Topic2 / Design1

Designing three phase autotransformer, for 3x400V/3x380V, 10kVA output power and 25% one phase unsymmetrical load

Input parameters

Input	Voltage	3 x 400V, +-10%, 50Hz, sine wave
	Wire	Cu, round, single insulated
	Layer insulation	No
	Final insulation	No
Output	Nominal output voltage	3 x 380V, star connection with 3 x 220V between phases and neutral line
	Nominal output current	3 x 15.15A and 1 x 3.78A UNSYMMETRICAL load
	Wire	Cu, round, single insulated
	Layer insulation	No
Core	Steel	M45, alternate stacking, not annealed
	Assembly	Gaped with 10 mil between E and I for limiting the magnetic flux of the unsymmetrical current.
Bobbin	Type	Single section
Design	Insulation class	B, max. operating temperature 120C,
	Ambient temperature	40C

Modifying the wire size from thermal point of view

Due to the fact that the program supports only the three phase symmetrical operation mode we need to compare the currents in both symmetrical and unsymmetrical operation mode, and modify the wire size by hand using the following pictures:

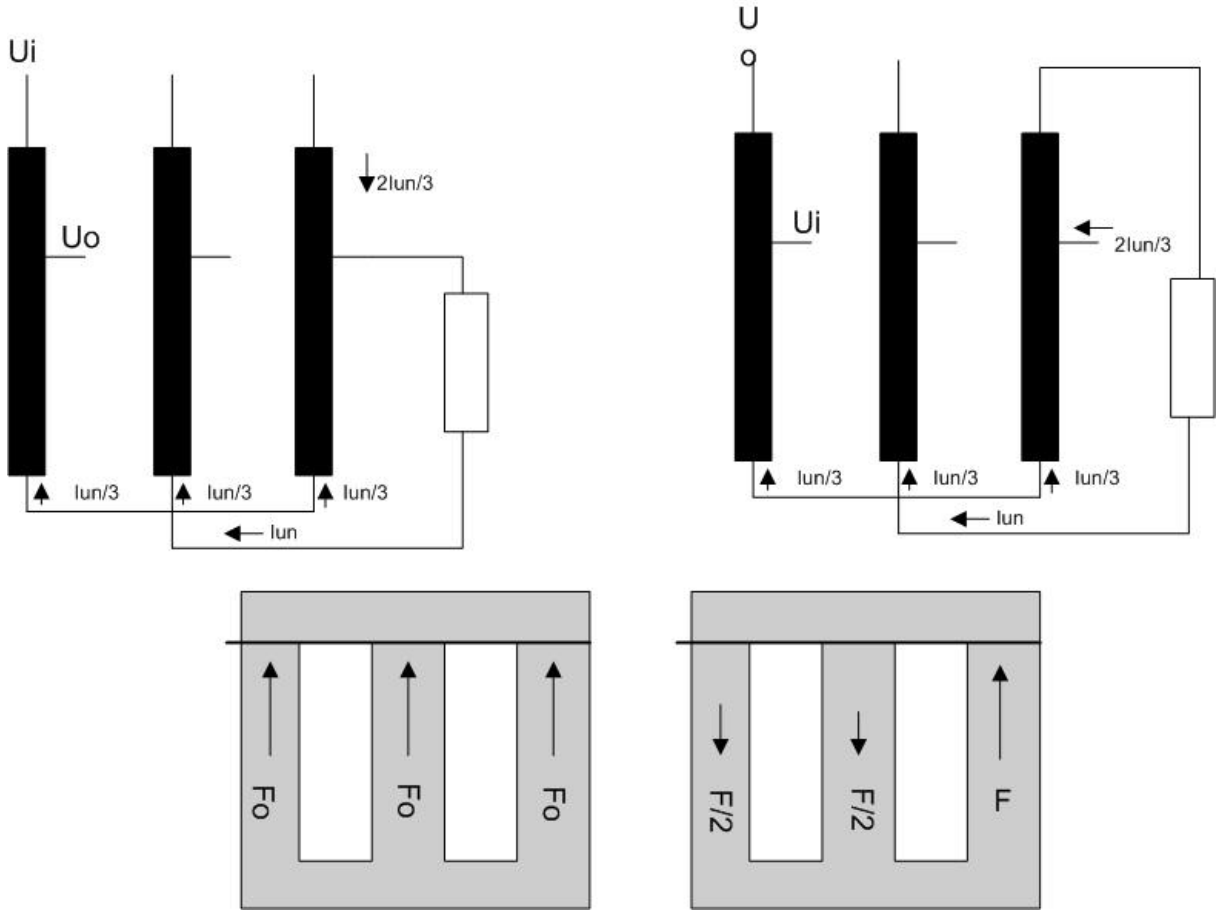
In the unsymmetrical operation mode the current between the neutral and Uo tap is Iun/3 = 3.78/3 = 1.26A. Between Ui and Uo taps the max current is 2Iun/3 = 2.52A

In the symmetrical operation mode the current between the neutral and Uo tap is (1-Uo/Ui)In= 0.635A (view the segment currents on the last page). Between Ui and Uo taps the max current is Ii = 14.6A.

If we compare the currents between the neutral and the Uo tap then we have to follow this procedure in order to design our autotransformer from thermal point of view properly:

1. Run the program in the symmetrical operation mode and select a bigger core in order to get the build approx. 40%

2. **Increase the wire cross section of the winding between the neutral and the Uo tap approx. by the factor (1.26/0.635)^2 = 3.93**



Calculating the induction during the unsymmetrical operation mode

Finally we need to check the size of the inductions Bo and B of the magnetic fluxes Fo and F.

1. The magnetic fluxes Fo are equal by size and phase. They flow through the legs and close their loops outside the core. They are normally very small and can be neglected.
2. Note that the ampere-turns of the no-load current Wi x Io = 845 x 0.268 = 226 excites over one legs the main induction of 1.3T (set on the input screen).
3. The magnetic flux F is driven by ampere-turns (on the leg with the unsymmetrical load) of the unsymmetrical current are:
   (2/3) x (Wi-Wo) x Iun = 0.666 x (845-812)x3.78 = 83
   Due to the fact that the phase delay between the main flux (driven by input voltage) and the flux F (driven by unsymmetrical current on the leg with the unsymmetrical load) is 90 degrees the max. induction in the leg during the unsymmetrical operation mode will be:
   Bmax = 1.3 x (1+(83/226)^2)^0.5 = 1.3 x 1.06 = 1.385T
4. **In order to get a very low influence of the unsymmetrical current the core has to be gaped by 10mil between the E and I part.**

#*0	DIAGNOSE	Page 0
Name	:3 X EI 3P120/(1_1/5)	
Steel	-:M45 Gauge 24 / 0.0250"	
Number of Sections	-:1	
max.Cu-Fill Factor	%:88.9	
max. parallel Wires	:1	
Induction on Load	T:1.374	
Max. Induction	T:1.357	
Max.Cu-Temp.rise on load	°K:50.8	
Max.Cu-Temp.rise no-load	°K:18.3	
Regulation	%:.4	
I^Inrush/I^nom-Factor	*:.9	
Input Current No-Load	%:1.8	

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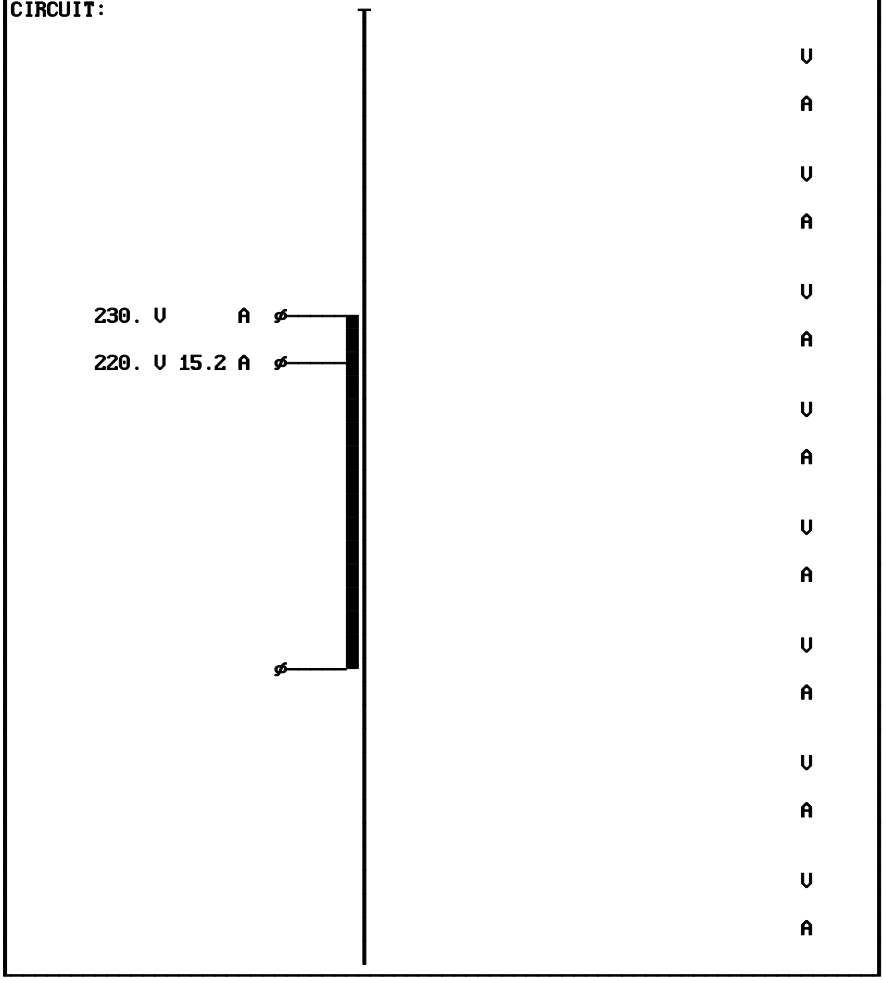
PRIMARY	U(V)	I(A)	SECOND. 1--- 2--- 3--- 4--- 5--- 6--- 7--- 8---
Circuit-:1	220.	15.2	Circuit-:
Overult*:1.00	230.		Volta. V:
Wire :0.0	.		Curre. A:
I/L. mil:0.	.		Wire :
I/E. mil:0.	.		I/L mil:
Formfac.:1.11	.		I/E mil:
Fre.Hz:50	.		
dI/Io :100	.		

Regulat. %:7.0	Steel -:17	Cooling *:1.00	Bobbin -:1
Udiode V:0.8	Induction T:1.37	Force ft/s:0.00	P/S-Order -:2
dUdiode V:.1	Remanence *:0.35	Bracket -:1	Rac/Rdc *:1.05
Ripple %:5.	W/kg *:1.00	Radiator -:0	Space *:2.00
Tmp. Amb.°C:40	VAr/kg *:1.00	Chassis -:1.00	Vertical -:1
Tmp.rise °K:60	Gap *:10.00	Channel in:0.00	Horizontal -:1
Time 1 Min:30.0	Annealed -:0	Cu-Surface*:1.00	Impregnat. -:2
Load 1 *:1.0	Stacking *:1.00	Rth-varni.*:1.00	Spread %:0
Time 2 Min:30.0	Hole -:1	Rth-comp. *:1.00	Selection -:2
Load 2 *:1.0	Assembly -:2	Case -:0	Criterion -:2

CIRCUIT:



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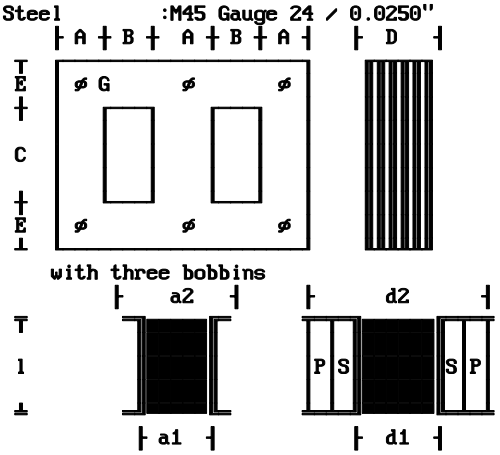
Name :3XEI 3P120/(1_1/5)
Steel :M45 Gauge 24 / 0.0250" /25.59



Weight	lb:8.27
Gap total	in:0.000
A-Limb	in:1.20
B-Width	in:1.20
C-Height	in:3.00
D-Stack	in:1.20
E-Yoke 1	in:1.20
F-Yoke 2	in:1.20
G-Hole	in:0.326
Radiator Fin	:0
Radiator Chan.	:0
a1	cm:1.36
a2	cm:2.35
d1	cm 1.36
d2	cm 2.35
l	cm:2.88
lp	cm:
ls	cm:
Margin	cm:0.06

X- Length 1	in:
Y- Width 1	in:
Z- Height 1	in:
x- Length 2	in:
y- Width 2	in:
z- Height 2	in:
w- Thickness	in:
Material	:
Potted	:

	Typ	Windun	MTI	DN	DN	Par	D/ø mil	B/ø mil	W/L	L	I/L mil	I/E mil	Weight lb	RWH %
1	1	812.4	C00	20.0	20.0	1	32.	32.	83	9.7	.	.	1.351	70.
2	1	845.6	C00	12.0	12.0	1	80.8	80.8	33	1.0	.	.	.444	36.
3														
4														
5														
6														
7														
8														
1														
2														
3														
4														
5														
6														
7														
8														
TOTAL													5.387	88.

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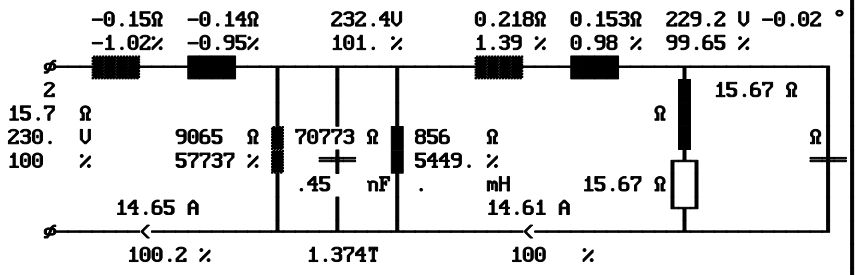
NOMINAL OPERATION at Temperature °C 90.4 and Overvoltage 1.00

Output Power on Load	W:10051	Output Power of Transfor.	W:10051
Cu Losses	W:12.41	Fe-Losses active	W:5.96
Short-Circuit-Volt. cold	%:0.28	Regulation	%:.35
Instantaneous pow. .5/95&	W:80606	Efficiency of Transformer	%:99.45
dT Fe average Surface	°K:47.1	dT primary	°K:50.9
dT Case aver. Surface	°K:.	dT secondary	°K:



DUTY CYCLE OPERATION at Amb.Temperature °C 40. and Overvoltage 1.00

dT Fe average Surface	°K:47.1	dT primary	°K:50.8
dT Gehäuse av. Surface	°K:.	dT secondary	°K:

NO LOAD OPERATION at Amb.Temperature °C 40. and Overvoltage 1.00

Losses active	W:6.19	Losses reactive	VAr:61.27
Current factor	%:1.83	Induction	T:1.357
dT Fe average Surface	°K:20.4	dT primary	°K:18.3
dT Gehäuse av. Surface	°K:.	Rezonance frequency	kHz:4.5

SHORT-CIRCUIT OPERATION at Amb.Temperature °C 40. and Overvoltage 1.00

Losses active	W:11903	Losses reactive	VAr:90161
Current factor cold	%:35427	Induction	T:1.36
dT Fe average Surface	°K:7461.	dT primary	°K:8768.
dT Gehäuse av. Surface	°K:.	dT secondary	°K:

PRIMARY (Tap:2)	1----	2----	3----	4----	5----	6----	7----	8-----
Voltage Input/Output	V:220.2	230.						
Out. Voltage no load	V:221.							
Current Input/Output	A:15.21	14.65						
Load on output	Ω:14.47							
Power factor of load	:1.000							
Current in segment	A:0.631	14.65						
Current density A/in^2	:787.1	2856.						
Icc-Current cold	A:5401.	5190.						
Io -Current	A:	0.268						
Inrush Current peak	^A:	19.56						
Inrush Current rms	A:	9.02						
Cu-Losses	W:	12.4						
Resistance cold	Ω:4.563	4.600						
Reactance	Ω:.9902	.0017						
Eddy-Current Factor	:1.	1.						

SECONDARY	1----	2----	3----	4----	5----	6----	7----	8-----
Output Voltage	V:							
Output Current	A:							
Out. Voltage no load	V:							
Sec. Voltage	V:							
Sec. Current	A:							
Current density A/in^2	:							
Sec. Voltage cold	V:							
Load on output	Ω:							
Power factor of load	:							
Icc cold	A:							
Cu-Losses warm	W:							
Resistance cold	Ω:							
Reactance	Ω:							
Eddy-Current Factor	:							
Capacitor	mF:							

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