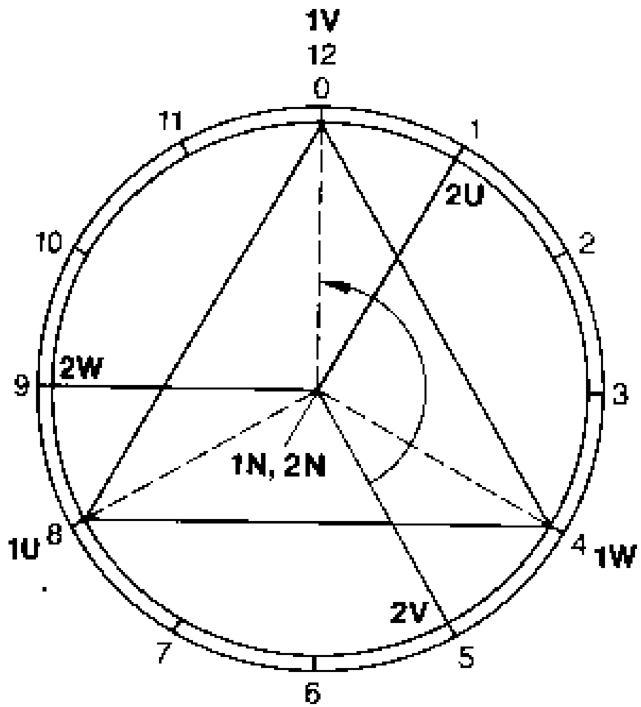
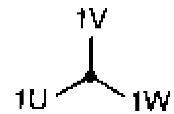
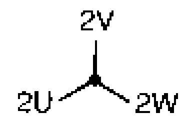
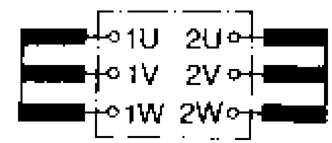
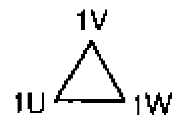
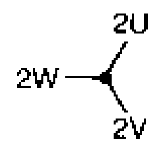
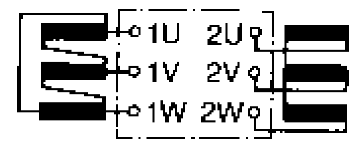
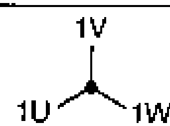
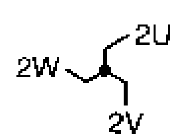
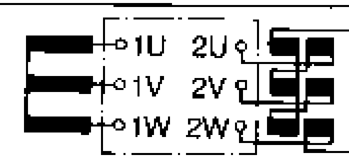


Figura 1.9/1
Determinación del indicativo en el ejemplo del grupo de conexión Dyn5

Tabla 1.9/4 Grupos de conexión preferentes

Designación VDE		Diagrama vectorial		Esquema de conexiones
Indicativo	Grupo de conexión[1])	tension superior	tension inferior	Lado de tensión superior / Lado de tensión inferior
0	Yy 0			
5	Dy 5			
	Yz 5			

[1]) En caso de que se haya extraído el punto estrella debe añadirse detrás del símbolo de conexión del arrollamiento una N o n

Grupos de conexión para transformadores de resina colada

En estos transformadores se utiliza principalmente el grupo de conexión Dyn5.

Tensión de cortocircuito

La tensión de cortocircuito es la existente en el lado de entrada, a la frecuencia nominal, si el lado de salida está en cortocircuito y por el lado de entrada del transformador fluye la corriente que corresponde a la toma del arrollamiento conectada.

Tensión nominal de cortocircuito U_z

La tensión nominal de cortocircuito U_z viene dada por el valor de la tensión de cortocircuito en la toma principal. Como magnitud referida a la tensión nominal U_N, se designa por u_z y se expresa en %.

$$u_z = \frac{U_z}{U_N} \cdot 100\,\%$$

u_z tensión nominal de cortocircuito en %
U_z tensión nominal de cortocircuito en V
U_N tensión nominal en V

Caída de tensión óhmica U_R

La caída de tensión óhmica U_R es la componente activa de la tensión nominal de cortocircuito U_z. Como magnitud relativa se designa por u_R y se obtiene partiendo de las pérdidas por cortocircuito P_k y de la potencia nominal S_N.

$$u_R = \frac{P_k}{S_N} \cdot 100\,\%$$

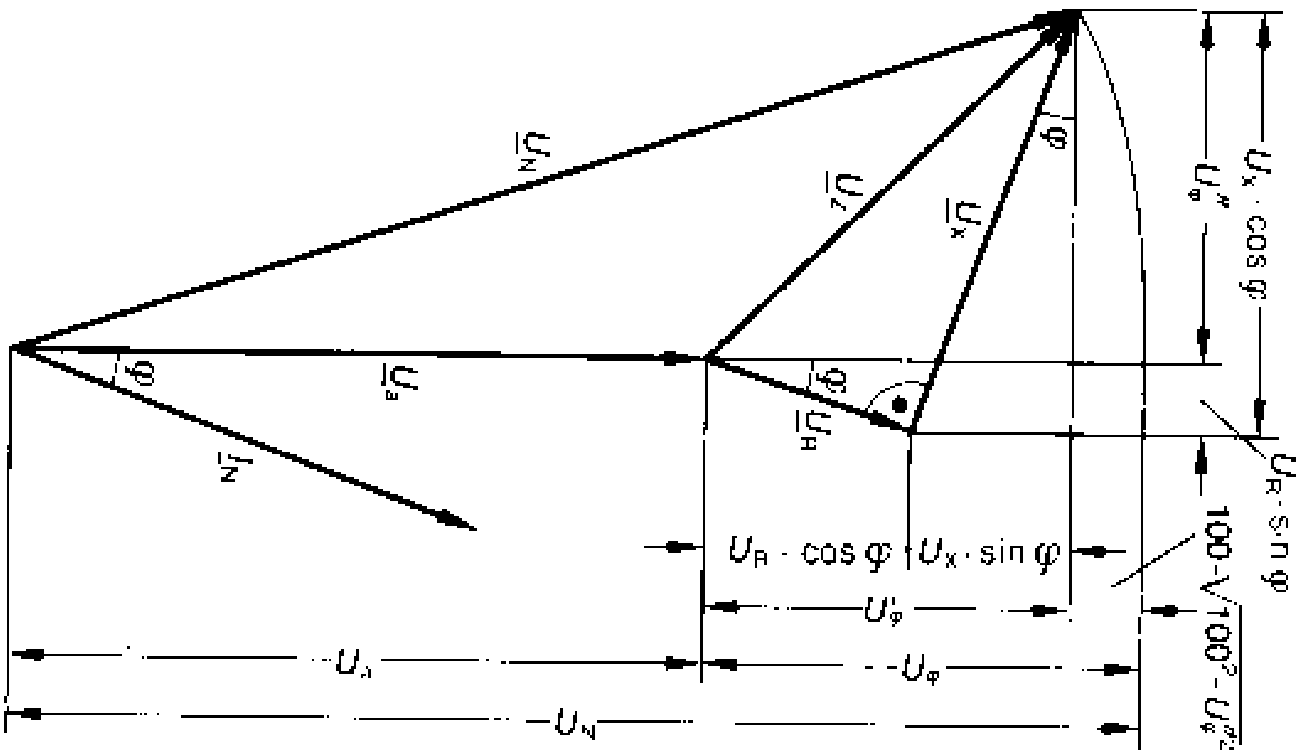
u_R caída de tensión óhmica en %
P_k pérdidas por cortocircuito en kW
S_N potencia nominal en kVA

Tensión de dispersión U_X

La tensión de dispersión U_X es la componente reactiva de la tensión nominal de cortocircuito U_z y se obtiene, como magnitud relativa, partiendo de u_z y u_R.

$$u_X = \sqrt{u_z^2 - u_R^2}$$

u_X tensión de dispersión en %
u_z tensión nominal de cortocircuito en %
u_R caída de tensión óhmica en %



U_N Tensión nominal
U_a Tensión de plena carga
U_z Tensión nominal de cortocircuito
U_X Tensión de dispersión
U_R Caída de tensión óhmica
U_φ Variación de tensión
I_N Intensidad nominal
φ Angulo de fase

Relación de transformación $ü = 1$
Los vectores elegidos no corresponden a los valores reales

La variación de tensión se establece en función de la tensión nominal U_N y se designa por u_φ. Se determina con la siguiente fórmula:

$$u_\varphi = u_\varphi' + 100 - \sqrt{100^2 \quad u_\varphi''^2}\,,$$

$$u_\varphi \approx u_\varphi' + \frac{u_\varphi''^2}{200}\,;$$

siendo

$$u_\varphi' = u_X \cdot \sin\varphi + u_R \cdot \cos\varphi\,,$$

$$u_\varphi'' = u_X \cdot \cos\varphi - u_R \cdot \sin\varphi\,.$$

u_φ Variación de la tensión en %
u_X Tensión de dispersión en %
u_R Caída de tensión óhmica en %
u_z Tensión nominal de cortocircuito en %
φ Angulo de fase

U_N Tensión nominal
U_a Tensión de plena carga
U_z Tensión nominal de cortocircuito
U_X Tensión de dispersión
U_R Caída de tensión óhmica
U_φ Variación de tensión
I_N Intensidad nominal
φ Angulo de fase

Relación de transformación $\ddot{u} = 1$
Los vectores elegidos no corresponden a
los valores reales

Se pretende calcular la tensión a plena carga U_a de un transformador con los siguientes datos: **Ejemplo**

Potencia nominal $S_N = 500$ kVA
Tensión nominal en el lado de salida $U_N = 400$ V
Tensión nominal de cortocircuito $u_z = 6\%$
Pérdidas por cortocircuito $P_k = 7{,}8$ kW
Factor de potencia $\cos\varphi = 0{,}8$

La tensión a plena carga U_a, en V, es:

$$U_a = U_N \cdot \left(1 - \frac{u_\varphi}{100\,\%}\right),$$

siendo $u_\varphi \approx u'_\varphi + \frac{u''^2_\varphi}{200}$

$$u'_\varphi = u_X \cdot \sin\varphi + u_R \cdot \cos\varphi$$
$$u''_\varphi = u_X \cdot \cos\varphi - u_R \cdot \sin\varphi$$
$$u_X = \sqrt{u_z^2 - u_R^2}$$
$$u_R = \frac{P_k}{S_N} \cdot 100\,\%.$$

De este cálculo resultan los siguientes valores numéricos:

$u_R = \frac{7{,}8\ \text{kW}}{500\ \text{kVA}} \cdot 100\,\% = 1{,}56\,\%$, ($u_R$ caída de tensión óhmica en %)

$u_X = \sqrt{6^2 - 1{,}56^2}\,\% = 5{,}79\,\%$, ($u_X$ tensión de dispersión en %)

$u'_\varphi = 5{,}79\,\% \cdot 0{,}6 + 1{,}56\,\% \cdot 0{,}8 = 4{,}72\,\%$,

$u''_\varphi = 5{,}79\,\% \cdot 0{,}8 - 1{,}56\,\% \cdot 0{,}6 = 3{,}7\,\%$,

$u_\varphi = 4{,}72\,\% + \frac{3{,}7^2\,\%}{200} = 4{,}79\,\%$. ($u_\varphi$ variación de tensión en %)

Por consiguiente, la tensión a plena carga es:

$$U_a = 400\ \text{V} \cdot \left(1 - \frac{4{,}79\,\%}{100\,\%}\right) = 380{,}8\ \text{V}.$$

La potencia nominal de los transformadores trifásicos es:

$$S_N = U_N . I_N . \sqrt{3}$$

La potencia aparente de salida

$$S_{AN} = U_a . I_N . \sqrt{3}$$

$$o$$

$$S_{AN} = S_N (1 - \frac{u_\varphi}{100\%})$$

La potencia activa P en Kw

$$P = S_{AN} . \cos\varphi \quad \text{o} \quad P = S_N (1 - \frac{u_\varphi}{100\%}) . \cos\varphi$$

Ejemplo:

Potencia nominal $\mathrm{S_n} = 500KVA$

Tension nominal de cc $\mathrm{u_z} = 6\%$

Factor de potencia $\cos\varphi$= 0,80

Variacion de tension $\mathrm{u_z} = 4,79\%$

$$P = S_N (1 - \frac{u\varphi}{100\%}) \cos\varphi,$$

$$P = 500KVA(1 - \frac{4,79\%}{100}).0,8$$

$$P = 380,8Kw$$

Selección de transformadores

- Datos característicos: Los datos característicos del transformador: potencia nominal, la relación de transformación nominal y la tensión de cc vienen determinados por las condiciones de la red.
- Cálculo de la potencia nominal.- Se considera:
  - El consumo máximo de la potencia activa, determinado durante el proyecto o por medición.
  - Una reserva de potencia
  - El factor de potencia esperado.
  - Y luego se calcula la potencia nominal Sn.
- En las redes de distribución se elige u_z = 4%, para mentener reducida la caída de tensión.
- En las redes industriales de gran potencia se utilizan transformadores con $u_z = 6\%$ debido a las solicitaciones a la que puede ser sometida la instalación en caso de cc.

Servicio en paralelo

- Se distingue entre:
  - Servicio en paralelo de barras colectoras y
  - Servicio en paralelo de redes.
- Para poder realizar un perfecto servicio en paralelo se requiere (sobre todo cuando se trata de barras colectoras)
  - Igual grupo de conexión. YY//YY, DD//DD, YY o DD//YD o DY (no se puede), DY//DY, YD//DY (no es evidente)
  - Igual relación de transformación nominal. Inclusive los taps.
- Tensiones nominales de cc aproximadamente iguales, con lo cual la carga se parte según su capacidad. (No deben diferir en mas del 10%). A ser posible el transformador con la potencia nominal más reducida ha de tener la tensión nominal de cc mayor.
- Es deseable que u_r y u_x sean iguales entre si. Se logra que la potencia total de la unión sea la suma de las potencias individuales de c/trafo.
- Relación entre potencias nominales.
  - En los transformadores a conectar en paralelo no debe ser mayor de 3:1

Tabla 1.9/7
Uniones de los bornes en transformadores con los grupos de conexión del mismo indicativo, por ejemplo, con los indicativos 5 y 11

Indicativo requerido	Indicativo existente	Conexión a las bornas	
		Tensión superior L1 L2 L3	Tensión inferior L1 L2 L3
5	5	1U 1V 1W	2U 2V 2W
	11	1U 1W 1V ó 1W 1V 1U ó 1V 1U 1W	2W 2V 2U 2V 2U 2W 2U 2W 2V
11	11	1U 1V 1W	2U 2V 2W
	5	1U 1W 1V ó 1W 1V 1U ó 1V 1U 1W	2W 2V 2U 2V 2U 2W 2U 2W 2V

La distribución de carga en caso de servicio en paralelo de barras colectoras se determina de manera aproximada con ayuda de las siguientes fórmulas:

$$S_1 = S_{tot} \cdot \frac{S_{N1}}{S_{N1} + S_{N2} + \ldots} \cdot \frac{u_{zd}}{u_{z1}},$$

$$S_2 = S_{tot} \cdot \frac{S_{N2}}{S_{N1} + S_{N2} + \ldots} \cdot \frac{u_{zd}}{u_{z2}},$$

$$S_3 = S_{tot} \cdot \frac{S_{N3}}{S_{N1} + S_{N2} + \ldots} \cdot \frac{u_{zd}}{u_{z3}}.$$

Tensión media de cortocircuito:

$$u_{zd} = \frac{S_{N1} + S_{N2} + \ldots}{\frac{S_{N1}}{u_{z1}} + \frac{S_{N2}}{u_{z2}} + \ldots}$$

S_{tot}	Carga total en kVA	de todos los transformadores en paralelo
u_{zd}	Tensión media de cortocircuito en %	
S_1, S_2, S_3	Carga en kVA	del primer, segundo y tercer transformador en paralelo
S_{N1}, S_{N2}, S_{N3}	Potencia nominal en kVA	
u_{z1}, u_{z2}, u_{z3}	Tensión nominal de cortocircuito en %	

Se pretende conectar en paralelo a barras colectoras de tensión superiore e inferior tres transformadores con las potencias nominales $S_{N1} = 250$ kVA, $S_{N2} = 400$ kVA y $S_{N3} = 630$ kVA. Las tensiones nominales de cortocircuito son $u_{z1} = 3{,}6\%$, $u_{z2} = 4\%$, $u_{z3} = 4{,}4\%$. La carga total S_{tot} ha de ser igual a 1250 kVA.

$$u_{zd} = (S_{N1} + S_{N2} + S_{N3}) : \left(\frac{S_{N1}}{u_{z1}} + \frac{S_{N2}}{u_{z2}} + \frac{S_{N3}}{u_{z3}}\right),$$

$$u_{zd} = (250\,\text{kVA} + 400\,\text{kVA} + 630\,\text{kVA}) : \left(\frac{250\,\text{kVA}}{3{,}6\%} + \frac{400\,\text{kVA}}{4\%} + \frac{630\,\text{kVA}}{4{,}4\%}\right),$$

$$u_{zd} = 4{,}1\%.$$

$$S_1 = S_{tot} \cdot \frac{S_{N1}}{S_{N1} + S_{N2} + S_{N3}} \cdot \frac{u_{zd}}{u_{z1}},$$

$$S_1 = 1250\,\text{kVA} \cdot \frac{250\,\text{kVA}}{250\,\text{kVA} + 400\,\text{kVA} + 630\,\text{kVA}} \cdot \frac{4{,}1\%}{3{,}6\%},$$

$$S_1 \approx 278\,\text{kVA}.$$

$$S_2 = S_{tot} \cdot \frac{S_{N2}}{S_{N1} + S_{N2} + S_{N3}} \cdot \frac{u_{zd}}{u_{z2}},$$

$$S_2 = 1250\,\text{kVA} \cdot \frac{400\,\text{kVA}}{250\,\text{kVA} + 400\,\text{kVA} + 630\,\text{kVA}} \cdot \frac{4{,}1\%}{4\%},$$

$$S_2 \approx 400\,\text{kVA}.$$

$$S_3 = S_{tot} \cdot \frac{S_{N3}}{S_{N1} + S_{N2} + S_{N3}} \cdot \frac{u_{zd}}{u_{z3}},$$

$$S_3 = 1250\ \text{kVA} \cdot \frac{630\ \text{kVA}}{250\ \text{kVA} + 400\ \text{kVA} + 630\ \text{kVA}} \cdot \frac{4{,}1\%}{4{,}4\%},$$

$$S_3 \approx 572\ \text{kVA}.$$

$$S_1 \approx 278\ \text{kVA}$$

$$S_2 \approx 400\ \text{kVA}$$

$$S_3 \approx 572\ \text{kVA}$$

$$S_{tot} \approx 1250\ \text{kVA}$$

Esto significa que el transformador 1, con la menor tensión nominal de cortocircuito, queda sobrecargado en un 11% aproximadamente, mientras que el transformador 3 no presta servicio a plena carga.

Reducción de la carga total en caso de servicio en paralelo

Para aliviar el transformador 1, hay que reducir la carga total y repetir el cálculo. Disminuyendo la carga total, por ejemplo, a 1125 kVA, se obtiene la siguiente distribución de carga:

$$S_1 = 278\ \text{kVA} \cdot \frac{1125\ \text{kVA}}{1250\ \text{kVA}} = 250{,}2\ \text{kVA}$$

$$S_2 = 400\ \text{kVA} \cdot \frac{1125\ \text{kVA}}{1250\ \text{kVA}} = 360{,}0\ \text{kVA}$$

$$S_3 = 572\ \text{kVA} \cdot \frac{1125\ \text{kVA}}{1250\ \text{kVA}} = 514{,}8\ \text{kVA}$$

$$S_{tot} = 1125{,}0\ \text{kVA}$$

Valores orientativos para el accionamiento de cartuchos fusibles HH

Potencia nominal del transformador KVA	Tensión de Servicio				
	3KV	6KV	10KV	20KV	30KV
	Intensidad Nominal del cartucho fusible HH (Amp)				
50	40	25	16	10	6.3
75	63	40	25	16	10
100	63	40	25	16	10
125	63	63	40	25	16
160	100	63	40	25	16
200	100	63	40	25	16
250	100	63	40	25	16
315	100	63	40	25	16
400	..	63	63	25	25
500	..	100	63	40	25
630	..	100	63	40	25
800	..	100	100	40	..
1000	..	..	100	63	..

Duración máxima admisible de los cortocircuitos

Potencia nominal del transformador Sn (KVA)	Intensidad admisible permanente de cc Ik adm (Amp)	Tensión nominal de corto circuito uz %	Duración máxima admisible de cortocircuito s
hasta 630	25*In	4	2
superior a 630 hasta 2500	16.7*In	6	4

Factor de Choque

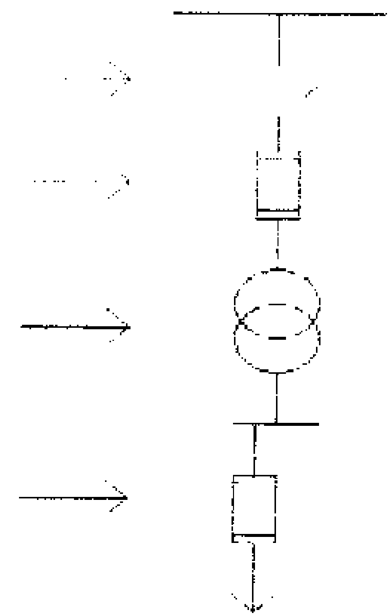
- Is= $I_{k\ adm} * \chi * \sqrt{2}$
- Donde: $\chi = 1.02 + 0.97 e^{-3.1 * R/X}$

X/R	1	1.5	2	3	4	5	6	8	10	15	25	50	Inf.
$\chi * \sqrt{2}$	1.51	1.63	1.75	1.95	2.09	2.19	2.28	2.38	2.46	2.56	2.66	2.75	2.83

TRANSFORMER PROTECTION BASICS

Let us first review the components used in a typical transformer circuit :

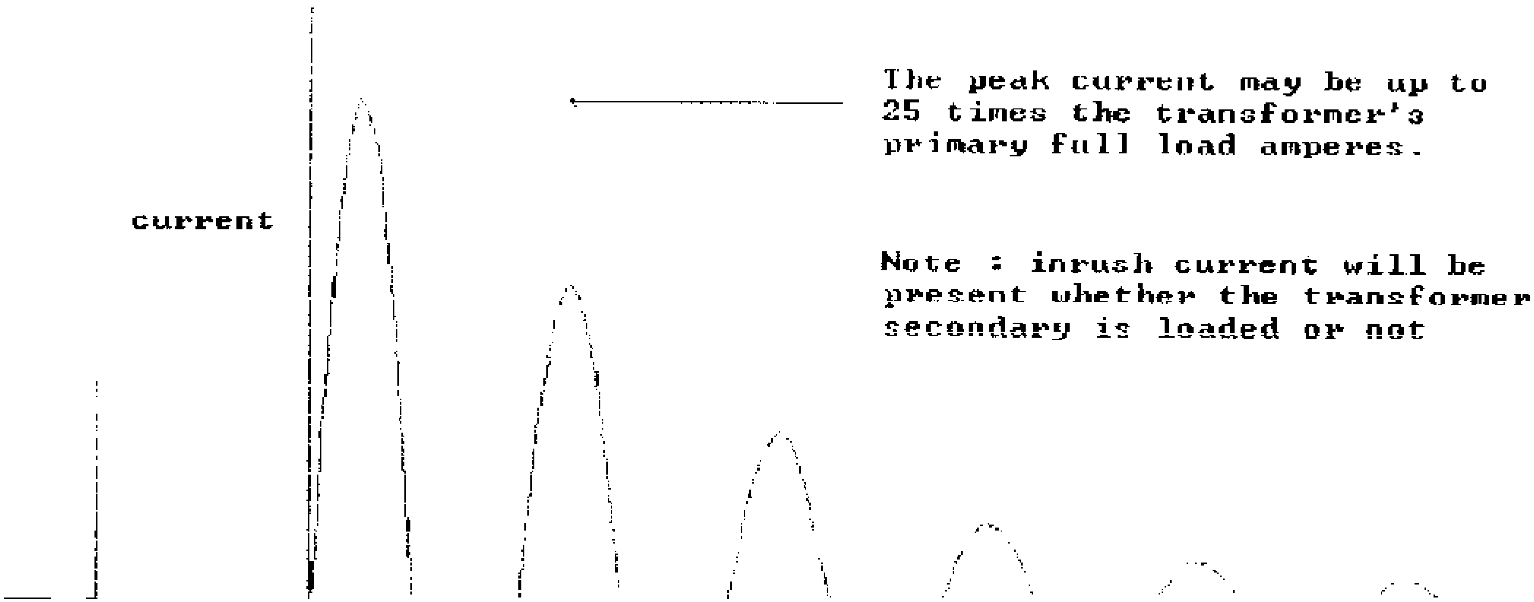
1. Disconnect switch. Used to remove the supply from the transformer primary windings and isolate the circuit for safety or maintenance.
2. Current-limiting fuse. Used to protect the transformer, wiring and other components from from damage by short-circuit faults and possibly overloads.
3. Transformer. Used to raise or lower the voltage of the power distribution system.
4. Secondary current-limiting fuse. Used to protect secondary wiring and other components downstream from damage by overloads or short-circuit faults.

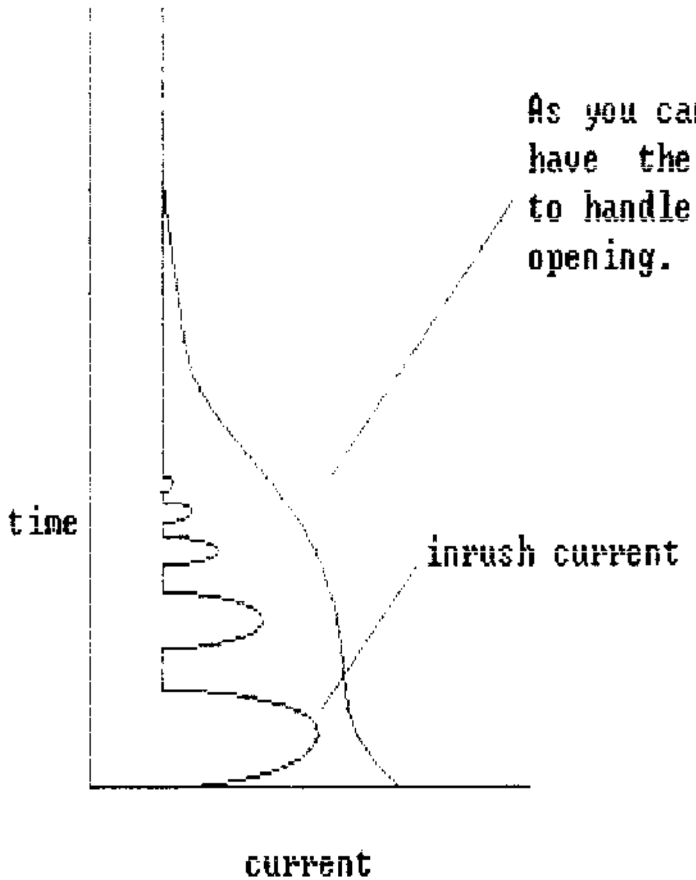


TRANSFORMER CHARACTERISTICS

Transformers come in many different types, shapes and sizes. The m
common are low-voltage 1-phase and 3-phase types. When a transformer
switched on its core may saturate, causing a large inrush of magnetiz
current into the primary winding. The inrush current is greatest dur
the first 1/2 cycle (about 0.01 sec) and then dies away over seve
cycles.

This is illustrated below :

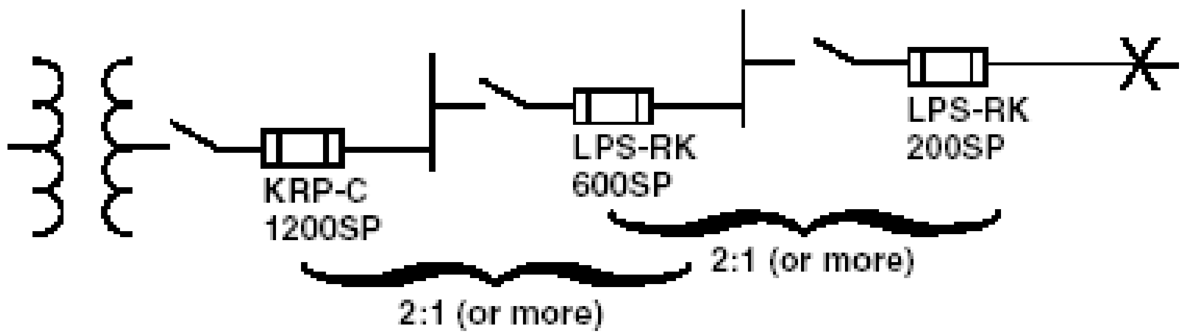




As you can see, time delay fuses have the characteristics needed to handle inrush currents without opening.

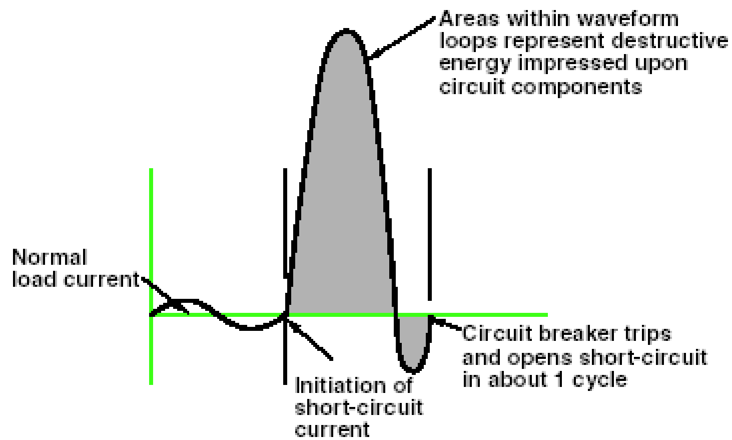
Selective Coordination - Prevention of Blackouts

The coordination of protective devices prevents system power outages or blackouts caused by overcurrent conditions. When only the protective device nearest a faulted circuit opens and larger upstream fuses remain closed, the protective devices are "selectively" coordinated (they discriminate). The word "selective" is used to denote total coordination. . .isolation of a faulted circuit by the opening of only the localized protective device.

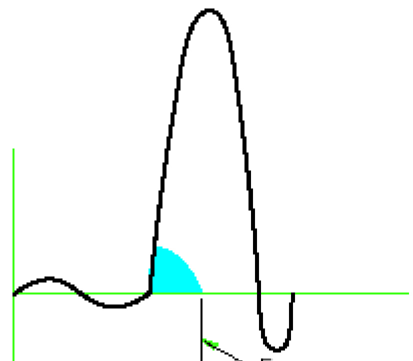


This diagram shows the minimum ratios of ampere ratings of LOW-PEAK® YELLOW fuses that are required to provide "selective coordination" (discrimination) of upstream and downstream fuses.

Current-Limitation - Component Protection



A non-current-limiting protective device, by permitting a short-circuit current to build up to its full value, can let an immense amount of destructive short-circuit heat energy through before opening the circuit.



In its current-limiting range, a current-limiting fuse has such a high speed of response that it cuts off a short-circuit long before it can build up to its full peak value.

Table 450.3(A) Maximum Rating or Setting of Overcurrent Protection for Transformers Over 600 Volts (as a Percentage of Transformer-Rated Current)

		Primary Protection over 600 Volts		Secondary Protection (See Note 2.)		
				Over 600 Volts		600 Volts or Less
Location Limitations	Transformer Rated Impedance	Circuit Breaker (See Note 4.)	Fuse Rating	Circuit Breaker (See Note 4.)	Fuse Rating	Circuit Breaker or Fuse Rating
Any location	Not more than 6%	600% (See Note 1.)	300% (See Note 1.)	300% (See Note 1.)	250% (See Note 1.)	125% (See Note 1.)
	More than 6% and not more than 10%	400% (See Note 1.)	300% (See Note 1.)	250% (See Note 1.)	225% (See Note 1.)	125% (See Note 1.)
Supervised locations only (See Note 3.)	Any	300% (See Note 1.)	250% (See Note 1.)	Not required	Not required	Not required
	Not more than 6%	600%	300%	300% (See Note 5.)	250% (See Note 5.)	250% (See Note 5.)
	More than 6% and not more than 10%	400%	300%	250% (See Note 5.)	225% (See Note 5.)	250% (See Note 5.)

Notes:

1. Where the required fuse rating or circuit breaker setting does not correspond to a standard rating or setting, a higher rating or setting that does not exceed the next higher standard rating or setting shall be permitted.

2. Where secondary overcurrent protection is required, the secondary overcurrent device shall be permitted to consist of not more than six circuit breakers or six sets of fuses grouped in one location. Where multiple overcurrent devices are utilized, the total of all the device ratings shall not exceed the allowed value of a single overcurrent device. If both circuit breakers and fuses are used as the overcurrent device, the total of the device ratings shall not exceed that allowed for fuses.

3. A supervised location is a location where conditions of maintenance and supervision ensure that only qualified persons monitor and service the transformer installation.

4. Electronically actuated fuses that may be set to open at a specific current shall be set in accordance with settings for circuit breakers.

5. A transformer equipped with a coordinated thermal overload protection by the manufacturer shall be permitted to have separate secondary protection omitted.

Table 450.3(B) Maximum Rating or Setting of Overcurrent Protection for Transformers 600 Volts and Less (as a Percentage of Transformer-Rated Current)

Protection Method	Primary Protection			Secondary Protection (See Note 2.)	
	Currents of 9 Amperes or More	Currents Less Than 9 Amperes	Currents Less Than 2 Amperes	Currents of 9 Amperes or More	Currents Less Than 9 Amperes
Primary only protection	125% (See Note 1.)	167%	300%	Not required	Not required
Primary and secondary protection	250% (See Note 3.)	250% (See Note 3.)	250% (See Note 3.)	125% (See Note 1.)	167%

Notes:

1. Where 125 percent of this current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, a higher rating that does not exceed the next higher standard rating shall be permitted.

2. Where secondary overcurrent protection is required, the secondary overcurrent device shall be permitted to consist of not more than six circuit breakers or six sets of fuses grouped in one location. Where multiple overcurrent devices are utilized, the total of all the device ratings shall not exceed the allowed value of a single overcurrent device.

3. A transformer equipped with coordinated thermal overload protection by the manufacturer and arranged to interrupt the primary current shall be permitted to have primary overcurrent protection rated or set at a current value that is not more than six times the rated current of the transformer for transformers having not more than 6 percent impedance and not more than four times the rated current of the transformer for transformers having more than 6 percent but not more than 10 percent impedance.

Selective Coordination

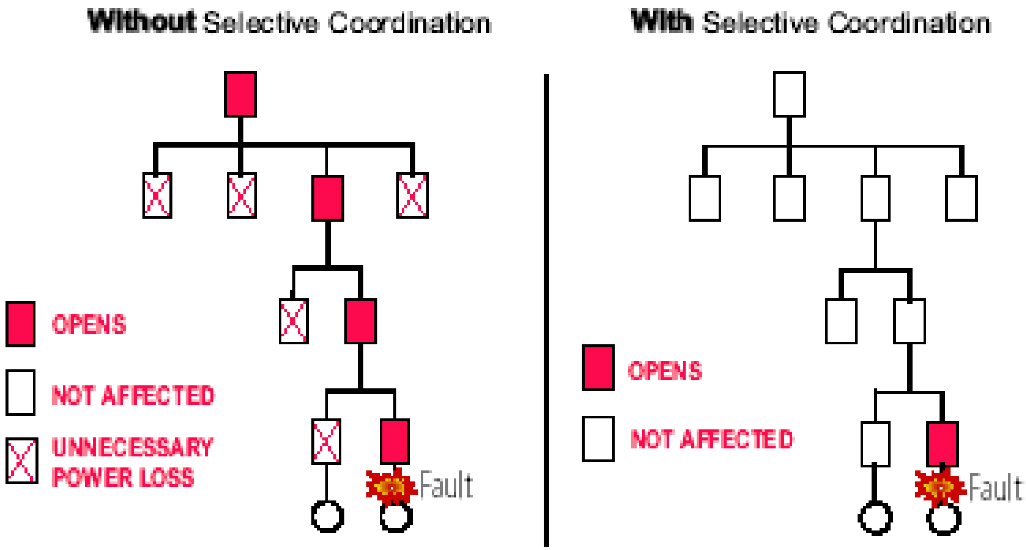
What Is Selective Coordination?

Today, more than ever, one of the most important parts of any installation - whether it is an office building, an industrial plant, a theater, a high-rise apartment or a hospital - is the electrical distribution system. Nothing will stop all activity, paralyze production, inconvenience and disconcert people and possibly cause a panic more effectively than a major power failure.

ISOLATION of a faulted circuit from the remainder of the installation is MANDATORY in today's modern electrical systems. Power BLACKOUTS CANNOT be tolerated.

We may then define selective coordination as "THE ACT OF ISOLATING A FAULTED CIRCUIT FROM THE REMAINDER OF THE ELECTRICAL SYSTEM, THEREBY ELIMINATING UNNECESSARY POWER OUTAGES. THE FAULTED CIRCUIT IS ISOLATED BY THE SELECTIVE OPERATION OF ONLY THAT OVERCURRENT PROTECTIVE DEVICE CLOSEST TO THE OVERCURRENT CONDITION."

Selective Coordination: Avoids Blackouts

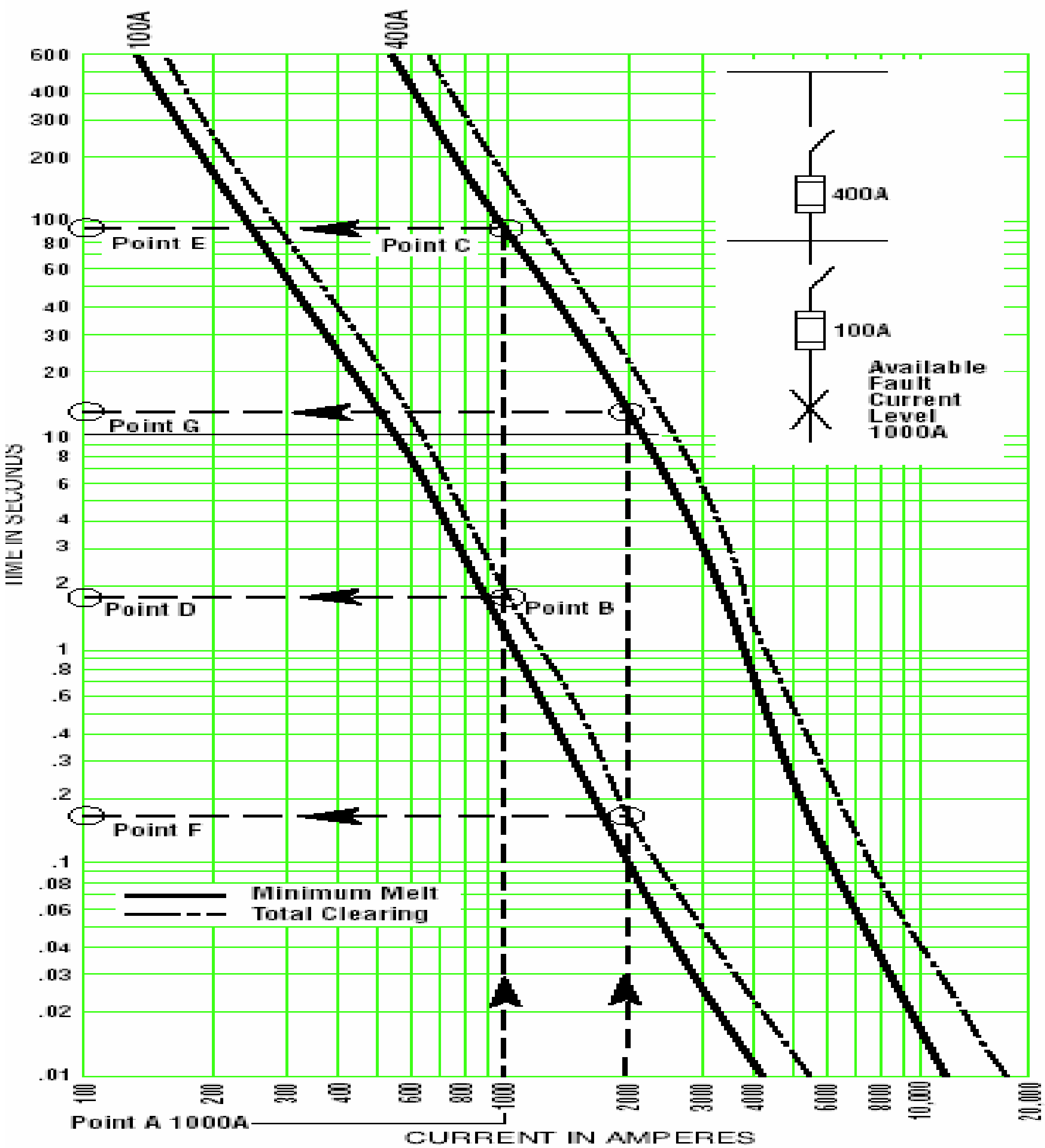


Coordination Analysis

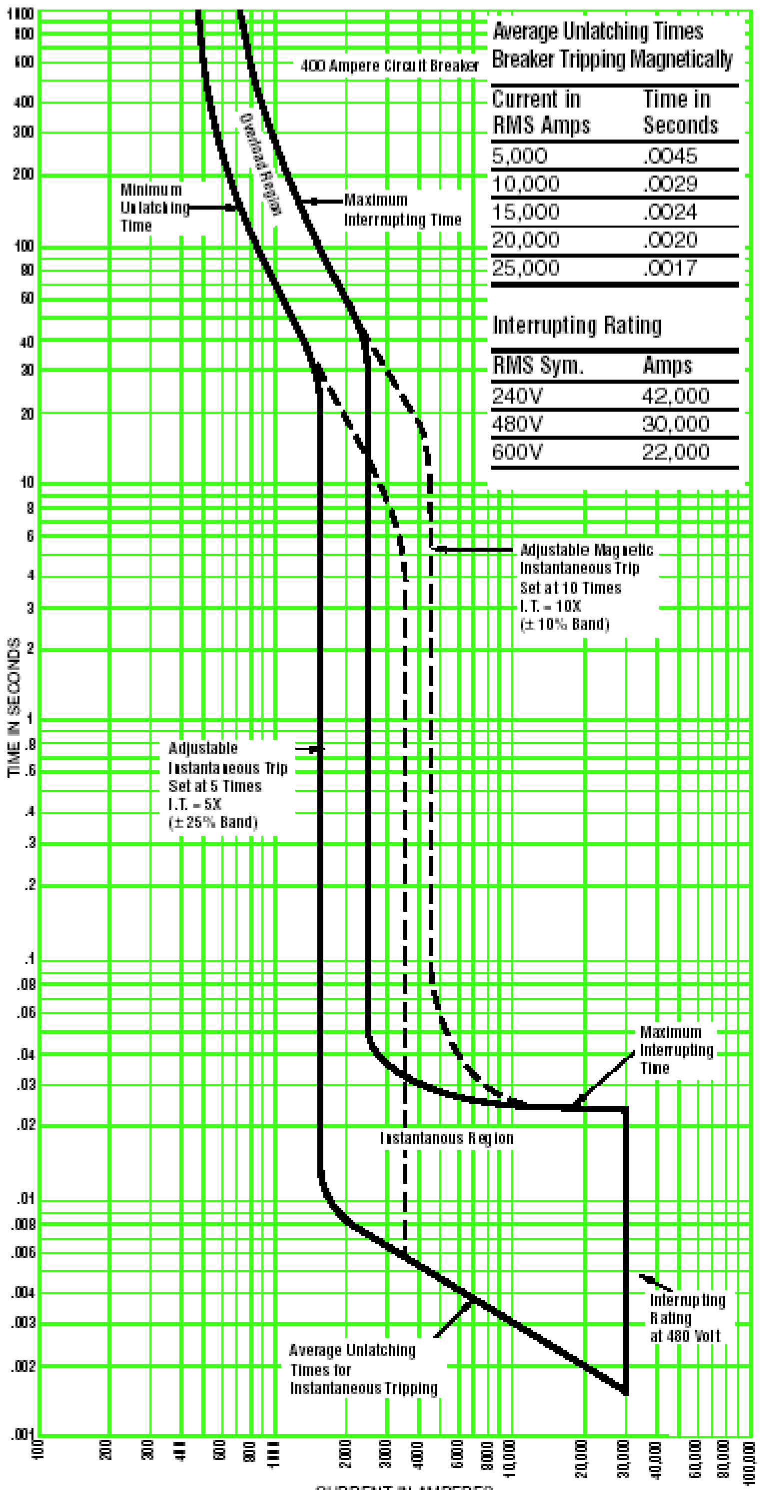
The next several pages cover coordination from various perspectives. The major areas include:

Fuse curves
Fuse selective coordination analysis
Circuit breaker curves
Circuit breaker coordination analysis
Ground Fault Protection–coordination

Fuse Selective Coordination



Typical Circuit Breaker Time-Current Characteristic Curve



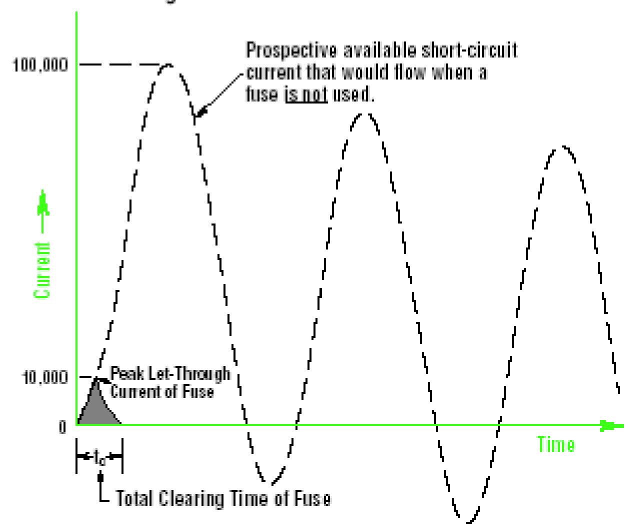
Average Unlatching Times Breaker Tripping Magnetically

Current in RMS Amps	Time in Seconds
5,000	.0045
10,000	.0029
15,000	.0024
20,000	.0020
25,000	.0017

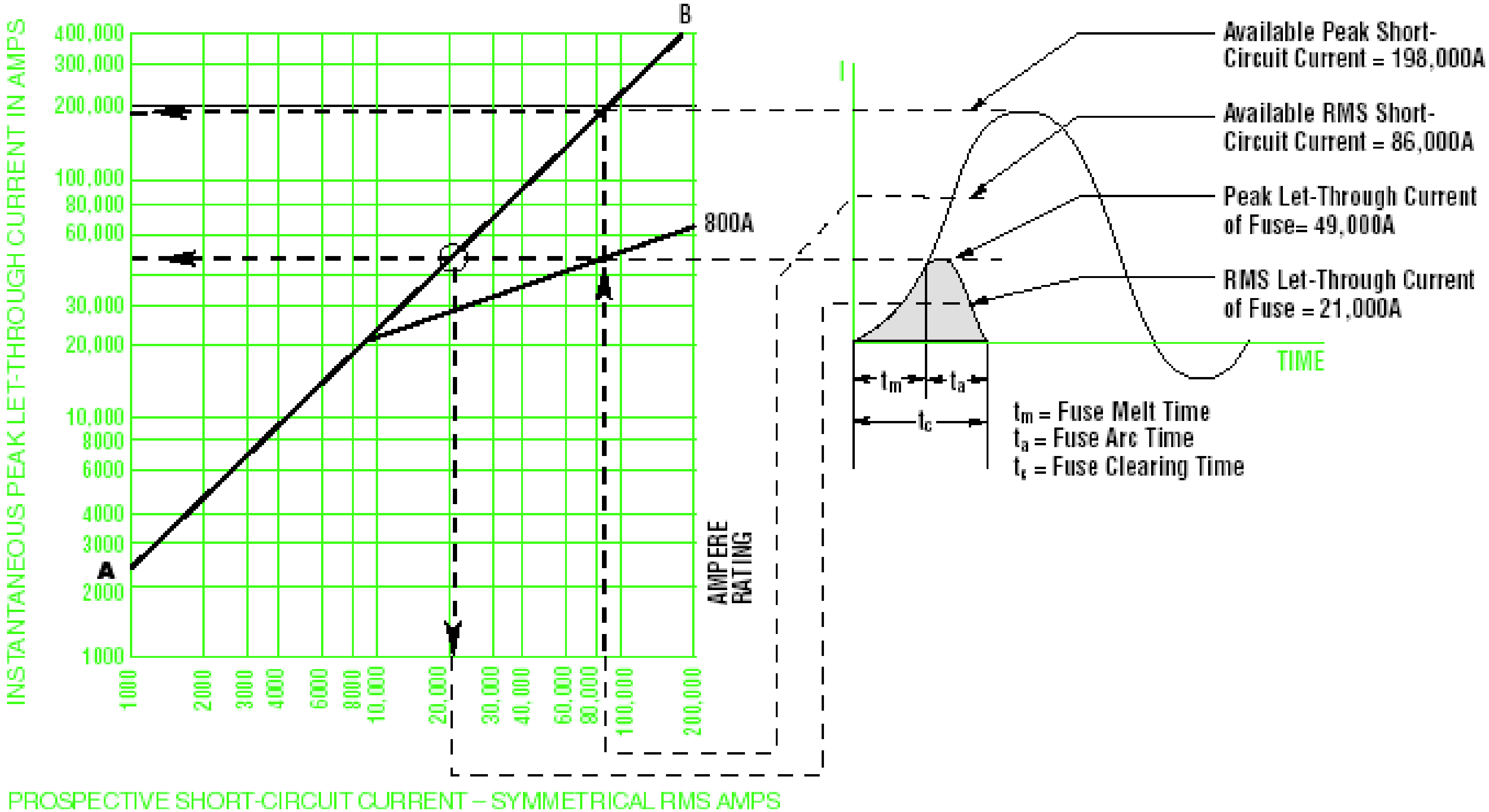
Interrupting Rating

RMS Sym.	Amps
240V	42,000
480V	30,000
600V	22,000

Current-Limiting Effect of Fuses



Analysis of a Current-Limiting Fuse



LOADS PRODUCING HARMONIC CURRENTS

- Electronic Lighting Ballast
- Electric Arc Furnaces
- Electric Welding Equipment
- Industrial Process Controls
- Saturated Transformers
- Medical Equipment
- Adjustable Speed Drives
- Personal Computers
- Solid State Rectifiers
- UPS Systems
- Solid State Elevator Controls

Harmonic: A sinusoidal waveform with a frequency that is an integral multiple of the fundamental 60 Hz frequency.

60 Hz fundamental
120 Hz 2nd harmonic
180 Hz 3rd harmonic
240 Hz 4th harmonic, etc.

Triplen Harmonics: Odd multiple of the 3rd harmonic (3rd, 9th, 15th, 21st, etc.)

Harmonic Distortion: Non-linear distortion of a system characterized by the appearance in the output of harmonic currents (voltages) when the input is sinusoidal.

Voltage Harmonic Distortion (VHD): Voltage harmonic distortion is distortion caused by harmonic currents flowing through the system impedance. The utility power system has relatively low system impedance, and the VHD is very low. VHD on the distribution power system can be significant due to its relatively high system impedance. $E + I^2R$ Ohm's Law

Total Harmonic Distortion (THD): The square root of the sum of the square of all harmonic currents present in the load excluding the 60 Hz fundamental. It is usually expressed as a percent of the fundamental.

Harmonic Spectrum "K" Factor: The sum of the product of each harmonic current squared and that harmonic number squared for harmonics from the fundamental (60 Hz) to the highest harmonic of any measurable consequence. When the "K" factor is multiplied by the stray losses of the transformer, the answer represents the loss in the transformer caused by harmonic currents. When these losses are added to the I^2R losses of the transformer, the total load losses are known.

K-Factor By Type of Load

K-1	Resistance Heating Incandescent Lighting Electric Motors Control Transformers Distribution Transformers	K-13	Telecommunications Equipment Branch Circuits in Classrooms Health Care Facilities
K-4	Welders Induction Heaters HID Lighting Fluorescent Lighting Solid State Controls	K-20	Main Frame Computers AC Variable Speed Drives Circuits With DP Equipment Personal Computers Computer Terminals

The Following are steps to take in alleviating the many problems encountered when harmonics are present in an electric distribution system.

1. Inventory all equipment that may generate harmonic currents.
2. List the nonlinear loads which are on each branch circuit.
3. Record true RMS current in each phase at the service entrance.
4. Record the neutral current of the transformer secondary.
5. Compare the measured neutral current to the anticipated current due to phase imbalance. If the phase currents are equal, the vector sum of the neutral currents will add up to zero. If excessive amounts of triplen harmonics are present in the neutral, neutral current may exceed phase current. Consult the NEC® for the maximum capacity for each of the conductors that have been measured.
6. Measure each feeder for harmonic content. A high degree at this location is often heard as a buzzing sound. A voltage THD reading is also useful at this location.

One option in distribution system if harmonics are present is to de-rate the transformer supplying the system. De-rating K factors can be applied specifically to transformers to ensure dangerous heating will not result when supplying load currents which are rich in harmonic content.
The K factor is determined by measuring the True RMS current of each harmonic, multiplied by the harmonic order and squared. The total sum is then multiplied by the eddy current losses. The K factor of a transformer should be thought of as the index of the transformer's ability to handle nonlinear load currents without abnormal heating.
The alternate method for de-rating transformers is for buildings which supply single phase, 120 VAC receptacles. This method is established by The Computer & Business Equipment Manufacturers Associations (CBEMA).

CBEMA De-rating Factor = 1.414 divided by Crest Factor

Crest Factor (CF) = Peak Value divided by RMS Value

De-rating certain types of electrical equipment is the easiest way to limit the effects increased heating has on equipment. A 25% de-rating for transformers and generators is commonly employed in industry.
Filtering is currently the most common method used to limit the effects that harmonics present to the rest of the system. Filters typically consist of tuned series L-C circuits. Filter impedance is negligible with respect to the rest of the distribution system. These filter products are commercially available under different trade names. Most filter products are no more than 50% effective. The best solution is to install transformers, with the appropriate K rating and wiring that is sized to meet the equipment and systems needs.