Introduction

Frequency converters develop heat when they are operating. The heat loss depends on a number of factors: mains voltage, switch frequency, load, and motor cable length. The heat loss is typically 3-4 % of the nominal output power. This heat has to be transported away from the VLT to avoid overheating the VLT. The frequency converter removes the heat by forced convection via a fan in the drive. This heats up the air in the cabinet where the VLT is installed. External measures have to be taken to remove the heat from the cabinet. Some of the heat is transported through the walls of the cabinet. This portion can normally be neglected when dimensioning airflows for cooling frequency converters, as the heat transport capabilities of typical cabinets are less than 50 W. The typical way to remove heat from cabinets is by mounting a fan in the cabinet door or walls, as illustrated on Figure 1.

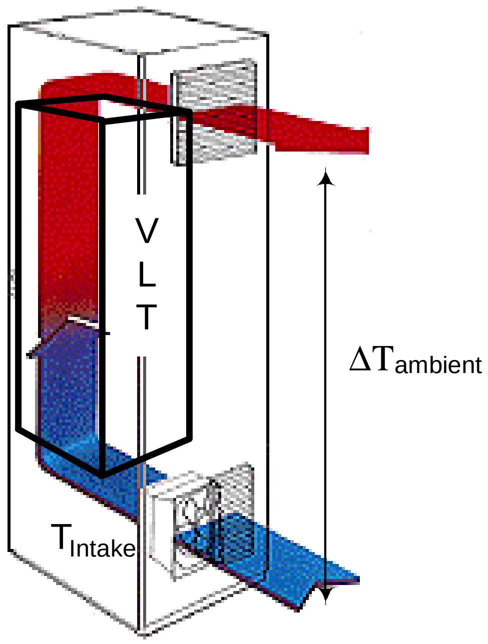

Figure 1 Heat removal from cabinets

Two temperatures are involved when dimensioning VLT cooling needs: $T_{average}$ and T_{max}. $T_{average}$ is the average temperature over 24 hr. This temperature limits the long-term effects of high temperature, i.e. premature aging of the electrolytic capacitors. T_{max} is the maximum temperature where the VLT can run continuously at full load. Exceeding this temperature requires derating of the frequency converters output, as described in the Design guide. Both temperatures refer to the intake temperature of the VLT, that is the temperature just below the VLT. The temperatures can be found in the Design Guides of each VLT type. $T_{average}$ must be 5K (5°C) lower than T_{max}. If there is no natural 24 hr temperature variation, for instance between night and day, $T_{average}$ must be used to dimension the cabinet cooling. The lifetime of the VLT will otherwise be reduced.

The fan curve

The governing principle in fan selection is that any given fan can only deliver one flow at one pressure in a particular system. This "operating point" is determined by the intersection of the fan static pressure curve and the system pressure curve.

Figure 2 illustrates the operating points of both high and low resistance systems. It is best to select a fan that will give an operating point being toward the high flow, low-pressure end of the performance curve to maintain propeller efficiency and to avoid propeller stall. Each particular cabinet design should be analyzed for possible reduction in the overall resistance to airflow. Other considerations, such as available space and power, noise, reliability, and operating environment should also be brought to bear on fan choice.

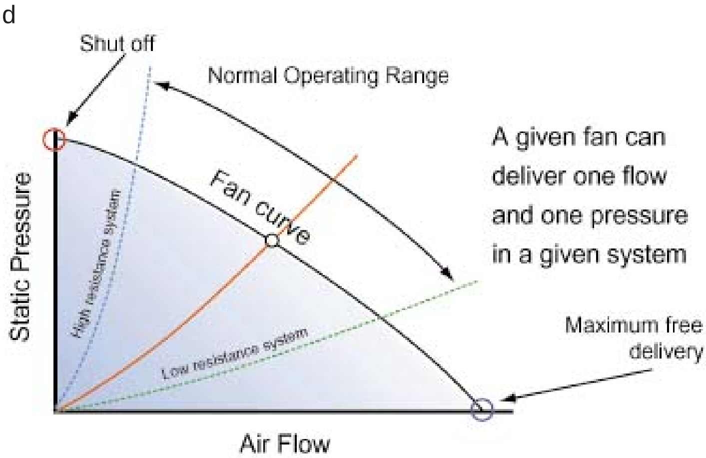

Figure 2 Fan/system Interaction

Estimate the Required Airflow

The required volumetric flow rate can be calculated from:

$$G = \frac{Q}{\rho c_P \Delta T}; \quad [m^3/s]$$

Where:

G =	volumetric flow rate, [m³/s]
Q =	total amount of heat loss in cabinet, [W]
ρ =	density of air, [kg/m³]. Equals 1.275 kg/m³ for dry air at 0°C and 1 bar.
c_P = kJ/	specific heat of air, [kJ/kg×K]. Equals 1.01 kg×K for dry air at 0°C and 1 bar.
ΔT =	air temperature difference, [K]. Difference between exhaust and intake air temperature. If T_{max} or $T_{average}$ shall be used, see page 1.

This yields a rough estimate of the airflow needed to transport a given amount of heat at sea level. It should be noted that it is the mass flow rate of air, not the volumetric flow rate, which governs the amount of cooling. A typical temperature difference between exhaust and intake air is 5K (equal to Δ5°C). Also note that the heat transfer capability of humid air is less than for dry air, and that air density is reduced at elevated places and higher temperatures. In general cases the following equation can be used to estimate the required airflow in the cabinet:

$$G = 3.1\frac{Q}{\Delta T}; \quad [m^3/h], \textit{ at } 20°C \textit{ and } 101.3kPa$$

This should be considered as the minimum amount of air required. We recommend a safety margin of at least 20 % to make sure the airflow is sufficient to ensure an acceptable operating temperature of the VLT.

Most cabinet suppliers are able to advise regarding thermal design. Some also have computer programs to aid in the dimensioning and selection process.

<u>Example</u>

Five VLT 5006 are to be built into the same cabinet, all dimensioned to be run at full load. The ambient air temperature is 40°C (intake temperature). The power loss of one VLT 5006 at full load is 198 W.
(The desired temperature increase through the cabinet is 5°C, which converts to 5°K).
Determine the necessary amount of airflow in the cabinet?

We start by calculating the total amount of power loss in the cabinet:

$$P_{total} = 5 \cdot 198W = 990W$$

The heat transport through the cabinet walls is ignored, and the temperature difference is assumed to be 5K. The equation above gives the following required airflow:

$$G = 3.1\frac{990\,W}{5K} = 614\ [m^3/h]$$

Cabinet Cooling Hints

In addition to selecting a fan, there may be some choice in the location of the fan or fans, and in this regard, the illustration in Figure 3 may prove useful. The following comments should also be kept in mind with regard to fan location:

1) Locate components with highest heat dissipation near the enclosure air exits.

2) Size the enclosure air inlet and exit vents at least as large as the venturi opening of the fan used.

3) Allow enough free area for air to pass with velocity less than 7 meters/sec.

4) Avoid hot spots by spot cooling with a small fan.

5) Locate components with the most critical temperature sensitivity nearest to inlet air to provide the coolest airflow.

6) Blow air into cabinet to keep dust out, i.e. pressurize the cabinet.

7) Use the largest filter possible, in order to:
   a. Increase dust capacity
   b. Reduce pressure drop.

8) Always place the cabinet exhaust higher than the top of the VLT.

9) Make sure the airflow from the VLT isn't “shorted”. I.e. a large portion of the VLT intake air should not be the exhaust air from the VLT. Mounting baffles in the cabinet can for instance avoid this.

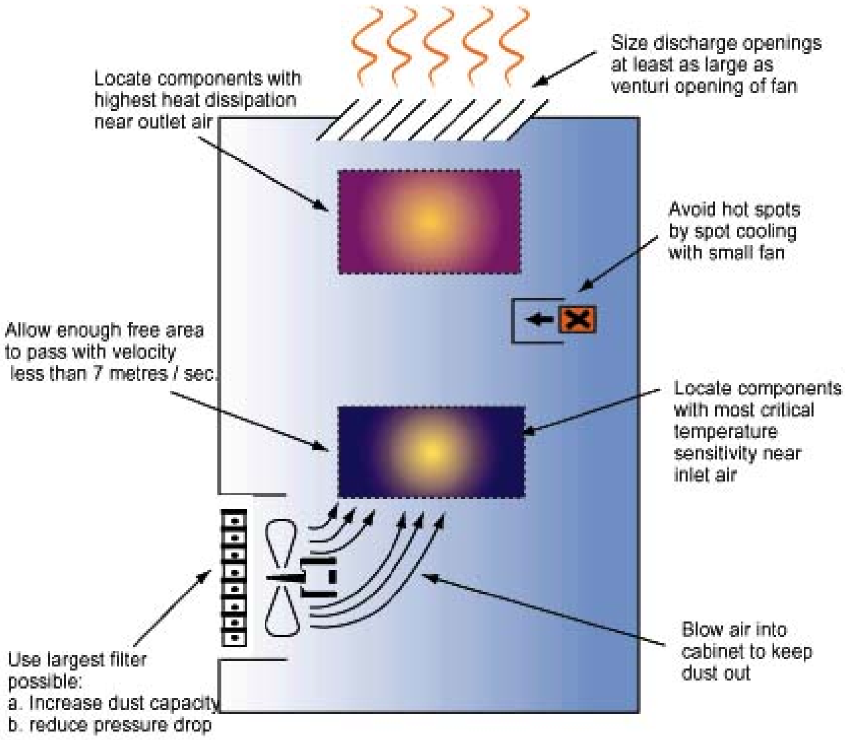

Figure 3 Cabinet Cooling Hints