Technical Note 1

Cooling and Ventilation requirements

of Variable Speed Drives and Soft Starters

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Note: This article is intended as a guideline only. It is the responsibility of the installer to define and accommodate all environmental factors influencing enclosure selection and to liaise with their enclosure supplier to confirm enclosure suitability

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Section 1.0 - Introduction

This document is intended to be a guide for the installation of Variable Speed Drives and Soft Starters to ensure adequate cooling or ventilation is provided. All power electronic equipment will dissipate heat which must be removed to prevent overheating of the semiconductor devices or other components. The installation and environmental factors must be considered with all external sources of heat removed or minimised. An important consideration is the effects of direct sunlight, in which all precautions should be taken to remove the effects by providing adequate shelter.

The scope of this technical note is to provide guidance to calculate ventilation / cooling requirements, but the calculations make no consideration for external factors such as direct sunlight, other heat sources etc.

Section 2.0 – Heat Dissipation

All Power electronic equipment generates heat during operation which must be removed to maintain the equipment operating temperature below its rated value. The first step is to calculate how much heat the equipment generates. This is dependant upon the type of equipment and how it is configured and operated.

2.1 Soft Starters

Soft Starters use power devices in the form of thyristors or SCR's which generally have an efficiency of about 99%. Soft Starters may be configured to operate in a continuous or bypass mode. Continuous is when the SCR's are dissipating heat whist ever the motor is running. In bypass configuration the SCR's are only operating during starting and stopping, all other times the SCR's are bypassed using a bypass contactor. When the SCR's are bypassed they dissipate no heat, therefore minimising the ventilation required. The reduced heat dissipation is a common deciding factor for bypass configuration.

2.1.1 Calculating the heat dissipation

The heat produced by the soft starter can be calculated from the motor full load current rating according to the following formula:

1. *Continuous Duty* $P_{LOSS} = FLC \times 4.5$

2. *Bypass Duty* $P_{LOSS} = (FLC \times SC \times 4.5 \times t \times N) / 3600$

P_{LOSS}	*Power dissipated by soft starter, in W (Watts)*
FLC	*Motor full load current, in A (Amps)*
t	*Starting time, in seconds*
N	*Number of starts per hour.*
SC	*Average starting current expressed as per unit of FLC*

Example:

What is the expected heat dissipation of a 22kW motor of 42A FLC operating at 5 starts per hour at 15 seconds per start at a start overload 300% FLC.

Continuous Duty	P_{LOSS}	= 42 x 4.5	= 189 W
Bypass Duty	P_{LOSS}	= (42 x 3 x 4.5 x 15 x 5) / 3600	= 12 W

2.2 Variable Speed Drives

The thermal losses of the Variable Speed Drive may for all practical purposes be assumed to be about 3%. Smaller Variable Speed Drives are approximately 4% and as the drive increases in size the percentage of thermal losses decreases to about 3%.

Example:

What is the estimated heat generated by a 40A VSD controlling a 22kW motor at full load?

P_{LOSS} = 22kW x 0.03

= 0.66kW

= 660W

2.3 Auxiliary Equipment

Where additional equipment is mounted in the same enclosure as the soft starter or Variable Speed Drive, any heat generated by such auxiliary equipment must be added to the total heat generated. Equipment suppliers can provide details of the heat generated by their equipment.

2.4 Installation alternatives

Variable Speed Drives and Soft Starters are available in different types of enclosures like most electrical equipment to suit the environment which they are to be installed. The type of enclosure supplied is based on the level of protection offered against water and objects, known as an IP rating. If the protection offered is not adequate for the environment to be installed then the alternatives need to be investigated.

These alternatives may include;

- Use a product with higher protection rating.

  Zener Drives are available in IP30, IP66 and also Stainless Steel IP66 which means they may be installed without further protection..

- Relocate to alternative location.

  This is sometimes necessary when the environment may be extremely corrosive or flammable.

- Install equipment in an enclosure with a higher protection rating.

  When equipment that generates heat is installed into another enclosure the heat must be dissipated. If this heat is not removed the heat inside will build up to a level which will affect the reliable operation of the equipment, reduce the life expectancy of the product or cause failure to other equipment. If choosing to ventilate an enclosure this may reduce the protection rating to an unacceptable level.

3.1 Dissipation of Heat Generated inside an Enclosure

The heat generated within an enclosure may be dissipated by:

- The enclosure wall surface area (ie. non ventilated)
- Forced air ventilation
- Heat exchanger or water cooling (not dealt with in this article)

The dimensions of the enclosure, how it is mounted and the outside ambient temperature will then define the amount of heat that can be dissipated through the exposed surfaces of the enclosure. Where the surface area of the enclosure is insufficient to dissipate the heat generated inside the enclosure, the remaining heat may be removed by forced ventilation.

3.2 Non Ventilated Enclosure

Non ventilated enclosures rely on the heat being dissipated through the walls of the enclosure. The better heat conduction of the enclosure the more heat dissipated. For this reason metal enclosures are far better at dissipating heat than plastic enclosures.

The power that can be dissipated in a given exposed surface area is;

$$P_{ESA} = k \times S \times \Delta T$$

P_{ESA}	Power dissipated from within the enclosure via exposed surface area in W (Watts)
k	Heat transfer coefficient [sheet metal ~ 5.5W/m^{2}K, plastic ~ 3.5W/m^{2}K]
S	Corrected enclosure surface area of the enclosure, in m^2 in accordance with IEC890. Details on calculating the value of S are provide in section 3.2.1
ΔT	Temperature differential (inside enclosure - outside ambient), in °C

Example:

A 110kW 187A motor is started using a soft starter where the starting time is 30 seconds with overload current of 450% and 3 starts per hour. The soft starter is rated for 45°C ambient and the outside ambient is worst case 35°C. Select a suitable enclosure size for bypass operation. Installed in a single enclosure mounted against a wall: dimensions 1000mm(H) 800mm(W) 320mm(D)

Bypass Duty P_{LOSS} = (187 x 4.5 x 4.5 x 30 x 3) / 3600 = 95 W

(For purpose of this example, the only auxiliary equipment losses (line contactor and bypass contactor) are considered negligible and hence ignored.)

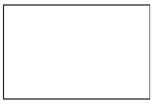
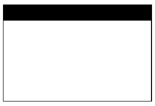
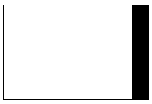
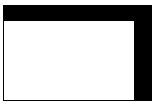
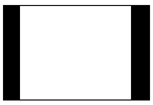
Effective enclosure area: S = 1.4 x 0.8 x (1+ 0.32) + 1.8 x 0.32 x 1 = 2 m^2

P_{ESA} = 5.5 x 2 x 10 = 110 W

Therefore, P_{ESA} > P_{LOSS} so that enclosure is suitable without any ventilation

3.2.1 Calculation of S

The value of S is the corrected enclosure surface area based on the method of installation in accordance with IEC60-890. S is calculated by using the appropriate formula below.

Enclosure Position	Location (IEC60-890)	Formula for calculating S
	Accessible on all sides	S = 1.8 x H x (W + D) + 1.4 x W x D
	Placed against a wall	S = 1.4 x W x (H + D) + 1.8 x D x H
	End of a row of enclosures	S = 1.4 x D x (H + W) + 1.8 x W x H
	End of a row of enclosures with the back against the wall	S = 1.4 x H x (W + D) + 1.4 x W x D
	Intermediate in a row of enclosures	S = 1.8 x W x H + 1.4 x W x D + D x H
	Intermediate in a row of enclosures with the back against the wall	S = 1.4 x W x (H + D) + D x H
	Intermediate in a row of enclosures back against the wall with top part covered	S = 1.4 x W x H + 0.7 x W x D + D x H

3.3 Ventilated Enclosure

With ventilated enclosure the heat is dissipated by forcing ambient air in or out of the enclosure. The objective is to circulate the air through the enclosure, so it is not critical whether the fan creates a pressure or vacuum in the enclosure (ie blows in or out). Generally ambient air is drawn in at the bottom of the cabinet through and discharged through a ventilation opening at the top. The outlet should be placed above the highest mounted drive or starter.

Filters installed on Fan units provide a better protection rating (normally max IP54) but impede the flow of air. It is important to check the manufacturer's specifications when a filter is fitted. Additionally, if the filter collects any dust the airflow will be reduced significantly and needs to be considered in your selection decision and design.

The volume of air required can be estimated using the formula.

$$V = (3.1 \times P_{EXHAUST}) / \Delta T$$

V	Volume of air flow required, in m^3/hr
$P_{EXHAUST}$	Power exhausted from within the enclosure, in W (Watts)
ΔT	Temperature differential (inside enclosure - outside ambient), in °C

Example:

Three (3) 4kW Variable Speed Drives are to be installed in an enclosure. Calculations based on operating at full capacity of the drive. Assuming a power loss of 3.5% and a temperature differential of 10°C.

P_{LOSS} = (4kW x 0.035) x 3 (ie. 3 drives)

= 420Watts

Volume = $(3.1 \times P_{EXHAUST}) / \Delta T$

= (3.1 x 420) / 10

= 130 m^3/hr

Therefore, a fan or combination of fans would be required to provide 130m^3/hr of airflow.

Section 4 – Other Considerations

4.1 Equipment Spacing

To adequately exhaust heat generated, certain minimum clearances must be maintained around the VSD and soft starter. Please refer to the product installation manual for details.

4.2 Equipment / stirring Fans

Stirring fans can distribute the heat evenly throughout the enclosure to avoid hot spots. Fans can be controlled to run for a given time at starting or temperature controlled to extend fan life and reduce audible noise.

4.3 Forced Ventilation

Where ventilation is used to exhaust heat, care should be taken with regard to IP rating of the enclosure. Furthermore the size of the air intake should be at least the size of the exit and if more than one fan is used then the fans should be the same. Remember where filters are used you must take into account pressure drops across the filters. Filters should be inspected regularly for blockage as part of the maintenance schedule to ensure free air flow and correct operation. Force ventilation may also be temperature controlled to minimize running time and increase the life expectancy of the fans.

4.4 Equipment De-rating

The components of electronic equipment are designed to operate under full load at a particular maximum temperature. By reducing the load, the internal operating temperature will be reduced allowing the equipment to operate in a higher ambient temperature. Please refer to the instruction manual or contact your local Zener representative for manufacture de-rating.

4.5 Solar Heating

Exposure of the enclosure to the sunlight (direct or reflected) will result in solar heating. Proper use of a shelter will reduce such heating; and enclosure material and paint colours have different absorption properties of solar energy. Variable Speed Drives and Soft Starters should not be mounted in direct sunlight or on hot surfaces.

4.6 Environment

The environment of an installation determines the type of enclosure to be used. Where dust and water (or moisture) are present one may consider using an IP66 enclosure which would then rely entirely on radiated heat loss for cooling or a heat exchanger will be needed. For aggressive environments one may use a stainless steel or plastic enclosure. If a fan or fan/filter is installed the IP66 rating will be degraded.

The MSC-3 provides an easy solution with the IP66 or the stainless steel IP66 enclosure option. All the heat loss is taken care of and can be directly mounted on a wall (see instruction manual for further information). The VSD has an integral dual compartment heat exchanger where the VSD electronic components are housed in a totally enclosed compartment, and the heat from the VSD is ventilated in a separate compartment housing the heatsink and ventilation fan (no filters are used). The VSD can be field mounted closer to the motor thus reducing costs of screened cable.