

# INTRODUCTION TO ELECTRIC MACHINES

1 Magnetic circuits theory

2 **Transformers**

Most pictures come from Jesús Fraile Mora "Máquinas Eléctricas" 5ª ed. 2003, McGraw Hill

1

2

## TRANSFORMERS

- **Actual transformers**

- Accessories

- Transformer model

- Special transformers

2

# ACTUAL TRANSFORMERS

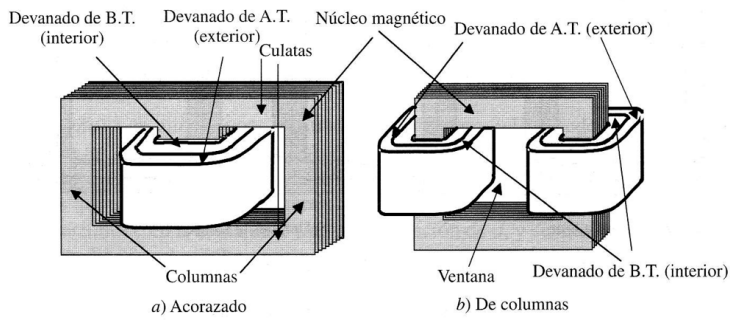


Figura 3.1. Circuitos magnéticos de transformadores monofásicos.

Three-phase  
power  
transformer

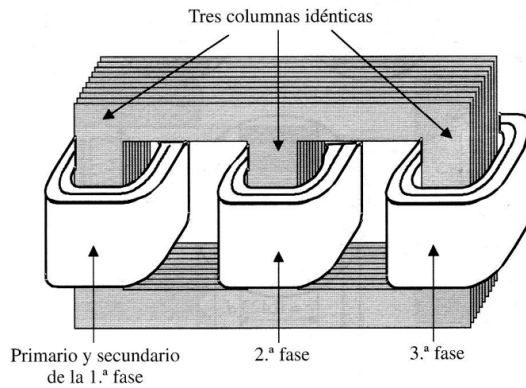
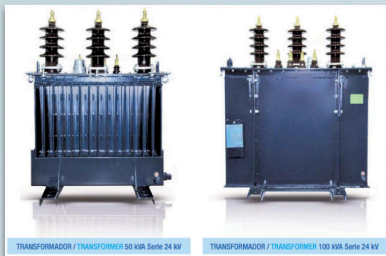
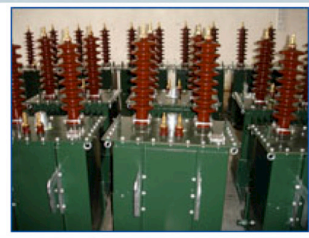
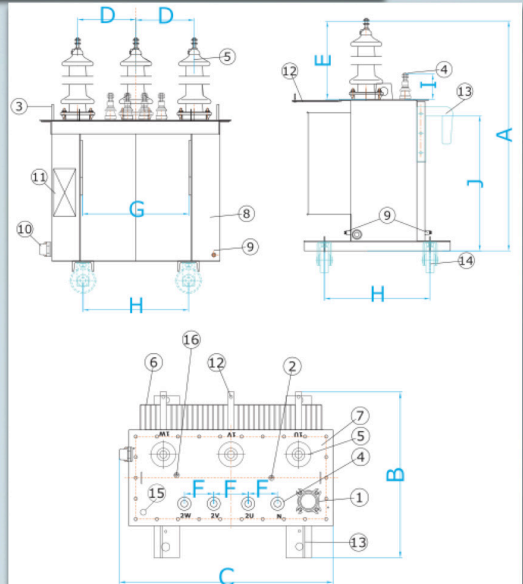


Figura 3.2. Circuito magnético y devanados de un transformador trifásico.

# ACTUAL TRANSFORMERS



Distribution  
power  
transformers  
24 kV up to  
160 kVA



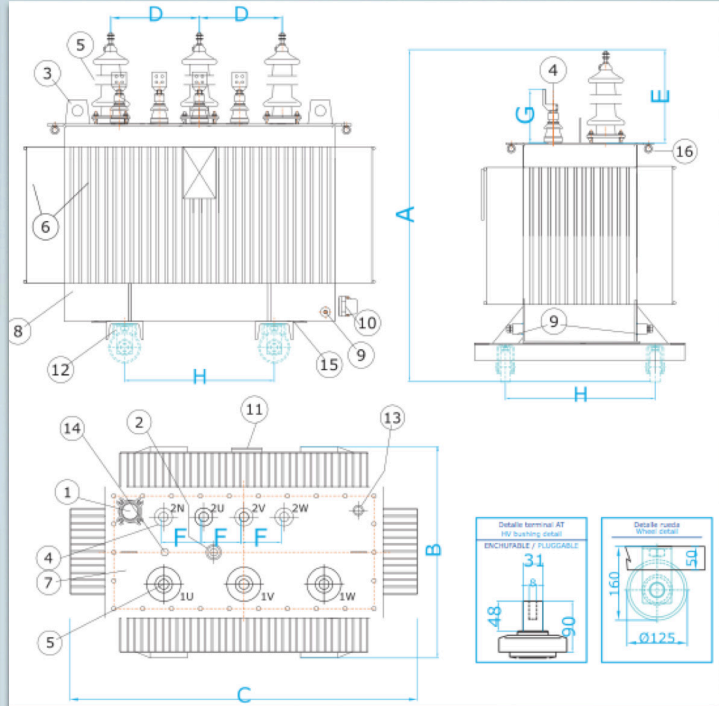
**DIMENSIONES Y PESOS / DIMENSIONS AND WEIGHTS Serie 24 kV**

POTENCIA / POWER kVA	A mm	B mm	C mm	D mm	E mm	F mm	G mm	H mm	I mm	VOL. ACETE / OIL L	PESO / MASS kg
50	1160	740	850	275	385	80	420	520	125	110	400
100	1240	740	960	275	385	80	420	520	125	140	610
160	1280	830	1000	275	385	80	420	520	125	190	770



# ACTUAL TRANSFORMERS

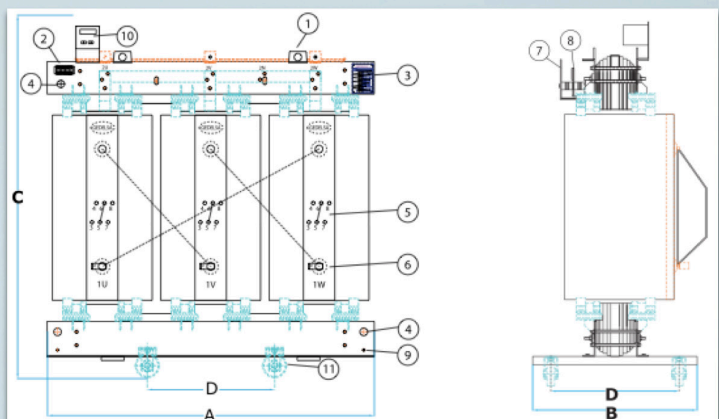
Distribution power transformers: 24 kV up to 2500 kVA



DIMENSIONES Y PESOS / DIMENSIONS AND WEIGHTS Serie 24 kV												
POTENCIA / POWER kVA	A				E				VOL. ACEITE / OIL L	PESO / MASS kg		
	PA mm	PE mm	B mm	C mm	PA mm	PE mm	F mm	G mm				
250	1485	1300	910	1250	275	385	90	150	220	520	230	950
400	1575	1410	1020	1450	275	385	90	150	220	670	300	1300
630	1645	1530	1140	1600	275	385	90	150	270	670	360	1700
800	1665	1550	1180	1750	275	385	90	150	270	670	420	1900
1000	1810	1700	1180	1860	275	385	90	150	335	670	500	2200
1800	1960	1850	1500	2200	275	385	90	200	360	820	1000	3800
2500	2200	2090	1850	2500	275	385	90	200	400	1070	1500	6000

# ACTUAL TRANSFORMERS

Dry type power transformers



# ACTUAL TRANSFORMERS

## Core

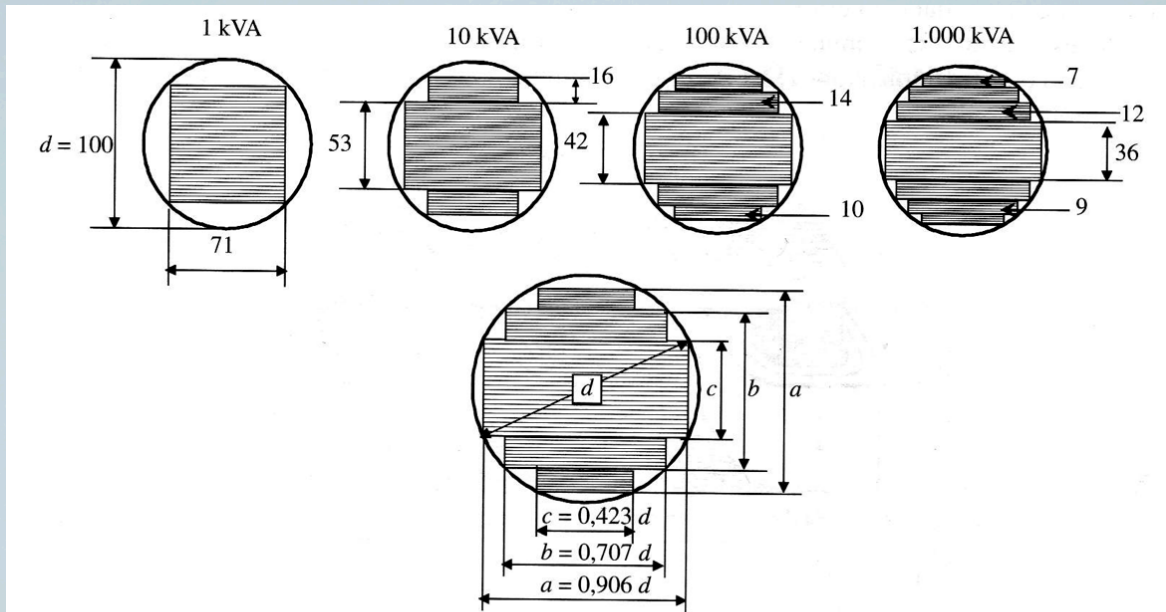


Figura 3.4. Núcleos de transformador tipo cruciforme.

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# ACTUAL TRANSFORMERS

## Windings

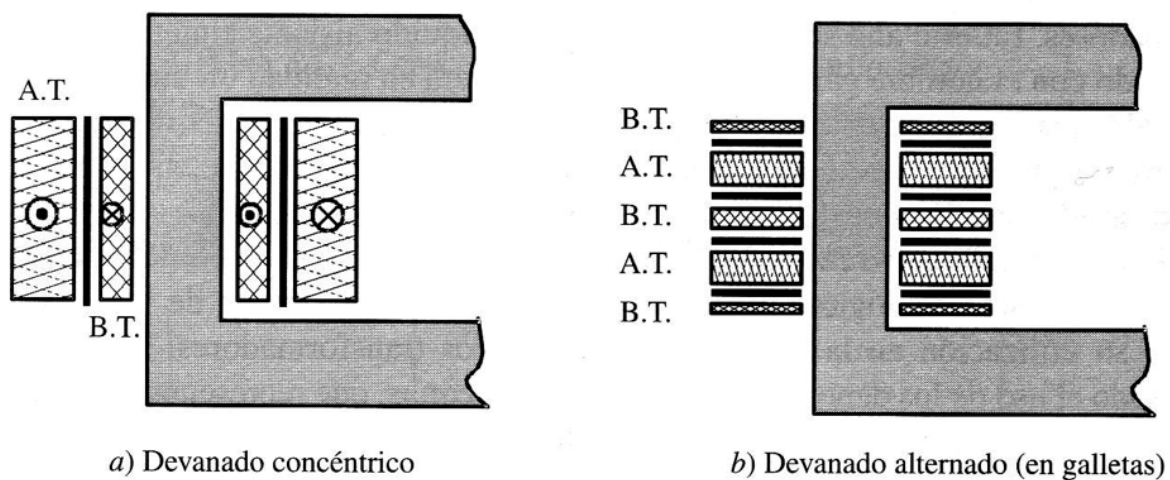


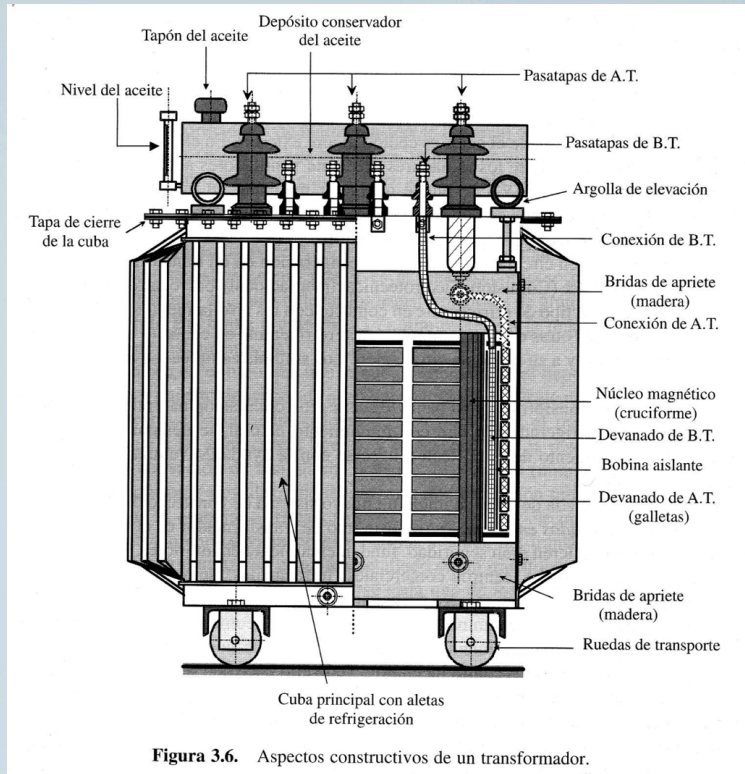
Figura 3.5. Devanados concéntricos y alternados.

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# ACTUAL TRANSFORMERS

Transformer parts and accessories



# TRANSFORMER MANUFACTURING

## Manufacturing Systems

- 1 Magnetic Circuit (core)
- 2 Coils
- 3 Coils in Dry Transformers
- 4 Tank
- 5 Laboratory

1

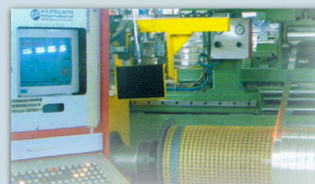
2

3

4

5

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Please visit [www.gedelsa.es](http://www.gedelsa.es)  
[youtube: TrafosGedelsa](https://www.youtube.com/channel/UC...)

# 2

# TRANSFORMERS

- Actual transformers

- **Accessories**

- Transformer model

- Special transformers

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## ACTUAL TRANSFORMERS

Relay  
Buchholz

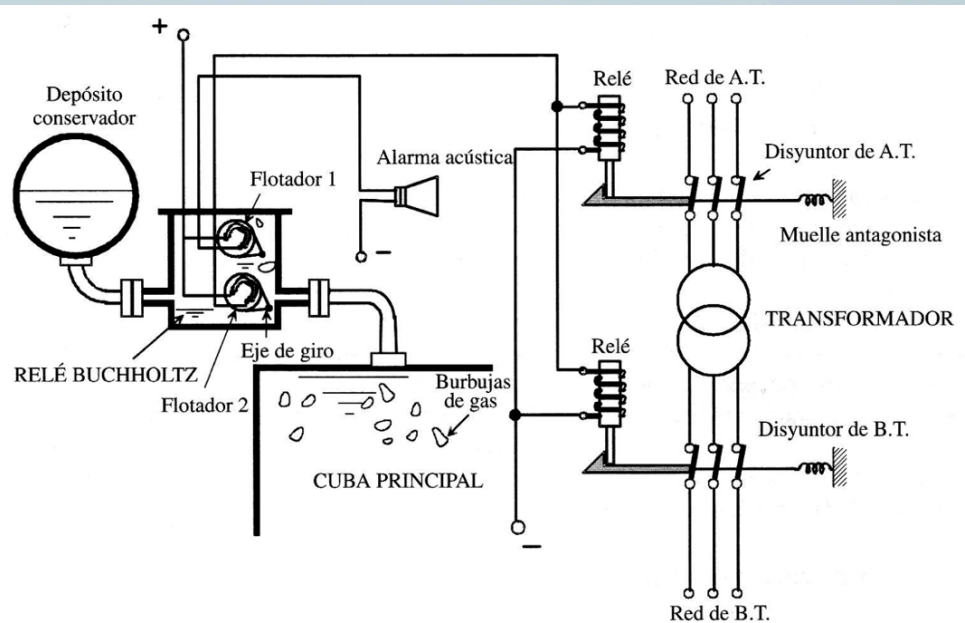


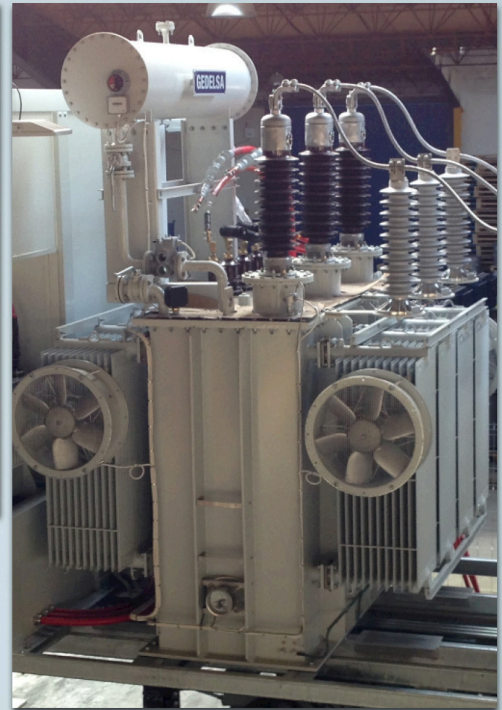
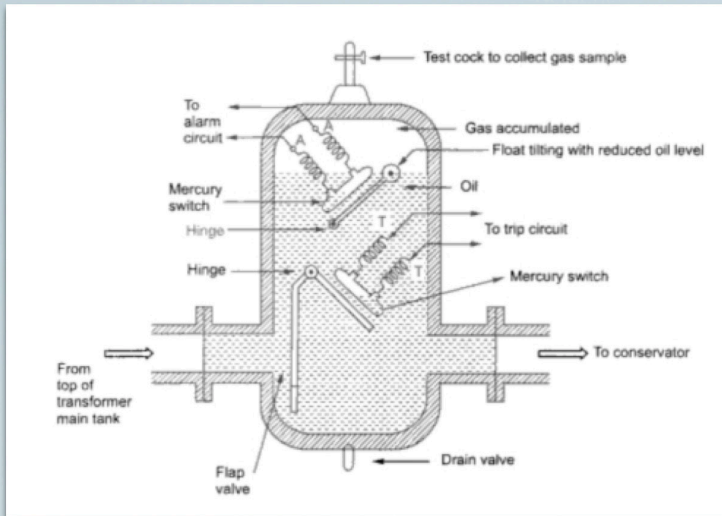
Figura 3.7. Relé Buchholz y esquema eléctrico de protección.

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# ACCESSORIES

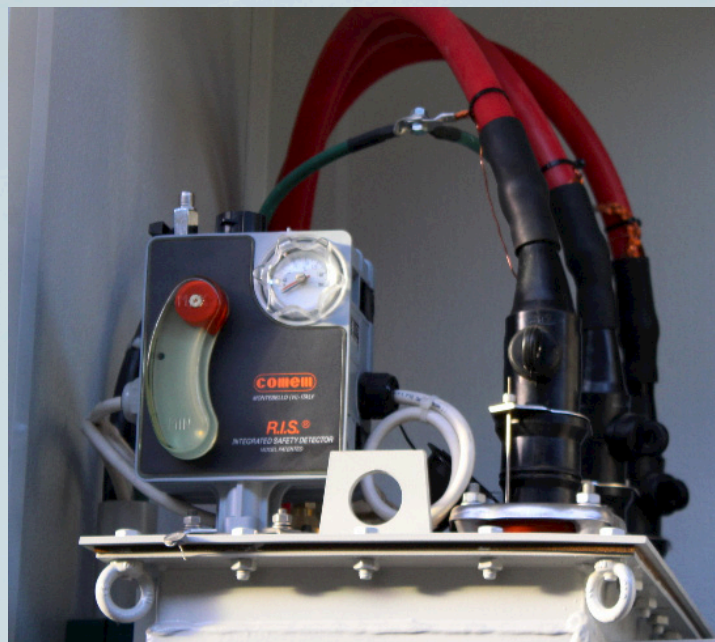
## Relay Buchholz



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# ACCESSORIES

## Relay DGPT2



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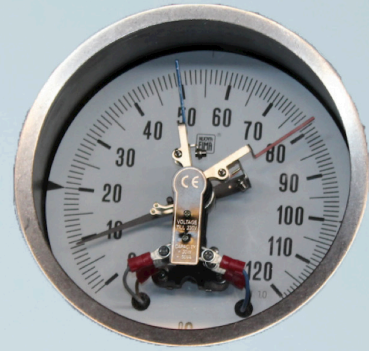
# ACCESSORIES



Oil level indicator



Current transformers

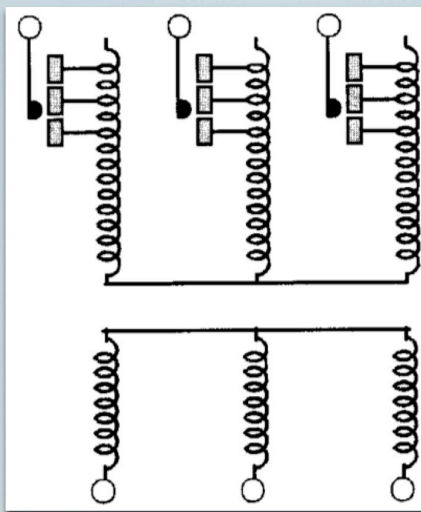


Alarm & trip thermometer

Others...

# ACCESSORIES

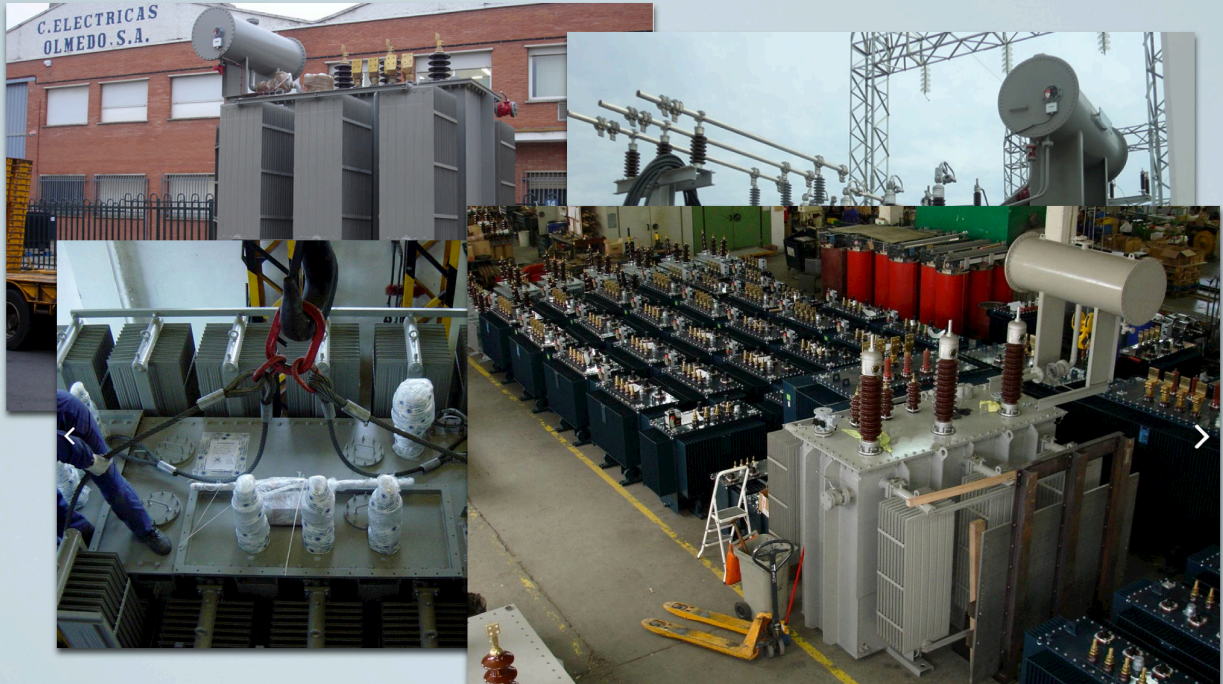
On-load tape changer  
Off-load tape changer





# MEDIUM & BIG TRANSFORMERS

Oil filled power transformers



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# MEDIUM & BIG TRANSFORMERS

Mobile power substations

PSF 60 kV / 5.5 kV - 5 MVA



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# 2

# TRANSFORMERS

- Actual transformers

- Accessories

- Transformer model**

- Special transformers

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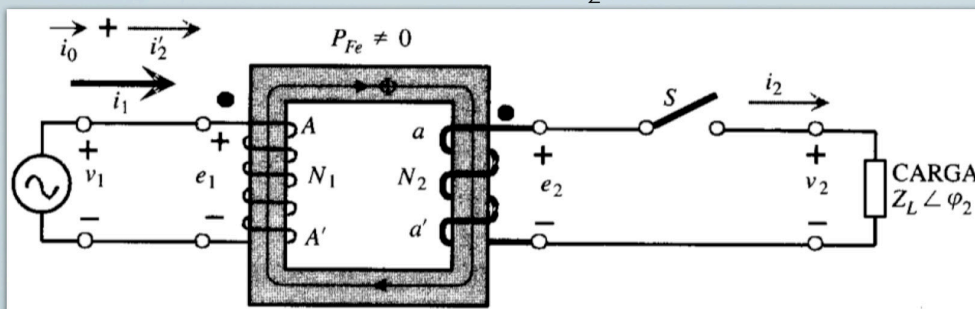
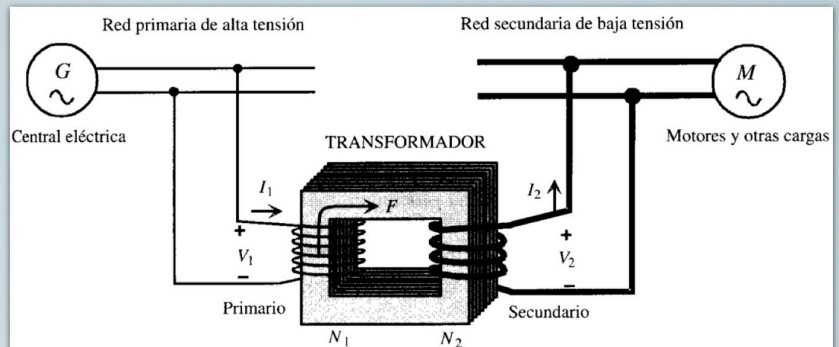
## TRANSFORMER ELECTRICAL MODEL

$$e_1 = N_1 \frac{d\Phi}{dt}; \quad e_2 = N_2 \frac{d\Phi}{dt}$$

$$\frac{e_1}{e_2} = \frac{N_1}{N_2}; \quad \text{if } \begin{cases} V_1 = e_1 \\ V_2 = e_2 \end{cases}$$

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = m$$

if  $P_1 = P_2 \rightarrow v_1 i_1 = v_2 i_2; \quad i_2 = i_1 \frac{v_1}{v_2} = m i_1$  Single phase ideal transformer

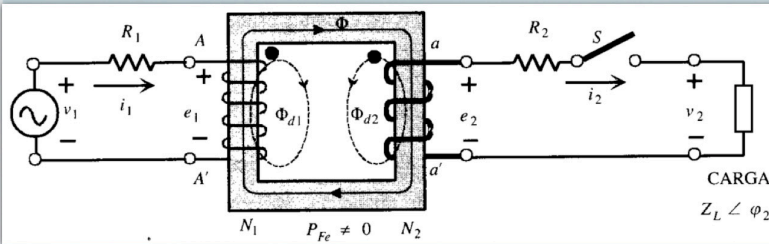


$$\bar{I}_1 = \bar{I}_0 + \frac{\bar{I}_2}{m}$$

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# TRANSFORMER ELECTRICAL MODEL

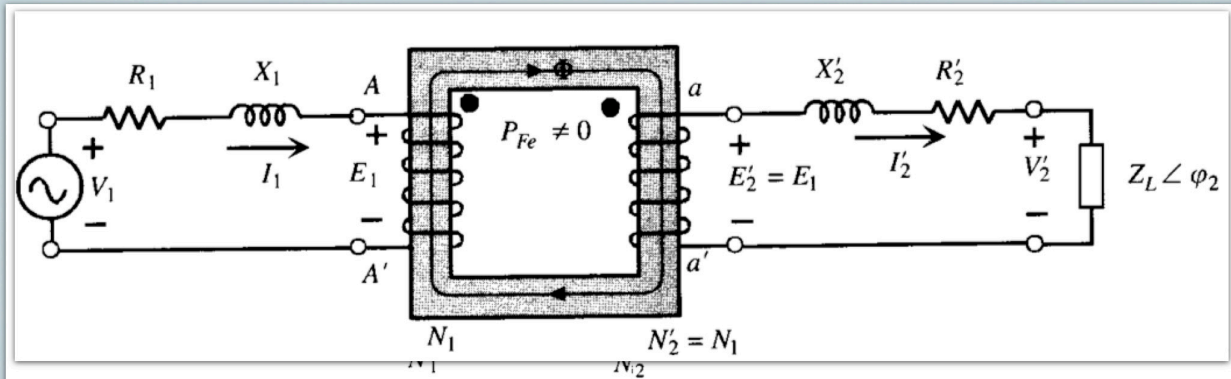


$$\Phi_1 = \Phi + \Phi_{d1}; \quad \Phi_2 = \Phi + \Phi_{d2}$$

$$L_{d1} = N_1 \frac{d\Phi_{d1}}{di_1} \rightarrow X_1 = L_{d1} \omega$$

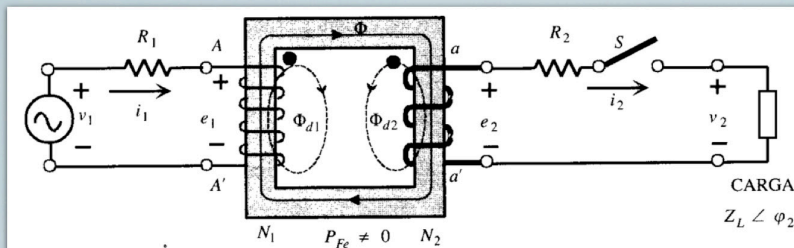
$$L_{d2} = N_2 \frac{d\Phi_{d2}}{di_2} \rightarrow X_2 = L_{d2} \omega$$

Real transformer with series resistances and dispersion magnetic fluxes in both windings



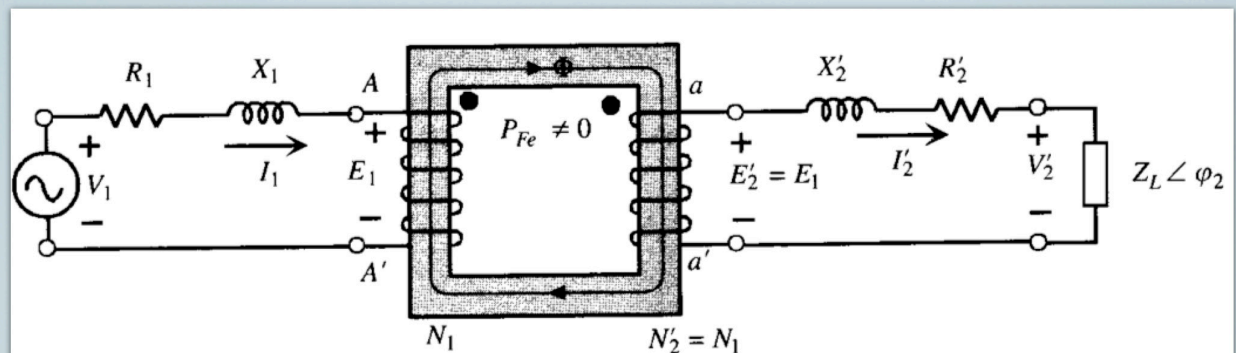
Similar model with extra inductances

# TRANSFORMER ELECTRICAL MODEL



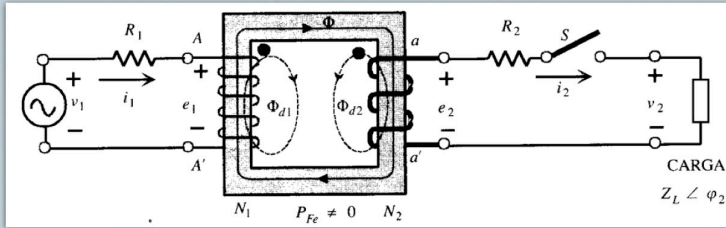
Equivalent electrical circuit:

Reduction of both windings to the same turns number



$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = m; \quad \text{if } N'_2 = N_1: \quad \frac{E_1}{E'_2} = \frac{N_1}{N'_2} = 1; \quad E'_2 = E_1 = m E_2$$

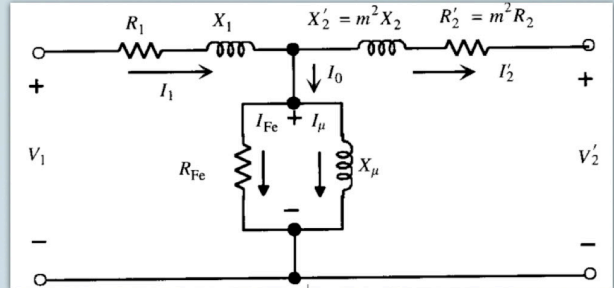
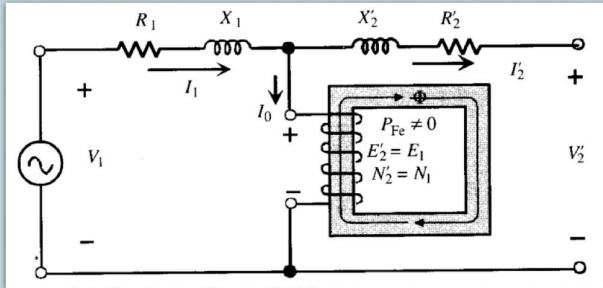
# TRANSFORMER ELECTRICAL MODEL



Equivalent electrical circuit:

Reduction of both windings to the same turns number

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = m; \text{ if } N'_2 = N_1; \frac{E_1}{E'_2} = \frac{N_1}{N'_2} = 1; E'_2 = E_1 = m E_2$$



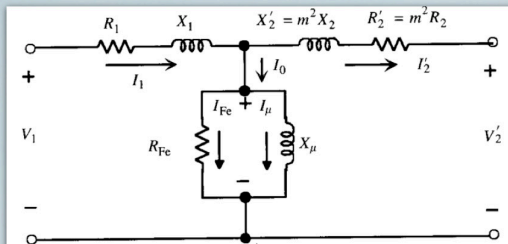
$$V'_2 = m V_2; \quad R'_2 = m^2 R_2; \quad I'_2 = \frac{I_2}{m}$$

$$X'_2 = m^2 X_2; \quad \bar{Z}'_L = m^2 \bar{Z}_L;$$

Equivalent electrical circuit reduced to the primary side because  $N'_2 = N_1$

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# TRANSFORMER ELECTRICAL MODEL



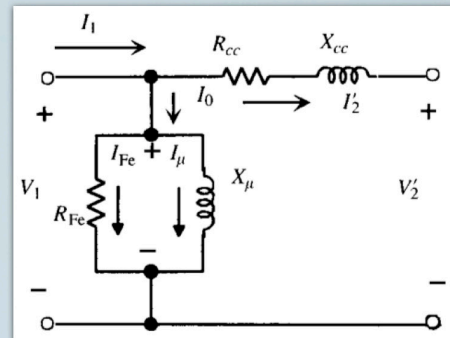
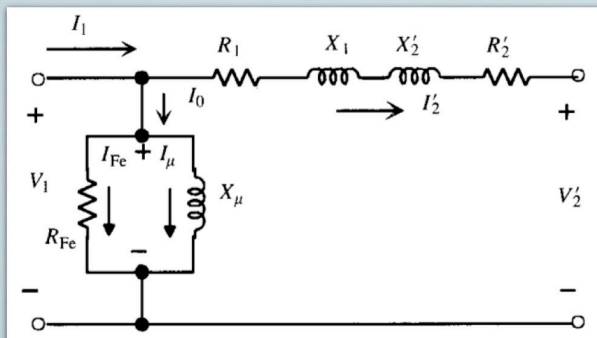
Equivalent electrical circuit:

Simplifications

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = m; \text{ if } N'_2 = N_1; \frac{E_1}{E'_2} = \frac{N_1}{N'_2} = 1; E'_2 = E_1 = m E_2$$

$$V'_2 = m V_2; \quad R'_2 = m^2 R_2; \quad I'_2 = \frac{I_2}{m}$$

$$X'_2 = m^2 X_2; \quad \bar{Z}'_L = m^2 \bar{Z}_L;$$



$$R_{cc} = R_1 + R'_2$$

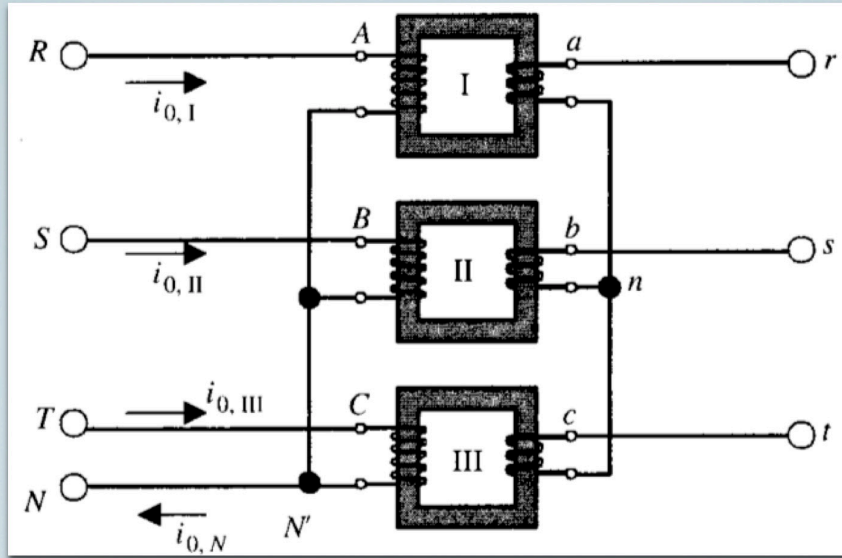
$$X_{cc} = X_1 + X'_2$$

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# THREE-PHASE TRANSFORMERS

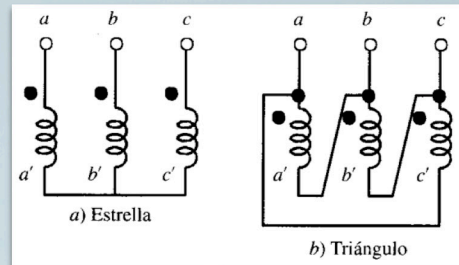
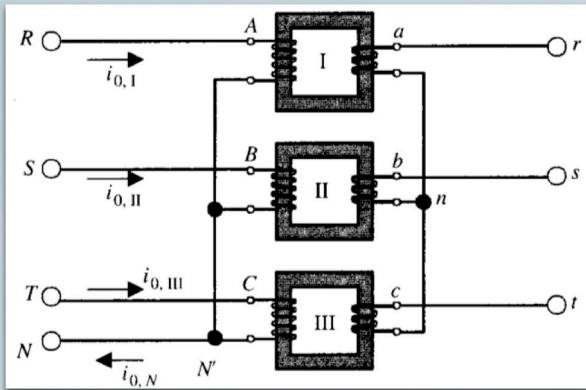
Three-phase MV grid



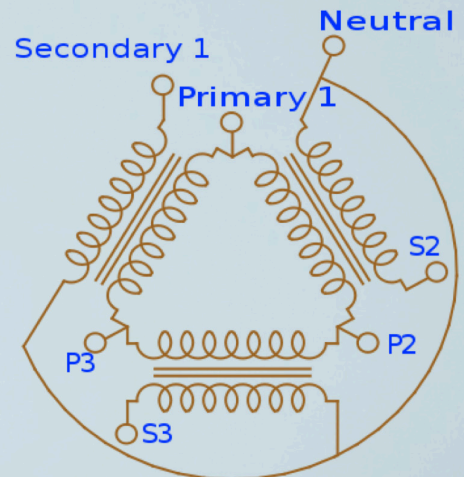
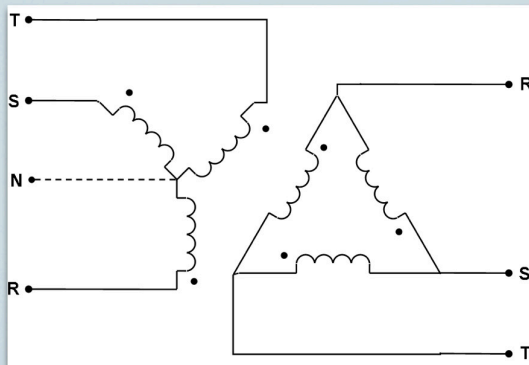
Three-phase LV grid

Bank of three single-phase transformers

# THREE-PHASE TRANSFORMERS



Star-triangle  
Wye-Delta  
Yd  
connection



# THREE-PHASE TRANSFORMERS

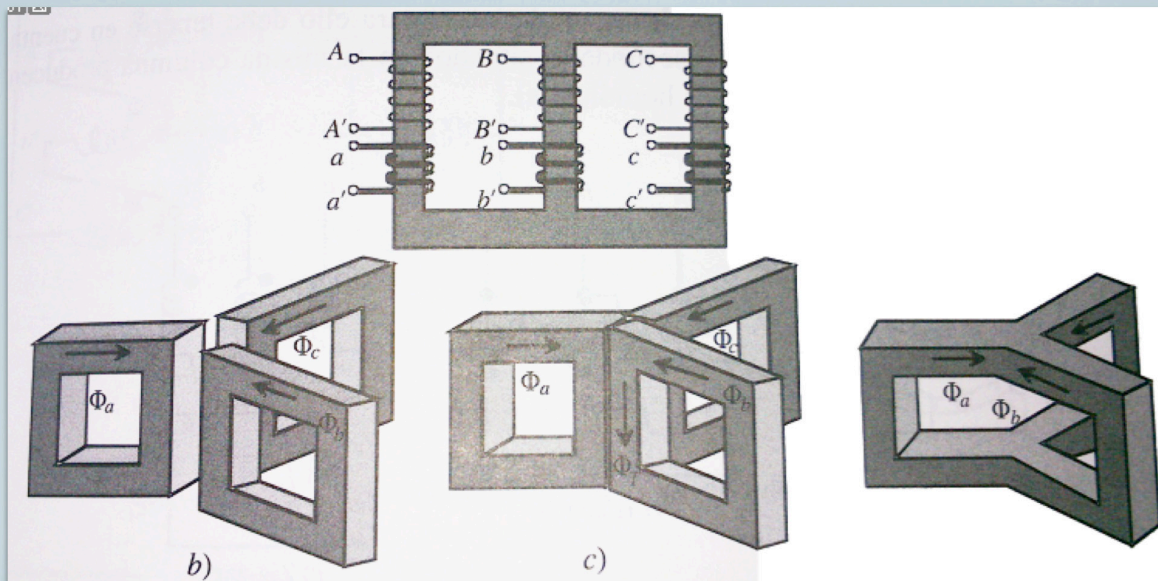
Most frequent connections

0 (0°)	Dd0		6 (180°)	Dd6	
	Yy0			Yy6	
	Dz0			Dz6	
5 (150°)	Dy5		11 (330°)	Dy11	
	Yd5			Yd11	
	Yz5			Yz11	

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# THREE-PHASE TRANSFORMERS

Single three-legged core



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# TRANSFORMER TESTS

IEC EN 60076-1:2011



IEC 60076-1

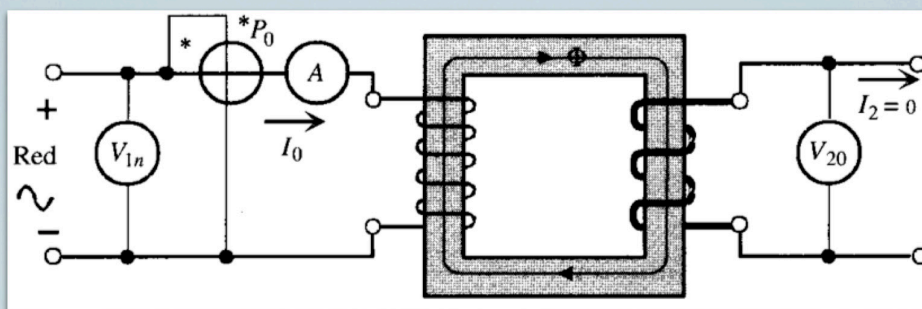
Edition 3.0 2011-04

INTERNATIONAL

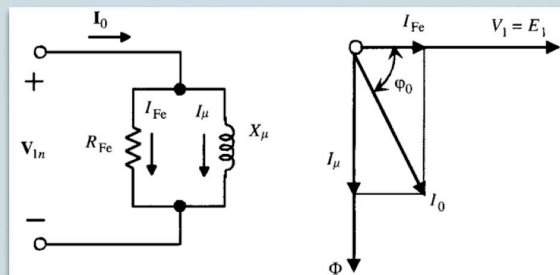
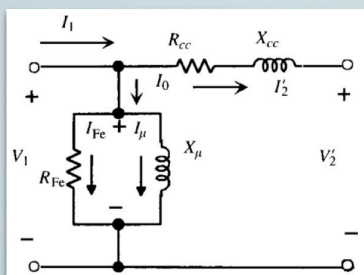
11 Tests .....	44
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# TRANSFORMER TESTS

## NO-LOAD TEST



$$V_0 \approx V_{1n}; \quad P_0 = V_0 I_0 \cos \varphi_0 \rightarrow P_{Fe}$$



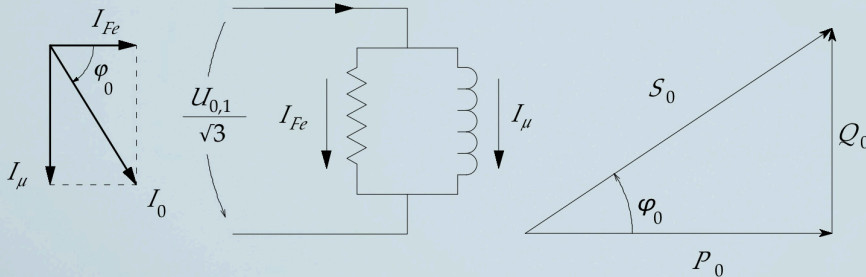
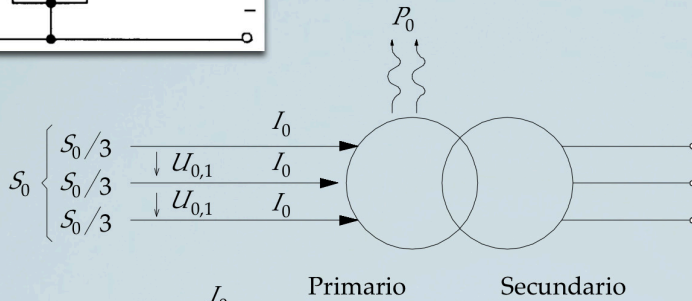
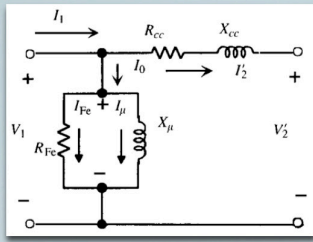
$$\cos \varphi_0 \rightarrow \frac{P_{Fe}}{V_0 I_0}$$

$$R_{Fe} \rightarrow \frac{V_1}{I_{Fe}} = \frac{V_1}{I_0 \cos \varphi_0}$$

$$X_{\mu} \rightarrow \frac{V_1}{I_{\mu}} = \frac{V_1}{I_0 \sin \varphi_0}$$

# TRANSFORMER TESTS

## NO-LOAD TEST



$$\frac{P_0}{3} = \frac{U_{0,1}}{\sqrt{3}} I_0 \cos \varphi_0$$

$$\cos \varphi_0 = \frac{\sqrt{3} P_0}{3 U_{0,1} I_0}$$

$$R_{Fe} \rightarrow \frac{U_{0,1}/\sqrt{3}}{I_{Fe}} = \frac{U_{0,1}/\sqrt{3}}{I_0 \cos \varphi_0}$$

$$X_{\mu} \rightarrow \frac{U_{0,1}/\sqrt{3}}{I_{\mu}} = \frac{U_{0,1}/\sqrt{3}}{I_0 \sin \varphi_0}$$

$$Z_0 = \frac{U_{0,1}/\sqrt{3}}{I_0} = \left| \frac{1}{\frac{1}{R_{Fe}} + \frac{1}{jX_{\mu}}} \right|$$

$$\frac{Q_0}{3} = \frac{U_{0,1}}{\sqrt{3}} I_0 \sin \varphi_0$$

$$Q_0 = \sqrt{3} U_{0,1} I_0 \sin \varphi_0$$

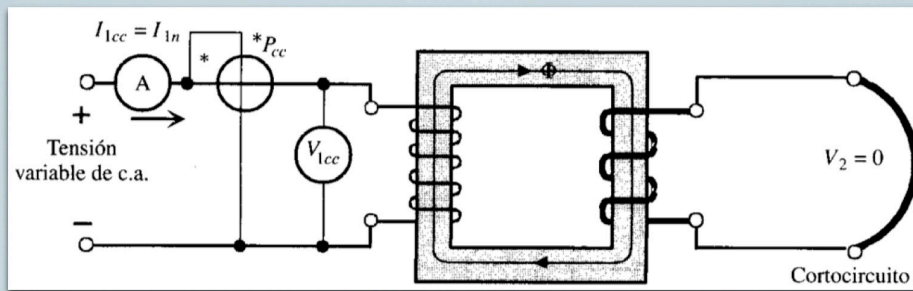
$$Q_0 = P_0 \operatorname{tg} \varphi_0$$

$$S_0 = \sqrt{P_0^2 + Q_0^2} = \sqrt{3} U_{0,1} I_0$$

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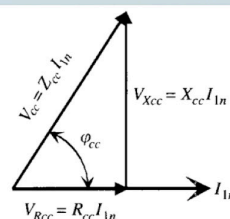
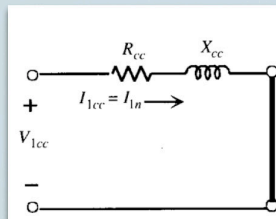
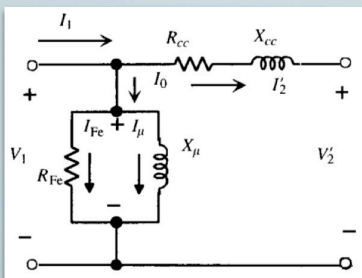
# TRANSFORMER TESTS

## SHORT CIRCUIT TEST



$$I_{1cc} \approx I_{1n}; \quad P_{cc} = V_{1cc} I_{1cc} \cos \varphi_{cc} \rightarrow P_{series}$$

$$\cos \varphi_{cc} \rightarrow \frac{P_{cc}}{V_{1cc} I_{1cc}}$$



$$R_{cc} \rightarrow \frac{V_{1cc} \cos \varphi_{cc}}{I_{1cc}}$$

$$X_{cc} \rightarrow \frac{V_{1cc} \sin \varphi_{cc}}{I_{1cc}}$$

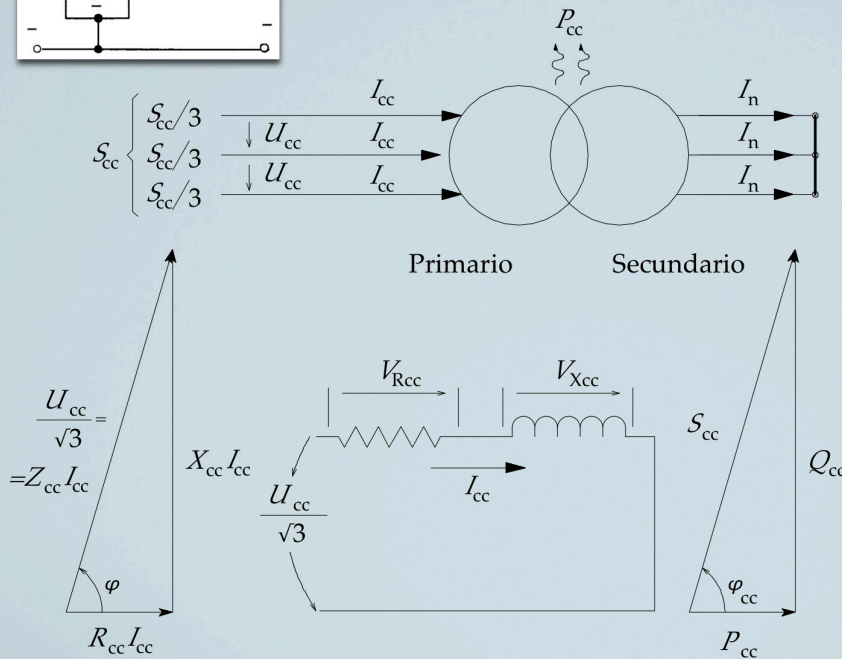
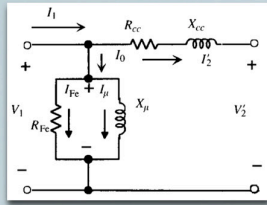
$$\varepsilon_{cc} \% \rightarrow \frac{V_{1cc}}{V_{1n}} \times 100$$

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# TRANSFORMER TESTS

## SHORT CIRCUIT TEST



$$\frac{P_{cc}}{3} = \frac{U_{cc,l}}{\sqrt{3}} I_{cc} \cos \varphi_{cc}$$

$$\cos \varphi_{cc} = \frac{\sqrt{3} P_{cc}}{3 U_{cc,l} I_{cc}}$$

$$R_{cc} \rightarrow \frac{V_{Rcc}}{I_{cc}} = \frac{U_{cc,l} / \sqrt{3} \cos \varphi_{cc}}{I_{cc}}$$

$$X_{cc} \rightarrow \frac{V_{Xcc}}{I_{cc}} = \frac{U_{cc,l} / \sqrt{3} \sin \varphi_{cc}}{I_{cc}}$$

$$Z_{cc} \rightarrow \sqrt{R_{cc}^2 + X_{cc}^2} = \frac{U_{cc,l} / \sqrt{3}}{I_{cc}}$$

$$\frac{Q_{cc}}{3} = \frac{U_{cc,l}}{\sqrt{3}} I_{cc} \sin \varphi_{cc}$$

$$Q_{cc} = \sqrt{3} U_{cc,l} I_{cc} \sin \varphi_{cc}$$

$$Q_{cc} = P_{cc} \operatorname{tg} \varphi_{cc}$$

$$S_{cc} = \sqrt{P_{cc}^2 + Q_{cc}^2} = \sqrt{3} U_{cc,l} I_{cc}$$

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# TRANSFORMER TESTS

## 1. El ensayo

## 2. El ensayo

## 3. El protocolo

## 4. Valores declarados:

## 5. Verifique el rendimiento

## Solución:

## Los datos

## Los resultados

## Los cálculos

## Los resultados

## Los cálculos

## Los resultados

## Los cálculos

## Los resultados

3. El protocolo  
queño tamaño  
cuito del 8,99%  
Valores declara  
S<sub>n</sub> =  
U<sub>1</sub> =  
U<sub>2</sub> =  
f =  
Vacío:  
U<sub>0</sub> =  
I<sub>0</sub> =  
P<sub>0</sub> =  
Cortocircuito:  
U<sub>cc</sub> =  
I<sub>cc</sub> =  
P<sub>cc</sub> =  
Otro  
I<sub>n1</sub> =  
I<sub>n2</sub> =  
m =  
I<sub>0</sub> (%) =  
Z<sub>0</sub> =  
Q<sub>0</sub> =  
S<sub>0</sub> =  
Pérdidas =  
PEI = 99,47%

4. Valores declarados:  
S<sub>n</sub> = 1000 kVA  
U<sub>1</sub> = 15000 V  
U<sub>2</sub> = 420 V  
f = 50 Hz  
Vacío:  
U<sub>0</sub> = 419,65 V  
I<sub>0</sub> = 3,45 A  
P<sub>0</sub> = W  
Cortocircuito:  
U<sub>cc</sub> = 908,25 V  
I<sub>cc</sub> = 38,35 A  
P<sub>cc</sub> = W  
Otros parámetros declarados:  
I<sub>n1</sub> = 38,49 A  
I<sub>n2</sub> = 1374,6 A  
m = 35,71  
I<sub>0</sub> (%) = 0,251 %  
Z<sub>0</sub> = 257758 Ω  
Q<sub>0</sub> = 2325 VAr  
S<sub>0</sub> = 2508 VA  
Pérdidas = 8370 W  
PEI = 99,52 %  
Pérdidas = 3695 W  
PEI = 99,41 %

Verifique el rendimiento de este transformador del que el fabricante no ha proporcionado los valores de pérdidas en vacío ni en cortocircuito. ¿Tiene realmente el rendimiento declarado?

Solución:

Las pérdidas no indicadas son P<sub>0</sub> = 940 W y P<sub>cc</sub> = 9000 W, valores fuera de normas. Las pérdidas totales son 9940 W, mayores que las anotadas en el protocolo, y el rendimiento auténtico es PEI = 99,42%, inferior al declarado.

Z<sub>cc</sub> = 13,673 Ω  
Q<sub>cc</sub> = 59655 VAr  
S<sub>cc</sub> = 60330 VA  
ε<sub>cc</sub>(%) = 6,06 %  
ε<sub>Rcc</sub>(%) = 0,90 %  
ε<sub>Xcc</sub>(%) = 5,99 %  
X/R = 6,6

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# TRANSFORMER TESTS

22.5.2014

ES

Diario Oficial de la Unión Europea

L 152/1

## EFFICIENCY

II

(Actos no legislativos)

## REGLAMENTOS

REGLAMENTO (UE) N° 548/2014 DE LA COMISIÓN

de 21 de mayo de 2014

por el que se desarrolla la Directiva 2009/125/CE del Parlamento Europeo y del Consejo en lo que respecta a los transformadores de potencia pequeños, medianos y grandes

LA COMISIÓN EUROPEA,

Visto el Tratado de Funcionamiento de la Unión Europea,

Vista la Directiva 2009/125/CE del Parlamento Europeo y del Consejo, de 21 de octubre de 2009, por la que se instaaura un marco para el establecimiento de requisitos de diseño ecológico aplicables a los productos relacionados con la energía (<sup>1</sup>), y, en particular, su artículo 15, apartado 1,

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# TRANSFORMER TESTS

ANEXO I

## Requisitos de diseño ecológico

### 1. Requisitos mínimos de rendimiento o eficiencia energéticos para transformadores de potencia medianos

Los transformadores de potencia medianos deberán cumplir los máximos permitidos para pérdidas debidas a la carga y pérdidas en vacío o los valores del índice de eficiencia máxima (PEI) establecidos en los cuadros I.1 a I.5, salvo los de montaje en postes, que deberán cumplir los máximos permitidos para pérdidas debidas a la carga y pérdidas en vacío establecidos en el cuadro I.6.

#### 1.1. Requisitos para transformadores de potencia trifásicos medianos de potencia asignada no superior a 3 150 kVA

Cuadro I.1: Pérdidas máximas debidas a la carga y en vacío (en W) para transformadores de potencia trifásicos medianos sumergidos con una bobina de  $U_m \leq 24\text{kV}$  y otra de  $U_m \leq 1,1\text{kV}$

Potencia asignada (kVA)	1ª etapa (a partir del 1 de julio de 2015)		2ª etapa (a partir del 1 de julio de 2021)	
	Pérdidas máximas debidas a la carga $P_k$ (W) (*)	Pérdidas máximas en vacío $P_v$ (W) (*)	Pérdidas máximas debidas a la carga $P_k$ (W) (*)	Pérdidas máximas en vacío $P_v$ (W) (*)
$\leq 25$	$C_k$ (900)	$A_v$ (70)	$A_k$ (600)	$A_v - 10\%$ (63)
50	$C_k$ (1 100)	$A_v$ (90)	$A_k$ (750)	$A_v - 10\%$ (81)
100	$C_k$ (1 750)	$A_v$ (145)	$A_k$ (1 250)	$A_v - 10\%$ (130)
160	$C_k$ (2 350)	$A_v$ (210)	$A_k$ (1 750)	$A_v - 10\%$ (189)
250	$C_k$ (3 250)	$A_v$ (300)	$A_k$ (2 350)	$A_v - 10\%$ (270)
315	$C_k$ (3 900)	$A_v$ (360)	$A_k$ (2 800)	$A_v - 10\%$ (324)
400	$C_k$ (4 600)	$A_v$ (430)	$A_k$ (3 250)	$A_v - 10\%$ (387)
500	$C_k$ (5 500)	$A_v$ (510)	$A_k$ (3 900)	$A_v - 10\%$ (459)
630	$C_k$ (6 500)	$A_v$ (600)	$A_k$ (4 600)	$A_v - 10\%$ (540)

## EFFICIENCY

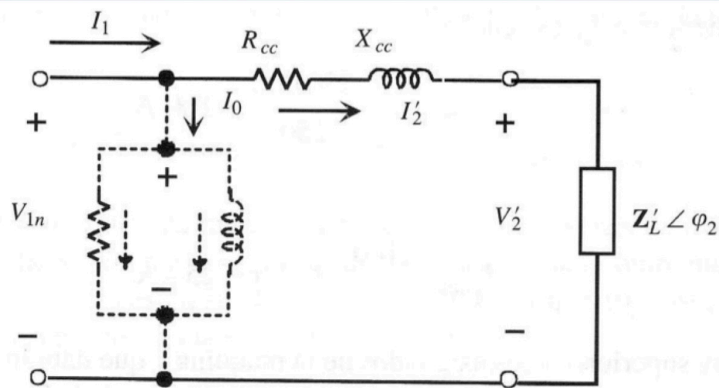
European Peak Efficiency Index:

$$PEI = 1 - \frac{2(P_0 + P_{c0})}{S_n \sqrt{\frac{P_0 + P_{c0}}{P_{cc}}}}$$

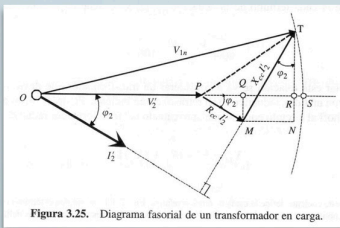
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# VOLTAGE DROP (REGULATION)



**Figura 3.24.** Circuito eléctrico equivalente para determinar la caída de tensión de un transformador.



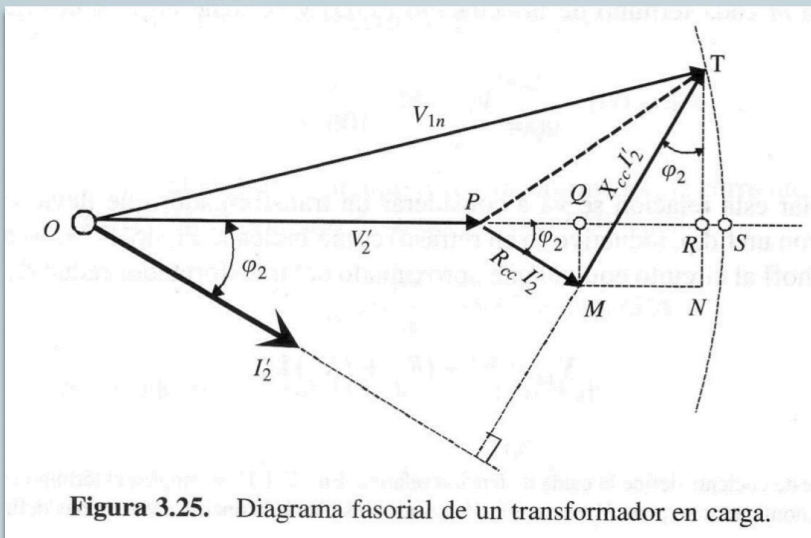
**Figura 3.25.** Diagrama fasorial de un transformador en carga.

Load coefficient:  $C = \frac{I_2}{I_{2n}} = \frac{I_1}{I_{1n}}; C\% \approx \frac{S_{load}}{S_n} \times 100$

$$\epsilon_c \% = \frac{V_{1n} - V'_2}{V_{1n}} \times 100 = C(\epsilon_{R_{cc}} \cos \varphi_2 + \epsilon_{X_{cc}} \sen \varphi_2)$$

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# VOLTAGE DROP (REGULATION)



**Figura 3.25.** Diagrama fasorial de un transformador en carga.

More precise calculation:

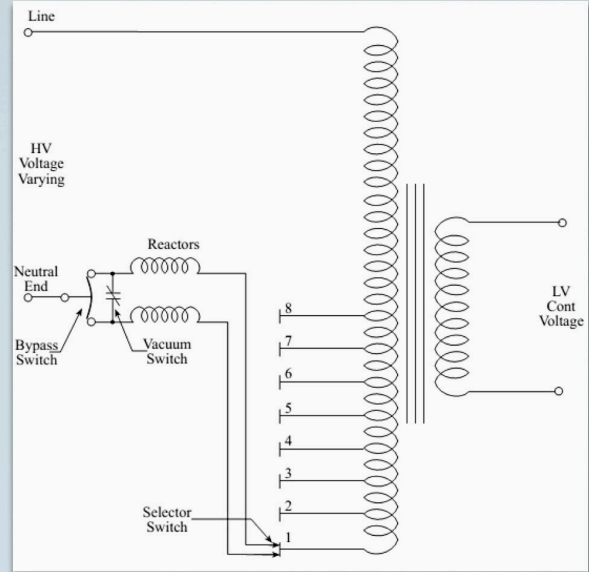
$$\epsilon_c \% = C(\epsilon_{R_{cc}\%} \cos \varphi_2 + \epsilon_{X_{cc}\%} \sen \varphi_2) + \frac{(C\epsilon_{R_{cc}\%} \sen \varphi_2 + C\epsilon_{X_{cc}\%} \cos \varphi_2)^2}{2}$$

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# TRANSFORMER TAPPINGS



220 kV / 66 kV  
± 1,25% 4  
tappings



Toma	1	2	3	4	5	6	7	8	9
Regulación	95.00%	96.25%	97.50%	98.75%	100%	101.25%	102.50%	103.75%	105.00%
Tensión secundario $kV$	62.70	63.53	64.35	65.18	66	66.83	67.65	68.48	69.30
Relación $m$	3.5088	3.4632	3.4188	3.3755	3.3333	3.2922	3.2520	3.2129	3.1746

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# TRANSFORMER TAPPINGS

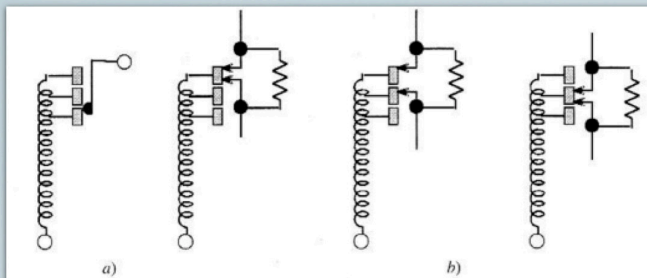
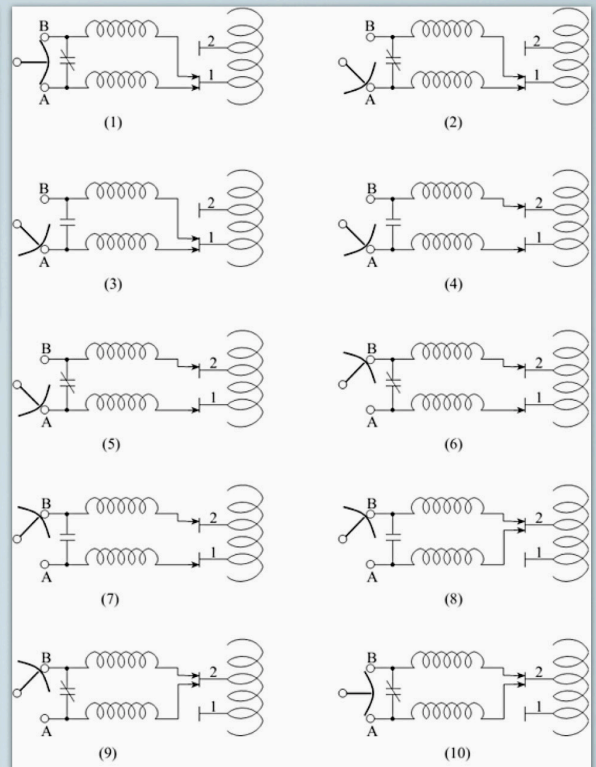


Figura 3.54. Detalle del funcionamiento del cambiador de tomas en carga.

<http://electrical-engineering-portal.com>

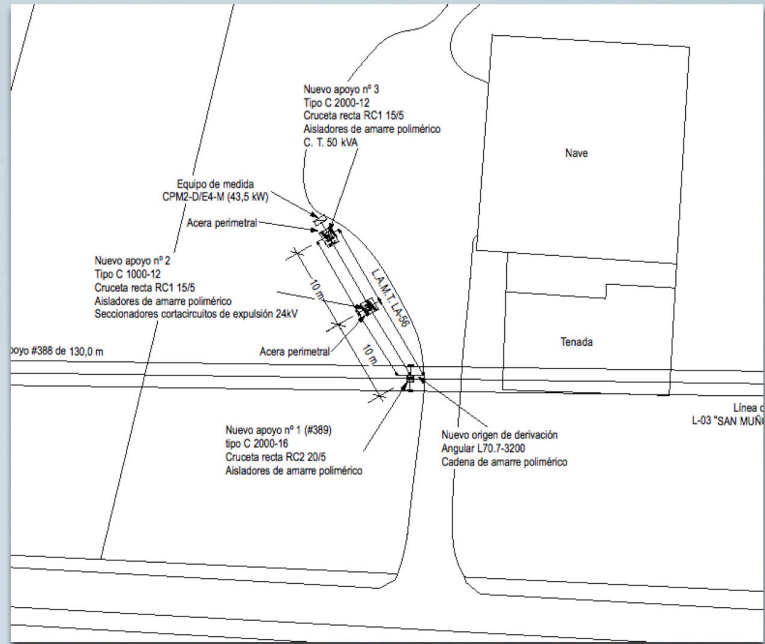
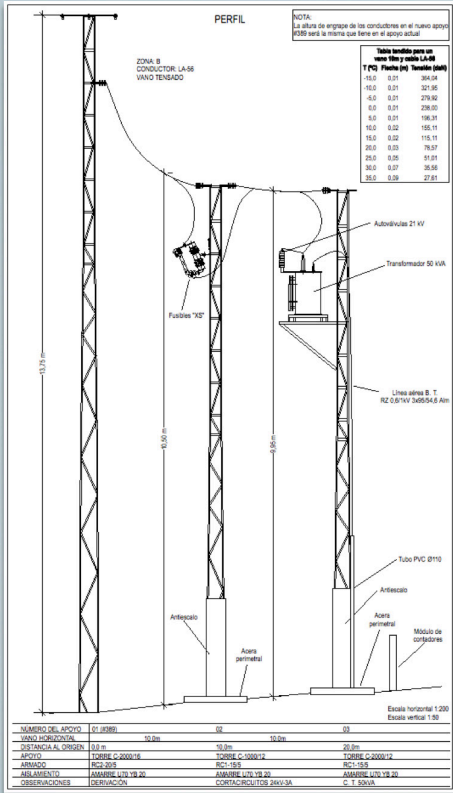
- 1 Present position – tap changer selected to tap 1, bypass switch in, A + B, home position.
- 2 Bypass switch selects lower circuit arm.
- 3 Vacuum switch opens, removing load current from upper circuit arm freeing one half of selector switch for move.
- 4 As there is no load current on upper arm of selector switch, it moves to tap 2.
- 5 Vacuum switch closes – both selector switches on load, circulating current is limited by reactors.
- 6 Bypass switch selects upper arm circuit arm. No arcing occurs as vacuum switch is closed and in parallel.
- 7 Vacuum switch opens, removing load current from lower circuit arm, freeing lower selector switch for move.
- 8 As there is no load current on lower arm of selector switch, it moves to tap 2.
- 9 Vacuum switch closes – both selector switches on load, in parallel, on tap 2.
- 10 With vacuum switch closed and selector switch on a single tap, the bypass switch can now return to its home position. Both reactor circuits stay normally in parallel. The tap change is now complete.



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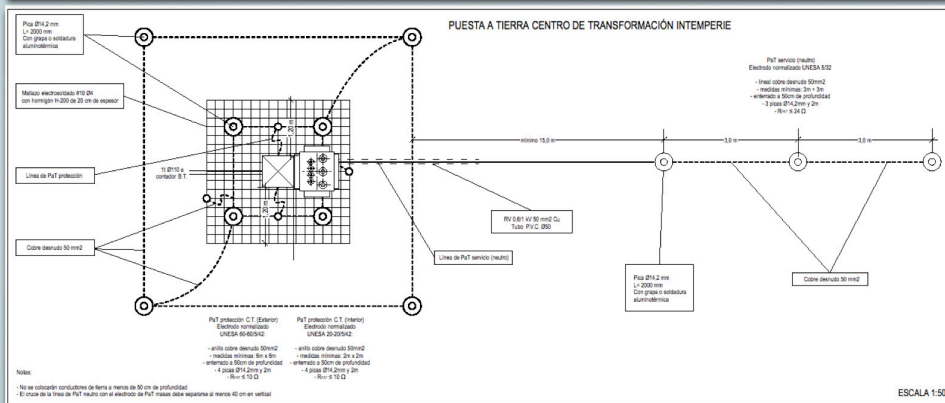
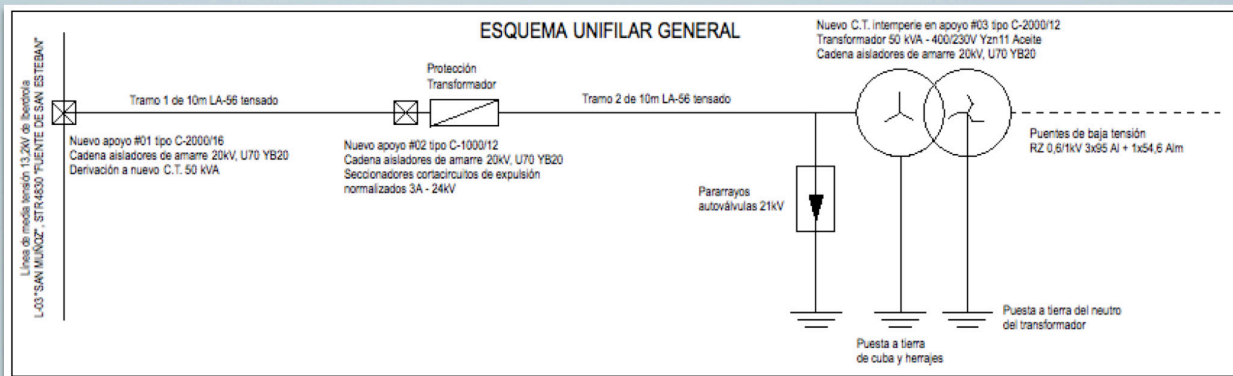


# ELECTRICAL FAILURES



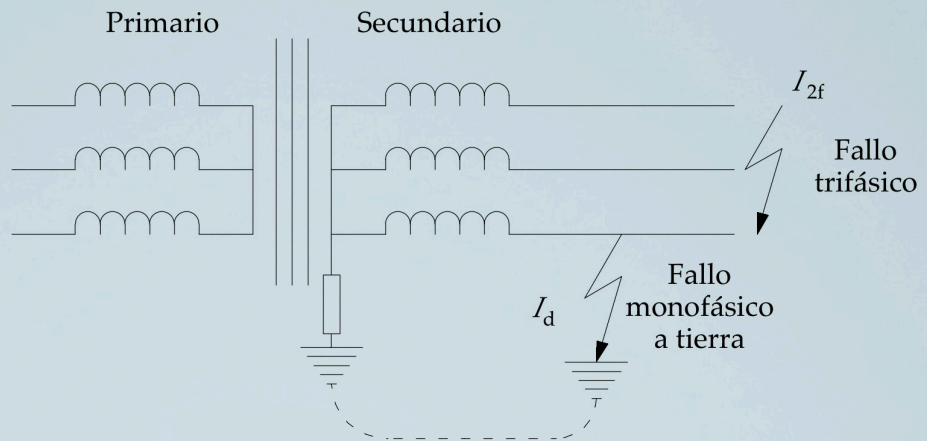
Deviation from main power line

# ELECTRICAL FAILURES



Earthing of the neutral

# ELECTRICAL FAILURES



Short circuit conditions (three-phase failure):

$$\begin{aligned}
 & \left. \begin{array}{l} \text{- Short circuit test: } U_{lcc} \rightarrow I_{ln} \\ \text{- Electrical failure: } U_{ln} \rightarrow I_{lf} \end{array} \right\} I_{lf} = I_{ln} \frac{U_{ln}}{U_{lcc}} = \frac{I_{ln}}{U_{lcc}/U_{ln}} = \frac{I_{ln}}{\epsilon_{cc}} = \frac{I_{ln}}{\epsilon_{cc}\%/100} = \frac{I_{ln} \times 100}{\epsilon_{cc}\%} \\
 & I_{2f} = m I_{lf} = \frac{U_{ln}}{U_{2n}} I_{lf}
 \end{aligned}$$

Earth default: limited by ground impedance

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## 2

# REAL TRANSFORMERS

- Actual transformers

- Accessories

- Transformer model

- **Special transformers**

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# AUTOTRANSFORMERS

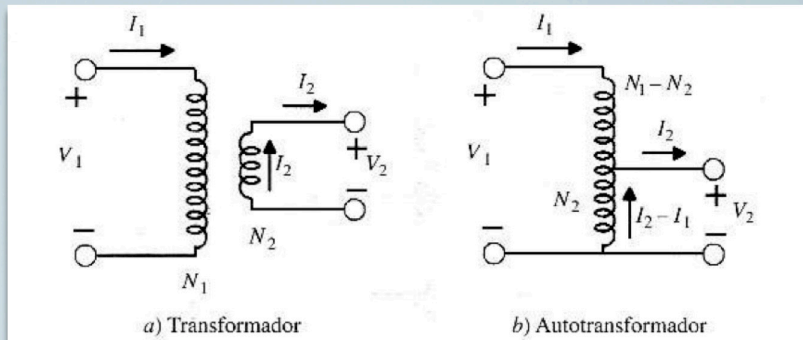
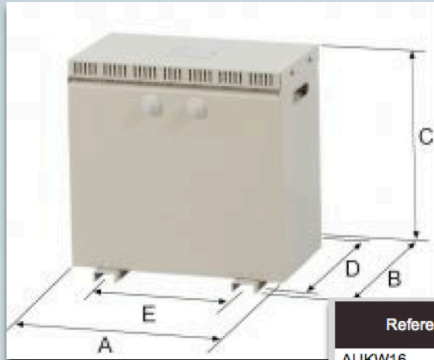
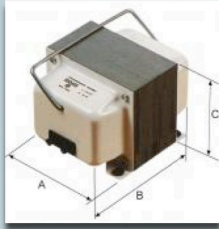


Figura 3.49. Comparación entre un transformador y un autotransformador.

Referencia	Potencia	Dimensiones mm						Peso kg
		A	B	C	D	E	Ø	
AUKW16	16 kVA	525	415	640	375	350	12	62
AUKW20	20 kVA	525	415	640	375	350	12	74
AUKW25	25 kVA	595	415	708	375	350	12	79
AUKW31.5	31,5 kVA	595	415	708	375	350	12	92
AUKW40	40 kVA	595	415	708	375	350	12	98
AUKW50	50 kVA	595	415	708	375	350	12	123
AUKW63	63 kVA	789	490	865	450	415	13	142
AUKW80	80 kVA	789	490	865	450	415	13	183
AUKW100	100 kVA	789	490	865	450	415	13	210

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# VOLTAGE TRANSFORMERS

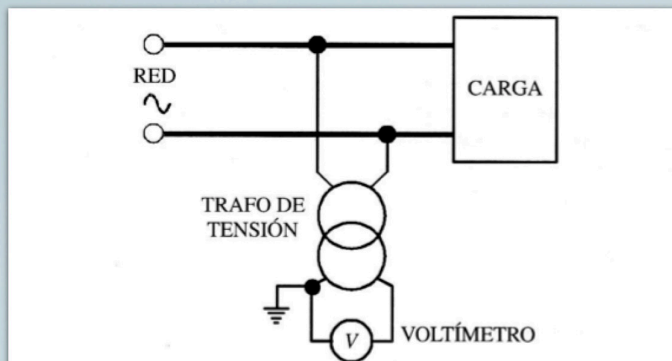
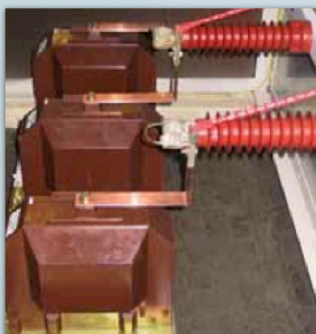


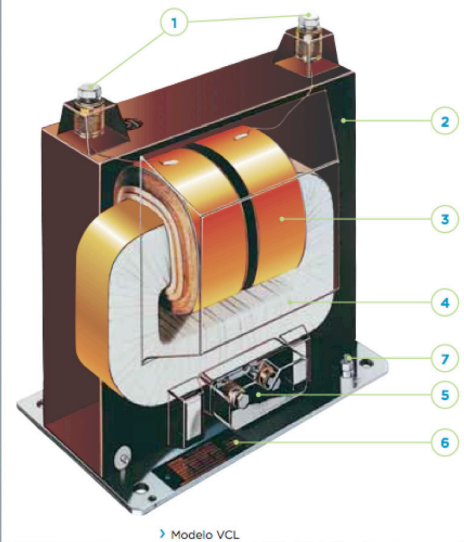
Figura 3.55. Transformador de tensión alimentando un voltímetro.



## SECCIÓN



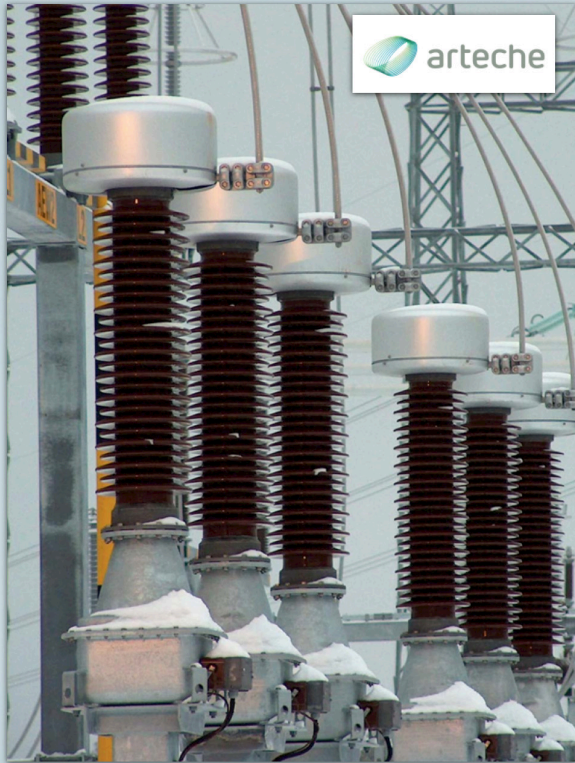
1. Terminales primarios
2. Aislador (resina)
3. Arrollamiento primario
4. Núcleo
5. Caja de terminales secundarios
6. Base
7. Terminal de tierra



Modelo VCL

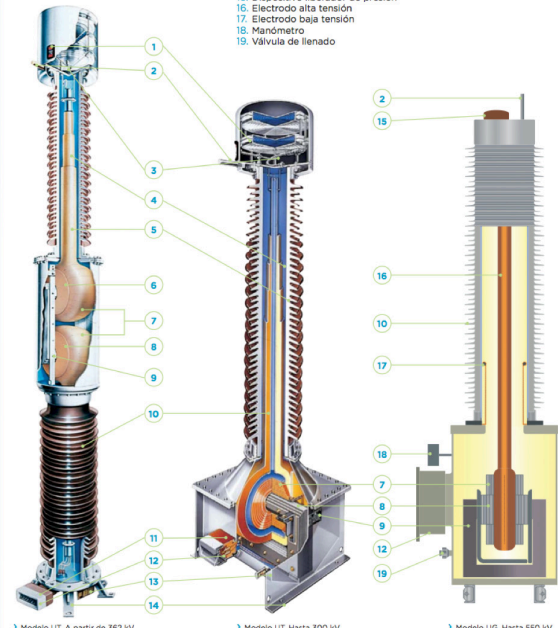
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# VOLTAGE TRANSFORMERS



## SECCIONES

1. Indicador de nivel de aceite
2. Terminal primario
3. Compensador de volumen de aceite
4. Borna condensadora
5. Aislamiento papel-aceite
6. Arrollamiento de compensación
7. Arrollamientos primarios
8. Arrollamientos secundarios
9. Núcleo
10. Aislamiento (porcelana o silicona)
11. Toma medida tangente delta
12. Caja terminales secundarios
13. Toma de muestras de aceite
14. Terminal de puesta a tierra
15. Dispositivo liberador de presión
16. Electrodo alta tensión
17. Electrodo baja tensión
18. Manómetro
19. Válvula de llenado



# CURRENT TRANSFORMERS

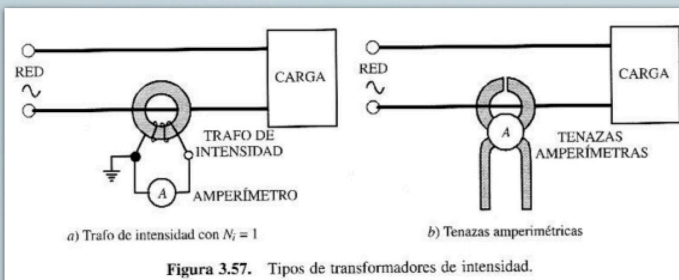
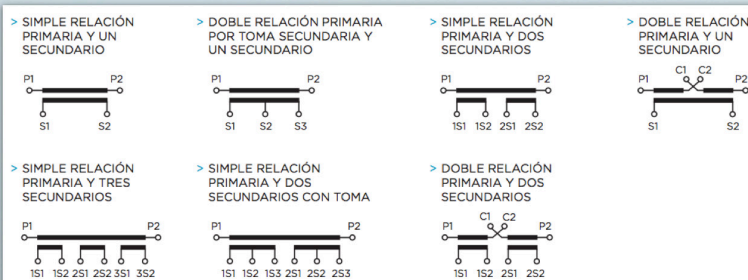


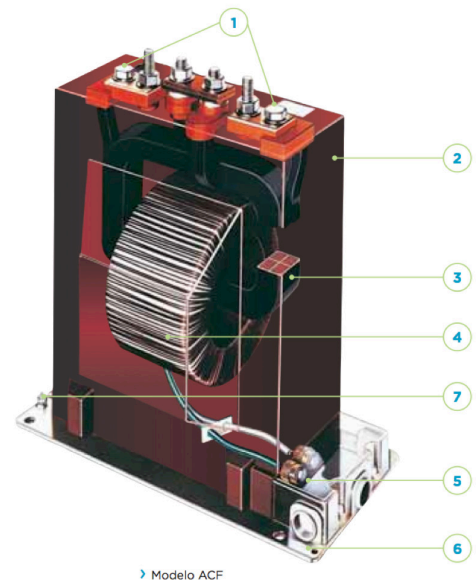
Figura 3.57. Tipos de transformadores de intensidad.



## SECCIÓN



1. Terminales primarios
2. Aislador (resina)
3. Arrollamiento primario
4. Núcleo y bobinado secundario
5. Caja de terminales secundarios
6. Base
7. Terminal de tierra



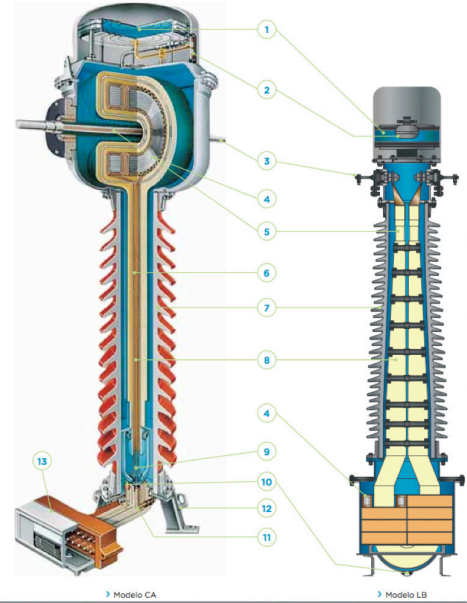


# CURRENT TRANSFORMERS



## SECCIONES

- |   |                                    |
|---|------------------------------------|
| 1. Compensador de volumen de aceite     | 6. Conductores secundarios         |
| 2. Indicador de nivel de aceite         | 7. Aislador (porcelana o silicona) |
| 3. Terminal primario                    | 8. Borna condensadora              |
| 4. Núcleos y arrollamientos secundarios | 9. Conexión de tierra reforzada    |
| 5. Conductor primario                   | 10. Toma de muestras de aceite     |



# POWER METER

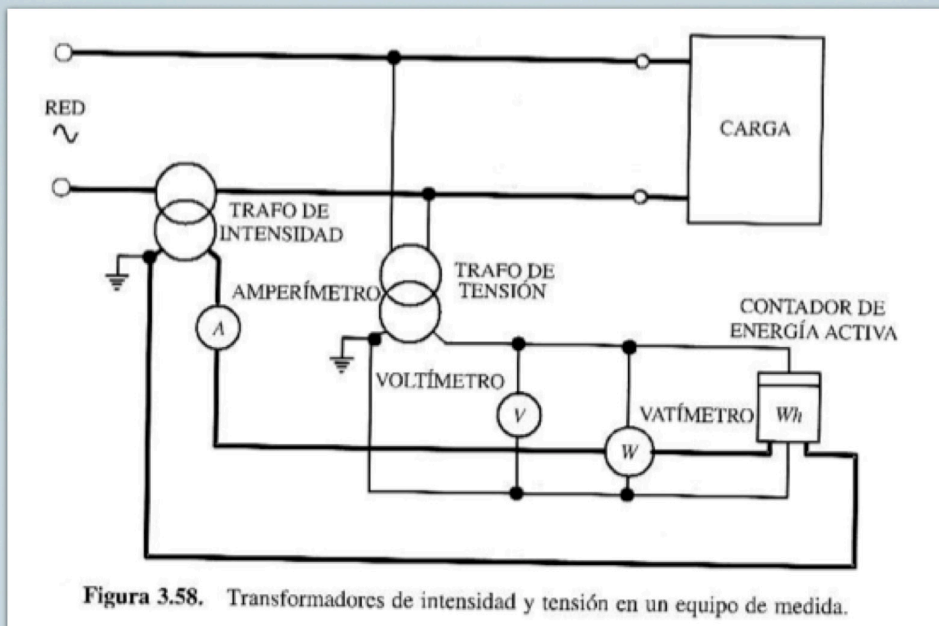


Figura 3.58. Transformadores de intensidad y tensión en un equipo de medida.