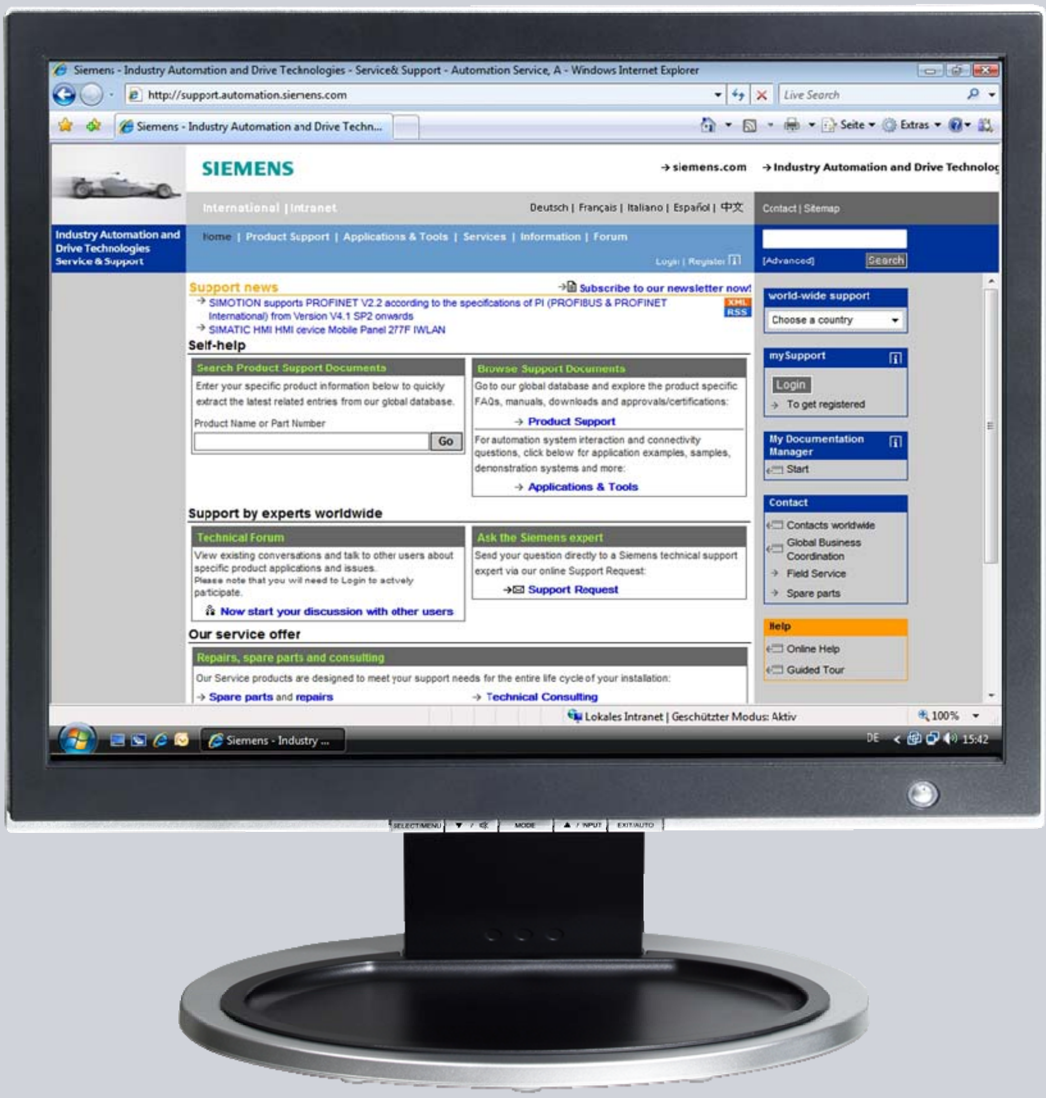
Power losses and calculation of the temperature rise

MICROMASTER 4

FAQ • October 2010



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Question

What are the power losses of MICROMASTER Drives and accessories and how is temperature rise calculated?

Answer

Like all electrical equipment, inverter drives produce waste heat. This heat must be removed to prevent the drive overheating. As most commercial electronics is limited to 70°C (the internal junction temperature must be limited to 125°C or 150°C, but is usually maintained below this), the maximum temperature of the cooling air surrounding, or supplied to the drive is therefore limited to 50°C. For some types and applications, this is reduced further to 40°C (see operating instructions and specification for details).

It is normal to install the drives, together with other equipment, in a cabinet or similar installation. The temperature of the air inside the cabinet must therefore be calculated.

In some cases, cooling air may be supplied by an external fan or ducting. In these cases, the calculation will need to account for the amount of air, as well as its temperature.

As part of the design of the installation, the following steps should allow the calculation of the temperature rise, and a suitable cooling system selected.

1. Determine the total power dissipated in the cabinet under worst case conditions (= ambient temperature in the cabinet).
2. Determine the maximum temperature of the air outside the cubicle, or the temperature of the air fed to the cubicle if ducted air is used.
3. Calculate the temperature rise. If this is too high, consider a different cooling solution (see PDF_additional_text).

Details to calculate the temperature and power losses are in the following file.

Table of content

1 Power Dissipation

Power Dissipation is the sum of all the power losses within the cubicle. This should take account of all equipment within the cubicle that may dissipate heat such as transformers, power supplies, PLCs etc. as well as the drive and its accessories.

1.1 Drive power losses

The inverter efficiently is stated as 97% or 95% – 97%. However, this does not relate to the “Drive Power” as stated in the handbook, but to the electrical power handling by the drive.

For example, a 7.5 kW drive and motor will deliver 7.5 kW of mechanical power at the shaft.

However, there will be mechanical and electrical losses in the motor, as well as reactive currents due to the motor power factor. Therefore a 7.5 kW inverter will need to deliver up to 9 or 10 kW of electrical power, and 10 – 12 kVA of “Volts and Amps”.

Please note that not for every inverter data is available[i].

Therefore if no other data is available, the full load losses of an inverter can be taken as 6% of the kW rating.

For loads less than full load, the loss may be taken as in proportion to the full load losses, but never less than one quarter of the full load losses.

On smaller drives (below 1 kW) these losses will be higher.

The following data is provided for MICROMASTER:

[i] For fields marked with “---“, or MLFB not mentioned, no data are available.

1.1.1 MICROMASTER 420

Mains operating voltage 1 AC 200 V to 240 V

No data are available

Mains operating voltage 3 AC 200 V to 240 V

Power CT (kW)	Losses CT (W)	Frame Size
0,12	14	A
0,25	28	A
0,37	38	A
0,55	55	A
0,75	69	A
1,1	82	B
1,5	106	B
2,2	150	B
3	226	C
4	293	C
5,5	393	C

Mains operating voltage 3 AC 380 V to 480 V

Power CT (kW)	Losses CT (W)	Frame Size
0,37	---	A
0,55	---	A
0,75	---	A
1,1	---	B
1,5	---	B
2,2	122	B
3	164	B
4	212	B
5,5	237	C
7,5	317	C
11	460	C

1.1.2 MICROMASTER 430

Mains operating voltage 3 AC 380 V to 480 V

Leistung VT (kW)	Verluste VT (W)	Baugröße
7,5	382	C
11	522	C
15	643	C
18,5	763	D
22	842	D
30	1160	D
37	1496	E
45	1299	E
55	2667	F
75	3516	F
90	2713	F
110	2585	Fx
132	3368	Fx
160	4026	Gx
200	4795	Gx
250	5801	Gx

1.1.3 MICROMASTER 440

Note: Losses on filtered and unfiltered drives are virtually the same.

Mains operating voltage 1 AC 200 V to 240 V

No data are available

Mains operating voltage 3 AC 200 V to 240 V

Leistung CT (kW)	Verluste CT (W)	Leistung VT (kW)	Verluste VT (W)	Baugröße
0,12	14	---	---	A
0,25	28	---	---	A
0,37	38	---	---	A
0,55	55	---	---	A
0,75	69	---	---	A
1,1	82	---	---	B
1,5	106	---	---	B
2,2	150	---	---	B
3	226	---	---	C
4	293	5,5	---	C
5,5	393	7,5	---	C
7,5	---	11	---	D
11	---	15	---	D
15	---	18,5	---	D
18,5	---	22	---	E
22	---	30	---	E
30	---	37	---	F
37	---	45	---	F
45	---	55	---	F

Mains operating voltage 3 AC 380 V to 480

Leistung CT (kW)	Verluste CT (W)	Leistung VT (kW)	Verluste VT (W)	Baugröße
0,37	55	---	---	A
0,55	72	---	---	A
0,75	93	---	---	A
1,1	131	---	---	A
1,5	173	---	---	A
2,2	155	---	---	B
3	203	---	---	B
4	269	---	---	B
5,5	265	7,5	382	C
7,5	382	11	522	C
11	522	15	643	C
15	643	18,5	763	D
18,5	711	22	842	D
22	842	30	1160	D
30	1074	37	1496	E
37	1247	45	1299	E
45	2182	55	2667	F
55	2667	75	3516	F
75	2210	90	2713	F
90	2245	110	2585	Fx
110	2762	132	3368	Fx
132	3332	160	4026	Gx
160	3914	200	4795	Gx
200	4500	250	5801	Gx

Mains operating voltage 3 AC 500 V to 600 V

No data are available

2 Accessory power losses

Drives are often installed with an input or output choke, which themselves have losses. These losses of these componetes must be included in the total cubicle losses (together with other equipment).

Losses may again be recalculated for loads less than full load, but in this case should not be taken as less than one half in any case.

Braking resistors losses will be dependent on load cycling, and should be included in calculations if the resistor is inside the cabinet.

2.1 Input or main supply chokes

Frame Size	MLFB	Power Loss (W)
A	6SE6400-3CC00-2AD3	6
A	6SE6400-3CC00-4AD3	12.5
A	6SE6400-3CC00-6AD3	7.5
B	6SL3203-0CD21-0AA0	9
B	6SL3203-0CD21-4AA0	27
C	6SL3203-0CD22-2AA0	98
C	6SL3203-0CD23-5AA0	37
D	6SE6400-3CC05-2DD0	92
D	6SL3203-0CJ24-5AA0	90
D	6SL3203-0CD25-3AA0	90
E	6SE6400-3CC08-8EC0	180
E	6SE6400-3CC08-3ED0	145
E	6SL3203-0CJ28-6AA0	170
F	6SE6400-3CC11-7FD0	280
F	6SE6400-3CC11-2FD0	280
Fx	6SL3000-0CE32-3AA0	240
Fx	6SL3000-0CE32-8AA0	210
Gx	6SL3000-0CE33-3AA0	233
Gx	6SL3000-0CE35-1AA0	365

For smaller chokes, assume 1% loss of drive power rating at full load.

2.2 Output or motor chokes

Frame Size	MLFB	Power Loss (W)
A	6SE6400-3TC00-4AD3	11
A	6SE6400-3TC00-4AD2	5
B	6SE6400-3TC01-0BD3	50
C	6SE6400-3TC03-2CD3	65
D	6SE6400-3TC05-4DD0	200
D	6SE6400-3TC03-8DD0	200
D	6SE6400-3TC03-2DE0	189
E	6SE6400-3TC08-0ED0	170
E	6SE6400-3TC07-5ED0	270
F	6SE6400-3TC15-4FD0	250
F	6SE6400-3TC14-5FD0	470
F	6SE6400-3TC06-2FE0	331
F	6SE6400-3TC08-8FE0	451
F	6SL3000-2BE32-1AA0	490
F	6SL3000-2BE32-6AA0	500

For lager chokes, assume 1% loss of drive power rating at full load.

2.3 EMC or main supply filter

MLFB	Power Loss (W)
6SL3000-0BE32-5AA0	15
6SL3000-0BE34-4AA0	49
6SL3000-0BE36-0AA0	55

LC or motor filters

MLFB	Power Loss (W)
6SE6400-3TD03-7DD0	210
6SE6400-3TD04-8DD0	240
6SE6400-3TD06-1DD0	280
6SE6400-3TD07-2ED0	300
6SE6400-3TD11-5FD0 (37kW)	340
6SE6400-3TD11-5FD0 (45kW)	460
6SE6400-3TD15-0FD0	530
6SE6400-3TD18-0FD0	560
6SE6400-3TD00-4AD0	60
6SE6400-3TD01-0BD0	100
6SE6400-3TD03-2CD0	125
6SL3000-2CE32-3AA0	600
6SL3000-2CE32-3AA1	600
6SL3000-2CE32-8AA0	690
6SL3000-2CE33-3AA0	530
6SL3000-2CE34-1AA0	700
6SE6400-3TD01-0CE0	65
6SE6400-3TD02-3CE0	125
6SE6400-3TD02-3DE0	260
6SE6400-3TD03-2DE0	280
6SE6400-3TD03-7DE0	300
6SE6400-3TD04-8EE0	430
6SE6400-3TD06-1EE0	450
6SE6400-3TD07-1FE0	530
6SE6400-3TD10-0FE0	550
6SE6400-3TD11-5FE0	640

3 Determing the ambient temperature and cooling air

Determine the temperature of the air outside the cabinet, or the temperature of the air supplied to the cabinet. Bear in mind the effect of the season, sunlight, and other equipment. The temperature in a large factory in summer with all the equipment running will be very different to that in winter during commissioning.

Calculating the temperature rise

Two simple formulae can be used to calculate the temperature rise in the cubicle.

Naturally cooled cubicle

If no external air is fed to the cubicle, and no cooling fan is fitted to exchange air in the cubicle, the temperature rise can be estimated using the total power dissipated within the cubicle and the exposed surface area of the cubicle as follows:

Temperature rise = Total power dissipated (W) / (5.5[ii] * Exposed surface of cubicle (m^2))

Example:

If the total power dissipated in a cubicle is 300W, and the exposed surface area of the cubicle is 4m^2 (typically roof, sides and front; note that the floor and back are not normally exposed), then the rise in temperature above the external ambient temperature (in the cubical) will be 13.6°C.

T_{rise} = 300 / (5.5 x 4) = 13.6°C rise

If the worst case external temperature is 40°C, then temperature within the cubicle could rise to 53.6°C, which is too high for most electronic equipment including MM4 drives, so another solution must be found.

Fan cooled cubicle

If the cubicle is ventilated by a fan, then temperature rise within the cubicle can be calculated using the following formula:

Temperature rise = (0.053[iii] * Total power dissipated (W)) / Air flow in cubicle (m^3/min)

So in the above example, if the cubicle is fitted with a small fan (such as the fan used on MM4 FSC 3.28m^3/min) the temperature rise will be 4.8°C

T_{rise} = (0.053 * 300) / 3.28 = 4.8°C

In a 40°C external ambient temperature, the internal ambient temperature rises up to 44.8°C. This figure is acceptable.

[ii] factor found out experimentally
[iii] factor found out experimentally

Note that when force ventilating a cubicle it may be necessary to taken account of dust or other pollution. If a fan filter is fitted, this may reduce the airflow and require maintenance.

Also note: flow rates are often given as cubic feet per minute (cfm), so to convert to cubic metres per minute (m³/min) use the following multiplier:

m³/min = cfm * 0.0283

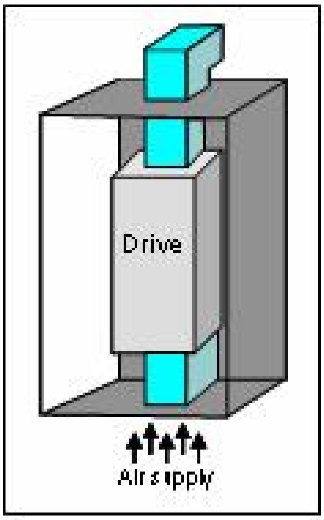
Example:

for a given air flow of 116.3cfm this is 3.29m³/min (116.3 * 0.0283)

High dissipation conditions

Where it is not possible to obtain sufficient cooling using the above methods, external air may be ducted to the drive or cubicle, or cubicle air conditioning installed.

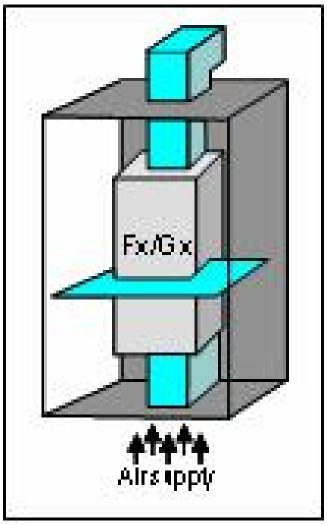
External ducting



Cool air ducting from outside is a good solution, especially where large volumes of air are needed. For example, an Fx 90 kW drive needs 225 litres of air per second at 40°C maximum temperature. Therefore separately supplied air directly to the air inlet of the drive will ensure good airflow, and ducting of exhaust air will reduce heating of other equipment.

Unless care is taken, the drive fan will simply circulate air within the cubicle, leading to a rapid temperature rise.

Ducting, or a least partitioning of cubicle interior, is recommended for Fx and Gx drives



Air conditioning

Air conditioning units are available that will cool the inside of the cubicle. The supplier of these units will be able to provide data concerning temperature rise; power dissipation calculations inside the cubicle will be needed. Care must also be taken when the units are switched on after shut down or maintenance, as the subsequent drop in temperature may cause condensation inside the cubicle. Air conditioning units are expensive.

4 Examples

1. Installation on a small machine

Two MM420 1.5 kW drives are fitted to a small machine, with some other equipment which dissipates 30W.

The cubicle is part of the machine, and has a total of 3m² exposed surface.

The maximum external temperature is 35°C (typical European factory).

Total dissipation:

2 *106W + 30W = 242W

Temperature rise = 242 / 5.5 * 3 =13.8°C

Maximum temperature = 35°C + 13.8°C = 49°C

The maximum temperature is below the limit, the instalation is OK!

2. Large control cubicle in middle east

Four 18.5 kW MM430 400V drives, fitted with input chokes, are installed in a large cubicle together with two 7.5 kW MM440 400V drives without chokes. The cubicle is in a temperature controlled plant room maintained at 25°C.

Power dissipation:

MM430 18.5 kW, 763W

Chokes: 6SE6400-3CC04-4DD0 115W

MM440 7.5 kW, 382W

Total dissipation = ((763W + 115W) x 4) + (2 x 382W) = 4276W

Cubicle is 4m long 2m high and 1m deep, with all sides open except base.

Total exposed area:

2 sides each 2 x 4m = 16m²

2 ends each 2 x 1m = 4m²

Top 1 x 4m = 4m²

Total 24m²

The temperature rise inside cubicle = 4276 / (5.5 x 24) = 32.4°C

The temperature inside cubicle 32°C + 25°C = 57°C too much all drives, especially as MM430 are rated at 40°C maximum.

Eliminate this with fitting four fans, one to each door; say 4.0m³/min

Whereby the temperature rise = (0.053 * 4276) / (4 x 4.0) = <u>14.2°C</u>, and the Cubicle temperature = 14.2°C + 25°C = <u>39.2°C</u>. This is OK!

4.1 Summary

- Calculate the worst case dissipation for all equipment.
- Check the worst case external temperature.
- Calculate the temperature rise, redesign the cooling as needed.
- Take account of any contamination issues and consider maintenance procedures if necessary.

As always, care at the design stage will save problems in the field.

5 Appendix

5.1 History

Tabelle 5-1 History

Version	Date	Changes
V1.0	March 2006	First issue
V1.1	2007	
V1.2	September 2008	Text revised, tables enlarged
V1.3	Juli 2010	PDF revised
V1.4	October 2010	Choke data revised
V1.5	November 2010	Chapter 4 revised