Topic: Inrush Current / Design1

Designing three phase, low inrush current universal autotransformer for 3x208V/120V, 50/60Hz, 9A

Input parameters

Input	Voltage	3 x 380/400/480/690V, +-6%, star connection, 50/60HzHz, sine wave
	Wire	Cu, round, single insulated
	Layer insulation	No
	Final insulation	Yes
Output	Nominal output voltage	3 x 208, star connection with 3 x 120V between phases and neutral line
	Nominal output current	3 x 9A
	Wire	Cu, round, single insulated
	Layer insulation	No
Core	Steel	M45, not annealed
	Assembly	Gaped with 5mil between E and I for limiting the remanence in the core.
Bobbin	Type	Single section
Design	Insulation class	B, max. operating temperature 120C,
	Ambient temperature	40C

About “low” inrush current

Note that you can not prescribe the value of the inrush current. But using the following rules you can easy limit it under the value you need:

1. If you use cold rolled or grain oriented steel set the induction between 0.9 and 1.3.
2. Use high temperature rise to increase the resistance of windings.
3. Unfortunately the remanence cannot be calculated in an alternated stacked core and vary between 20% and 70% of the operating induction. If you want to get a small and enough accurate amount of the calculated inrush current then use the gaped core assembly to reduce the remanence. Normally 3-5mil gap is big enough to reduce the remanence less than 5% of the operating induction and increase the accuracy of the inrush current calculation. The control parameter of the gap size is the amount of the no-load current. A good no-load current is smaller than 25% of the nominal primary current.
4. If you design a transformer set the primary outside. Reduce the primary wire cross section and increase the secondary wire cross section so that the temperature rise and the output voltage stay under the value you need. Due to the fact that the primary resistance is higher the inrush current will be smaller.

If you use cold rolled or grain oriented steel and you set the nominal operating induction at 0.8-0.9T then the inrush current will be very small and can be neglected. Normally, in order to save the material costs the used operating induction is 1.1-1.3T

If the relationship between the peak value of the inrush current and the peak value of the nominal current of an inverter is less than 8 then the transformer can be connected to the inverter and the inrush current is low enough.

If the relationship between the rms value of the inrush current within the first period and nominal value of a slow fuse current is less than 15 then the slow fuse can be used on the primary side of transformers. If you don't want to use the slow fuse you can use the calculated rms inrush current (view the last design page) during the first period and calculate I^2t. With the calculated I^2t you can select any fuse from catalogue.

#*0	DIAGNOSE	Page 0
Name	:3 X EI 3P180/(2.0)	
Steel	-:M45 Gauge 24 / 0.0250"	
Number of Sections	-:1	
max.Cu-Fill Factor	%:87.9	
max. parallel Wires	:1	
Induction on Load	T:1.272	
Max. Induction	T:1.285	
Max.Cu-Temp.rise on load	°K:74.5	
Max.Cu-Temp.rise no-load	°K:24.2	
Regulation	%:3.5	
I^Inrush/I^nom-Factor	*:6.9	
Input Current No-Load	%:6.5	

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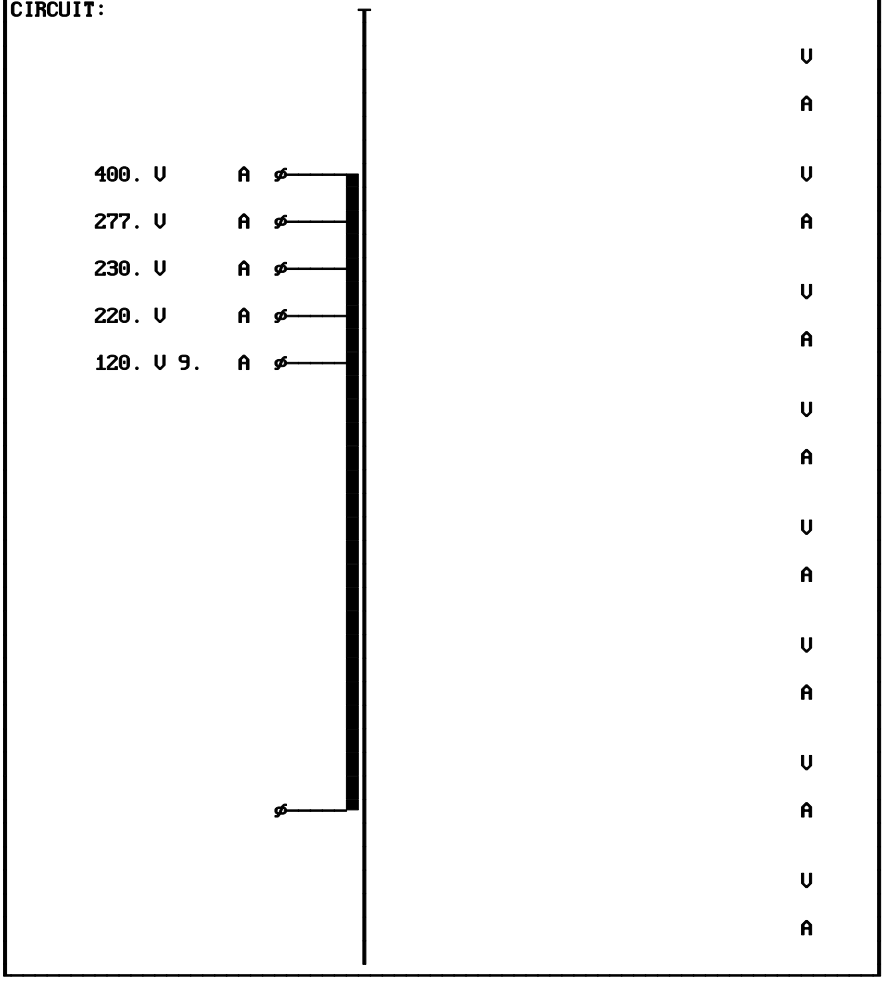
PRIMARY	U(V)	I(A)	SECOND. 1--- 2--- 3--- 4--- 5--- 6--- 7--- 8---
Circuit-:1	120.	9.	Circuit-:
Overult*:1.06	220.		Volta. V:
Wire :0.0	230.		Curre. A:
I/L. mil:0.	277.		Wire :
I/E. mil:0.	400.		I/L mil:
Formfac.:1.11	.		I/E mil:
Fre.Hz:50	.		
dI/Io :100	.		

Regulat. %:50.0	Steel -:17	Cooling *:1.00	Bobbin -:1
Udiode V:0.8	Induction T:1.27	Force ft/s:0.00	P/S-Order -:2
dUdiode V:.1	Remanence *:0.05	Bracket -:1	Rac/Rdc *:1.05
Ripple %:5.	W/kg *:1.00	Radiator -:0	Space *:0.95
Tmp. Amb.°C:40	VAr/kg *:1.00	Chassis -:1.00	Vertical -:1
Tmp.rise °K:75	Gap *:5.00	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. *:1.50	Selection -:2
Load 2 *:1.0	Assembly -:2	Case -:0	Criterion -:0

CIRCUIT:



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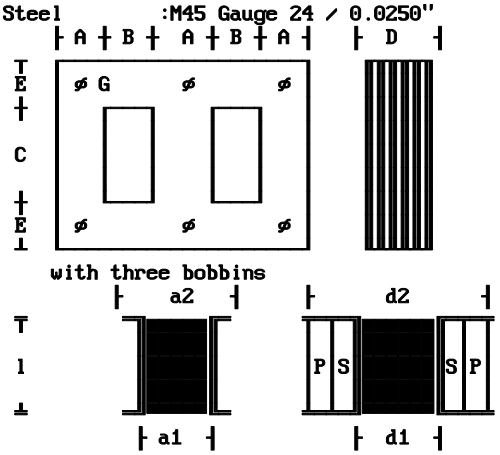
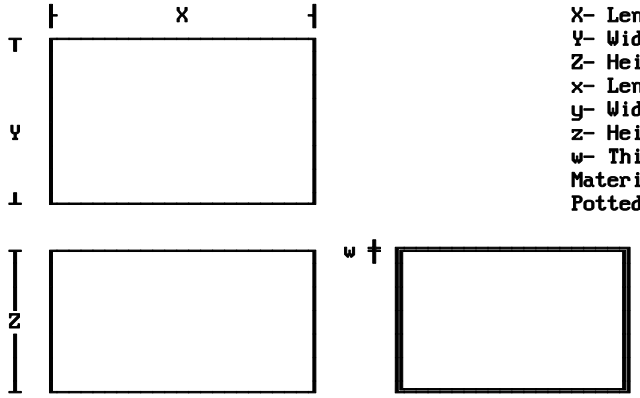
Name :3XEI 3P180/(2.0)
Steel :M45 Gauge 24 / 0.0250" /25.59



Weight	lb:30.97
Gap total	in:0.000
A-Limb	in:1.80
B-Width	in:1.80
C-Height	in:4.50
D-Stack	in:2.00
E-Yoke 1	in:1.80
F-Yoke 2	in:1.80
G-Hole	in:0.49
Radiator Fin	:0
Radiator Chan.	:0
a1	cm:2.03
a2	cm:3.53
d1	cm 2.20
d2	cm 3.76
l	cm:4.25
lp	cm:
ls	cm:
Margin	cm:0.13



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	204.7	C00	13.0	13.0	1	72.	72.	55	3.7	.	.	2.505	42.
2	1	364.6	C00	16.0	16.0	1	50.8	50.8	78	2.0	.	.	1.128	22.
3	1	377.7	C00	16.0	16.0	1	50.8	50.8	78	.17	.	.	.098	7.5
4	1	456.8	C00	16.0	16.0	1	50.8	50.8	78	1.0	.	.	.592	15.
5	1	660.2	C00	16.0	16.0	1	50.8	50.8	78	2.6	.	.	1.578	22.
6														
7														
8														
1														
2														
3														
4														
5														
6														
7														
8														
TOTAL													17.70	87.

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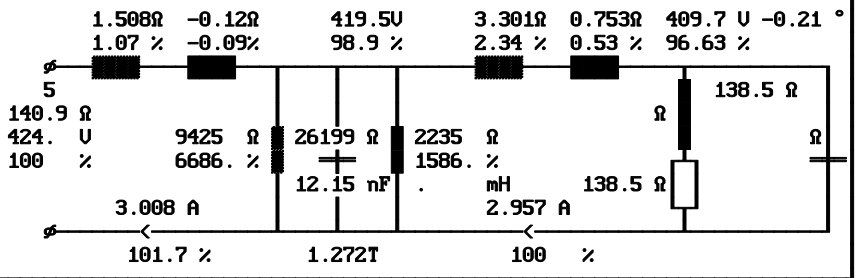
NOMINAL OPERATION at Temperature °C 113.5 and Overvoltage 1.06

Output Power on Load	W:3634.	Output Power of Transfor.	W:3634.
Cu Losses	W:41.64	Fe-Losses active	W:18.67
Short-Circuit-Volt. cold	%:2.46	Regulation	%:3.48
Instantaneous pow. .5/95&	W:4336.	Efficiency of Transformer	%:95.26
dT Fe average Surface	°K:65.6	dT primary	°K:74.5
dT Case aver. Surface	°K:.	dT secondary	°K:



DUTY CYCLE OPERATION at Amb.Temperature °C 40. and Overvoltage 1.06

dT Fe average Surface	°K:65.6	dT primary	°K:74.5
dT Gehäuse av. Surface	°K:.	dT secondary	°K:

NO LOAD OPERATION at Amb.Temperature °C 40. and Overvoltage 1.06

Losses active	W:20.06	Losses reactive	VAr:80.56
Current factor	%:6.51	Induction	T:1.285
dT Fe average Surface	°K:29.3	dT primary	°K:24.2
dT Gehäuse av. Surface	°K:.	Rezonance frequency	kHz:.5

SHORT-CIRCUIT OPERATION at Amb.Temperature °C 40. and Overvoltage 1.06

Losses active	W:50944	Losses reactive	VAr:9319.
Current factor cold	%:4060.	Induction	T:.897
dT Fe average Surface	°K:1320.	dT primary	°K:1923.
dT Gehäuse av. Surface	°K:.	dT secondary	°K:

PRIMARY (Tap:5)	1----	2----	3----	4----	5----	6----	7----	8-----
Voltage Input/Output	V:127.1	233.2	243.8	293.6	424.			
Out. Voltage no load	V:131.4							
Current Input/Output	A:9.533				3.008			
Load on output	Ω:13.33							
Power factor of load	:1.000							
Current in segment	A:6.536	3.005	3.006	3.007	3.008			
Current density A/in^2	:1606.	1482.	1483.	1483.	1484.			
Icc-Current cold	A:393.6				122.1			
Io -Current	A:				0.196			
Inrush Current peak	^A:				29.26			
Inrush Current rms	A:				12.29			
Cu-Losses	W:				41.6			
Resistance cold	Ω:.328	.9236	.9751	1.287	2.120			
Reactance	Ω:.0929	.0563	.0004	.0141	.0916			
Eddy-Current Factor	:1.	1.	1.	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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