



## Application Note

### European Low Voltage and EMC Directives and their application to systems incorporating Caledon thyristor

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#### INTRODUCTION

Thyristor stacks manufactured by Caledon Controls are designed to comply with European Low Voltage and EMC directives. The following notes highlight some of the more important aspects of compliance, and offer guidance to the user on systems considerations necessary to ensure complete system compliance.

#### LOW VOLTAGE DIRECTIVE

Caledon thyristor stacks are CE marked in compliance with the Low Voltage directive. They are self certificated, and the following standards have been applied in whole or in part in their design:-

1	EN 60947-1 1992	Low Voltage switchgear and controlgear, part 1, General rules.
2	EN 61010-1 1993	Safety requirements for electrical equipment for measurement, control and laboratory use, part 1, General requirements.
3	EN 50178 1997	Electronic equipment for use in power installations.

Two of the most important aspects covered by these standards are insulation requirements and temperature / overload considerations.

#### Insulation / Protection against electric shock

For the purposes of defining insulation requirements the environment in which the equipment is to be installed is categorised by 'installation (overvoltage) categories' and 'pollution degree'. The overvoltage category defines the electrical environment. In any particular category the equipment may be expected to have to withstand overvoltages caused by, for example, inductive load switching or lightning strikes. Thyristor applications generally fall into installation category 3 - fixed installations at distribution level. The pollution degree defines the physical 'micro-environment' in which the equipment is installed. The accepted degree for power electronics is 2. Normally only non-conductive pollution occurs. Occasionally a temporary conductivity caused by condensation may be expected, but only while the equipment is out of operation.

Caledon thyristor stacks are designed with an impulse withstand voltage of 4kV. This corresponds in the standards to installation category 3, and supply voltage (line to earth) up to 300V (AC RMS). This corresponds to 520V line to line (480V nominal supply) on most distribution systems, in which the supply transformer is star connected with earthed star point. This does not preclude the use of the stacks in higher voltage systems (provided the thyristor devices are suitably rated), but precautions may be necessary (surge arrestors) to limit the expected impulse voltage level, to ensure systems compliance with the above standards.

The defined pollution degree enables the stack designer to determine the required creepage distances required across surfaces separating live parts, to ensure adequate insulation. The installer must therefore ensure that the pollution degree does not exceed that specified. This means that, sources of conductive dust, eg carbon/graphite must be excluded from the cabinet in which the stack is installed.

The insulation between mains circuits and control circuits meets the requirements for reinforced insulation. Control circuits have an isolation withstand capability of 1000V RMS to ground, or between galvanically isolated circuits.

To ensure that the stack insulation is not compromised by the installation, where cables associated with different circuits are grouped together, the insulation of the cables must be suitable for the voltage of the highest voltage circuit in the group.

The stacks incorporate a clear polycarbonate cover designed to protect against accidental contact with live parts. This does not necessarily completely prevent contact with live parts, and they should be installed in a cabinet requiring a tool to gain access, and access should be restricted to suitably trained and qualified personnel.

#### Temperature / overload

All current Caledon thyristor stacks incorporate integral semiconductor fuses. These are intended to provide short circuit protection for the thyristor devices, by limiting the peak half cycle surge current and total energy let through. They only provide limited protection against long term overload. The stack ratings are coordinated with standard HBC fuse values, and the supply cables should be protected with gG fuses or circuit breakers rated the same as, or lower current than the stack. All the stacks with fan cooling also incorporate automatically resetting thermal cut outs, which monitor the heatsink temperature, and ensure that they do not rise to an unsafe temperature.

The stacks are rated for a maximum ambient operating temperature of 50°C. This refers to the ambient air temperature entering the heatsinks at the base of the stack. The design of an installation must however take into account the ratings of cables and other switchgear within the cabinet. Elevated temperatures also shorten the life of some electronic components, notably electrolytic capacitors, which dry out. It is good practice to design for lower ambient temperatures under normal conditions. A major cause of elevated temperatures in a cabinet containing thyristor stacks is the power dissipated by the thyristor devices, which may be approximated in watts as  $1.5 \text{ to } 2 \times (\text{RMS current}) \times (\text{Number of controlled lines})$ . The exhaust air temperature from the stack will be higher than ambient by up to 20°C. It is not good practice to mount other items of control gear directly in the exhaust airflow. In particular the current carrying capability of fuses or circuit breakers will

be significantly reduced if this is done. A tidy solution is to mount circuit breakers or fuses supplying the stack on a sub-chassis mounted forward from the main chassis on which the stack is mounted. The exhaust air then passes behind these components. Thyristor stacks should not be mounted one above the other, as this will significantly derate the upper unit, which, for rating purposes will be operating in an ambient equal to the exhaust air temperature of the lower unit. Heat from the thyristors, together with that dissipated by the semiconductor fuses will also raise the temperature of the busbars to which outgoing cables are connected, and high temperature cables should be used. The cross-section of the cables and their ventilation will influence the temperature of the connection studs, and the guide below shows recommended minimum cross sections.

**Guide to minimum cable sizes**

The following is a guide only, as installation conditions will vary. A maximum control cabinet temperature of 50°C has been assumed, with cables routed in free air in the immediate vicinity of the stack, and passing into trunking in groups of three. The cable protective fuse or circuit breaker rating has been assumed to be equal to the stack current rating. For currents up to 200A a cable with a maximum operating temperature of 85/90°C has been assumed. For 315A and above a cable with a maximum operating temperature of 125°C has been assumed. We recommend the use of cables with silicone rubber insulation, such as rubber insulated coil lead type 5 to BS7655. Alternatively busbars or flexible busbars may be used.

STACK RATING	CABLE CROSS SECTION	STACK RATING	CABLE CROSS SECTION
80A	25mm <sup>2</sup>	315A	150mm <sup>2</sup>
125A	50mm <sup>2</sup>	400A	150mm <sup>2</sup> or 2 x 120mm <sup>2</sup>
160A	70mm <sup>2</sup>	600A	2 x 150mm <sup>2</sup>
200A	120mm <sup>2</sup>	800A	2 x 150mm <sup>2</sup>

**ELECTROMAGNETIC COMPATIBILITY (EMC)**

Considerable effort has been expended in the design of Caledon's thyristor stacks, to ensure that the integral control electronics fully meets the requirements of the European emc directive, and to ensure that the units can be designed in to compliant systems with the minimum of effort.

The stacks have been characterised for an industrial environment, which for the purposes of the standards is defined as a site having its own distribution transformer for the use of one industrial user. The smaller sizes would also be suitable for commercial / light industrial supplies.

**Immunity**

The stacks fully meet the immunity requirements of EN50 082 part 2, the EC generic standard for an industrial environment and show no degradation of performance. In particular, the immunity to conducted interference is high, and there are no observable effects, other than controlled shut down, when tested to higher levels of interference than those specified in the above standard. This is particularly important for thyristor equipment of this type, which often operates in the worst kind of heavy electrical environment, and yet is required to accurately synchronise to the line voltage waveform.

Equipment which meets the immunity requirements of EN 50 082 part 2, by definition also meets the requirements of part 1, the standard for light industrial and commercial environment, which is less severe.

EN 50082-2 has been superseded by EN 61000-6-2 : 1999, which is aligned with IEC 61000-6-2 : 1999. Our stacks will also meet the requirements of this standard. The date of cessation of presumption of conformity of the superseded standard is April 2002.

It is not specifically necessary to use screened cable for the wiring of control circuits to achieve this immunity level. We recommend that good wiring practice be followed within the control panel, taking care to avoid running signal wiring parallel to high current or switching circuits as far as is reasonably practical. If signals are sourced from outside the panel we recommend that screened cable be used outside the panel, and the screen earthed at the point of entry to the panel. This is most conveniently undertaken using special glands, but if pigtails are used these should be earthed to the metalwork as directly as possible. If screened cable is used between the entry to the panel and the stack, then the screen should be earthed to the metalwork near the stack. Incorrect earthing of screened cables can result in worse performance than using non-screened cables.

**Emissions**

Emissions can be divided into two categories:-

- 1 Those associated with the control electronics.
- 2 Those associated with the control of the load current, which are a system consideration, dependent on the interaction between two or more components of the system.

The control electronics of all the thyristor stacks meet the requirements of EN50 081 part 1, the generic standard for an industrial environment. The level of emissions is low enough to ensure that there should be no problems in systems incorporating multiple units, where the cumulative effect has to be considered.

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Emissions associated with load switching, which are conducted, may be further subdivided into two categories:-

- 1 Emissions which are emitted continually while the stack is conducting.
- 2 Short term emissions associated with the switch on and switch off (clicks).

We believe that the drive circuits used in our thyristor stacks ensure that the levels of such emissions are among the lowest available, and are extremely unlikely to cause interference with other equipment.

Thyristors only conduct current in one direction, and for the control of AC power are arranged in pairs back to back. Repetitive emissions are caused at the zero crossing of the current waveform, on every cycle, when conduction is transferred from one device to the other (100 Hz repetition rate with 50Hz supply). This results in a slight discontinuity in the waveform, with relatively sharp edges, which generates rf emissions at the low end of the frequency spectrum specified in the standard. In practice the measurement at the lowest frequency, 150 kHz, is the significant one, and by 500 kHz emissions have fallen to a negligible level. If the current transfer is performed well, the level of interference should fall below the level allowed by the standard without the use of additional filters. In the SR series stacks a MOSFET driver is used. This achieves a level of emissions, which in conjunction with the integral capacitive filter should ensure compliance at current levels up to at least 800A (using multiple units) in industrial installations or 200A in light industrial or commercial installations where the emission levels allowed are lower. (Note that these levels are based on extrapolation of results obtained at lower current levels). In the STA series units, a sophisticated microprocessor controlled driver almost entirely eliminates crossover emissions, which are not likely to create a problem at any current level. To achieve this the load current in 3-phase systems must however be reasonably well balanced (within 15%).

A 'click' is defined as a short burst of emissions less than 200 milliseconds in duration, generally associated with a switching action, either off or on. EN50 081 part 2 allows up to 5 clicks per minute from an apparatus before placing restrictions on their amplitude. With all our stacks, because switch off intrinsically occurs at the zero of the current waveform, clicks associated with switch off are negligible. There are however clicks associated with the switch on.

In the case of the SR series stacks (resistive load), which operate with zero voltage switch on, these are of a low level, being caused by small errors in the actual switch on point. With the STA series stacks (transformer coupled load), switch on has to occur near the peak of the voltage waveform, with resultant increased emissions. These stacks still provide the lowest possible level of emissions when switching a transformer load.

Although the peak level of these emissions is higher than the 100Hz emissions, the CISPR measurement technique (quasi-peak) referenced by European standards creates an averaging effect, which means that the effective level depends on repetition frequency, and will be attenuated from the peak by approximately 17dB at 10Hz and 30dB at 1Hz or less. (The 100 Hz value is attenuated by approximately 6dB from the peak). Additionally, clicks are allowed to generate a higher level of emissions additional to the continuous emissions limit, given by the formula:

$$20 \log_{10} 30/N \text{ dB (where N is the repetition rate in clicks / minute)}$$

Note that this formula gives no benefit for click rates greater than 30 / minute!

With the SR series stacks cycle rates up to 10Hz should not present a problem in terms of emitted clicks. Note that if multiple unsynchronised units are used, the total number of clicks must be considered.

The standard cycle time of the STA series stacks is set at 15 seconds, and thus only 4 clicks per minute are generated, enabling compliance with the standard independent of the amplitude of the clicks for systems containing only one unit. The amplitude of the clicks is such that faster switching times are possible, probably up to 10 cycles / minute at most current levels, but the actual level of emissions depends on load current and transformer characteristics, and would have to be measured to determine compliance.

It is important to note that the standards will apply to the complete equipment of which the thyristor stack forms a part. Thus the cumulative effect of emissions from all devices within the equipment must be considered. It is the duty of the user to ensure that his equipment complies with the standards.

#### **SLIM**

The EMC Directive is in process of being re-drafted (SLIM - Simpler Legislation for the Internal Market). One of the biggest changes proposed is the way in which fixed installations (assemblies of apparatus intended to be used permanently at a pre-defined location) are treated. Apparatus intended only for that installation would not require to be CE marked (eg a one-off control panel). However there is no guarantee that these proposals will be implemented, and in any case they are not likely to be implemented before 2005.

#### **CONCLUSION**

We hope this brief guide has been useful. We should be pleased to discuss individual applications or queries, and to provide additional advice where possible.