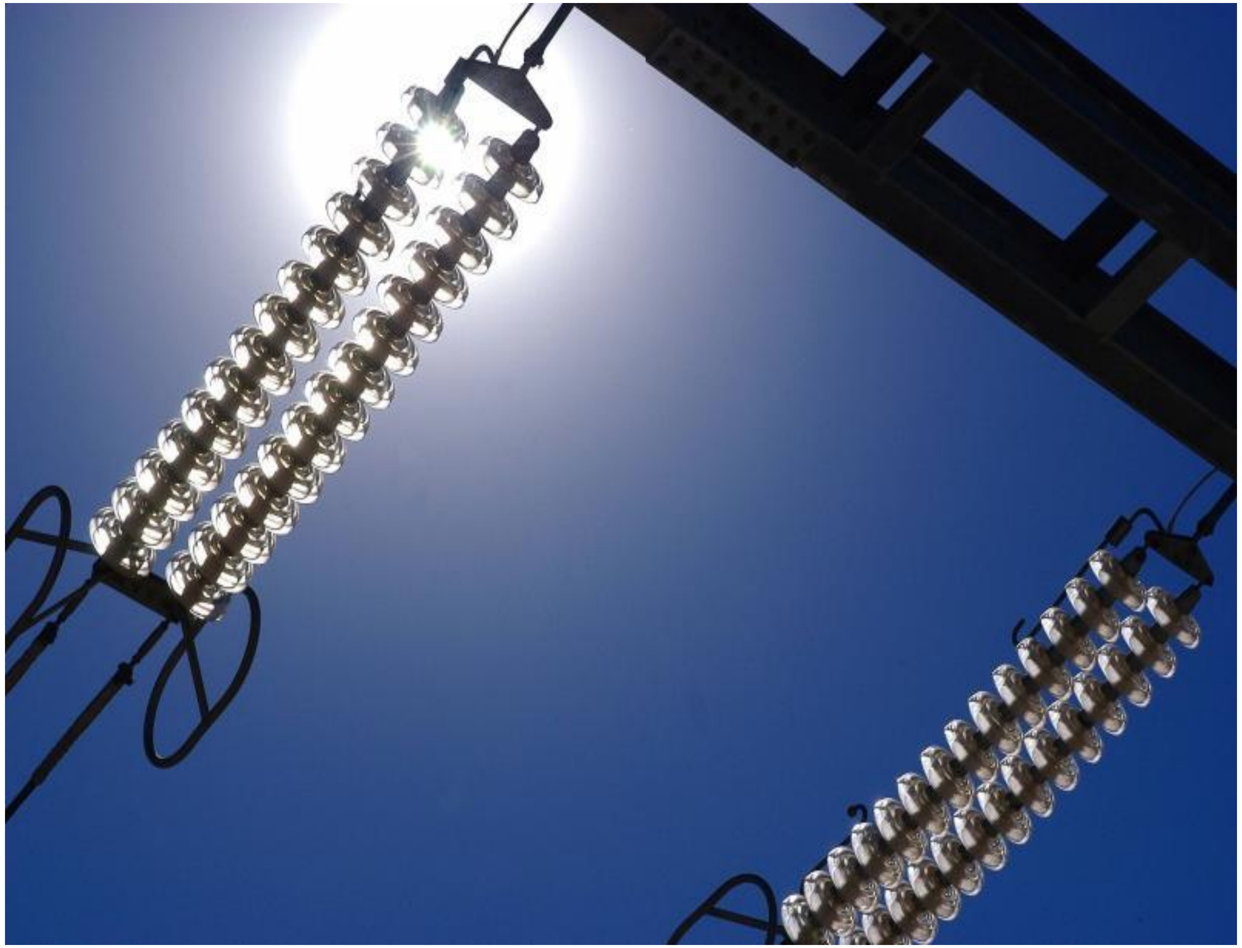
Arcing horns - Wikipedia

https://www.youtube.com/watch?v=PZ-2yJ1tcfY

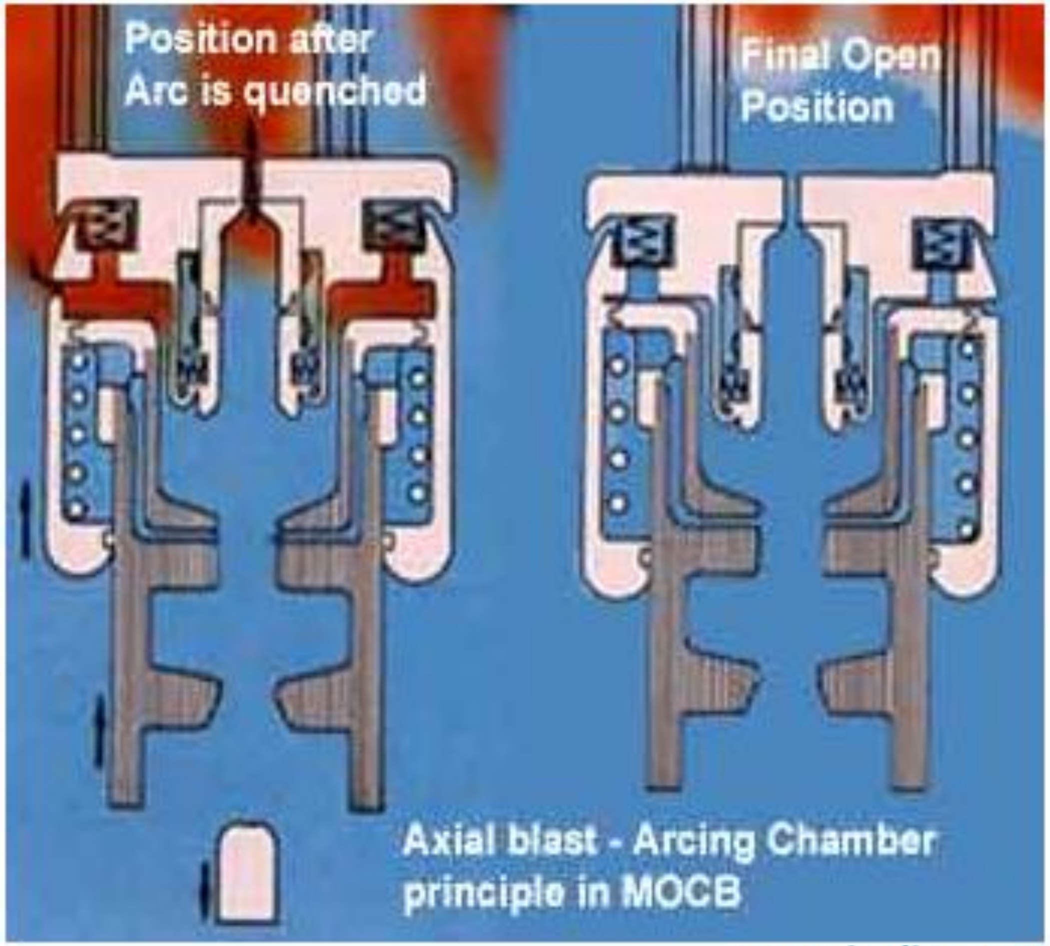
Medidas de control y protecciones

Herrajes

tipo raqueta



Alertas sobre el aislamiento longitudinal



Medidas de control y protecciones

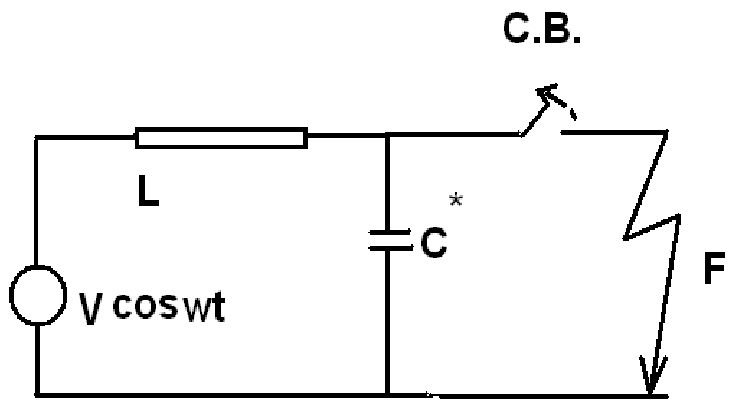
Alertas sobre
el aislamiento longitudinal

rayo sucesivo

Medidas de control y protecciones

Alertas sobre el aislamiento longitudinal

excesivo voltaje de recuperación TRV

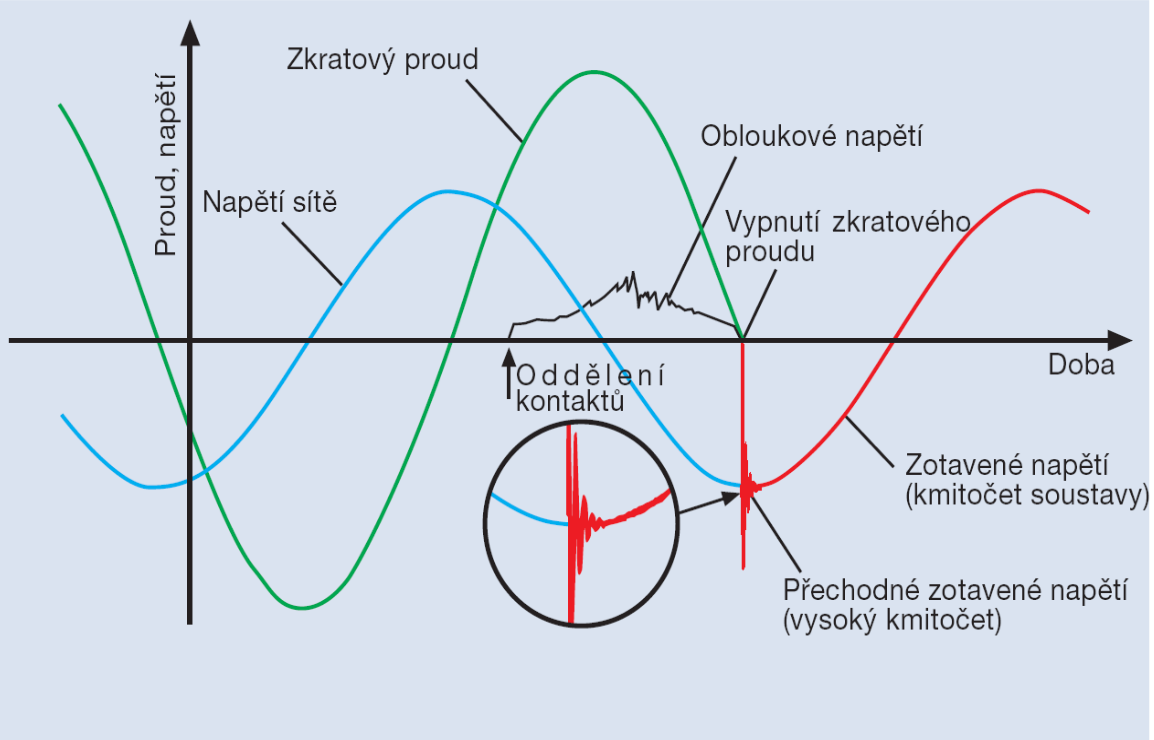


* :
Bushing ,CT, &so

Medidas de control y protecciones

Alertas sobre el aislamiento longitudinal

excesivo voltaje de recuperación TRV



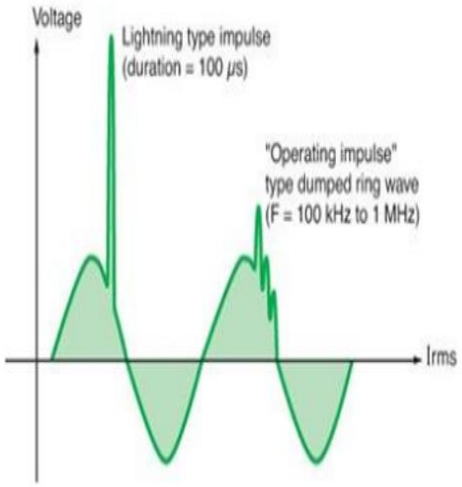
Průběh proudu a napětí během jednofázového vypínání ve vakuu.

Medidas de control y protecciones

Contribución de sistemas conexos

UNIT 2- SWITCHING TRANSIENTS

- OVERVOLTAGES



Medidas de control y protecciones

Engineering Education

Contribución de sistemas conexos

apantallamiento

de las subestaciones

Medidas de control y protecciones

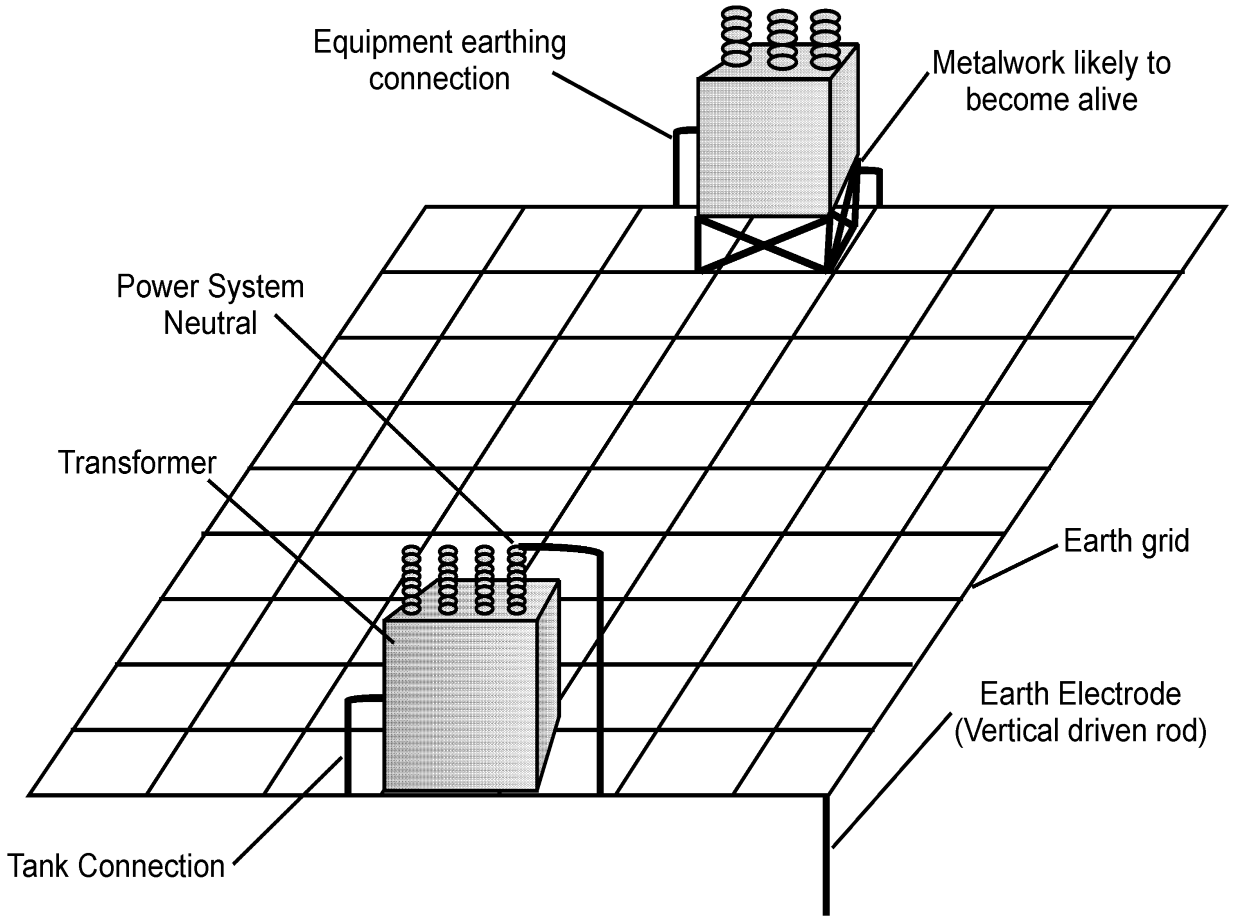
Contribución de sistemas conexos

sistema de puesta a tierra

sistema

torres

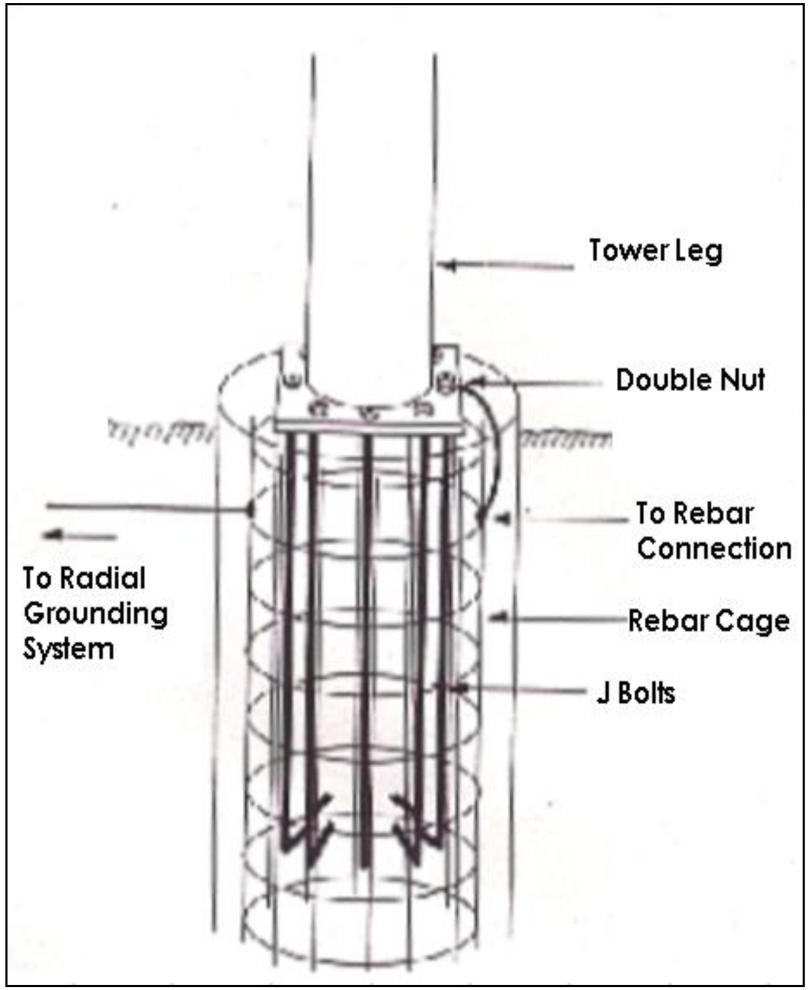
pararrayos



Medidas de control y protecciones

Contribución de sistemas conexos

sistema de puesta a tierra

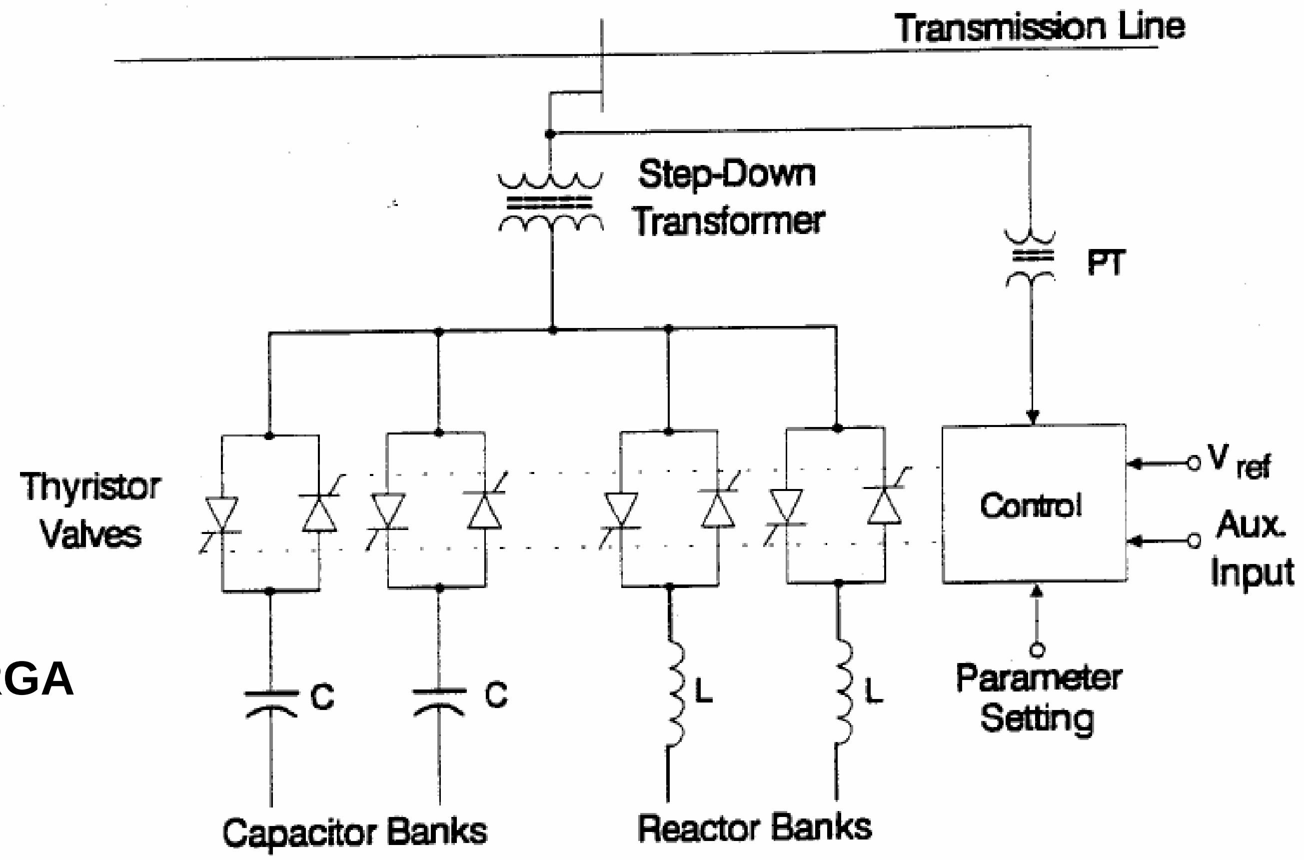


Medidas de control y protecciones

Contribución de sistemas conexos

compensador estático

SOBRETENSIÓN POR RECHAZO DE CARGA



Contribución de sistemas conexos

compensador estático