EMC Data Sheet

Commander S100

Variable Speed AC drive
for induction motors

Version 1.0

Safety Warnings

A Warning contains information which is essential for avoiding a safety hazard.

A Caution contains information which is necessary for avoiding a risk of damage to the product or other equipment

NOTE: A Note contains information which helps to ensure correct operation of the product.

Installation and Use

Information given in this data sheet is derived from tests and calculations on sample products. It is provided to assist in the correct application of the product and is believed to correctly reflect the behaviour of the product when operated in accordance with the instructions. The provision of this data does not form part of any contract or undertaking. Where a statement of conformity is made with a specific standard, the manufacturer takes all reasonable measures to ensure that its products are in conformance. Where specific values are given these are subject to normal engineering variations between samples of the same product. They may also be affected by the operating environment and details of the installation arrangement.

The manufacturer accepts no liability for any consequences resulting from inappropriate, negligent, or incorrect installation of the equipment.

The contents of this data sheet are believed to be correct at the time of printing. The manufacturer reserves the right to change the specification of the product, its performance, or the contents of the data sheet, without notice.

All electrical installation and maintenance work must be carried out by qualified electricians familiar with the requirements for safety and EMC. The installer is responsible for ensuring the product or system complies with all relevant laws in the country where it is to be used.

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Contents

1. Products

This EMC data sheet applies to the **Commander S100** series of general-purpose AC motor drives.

Table 1 Model numbers and ratings

Power	100V 1ϕ	200V			400V 3ϕ
		1ϕ	3ϕ	Dual 1/3ϕ	
0.18 kW	Frame 1: S100-01113	Frame 1: S100-01S13 Frame 2CI: S100-02S11	Frame 1: S100-01213		
0.25 kW	Frame 1: S100-01123	Frame 1: S100-01S23 Frame 2CI: S100-02S21	Frame 1: S100-01223		
0.37 kW	Frame 1: S100-01133	Frame 1: S100-01S33 Frame 2CI: S100-02S31	Frame 1: S100-01233		Frame 2: S100-02413
0.55 kW	Frame 3: S100-03113	Frame 1: S100-01S43 Frame 2CI: S100-02S41	Frame 1: S100-01243		Frame 2: S100-02423
0.75 kW	Frame 3: S100-03123	Frame 1: S100-01S53 Frame 2CI: S100-02S51	Frame 1: S100-01253		Frame 2: S100-02433
1.1 kW	Frame 3: S100-03133	Frame 2CI: S100-02S61		Frame 1: S100-01D63	Frame 2: S100-02443
1.5 kW		Frame 2CI: S100-02S71		Frame 1: S100-01D73	Frame 2: S100-02453
2.2 kW				Frame 3: S100-03D13	Frame 2: S100-02463
3.0 kW					Frame 3: S100-03413
4.0 kW					Frame 3: S100-03423

Power	100V 1ϕ		200V			400V 3ϕ	
	Input	Output	Input		Output	Input	Output
			1ϕ	3ϕ			
0.18 kW	7.2 A	1.2 A	3.3 A	2.0 A	1.2 / 1.4 A		
0.25 kW	8.5 A	1.4 A	3.8 A	2.3 A	1.4 / 1.6 A		
0.37 kW	10.4 A	2.2 A	4.7 A	2.8 A	2.2 / 2.4 A	1.9 A	1.2 A
0.55 kW	14.8 A	3.2 A	8.0 A	4.7 A	3.2 / 3.5 A	2.5 A	1.7 A
0.75 kW	20.0 A	4.2 A	9.5 A	5.7 A	4.2 / 4.6 A	3.0 A	2.2 A
1.1 kW	28.5 A	6.0 A	15.3 A		6.6 A	4.5 A	3.2 A
1.5 kW			18.4 A		7.5 A	5.6 A	3.7 A
2.2 kW			26.1 A		10.6 A	8.2 A	5.3 A
3.0 kW						13.2 A	7.2 A
4.0 kW						16.0 A	8.8 A

Note: 100V drives use a voltage-doubler at the input, so output 200V to the motor.

2. EMC Product Standards

2.1. Locations and Equipment Categories

The EMC product standard for variable speed drives, IEC 61800-3, defines four locations and four equipment categories:

- **Residential:** An area of land designated for domestic dwellings where the mains power within these locations is directly connected to the low-voltage public mains network. Examples include houses, apartments, and farm buildings housing people.
- **Commercial and light-industrial:** A location which is not residential where the mains supply is directly connected to the low-voltage public network or connected to a dedicated DC source which is intended to interface between the equipment and the low-voltage public mains network. Examples include shops, business premises, places of public entertainment, places of worship, general-public locations, hospitals, educational institutions, public traffic areas, railway stations, public areas of airports, common areas of buildings such as basements, control rooms, electrical service areas, workshops, laboratories, and service centres.
- **Industrial:** A location characterised by a separate power network, supplied from a high or medium voltage transformer, dedicated for the supply of the installation. Examples include metalworking, pulp and paper, chemical plants, car production, farm buildings, high-voltage areas of airports.
- **Equipment Category C1:** Equipment intended for use in a residential, commercial, or light-industrial locations.
- **Equipment Category C2:** Equipment rated for <1,000 V which is neither a plug-in device, nor a moveable device, and is not intended for use in a residential location. When used in a commercial or light industrial location it is intended to be installed and commissioned by a professional.
- **Equipment Category C3:** Equipment rated for <1,000 V intended for use in an industrial location and not intended for use in a residential, commercial, or light industrial location.
- **Equipment Category C4:** Equipment rated for ≥ 1,000 V, or rated current ≥ 400 A, or intended for use as part of a complex system in an industrial location.

2.2. Equivalent Standards

The Equipment Categories in IEC 61800-3 are equivalent to the levels in the related product and generic standards shown below:

Product Standard	Scope	Location	Generic EMC Standard	Equipment Category IEC 61800-3
EN 55011 (CISPR 11) Class B	Industrial, scientific, and medical equipment	Residential, commercial, and light-industrial locations	IEC 61000-6-3	C1
EN 55014 (CISPR 14)	Household electrical appliances			
EN 55022 (CISPR 22) Class B	Information technology equipment			
EN 55011 (CISPR 11) Class A Group 1	Industrial, scientific, and medical equipment	Industrial locations	IEC 61000-6-4	C2
EN 55022 (CISPR 22) Class A	Information technology equipment			

3. Immunity

3.1. Immunity Compliance

Drives comply with the immunity levels shown in Table 2.

Unless otherwise stated, immunity is achieved without additional measures such as filters or suppressors. To ensure correct operation the wiring guidelines specified in the *User Guide* must be followed. All external inductive components such as relays, contactors, and electromagnetic brakes must be fitted with appropriate suppression.

Table 2 Immunity test levels

Standard[1]	Type of immunity	Test specification (IEC 61800-3-2:2018)	Application	Level
IEC 61000-4-2: 2009	Electrostatic discharge	4 kV contact discharge 8 kV air discharge	Module enclosure	Level 2 (CD) Level 3 (AD) (industrial)
IEC 61000-4-3: 2020	Radio frequency radiated field	Prior to modulation: 10 V/m 80 - 1000 MHz 3 V/m 1.4 - 6.0 GHz 80% AM (1 kHz) modulation *IEC 61000-6-2:2020 levels*	Module enclosure	Level 3 (industrial)
IEC 61000-4-4: 2012	Fast transient burst	5 / 50 ns 2 kV transient at 5 kHz repetition frequency via coupling clamp	Control lines	Level 4 (industrial harsh)
		5 / 50 ns, 2 kV transient at 5 kHz repetition frequency by direct injection	Power lines	Level 3 (industrial)
IEC 61000-4-5: 2014+A1:2017	Surges	Common mode 2 kV 1.2 / 50µs wave shape	AC supply lines: line to earth	Level 3
		Differential mode 1 kV	AC supply lines: line to line	Level 3
		Common mode 1 kV	Control lines	See Note 2
IEC 61000-4-6: 2014	Conducted radio frequency	10 V prior to modulation 0.15 - 80 MHz 80% AM (1 kHz) modulation	Control and power lines	Level 3 (industrial)
IEC 61000-4-11: 2020	Voltage dips, short interruptions & variations	Voltage deviations >60s : ±10% Voltage dips: 0% 1 cycle 40% 10/12 cycles 70% 25/30 cycles 80% 250/300 cycles Voltage interruptions: 0% 250/300 cycles	AC supply lines	Class 3
IEC 61000-4-8: 2010	Power frequency magnetic field	1700 A/m RMS. 2400 A/m peak (2.1 mT RMS 3 mT peak) continuous at 50 Hz	Module enclosure	Exceeds level 5
IEC 61000-6-1: 2019	Generic immunity standard for the residential, commercial and light-industrial environment.			Complies
IEC 61000-6-2: 2019	Generic immunity standard for the industrial environment.			Complies
IEC 61800-3: 2018	Product standard for adjustable speed power drive systems (immunity requirements).		Meets immunity requirements for first and second environments	

[1] References to IEC standards are used throughout this EMC data sheet. In Europe the applicable standard is the equivalent harmonised EN standard.

[2] Additional protection may be needed where wire lengths are > 30 m – see below.

3.1.1. Surge immunity of control circuits

Drive control circuits are designed for general use within machines and small systems without any special precautions. The surge test simulates the effect of a lightning strike, or a severe electrical fault, where high transient voltages may exist between different points in the grounding system. This is a particular risk where circuits are routed outside of a building, or if the grounding system in a building is not well bonded.

In applications where control circuits are exposed to high-energy voltage surges special measures are required to prevent malfunction or damage. In general, circuits that are routed outside of the building where the drive is located, or are connected via cables longer than 30m need additional protection.

If required, one of the following techniques should be used to provide additional protection:

1. Screened cable: The cable screen may be connected to ground at both ends. The ground conductors at both ends of the cable must be bonded together by an earth cable (equal potential bonding cable) with cross-sectional area of at least 10 mm^2. This ensures that in the event of a fault, the fault current flows through the earth and not through the signal cable screen. If the building or plant has a well-designed common bonded network this additional bonding precaution is not necessary.

2. Additional over-voltage suppression: This applies to both analogue and digital inputs and outputs. A zener diode network or commercially available surge suppressor may be connected between the signal line and 0 V as shown in Figures 1 and 2.

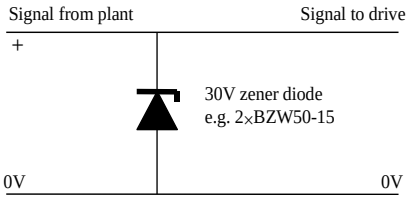


Figure 1
Surge suppression for digital and uni-polar analogue inputs and outputs

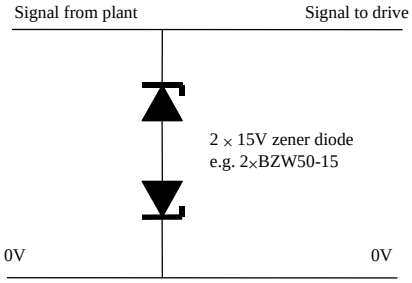


Figure 2
Surge suppression for bipolar analogue inputs and outputs

Surge suppression devices are available as DIN rail mounting modules, e.g. Phoenix Contact.

Unipolar	TT-UKK5-D/24 DC
Bipolar	TT-UKK5-D/24 AC

These devices are not suitable for fast digital data networks as the capacitance of the zener diode will adversely affect the signal.

3.1.2. Network cabling

In any of the protocols that support the use of Ethernet cable, such as 485 (serial protocol with 485 electrical interface), any CAT 6 or higher-grade cable should be adequate in terms of immunity to broadband noise (conducted and radiated immunity), fast transient burst and surge withstand capability.

4. Emission

4.1. General

Emissions occur over a wide range of frequencies. The effects are divided into three main categories:

- Low frequency effects, such as supply harmonics and notching.
- High frequency emissions below 30 MHz where emission is predominantly by conduction.
- High frequency emissions above 30 MHz where emission is predominantly by radiation.

4.2. Commander S100 Compliance

Commander S100-011*x*3, S100-02*xxx*, and **S100-03*xx*3** drives comply with Equipment Category C3 without external filters or line reactors (4kHz, up to 5m motor cable).

Commander S100-012*x*3, S100-01S*x*3, S100-01D*x*3 drives comply with Equipment Category C3 without external filters or line reactors (4kHz, up to 20m motor cable).

Commander S100-*xxxx*3 drives comply with Equipment Category C2 for conducted and radiated emissions when installed with an external EMC filter (4kHz, up to 5m motor cable).

Commander S100-02S*x*1 drives comply with Equipment Category C1 for conducted emissions frequencies below 30 MHz without an external filter (4kHz, up to 5m motor cable). Other models comply with Equipment Category C1 for conducted emissions frequencies below 30 MHz when installed with an external EMC filter.

Commander S100-*xxxx*1 drives comply with Equipment Category C2 for radiated emissions without an external EMC filter.

Commander S100 drives may need further mitigation methods to comply with Equipment Category C1 for frequencies higher than 30 MHz. These include the use of higher-grade motor cable with 360° screen connections, or special double screening. Refer to Section 5 of this datasheet.

NOTE: **In a domestic environment this product may cause radio interference, in which case supplementary mitigation measures may be required.**

4.3. Low Frequency Emissions

4.3.1. Supply voltage notching

The drives do not cause notching of the supply voltage.

4.3.2. Voltage fluctuations and flicker

When running at constant load the drive does not generate voltage fluctuations or flicker. However, variations in the load torque in the frequency range 0.5 Hz to 30 Hz can cause lighting flicker if the supply cables to the drive are shared with lighting circuits. Likewise, interference with other sensitive equipment can occur where cabling is shared between the drive supply and other sensitive circuits. This is shown in Figure 3.

The point of common coupling (PCC) should be at the source of the supply, where the shared series impedance is lowest.

Cabling shared between drive mains and lighting or other sensitive circuits should have the lowest possible resistance and inductance.

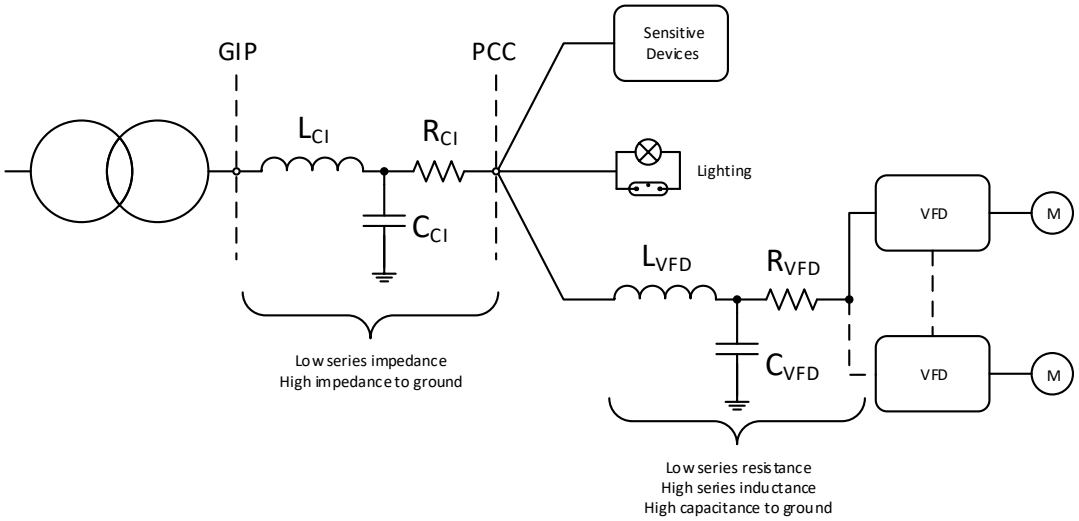


Figure 3 Cause of voltage fluctuations and flicker

When power is first applied the drive draws an inrush current which is lower than the rated input current.
This meets the requirements of IEC 61000-3-3.

4.3.3. Common mode harmonic emissions (crosstalk)

Commander S100 drives generate switching waveforms with frequency components in the audible range as well as the frequency range commonly used by telephone and data systems. Drive cables should be segregated from other power and signal cables.

4.3.4. Supply harmonics

The drive input current contains harmonics of the supply frequency. The harmonic levels are affected by the supply impedance (fault current level).

Table 6 shows the harmonic current levels of the drive's input current. The calculations assume a fault level of 5 kA. This is typical of a light industrial installation and exceeds the requirements of IEC 61800-3. If the fault current level of the supply is lower, the harmonic current levels will also be lower.

The RMS current in the table may differ from the maximum specified in the installation guide, since the latter is a worst-case value provided for safety reasons which takes account of permitted supply voltage imbalance. The motor efficiency also affects the current. A common IE2[3], 4 pole motor has been assumed. For balanced sinusoidal supplies, all even and triple harmonics are absent. The supply frequency used for calculations is 50 Hz. The harmonic percentages do not change substantially for other voltages and frequencies within the drive's specification.

Variable frequency drives usually account for a small amount of power within an electrical installation, which makes their contribution to total harmonic distortion unimportant. The importance of harmonic currents increases significantly when VFD's share the mains with other devices that are sensitive to the harmonic content.

To reduce harmonic interference there are two relatively straightforward ways to go about it:

- Reduce the impedance between GIP (Grid Integration Point) and PCC (Point of Common Coupling) as shown in Figure 3
- Insert a line reactor in the input cable to the drive.

4.3.5. Input line reactors (line chokes)

The harmonic current levels can be reduced by fitting reactors in the input supply lines to the drive. This also gives increased immunity to supply disturbances such as voltage surges caused by the switching of high current loads or power factor correction capacitors on the same supply circuit. It also allows for a slight increase in maximum continuous power and reduction of Earth current (lower RCD threshold required).

Table 7 and Table 8 show the harmonic currents when drives are fitted with the line reactors specified in Table 3 (or a combination of them).

Fitting the recommended line reactance from Table 3 causes a slight reduction in the DC link voltage, but still allows the full rated torque to be developed in a standard motor. Higher inductance values can be used but there will be some reduction of available torque at maximum speed. Lower inductance values can be used with the resulting harmonic currents estimated by linear interpolation between the values in Table 3 and Table 5.

The RMS current rating of the line reactor must be at least equal to the RMS input current rating of the drive. The peak current rating of the choke should be twice that of the drive value to avoid saturation.

[3] IEC 60034-30-1 defines the following efficiency classes for induction motors:
IE1 – Standard, IE2 – High, IE3 – Premium, IE4 – Super Premium

Table 3 Recommended line reactors

Commander S100-*xxxx*3

Drive rated voltage V	Drive rated power kW	Minimum line reactor inductance mH
100 1ϕ	0.18	11
	0.25	9.1
	0.37	6.2
	0.55	4.3
	0.75	3.3
	1.1	2.2
200 1ϕ	0.18	1.8
	0.25	9.1
	0.37	6.2
	0.55	4.3
	0.75	3.3
200 3ϕ	0.18	11
	0.25	9.1
	0.37	6.2
	0.55	4.3
	0.75	3.3
200 1/3ϕ	1.1	1ϕ 2.2
		3ϕ 2.2
	1.5	1ϕ 1.8
		3ϕ 1.8
	2.2	1ϕ 1.2
		3ϕ 1.2
400 3ϕ	0.37	24
	0.55	16
	0.75	12
	1.1	9.1
	1.5	6.2
	2.2	4.7
	3.0	3.3
	4.0	2.7

Commander S100-*xxxx*1 (internal C1 filter)

Drive rated voltage V	Supply Phases	Drive rated power kW	Minimum line reactor inductance mH
200	1	0.18	1.8
		0.25	9.1
		0.37	6.2
		0.55	4.3
		0.75	3.3
		1.1	2.2
		1.5	1.8

4.3.6. Effect of load on harmonics

The harmonics are proportional to the mechanical power delivered to the load by the motor (ie. the product of torque and speed). As the load is reduced, the motor current becomes increasingly reactive and the harmonics fall in absolute magnitude, but increase as a proportion of the fundamental.

4.3.7. Product family standards for harmonics

IEC 61000-3-2

This standard applies to equipment with a rated input current ≤16 A per phase and rated supply voltage of 230/400 V, 50 Hz *(limits for supplies ≤220 V have not yet been considered)*. Most **Commander S100** drives fall within Class A of this standard. Whilst professional equipment rated over 1 kW have no specified limits, the majority of **Commander S100** drives fall below 1 kW. The limits from Table 1 of the standard can be met by fitting line reactors as shown in Table 4 below.

Table 4 Line reactors for compliance with Table 1 of IEC 61000-3-2

Commander S100-*xxxx*3

Drive rated voltage V	Drive rated power kW	Minimum line reactor inductance mH
100 1ϕ	0.18	20
	0.25	16
	0.37	12
	0.55	8.2
	0.75	6.2
	1.1	4.3
200 1ϕ	0.18	75
	0.25	62
	0.37	47
	0.55	30
	0.75	24
200 3ϕ	0.18	47
	0.25	36
	0.37	27
	0.55	18
	0.75	15
200 1/3ϕ	1.1	1ϕ 16
		3ϕ 9.1
	1.5	3ϕ 6.8
400 3ϕ	0.37	82
	0.55	62
	0.75	51
	1.1	36
	1.5	30
	2.2	20
	3.0	15

Commander S100-*xxxx*1 (internal C1 filter)

Drive rated voltage V	Supply Phases	Drive rated power kW	Minimum line reactor inductance mH
200	1	0.18	75
		0.25	62
		0.37	47
		0.55	30
		0.75	24

IEC 61000-3-12

This standard applies to equipment rated between 16 A and 75 A per phase with a supply voltage of 230/400 V, 50 Hz (other distribution systems are specifically excluded). The harmonic limits are in Table 4 of the standard. The limits can be met by fitting larger line reactors, as shown in Table 5 below.

Table 5 Line reactors for compliance with Table 4 of IEC 61000-3-12

Commander S100-*xxxx*3

Drive rated voltage V	Drive rated power kW	Minimum line reactor inductance mH
200 1/3ϕ	1.5	1ϕ 12
	2.2	1ϕ 8.2
		3ϕ 4.7
400 3ϕ	4.0	11

Commander S100-*xxxx*1 (internal C1 filter)

Drive rated voltage V	Supply Phases	Drive rated power kW	Minimum line reactor inductance mH
200	1	1.5	12

The harmonic emission limits in IEC 61000-3-12, Table 4 assume a short circuit ratio (R_{SCE}) of at least 120.

R_{SCE} is the ratio of the short circuit power of the supply and the rated apparent power of the drive at the point of common coupling with other supply users. For detailed definitions refer to IEC 61000-3-12. Equipment containing **Commander S100** drives and required to meet this standard must include this requirement with the installation instructions.

4.3.8. Effect of load power on compliance with IEC 61000-3-12

The value of the required input reactor depends on the load power, i.e. the product of shaft speed and torque. The values given above are correct for the stated load, which is a common 4-pole IE2 induction motor delivering the specified load power. If the actual maximum continuous electrical load is less than this, the inductance must be scaled up in inverse proportion to the actual load. If tests according to IEC 61000-3-12 are carried out it is important to arrange for the equipment to be fully loaded to obtain valid results.

4.3.9. Further measures for reducing harmonics

It is unusual for harmonics to pose a problem unless more than 50% of the supply system capacity is accounted for by drives or other power electronic loads. Harmonic currents from drives add approximately arithmetically. It is usually most cost-effective to analyse a complete installation for harmonic current or voltage and to apply remedial measures such as harmonic filters, if necessary, for the entire installation at the common supply point.

NOTE: **When fitted with the recommended line reactor, the drive complies with IEC 61000-3-12 provided short-circuit power at the interface point between the user's supply and the public system (S_{SC}) is greater than 120 times the rated apparent power of the drive. It is the responsibility of the installer or user of the equipment to ensure, by consultation with the distribution network operator if necessary, that equipment is connected only to a supply with adequate short-circuit power.**

4.3.10. Harmonic Current Tables

Table 6 Harmonic currents without line reactor, 5 kA supply, Commander S100-xxxxx

Rated Voltage (V)	Output Current (A)	Motor Power (kW)	RMS I (A)	Fund. I (A)	THC /I_{ref} (%)	PWHC /I_{ref} (%)	Harmonic order, magnitude as % of I_{ref}															DPF Cos Ø	Power factor
							5	7	11	13	17	19	23	25	29	31	35	37	41	43	47	49	
100V 1ϕ	1.2	0.18	7.67	3.50	88.95	201.17	38.56	32.62	21.43	18.73	18.85	18.94	15.85	12.93	6.68	4.48	3.26	3.09	1.96	1.34	1.18	1.26	0.270	0.376
	1.4	0.25	9.09	4.40	87.33	192.64	39.28	31.74	18.44	16.49	18.78	18.91	14.89	11.63	5.92	4.44	3.29	2.69	1.55	1.40	1.26	1.03	0.263	0.394
	2.2	0.37	11.21	5.90	85.49	181.95	39.57	29.50	15.67	15.88	18.31	17.63	13.54	10.85	5.79	4.22	3.01	2.48	1.52	1.40	1.08	0.85	0.251	0.416
	3.2	0.55	18.05	8.80	18.05	8.80	88.39	137.1	40.43	34.12	24.19	21.69	17.28	13.95	6.32	3.56	2.73	2.49	1.02	0.83	1.08	0.81	0.36	0.53
	4.2	0.75	21.57	11.30	85.77	133.12	40.08	31.25	21.17	20.66	17.35	13.33	5.05	3.34	2.85	1.97	1.06	1.26	0.70	0.41	0.65	0.52	0.258	0.419
	6.0	1.1	29.19	17.00	81.88	121.15	38.45	25.52	19.15	20.80	15.58	10.92	5.05	3.76	1.99	1.70	1.07	0.87	0.72	0.54	0.48	0.41	0.235	0.447
200V 1ϕ	1.2	0.18	4.07	1.80	92.32	250.76	38.55	33.43	21.67	16.90	14.68	16.28	18.58	18.33	15.22	12.86	8.10	6.24	4.12	3.61	2.76	2.34	0.866	0.358
	1.4	0.25	4.80	2.20	88.14	233.70	38.21	31.70	18.43	14.38	14.38	15.78	17.04	16.68	14.12	12.10	7.58	5.73	3.91	3.53	2.56	2.08	0.857	0.378
	2.2	0.37	5.74	2.90	85.59	221.44	38.78	29.54	14.73	12.80	13.09	13.05	14.77	15.76	14.52	12.31	7.60	6.22	4.66	3.79	2.42	2.17	0.846	0.411
	3.2	0.55	9.77	4.40	89.76	223.72	37.17	30.81	20.63	19.75	22.17	22.17	17.59	13.71	5.92	3.47	3.12	3.04	1.63	0.96	1.23	1.29	0.860	0.371
	4.2	0.75	11.73	5.60	87.58	218.11	37.74	29.56	16.72	16.89	21.81	22.06	17.01	12.93	5.71	4.05	3.47	2.93	1.42	1.19	1.28	1.07	0.848	0.390
200V 3ϕ	1.2	0.18	2.11	1.00	76.38	220.63	40.76	35.04	22.02	16.21	11.65	10.42	13.62	9.13	15.59	5.74	12.30	3.30	6.56	2.13	3.61	1.77	0.96	0.51
	1.4	0.25	2.44	1.30	78.05	221.68	44.09	36.50	20.77	15.22	12.72	12.22	12.80	10.25	15.09	7.47	11.92	3.33	6.65	1.64	3.91	1.20	0.96	0.54
	2.2	0.37	2.95	1.70	74.67	208.26	44.92	34.88	17.46	14.13	13.67	12.54	11.64	11.41	13.27	9.71	10.27	4.26	5.93	1.88	3.73	0.89	0.95	0.58
	3.2	0.55	5.22	2.60	80.88	244.58	41.57	34.61	20.42	16.58	18.52	19.05	20.01	14.83	12.87	5.09	3.89	1.23	2.89	1.22	1.59	0.69	0.95	0.51
	4.2	0.75	6.16	3.30	79.30	237.00	42.87	34.21	18.56	15.73	19.21	20.53	20.57	17.19	10.85	5.82	3.74	1.86	2.51	0.63	1.60	0.58	0.95	0.54
200V 1/3ϕ	6.0	1.1 1ϕ	*19.57*	*8.70*	*90.59*	*110.96*	*40.90*	*37.58*	*28.83*	*23.90*	*14.26*	*9.99*	*3.34*	*1.13*	*1.51*	*1.87*	*1.52*	*1.07*	*0.33*	*0.46*	*0.71*	*0.66*	*0.859*	*0.365*
		3ϕ	14.13	5.30	71.89	122.40	35.46	30.20	26.35	17.49	15.62	6.28	6.62	0.87	1.95	0.96	1.75	1.11	0.97	0.66	0.77	0.52	0.94	0.44
	6.8	1.5 1ϕ	*24.75*	*11.10*	*89.66*	*102.51*	*41.02*	*37.46*	*28.24*	*23.12*	*13.27*	*9.01*	*2.62*	*0.58*	*1.42*	*1.63*	*1.14*	*0.71*	*0.37*	*0.52*	*0.53*	*0.41*	*0.838*	*0.359*
		3ϕ	16.27	6.60	72.98	118.29	37.61	32.92	26.99	18.96	15.65	6.50	6.46	0.74	1.50	0.94	1.91	0.79	1.11	0.49	0.77	0.44	0.95	0.47
	9.6	2.2 1ϕ	*33.33*	*16.10*	*88.11*	*67.17*	*42.88*	*37.93*	*25.63*	*19.26*	*8.21*	*4.10*	*0.79*	*1.75*	*1.67*	*1.12*	*0.28*	*0.52*	*0.63*	*0.48*	*0.22*	*0.28*	*0.847*	*0.393*
		3ϕ	21.95	9.60	72.19	91.66	39.70	34.56	25.96	18.35	11.85	5.28	3.14	1.72	1.91	0.97	1.60	0.22	0.91	0.30	0.69	0.31	0.96	0.50
400V 3ϕ	1.2	0.37	1.72	0.80	73.90	198.99	40.18	34.73	22.15	16.27	11.18	9.28	12.31	7.65	13.57	4.49	11.30	3.33	6.75	2.55	3.82	2.18	0.96	0.51
	1.7	0.55	2.16	1.20	76.54	200.40	45.37	37.05	20.22	14.74	12.72	12.11	11.16	9.15	12.66	7.19	10.84	3.45	6.92	1.83	4.29	1.17	0.96	0.56
	2.2	0.75	2.59	1.50	71.45	183.98	44.74	34.31	16.64	13.62	13.14	11.77	10.21	9.94	10.87	8.41	9.21	4.46	6.06	1.90	3.94	1.04	0.95	0.60
	3.2	1.1	3.89	2.20	76.85	222.13	44.45	34.84	18.20	14.81	14.55	14.18	14.92	14.07	14.65	9.37	8.13	2.71	4.39	1.43	2.60	0.65	0.95	0.57
	3.7	1.5	4.76	3.00	74.59	210.50	45.62	32.70	16.28	15.87	14.54	13.32	15.64	16.02	13.66	10.19	6.71	4.15	3.84	1.76	2.26	0.88	0.95	0.62
	5.3	2.2	7.01	4.20	76.63	217.32	44.30	32.86	17.61	16.53	18.30	19.26	19.84	16.97	9.47	5.29	4.03	2.64	2.17	0.88	1.68	0.36	0.95	0.59
	7.2	3.0	11.50	5.80	80.82	198.48	40.93	34.05	25.65	24.99	24.99	21.13	13.15	7.66	3.12	0.83	2.31	0.23	1.06	0.53	1.41	0.43	0.95	0.51
	8.8	4.0	13.79	7.60	79.00	202.24	41.38	31.45	22.92	25.65	27.80	24.26	13.25	7.16	2.09	2.05	2.02	0.37	1.21	0.80	0.73	0.22	0.96	0.55

Table 7 Harmonic currents with line reactor, 5 kA supply, Commander S100-xxxxx

Rated Voltage (V)	Output Current (A)	Motor Power (kW)	RMS I (A)	Fund. I (A)	THC /I_{ref} (%)	PWHC /I_{ref} (%)	Harmonic order, magnitude as % of I_{ref}															AC line choke nom. (mH)	DPF Cos Ø	Power factor
							5	7	11	13	17	19	23	25	29	31	35	37	41	43	47	49			
100V 1ϕ	1.2	0.18	4.01	3.30	56.06	11.65	17.94	6.75	2.79	2.19	1.24	0.97	0.67	0.55	0.40	0.37	0.29	0.24	0.19	0.19	0.15	0.13	5.1	0.255	0.658
	1.4	0.25	5.04	4.20	56.08	11.54	17.55	6.77	2.80	2.12	1.20	0.97	0.67	0.53	0.39	0.37	0.29	0.24	0.20	0.18	0.15	0.14	4.3	0.258	0.663
	2.2	0.37	6.86	5.60	57.04	11.63	19.14	6.42	2.67	2.28	1.29	0.93	0.64	0.58	0.42	0.36	0.28	0.25	0.20	0.19	0.15	0.14	3.0	0.268	0.665
	3.2	0.55	10.09	8.30	56.83	11.80	18.65	6.62	2.75	2.26	1.28	0.96	0.66	0.57	0.42	0.37	0.29	0.25	0.20	0.19	0.16	0.14	2.0	0.260	0.661
	4.2	0.75	13.06	10.70	56.60	11.70	18.58	6.47	2.69	2.23	1.27	0.95	0.66	0.57	0.42	0.37	0.29	0.26	0.21	0.20	0.17	0.15	1.6	0.266	0.666
	6.0	1.1	19.90	16.30	57.28	11.23	19.23	6.14	2.56	2.22	1.25	0.90	0.62	0.56	0.41	0.35	0.27	0.25	0.20	0.18	0.15	0.13	1.1	0.819	0.676
200V 1ϕ	1.2	0.18	2.19	1.70	64.51	15.90	28.11	8.54	4.09	2.59	1.47	1.40	0.91	0.75	0.58	0.46	0.36	0.35	0.28	0.25	0.22	0.19	11.0	0.864	0.626
	1.4	0.25	2.76	2.10	62.96	15.12	27.34	8.18	3.90	2.49	1.40	1.34	0.87	0.71	0.54	0.44	0.34	0.33	0.26	0.24	0.20	0.17	9.1	0.864	0.628
	2.2	0.37	3.78	2.90	66.22	16.20	30.18	9.68	4.48	2.47	1.53	1.35	0.85	0.80	0.59	0.48	0.39	0.33	0.27	0.26	0.21	0.20	6.2	0.863	0.625
	3.2	0.55	5.51	4.20	64.18	15.81	28.47	8.78	4.18	2.50	1.46	1.37	0.87	0.76	0.58	0.46	0.37	0.34	0.27	0.26	0.21	0.19	4.3	0.865	0.625
	4.2	0.75	7.19	5.50	65.37	15.85	29.50	9.28	4.34	2.45	1.48	1.34	0.85	0.78	0.58	0.46	0.38	0.32	0.26	0.25	0.20	0.19	3.3	0.864	0.626
200V 3ϕ	1.2	0.18	1.38	1.00	51.16	21.60	35.85	18.16	5.00	3.00	2.03	1.01	1.16	0.54	0.74	0.41	0.49	0.33	0.33	0.27	0.24	0.22	7.9	0.923	0.765
	1.4	0.25	1.57	1.30	56.43	21.78	42.87	22.63	5.94	4.31	2.66	1.61	1.49	0.83	0.93	0.52	0.61	0.37	0.42	0.28	0.31	0.22	7.5	0.929	0.778
	2.2	0.37	2.08	1.70	59.01	20.75	47.93	27.59	5.89	5.22	2.76	2.10	1.60	1.14	1.02	0.73	0.69	0.52	0.49	0.39	0.36	0.30	5.1	0.942	0.768
	3.2	0.55	3.12	2.50	56.19	21.22	43.05	23.50	5.77	4.48	2.61	1.67	1.49	0.84	0.94	0.51	0.64	0.35	0.45	0.26	0.32	0.20	3.4	0.930	0.770
	4.2	0.75	3.95	3.20	57.47	20.52	46.43	26.34	5.84	5.07	2.71	2.04	1.56	1.11	0.99	0.71	0.67	0.50	0.48	0.37	0.36	0.29	2.7	0.940	0.772
200V 1/3ϕ	6.0	1.1 1ϕ	*10.83*	*8.30*	*64.65*	*15.62*	*28.73*	*8.82*	*4.17*	*2.47*	*1.44*	*1.35*	*0.86*	*0.75*	*0.57*	*0.45*	*0.36*	*0.33*	*0.26*	*0.25*	*0.21*	*0.18*	*2.2*	*0.865*	*0.627*
		3ϕ	7.93	5.20	48.59	19.16	28.37	13.35	3.59	3.57	1.40	1.76	1.06	0.81	0.75	0.39	0.42	0.31	0.25	0.29	0.22	0.20	1.4	0.883	0.730
	6.8	1.5 1ϕ	*13.94*	*10.70*	*64.55*	*15.28*	*28.63*	*8.65*	*4.08*	*2.41*	*1.41*	*1.32*	*0.85*	*0.74*	*0.56*	*0.44*	*0.35*	*0.33*	*0.26*	*0.25*	*0.20*	*0.18*	*1.8*	*0.863*	*0.631*
		3ϕ	10.23	6.60	47.08	18.65	28.01	12.56	3.64	3.22	1.28	1.71	0.84	0.87	0.62	0.48	0.39	0.28	0.23	0.21	0.17	0.21	1.2	0.895	0.736
	9.6	2.2 1ϕ	*20.27*	*15.50*	*64.81*	*15.44*	*29.01*	*8.85*	*4.16*	*2.38*	*1.42*	*1.32*	*0.84*	*0.75*	*0.57*	*0.45*	*0.37*	*0.33*	*0.26*	*0.25*	*0.21*	*0.19*	*1.2*	*0.863*	*0.631*
		3ϕ	14.75	9.60	47.36	19.21	29.09	13.12	3.90	3.09	1.42	1.66	0.77	0.91	0.54	0.59	0.44	0.35	0.30	0.22	0.17	0.22	0.8	0.904	0.740
400V 3ϕ	1.2	0.37	1.19	0.80	47.54	20.83	32.29	15.59	4.56	2.31	1.92	0.80	1.10	0.48	0.65	0.37	0.38	0.31	0.24	0.29	0.17	0.25	16.2	0.925	0.764
	1.7	0.55	1.45	1.20	58.32	21.40	45.63	25.24	5.97	4.88	2.72	1.88	1.56	0.96	1.00	0.58	0.69	0.39	0.50	0.28	0.37	0.21	13.3	0.934	0.771
	2.2	0.75	1.88	1.50	57.43	19.93	46.87	27.02	5.68	5.08	2.67	2.04	1.55	1.11	0.99	0.72	0.67	0.51	0.47	0.39	0.35	0.30	9.6	0.943	0.768
	3.2	1.1	2.60	2.20	58.32	20.72	47.20	26.30	5.98	5.15	2.74	2.10	1.57	1.15	0.99	0.75	0.67	0.54	0.47	0.41	0.35	0.32	7.7	0.940	0.778
	3.7	1.5	3.67	2.90	59.87	19.70	49.43	29.65	5.48	5.21	2.65	2.10	1.55	1.17	0.99	0.77	0.68	0.55	0.48	0.41	0.36	0.32	4.9	0.947	0.757
	5.3	2.2	5.03	4.10	58.29	19.65	48.26	27.86	5.61	5.16	2.66	2.08	1.56	1.15	1.00	0.75	0.68	0.55	0.48	0.42	0.35	0.34	3.8	0.945	0.772
	7.2	3.0	6.86	5.60	57.30	20.82	45.39	25.29	5.87	4.91	2.68	1.93	1.53	1.02	0.97	0.63	0.67	0.43	0.48	0.31	0.37	0.23	2.7	0.936	0.772
	8.8	4.0	8.87	7.40	57.14	19.87	46.97	26.24	5.77	5.08	2.66	2.08	1.54	1.15	0.99	0.76	0.67	0.56	0.47	0.43	0.35	0.34	2.3	0.943	0.781

Table 8 Harmonic currents with line reactor needed to reduce the 5th harmonic current to < 40% of the reference current at full rated output power, 5 kA supply, Commander S100-xxxxx

Rated Voltage (V)	Output Current (A)	Motor Power (kW)	RMS I (A)	Fund. I (A)	THC /I_{ref} (%)	PWHC /I_{ref} (%)	Harmonic order, magnitude as % of I_{ref}																AC line choke nom. (mH)	DPF Cos Ø	Power factor
							5	7	11	13	17	19	23	25	29	31	35	37	41	43	47	49			
100V 1ϕ	1.2	0.18	3.33	3.10	34.65	6.53	7.95	3.57	1.76	1.14	0.69	0.57	0.36	0.32	0.23	0.20	0.16	0.14	0.12	0.11	0.09	0.08	20	0.182	0.661
	1.4	0.25	4.21	3.90	34.59	6.39	7.85	3.55	1.74	1.12	0.69	0.56	0.35	0.31	0.23	0.19	0.16	0.14	0.11	0.10	0.08	0.08	16	0.186	0.665
	2.2	0.37	5.66	5.30	35.41	6.52	7.85	3.62	1.76	1.13	0.70	0.57	0.36	0.32	0.23	0.20	0.16	0.14	0.12	0.11	0.09	0.08	12	0.194	0.672
	3.2	0.55	8.32	7.80	34.66	6.48	7.96	3.55	1.76	1.14	0.69	0.57	0.36	0.31	0.23	0.20	0.16	0.14	0.11	0.11	0.09	0.08	8.2	0.185	0.665
	4.2	0.75	10.84	10.10	35.38	6.53	7.82	3.62	1.75	1.12	0.70	0.56	0.36	0.32	0.23	0.20	0.16	0.14	0.12	0.10	0.08	0.08	6.2	0.193	0.672
	6.0	1.1	16.42	15.40	35.54	6.40	7.72	3.57	1.73	1.10	0.69	0.56	0.35	0.31	0.22	0.19	0.16	0.14	0.11	0.10	0.08	0.08	4.3	0.205	0.684
200V 1ϕ	1.2	0.18	1.69	1.60	37.36	7.04	8.02	3.96	1.83	1.16	0.77	0.59	0.40	0.35	0.24	0.22	0.17	0.15	0.13	0.11	0.10	0.09	75	0.791	0.654
	1.4	0.25	2.12	2.00	36.48	6.83	7.93	3.80	1.80	1.14	0.74	0.58	0.38	0.34	0.24	0.21	0.17	0.15	0.12	0.11	0.09	0.09	62	0.790	0.654
	2.2	0.37	2.85	2.70	36.84	6.82	7.89	3.81	1.79	1.14	0.74	0.58	0.38	0.34	0.24	0.21	0.17	0.15	0.12	0.11	0.09	0.09	47	0.792	0.656
	3.2	0.55	4.23	3.90	36.61	6.88	7.74	3.89	1.77	1.13	0.75	0.57	0.39	0.34	0.24	0.22	0.16	0.15	0.12	0.11	0.09	0.09	30	0.793	0.655
	4.2	0.75	5.46	5.10	36.71	6.87	7.77	3.84	1.78	1.13	0.75	0.57	0.39	0.34	0.24	0.22	0.17	0.15	0.13	0.11	0.10	0.09	24	0.793	0.656
200V 3ϕ	1.2	0.18	1.13	1.00	27.91	11.72	23.43	6.53	4.07	2.64	1.17	1.08	0.58	0.51	0.34	0.36	0.24	0.26	0.20	0.20	0.17	0.17	47	0.932	0.891
	1.4	0.25	1.47	1.20	27.19	11.16	21.85	6.00	3.72	2.41	1.01	1.04	0.46	0.52	0.27	0.38	0.21	0.28	0.20	0.21	0.17	0.16	36	0.930	0.885
	2.2	0.37	2.07	1.70	29.58	11.23	21.70	5.89	3.40	2.37	0.72	1.13	0.28	0.62	0.19	0.41	0.20	0.24	0.20	0.13	0.16	0.09	27	0.923	0.872
	3.2	0.55	2.92	2.40	27.55	11.27	22.12	6.06	3.77	2.43	1.03	1.05	0.45	0.53	0.28	0.38	0.22	0.28	0.20	0.21	0.17	0.16	18	0.930	0.885
	4.2	0.75	3.85	3.20	28.03	10.92	21.59	5.97	3.45	2.39	0.83	1.04	0.36	0.57	0.21	0.41	0.19	0.27	0.19	0.18	0.15	0.12	15	0.925	0.880
200V 1/3ϕ	6.0	1.1 1ϕ	*8.26*	*7.70*	*36.21*	*6.74*	*7.81*	*3.76*	*1.77*	*1.13*	*0.73*	*0.57*	*0.38*	*0.33*	*0.23*	*0.21*	*0.16*	*0.14*	*0.12*	*0.11*	*0.09*	*0.08*	*16*	*0.791*	*0.655*
		3ϕ	5.43	4.80	27.46	11.98	23.81	6.65	4.32	2.71	1.30	1.15	0.66	0.50	0.42	0.33	0.28	0.22	0.21	0.17	0.16	0.15	9.1	0.936	0.895
	6.8	1.5 1ϕ	*10.73*	*10.00*	*37.36*	*6.93*	*7.68*	*3.95*	*1.76*	*1.13*	*0.75*	*0.56*	*0.40*	*0.34*	*0.24*	*0.22*	*0.16*	*0.15*	*0.12*	*0.11*	*0.09*	*0.09*	*12*	*0.796*	*0.659*
		3ϕ	7.10	6.10	27.50	11.91	23.49	6.49	4.25	2.62	1.27	1.13	0.62	0.50	0.39	0.32	0.26	0.23	0.20	0.18	0.16	0.16	6.8	0.936	0.893
	9.6	2.2 1ϕ	*15.56*	*14.40*	*37.32*	*6.91*	*7.59*	*3.96*	*1.74*	*1.13*	*0.75*	*0.56*	*0.40*	*0.34*	*0.24*	*0.22*	*0.16*	*0.15*	*0.12*	*0.11*	*0.09*	*0.09*	*8.2*	*0.798*	*0.660*
		3ϕ	10.29	8.90	27.64	11.92	23.59	6.51	4.25	2.62	1.27	1.13	0.61	0.50	0.38	0.33	0.26	0.24	0.20	0.18	0.16	0.16	4.7	0.936	0.893
400V 3ϕ	1.2	0.37	0.96	0.80	29.50	12.63	23.84	6.48	4.28	2.51	1.26	1.18	0.54	0.56	0.35	0.38	0.26	0.30	0.22	0.23	0.20	0.18	82.0	0.934	0.884
	1.7	0.55	1.41	1.11	28.15	11.18	21.53	5.81	3.61	2.29	0.92	1.08	0.36	0.57	0.26	0.39	0.21	0.27	0.19	0.18	0.15	0.13	62.0	0.928	0.877
	2.2	0.75	1.91	1.50	29.22	10.91	20.86	5.62	3.20	2.27	0.61	1.12	0.20	0.61	0.18	0.38	0.20	0.21	0.21	0.09	0.17	0.06	51.0	0.921	0.868
	3.2	1.1	2.66	2.10	28.82	11.04	21.07	5.72	3.32	2.29	0.71	1.11	0.27	0.61	0.20	0.40	0.21	0.24	0.20	0.13	0.16	0.09	36.0	0.923	0.872
	3.7	1.5	3.70	2.90	28.88	10.21	19.66	5.31	2.81	2.10	0.55	0.98	0.27	0.53	0.23	0.32	0.23	0.19	0.20	0.12	0.14	0.09	30.0	0.917	0.863
	5.3	2.2	5.23	4.10	29.82	10.61	20.14	5.36	2.93	2.14	0.56	1.04	0.25	0.55	0.25	0.32	0.25	0.19	0.22	0.11	0.16	0.09	20.0	0.917	0.861
	7.2	3.0	6.52	5.40	27.07	10.84	21.61	5.99	3.56	2.41	0.93	1.01	0.43	0.53	0.24	0.39	0.20	0.27	0.19	0.19	0.15	0.15	15	0.928	0.885
	8.8	4.0	9.20	7.30	29.13	10.80	20.63	5.59	3.10	2.26	0.55	1.11	0.18	0.60	0.17	0.37	0.21	0.20	0.22	0.08	0.18	0.05	11	0.920	0.868

4.4. Conducted Emissions

4.4.1. General

Radio frequency emissions in the range from 150 kHz to 30 MHz are caused by the switching action of the main power devices (IGBTs) and are mainly conducted out of the equipment through electrical power wiring. It is essential for compliance with emission standards for the recommended filter and a shielded (screened) motor cable to be used. Most types of screened cable are suitable. The screen must be continuous for the entire length of the cable. For example, the screen formed by the structure of steel wire armoured cable is acceptable. The capacitance of the cable forms a load on the drive and filter, so should be kept to a minimum.

Compliance tests are carried out with cable having a capacitance between the three power cores and the screen of 450 pF/m, which is typical of steel wire screened cable commonly referred to as SY-cable. In addition to motor cable length, conducted emissions also vary with drive switching frequency. Selecting the lowest switching frequency will produce the lowest level of emission. In order to meet the stated standards, the drive, filter and motor cable must be installed correctly. Wiring guidelines are given in section 5 of this EMC data sheet.

The drive contains a cost-effective internal input filter (IF) which gives a reduction of about 30 dB in the level of emissions at the supply terminals. Unlike a conventional filter, the internal filter continues to provide this attenuation with a long motor cable. For practical purposes this filter in conjunction with a screened motor cable is enough to prevent the drive from causing interference to most good quality industrial equipment operating in the Second Environment in accordance with IEC 61800-3.

It is recommended for the filter to be used in all situations unless RCD limits are exceeded, or if the DC bus voltage has significant swing in relation to ground potential (>10 % line to ground) which can be the case in an IT earthing system where the ground potential is connected via the motor frame or through one of the drive output phases.

The User Guide gives instructions on how to disconnect the internal EMC filter from Earth.

For applications with strict requirements for radio frequency emissions, (e.g. the generic standards IEC 61000-6-4 or operation in the First Environment according to IEC 61800-3), The **Commander S100-xxxx1** model range should be used. Alternatively an optional external filter (EF) must be used with **Commander S100-xxxx3** models to meet the additional requirements.

The internal and external filters are complementary and work together. Both should be used whenever emissions in the <30 MHz range are of concern.

Typical earth leakage currents[4] due to the external EMC filter are shown in Table 13. Both filters shunt current to the Earth circuit, increasing PE currents. Since values shown in these tables were obtained with each device under standalone configuration, currents from both tables do not add arithmetically given they have different frequencies and time-zero phases, i.e. they add as vectors. Table 13 shows the typical operational earth leakage current of external EMC filters I_{LKext} as provided by the manufacturer, while Table 11 and Table 12 show the touch current values and typical operational PE current for each drive.

The values shown in Table 12, which are measured directly on the PE connection to the drive, assume a frequency window of DC to 1.5 kHz, which is a reasonable bandwidth for RCDs. This bandwidth, however, is manufacturer dependent and not necessarily stated. Some low-cost electronic RCDs have much higher bandwidth than 1.5 kHz.

External filters are designed to shunt higher frequencies (>0.15 MHz) of the Earth circuit current back to the drive, diverting them from supply and RCD circuits. The reported PE current, however, has nothing to do with the drive and is essentially a measure of the filter's internal component mismatch and coping with phase imbalance on the supply. This means that PE current for a setup of an external filter plus the drive's internal filter is not even equal to their vector addition, it should be lower. However, for the purpose of getting a rough worst case scenario value for PE current in a typical setup it might be acceptable to use the following approach (vector addition),

$$I_{LK_{Total}} < \sqrt{I_{LK_{ext}}^2 + I_{LK_{int}}^2}$$

[4] It is relatively common to find the term leakage associated with PE (protective earth) currents, but the term is vague and has been found applied indiscriminately to either PE currents, touch currents, both, or currents flowing through unwanted parts of a system.

4.4.2. Use of a ferrite ring

In some cases, passing the motor cable through a ferrite ring can reduce conducted emissions. The **Commander S100** family of drives already features an internal ferrite ring at the output stage. However, an additional ferrite ring can be added if found necessary and is usually beneficial.

The ferrite ring should be mounted close to the drive with the output power conductors (U, V and W but not E or the screen) passing once or twice through the central aperture, all together in the same direction.

Care should be taken to ensure the motor cable screen and PE connection to the EMC bracket are not compromised.

4.4.3. Measured results

Table 9 Conducted emissions [Individual Drive] 1Φ

		4kHz
Rated voltage V	Cable Length	Internal Filter Connected
100V 1-Phase Frame 1 **S100-011x3**	5 m	C3
100V 1-Phase Frame 3 **S100-031x3**	5 m	C3
200V 1-Phase Frame 1 **S100-01Sx3** **S100-01Dx3**	20 m	C3
200V 1-Phase Frame 2 **S100-02Sx1**	5 m	C1
200V 1-Phase Frame 3 **S100-03Dx3**	5 m	C3

Table 10 Conducted emissions, [Individual Drive], 3Φ

		4kHz
Rated voltage (V)	Cable Length	Internal Filter Connected
200V 3-Phase Frame 1 **S100-012x3 S100-01Dx3**	20 m	C3
200V Dual Phase Frame 3 **S100-03Dx3**	5 m	C3
400V 3-Phase Frame 2 **S100-024x3**	5 m	C3
400V 3-phase Frame 3 **S100-034x3**	5 m	C3

Notes:

1. Where the drive is incorporated into a system with rated input current exceeding 75A, the higher emission limits in IEC 61800-3 for commercial and light industrial locations are applicable - and no filter is required.
2. Operation without a filter is a practical cost-effective option in an industrial environment where existing levels of electrical noise are likely to be high and any electrical equipment in operation has been designed for such an environment. This is in accordance with IEC 61800-3 in commercial and light industrial locations. There is some risk of disturbance to other equipment, and in this case the user and supplier of the drive system must jointly take responsibility for correcting any problems that occur.
3. Filter current rating is matched to the drive's input current rating, not to a single drive output current capacity. Usage of an external filter with current rating that more closely matches the actual drive's expected input current is highly recommended as it will provide lower emissions.

4.4.3.1. Example Results Graph

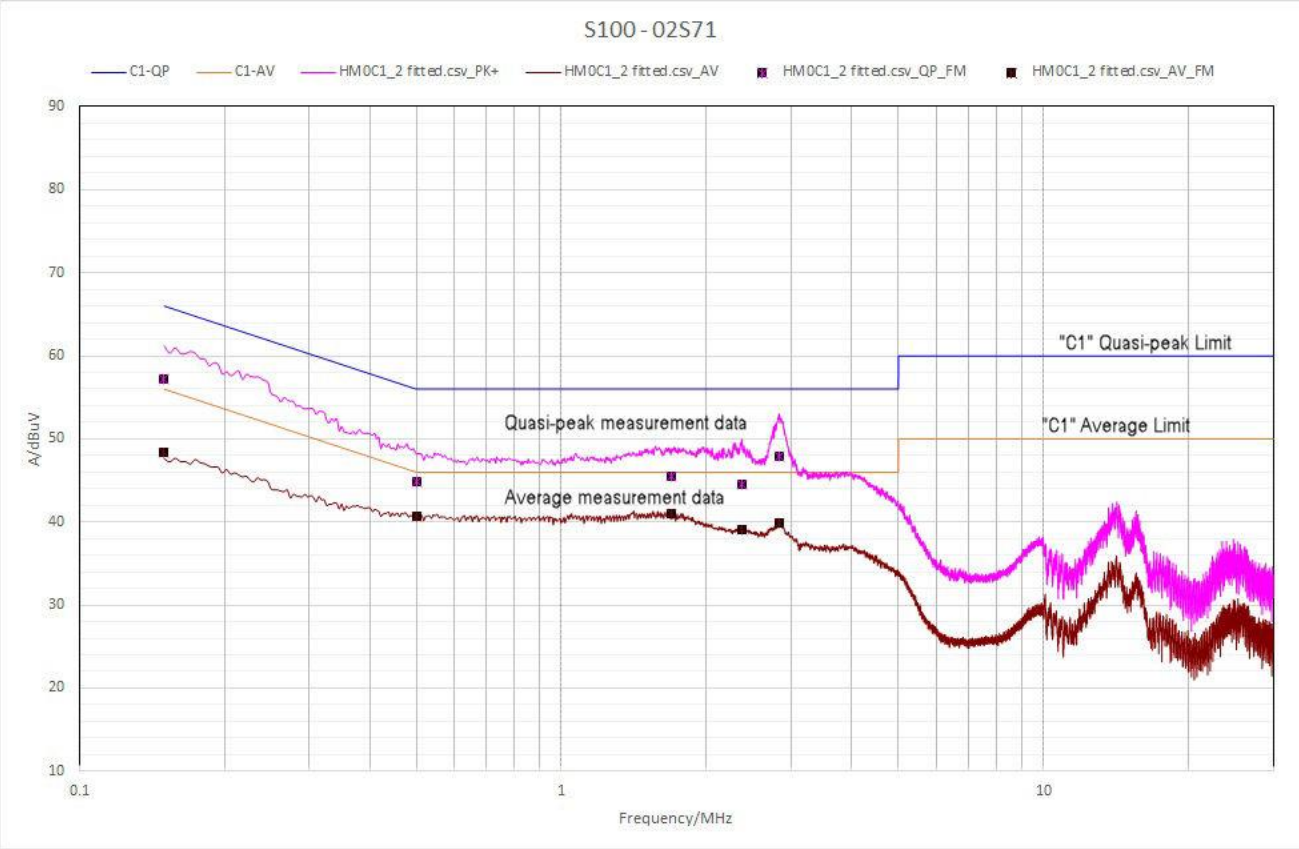


Figure 4 : Conducted Emissions Results. Drive model S100-02S71, 4kHz switching frequency, 5 metres 'SY' motor cable

4.4.4. Touch Current

Touch currents greater than the 3.5 mA limit specified in EN 61800-5-1 require a permanent low impedance, low inductance (eg. flat braided) connection between the drive's metal frame and PE that complies with local safety regulations for high protective earthing conductor current equipment.

Table 11 Typical operational touch current levels at 4 kHz switching frequency

		Internal Filter connected	Internal Filter not connected
Rated voltage V	Drive Model	Peak mA	Peak mA
100V 1-phase	S100-011x3	> 3.5 mA	< 3.5 mA
	S100-031x3		TN/TT Supply: < 3.5 mA Split-Phase: >3.5 mA @ >110V
200V 1-phase (C1)	S100-02Sx1	TN/TT Supply: > 3.5 mA Split-Phase: >3.5 mA @ >190V	N/A
200V 1-phase	S100-01xx3	> 3.5 mA	> 3.5 mA @ V_{supply} > 217V
200V 3-phase	S100-01xx3		> 3.5 mA @ V_{supply} > 250V
400V 3-phase	S100-024x3		> 3.5 mA
	S100-034x3		

Peak values evaluated according to EN 60990:2016 weighted for perception or startle-reaction connected to a common IE2 4 pole motor at a switching frequency of 4 kHz and motor cable length of 20 metres

4.4.5. Earth Leakage / RCD Compatibility

Where a residual current operated protective device (RCD) is used for protection it should be of "Type B" characteristics.

The earth leakage currents from multiple drives do not combine in a simple arithmetic manner: $I_{DRIVE1} + I_{DRIVE2} \neq I_{TOTAL}$.
It is therefore difficult to predict the protective earthing conductor current for a system of multiple drives based on measurements made on an individual drive. EN 60990 recommends the protective conductor current for a combined system of equipment should be measured.

Table 12 Typical earth leakage currents as seen by an RCD connected to a single drive

Rated voltage V	Drive Model	Motor Cable	Internal Filter	During Power Up mA_{RMS}			Motor Stopped mA_{RMS}	Motor Running mA_{RMS}
				5x I_n @ 10-40ms	2x I_n @ 10-150ms	1x I_n @ 10-300ms		
100V 1-phase TN/TT Supply	S100-011x3	2 m	✓	8.9	9.1	9.1	7.9	7.9
			×	1.7	1.7	1.7	0.1	0.7
		20 m	✓	7.1	7.3	7.5	7.9	8.6
			×	1.7	1.7	1.7	0.1	4.9
	S100-031x3	2 m	✓	8.4	9.9	12	20	20
			×	1.6	1.6	1.6	0.1	0.7
		20 m	✓	16	17	17	20	20
			×	1.6	1.6	1.5	0.1	3.8
100V 1-phase Split-Phase Supply	S100-011x3	2 m	✓	19	18	17	4.5	4.6
			×	1.7	1.7	1.7	0.1	0.3
		20 m	✓	4.2	4.4	4.5	4.5	4.8
			×	1.8	1.8	1.8	0.1	1.1
	S100-031x3	2 m	✓	20	20	20	11	11
			×	1.6	1.6	1.6	0.1	0.3
		20 m	✓	9.7	10	10	11	12
			×	1.6	1.6	1.6	0.1	1.0
200V 1-phase (C1) TN/TT Supply	S100-02Sx1	2 m	✓	3.2	3.3	3.4	3.6	3.6
		20 m	✓	3.9	3.9	3.9	3.6	4.2
200V 1-phase (C1) Split-Phase Supply		2 m	✓	8.4	8.0	7.6	2.0	2.0
		20 m	✓	4.0	3.9	3.8	2.0	2.4
200V 1-phase TN/TT Supply	S100-01xx3	2 m	✓	26	26	26	26	27
			×	1.7	1.7	1.7	0.1	1.0
		20 m	✓	33	37	38	27	27
			×	1.8	1.7	1.7	0.1	4.9
200V 1-phase Split-Phase Supply		2 m	✓	26	25	23	5.6	6.3
			×	1.7	1.7	1.7	0.1	0.3
		20 m	✓	9.8	9.5	9.2	5.8	6.9
			×	1.6	1.6	1.6	0.1	0.7
200V 3-phase	S100-01xx3	2 m	✓	45	43	41	9.9	11
			×	1.6	1.6	1.6	0.1	0.3
		20 m	✓	16	16	15	9.9	12
			×	1.7	1.7	1.7	0.2	1.1
	S100-03xx3	2 m	✓	24	23	22	9.6	10
			×	1.6	1.6	1.6	0.1	0.4
		20 m	✓	34	32	30	9.5	11
			×	1.6	1.6	1.6	0.2	1.1
400 3-phase	S100-024x3	2 m	✓	24	24	23	18	21
			×	1.7	1.7	1.7	0.1	0.6
		20 m	✓	23	22	22	18	23
			×	1.7	1.7	1.7	0.1	2.5
	S100-034x3	2 m	✓	21	21	21	15	17
			×	1.8	1.8	1.8	0.1	0.5
		20 m	✓	16	16	16	15	19
			×	1.7	1.7	1.7	0.1	2.5

Earth leakage measured with 1.5kHz bandwidth whilst drive operates at 4kHz switching frequency from maximum rated power supply voltage

4.4.6. Operation with IT (ungrounded) supplies

Unusual hazards can occur on ungrounded supplies with more than one source, for example on ships.
Contact the supplier of the drive for more information.

Special attention is required when using internal or external EMC filters with ungrounded supplies. In the event of a ground (earth) fault in the motor circuit the drive may not trip and the filter could be over stressed. In this case, either the filter must not be used (removed) or additional independent motor ground fault protection must be provided. For details of ground fault protection contact the supplier of the drive.

4.4.7. External filters

In multiple drive applications it is not required to have multiple filters. The emission levels shown in Table 9 and Table 10 have been measured using filters rated for the drive's current rating. A level met in Table 9 or Table 10 for a given cable length with a single cable will also be met by any number of drives in parallel with a combined cable length that matches the cable length in one of those tables.

Table 13 Optional external EMC filter ratings

Current Rating 40°C A	Voltage Rating V	Φ	Low Leakage	Nominal Leakage mA	L mm	W mm	D mm	Climatic Test Class	Terminal Torque Nm	CT part number
11	250	1	×	24.6	215	75	41	25/085/21	1.8	4200-1000
11	250	1	✓	2.38						4200-1001
25	110	1	×	11.7	261	78	41			4200-2000
18	250	1	×	24.6						4200-2001
18	250	1	✓	2.38						4200-2002
13	250	3	×	1.84						4200-2003
13	250	3	✓	1.84						4200-2004
6	480/275	3	×	4.31						4200-2005
6	480/275	3	✓	1.2						4200-2006
23	250	1	×	24	282	91	41			4200-3000
23	250	1	✓	3.4						4200-3001
17	250	3	×	0.7						4200-3004
17	250	3	✓	0.7						4200-3005
14	480/275	3	×	3.6						4200-3008
14	480/275	3	✓	1.32						4200-3009
24	250	1	×	24	334	116	41			4200-4000
24	250	1	✓	3.4						4200-4001
20	250	3	×	0.7						4200-4002
20	250	3	✓	0.7						4200-4003
17	480/275	3	×	3.6						4200-4004
17	480/275	3	✓	1.3						4200-4005

The requirements of IEC 61000-6-4 and IEC 61800-3 First Environment are met by **Commander S100-xxxx1** drives without additional filtering.
The built-in filter of **Commander S100-xxx3** drives complies with IEC 61800-3 Second Environment. An additional external filter is required for **Commander S100-xxx3** drives to meet the higher requirements of IEC 61000-6-4 and IEC 61800-3 First Environment.

4.4.8. Related product standards

The conducted emission levels specified in the standards above are equivalent to the levels required by the following product specific standards:

Table 14 Comparison of IEC 61800-3 and related emissions standards

Drive standard Equipment Category	Generic standard	Scope of Generic standard	Product standard	Scope of Product standard
C1	IEC 61000-6-3	Emission standard for residential, commercial and light-industrial environments	EN 55011 Class B CISPR 11 Class B	Industrial, scientific and medical equipment
			EN 55014 CISPR 14	Household electrical appliances
			EN 55022 Class B CISPR 22 Class B	Information technology equipment
C2	IEC 61000-6-4	Emission standard for industrial environments	EN 55011 Class A Group 1 CISPR 11 Class A Group 1	Industrial, scientific and medical equipment
			EN 55022 Class A CISPR 22 Class A	Information technology equipment

4.5. Radiated Emissions

4.5.1. Industrial emission standard IEC 61000-6-4

When installed in a standard metal enclosure according to the wiring guidelines in Section 5 of this EMC data sheet, and using the standard or low-leakage mains input filters, the drive will meet the C2 radiated emission limits required by the generic industrial emission standard IEC 61000-6-4. Without an external filter the drive will meet C3 radiated emission limits.

4.5.2. Related product standards

The radiated emission levels specified in IEC 61000-6-4 are equivalent to the levels required by the following product standards:

Table 15 Related radiated emission standards

Generic standard	Product standard	
IEC 61000-6-4	CISPR 11 Class A Group 1 CISPR 11 Class A Group 1	Industrial, scientific and medical equipment
	EN55022 Class A CISPR 22 Class A	Information technology equipment

4.5.3. Limits for radiated emission

Compliance was achieved in tests using representative enclosures and following the guidelines given. Every effort was made to ensure the arrangements were robust enough to be effective despite the normal variations which will occur in practical installations. However, no warranty is given that installations built according to these guidelines will necessarily meet the same emission limits as it is impossible to ensure the same materials are used, the exact same geometries are employed etc. The limits for emission required by the generic emission standards are summarised in the following table:

Table 16 Radiated emissions limits in IEC 61800-3

Frequency range (MHz)	Category C1	Category C2	Category C3	Units
30 - 230	30	40	50	dBµV/m Quasi peak
230 - 1000	37	47	60	

The limits apply at a measuring distance of 10m.
The measurements may be made at 3m with the limits increased by 10 dB.

4.5.4. Example test data

The test data is based on radiated emission measurements made on a standard steel enclosure containing a single drive with appropriate power supply. The drives whose results are shown in Table 17, Table 18 and Table 19 have the highest emission levels in this product range. The tests were carried out in a calibrated open area test site (OATS). Details of the test arrangement are described below:

A standard enclosure having dimensions 1900 mm (high) × 600 mm (wide) × 500 mm (deep) was used during tests. Two ventilation grilles, both 200mm square, are provided on the upper and lower faces of the door.

The drive is mounted alongside the EMC filter to the internal back-plate of the enclosure. The filter casing and drive's optional cable management bracket made electrical contact with the back-plate by the fixing screws. Standard unscreened power cables are used to connect the complete unit to the supply.

A suitably rated, standard AC induction motor is connected by 2 m of shielded cable (steel braided - type SY) and mounted externally.

The motor cable screen is clamped to the enclosure back-plate and bonded to the motor frame.
(alternatively the motor screen is bonded to the drive's optional cable management bracket)

An unscreened 3 m control cable is connected to the drive control terminals.

An unscreened 3 m status relay cable is connected to the drive.

A 2 m screened communications cable is connected to the drive. The screen is not electrically connected to the drive or cubicle back-plate.

The drive operates at 10 Hz, with a switching frequency of 4 kHz. No additional EMC preventative measures were taken, e.g. RFI gaskets around the cubicle doors.

The following tables summarise the results for radiated emission, showing the highest measurements over the frequency range 30 to 1000 MHz:

Table 17 Radiated emission measured levels, 100V, model S100-03113

Test frequency (MHz)	Measured level (dBµV/m)	Equipment category C2 limit (dBµV/m)	Margin (dBµV/m)
30.0	39.54	50	10.46
30.0 -90° position	38.39	50	11.61
30.0 -45° position	37.47	50	12.53
30.12	34.81	50	15.19
30.18	36.84	50	13.16

Table 18 Radiated emission measured levels, 200V, model S100-02571

Test frequency (MHz)	Measured level (dBµV/m)	Equipment category C2 limit (dBµV/m)	Margin (dBµV/m)
30.00	34.98	40.00	5.02
30.12	35.06	40.00	4.94
40.50	34.00	40.00	6.0
40.86	35.48	40.00	4.52
42.90	34.83	40.00	5.17
42.96	32.53	40.00	7.47

Table 19 Radiated emission measured levels, 400, model S100-03423

Test frequency (MHz)	Measured level (dBµV/m)	Equipment category C3 limit (dBµV/m)	Margin (dBµV/m)
36.96	43.77	50.00	6.23
46.98	44.48	50.00	5.52
48.06	43.12	50.00	6.88
48.12	43.63	50.00	6.37
48.24	42.22	50.00	7.78
48.54	44.13	50.00	5.87

4.5.5. Enclosure construction

In many installations an enclosure has a back-plate which is used to mount variable speed drives together with the EMC filters and ancillary equipment. The motor cable should be bonded to the back-plate close to the drive before it leaves the enclosure wall. However, there is no disadvantage if the motor cable is bonded at the point of exit as well, through the normal gland fixings, if the inside of the cabinet is not painted.

Depending on construction, the enclosure wall used for cable entry may have separate panels and could make poor electrical contact at high frequencies with the remaining structure. If the motor cable is only bonded to these surfaces and not to a non-painted back-plate, then the enclosure may provide insufficient attenuation of RF emission. It is the bonding to a common metal plate which minimises radiated emission.

5. Installation and Wiring Guidelines

5.1. General

The wiring guidelines on the following pages should be observed to achieve minimum emissions and maximum immunity. The use of 360° ground terminations on shielded cables is beneficial, but not necessary unless specifically stated in the instructions.

1. Emissions are higher with long motor cables and high switching frequencies. Shorter motor cables and low switching frequencies reduce emissions.

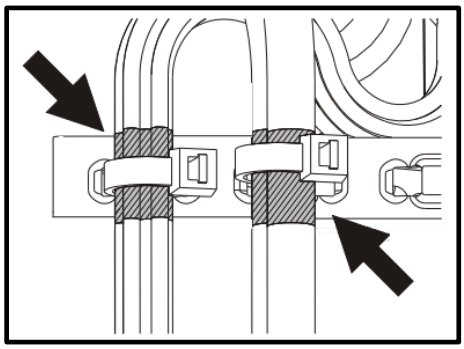
2. The correct external filter **must** be fitted at the input to the drive to achieve equipment category C2 compliance for radiated emissions.

3. The filter must make good direct electrical contact with the metal back-plate. Any paint or other non-conducting coating must be removed.

4. Where the EMC filter is mounted next to the drive. The output connections of the filter should be placed as close as possible to the drive mains input, with wires between the filter and drive input as short as possible.

5. The drive's EMC backplate screw (bottom-centre) must make good electrical contact with either the body of the filter, or the enclosure backplate, depending whether the drive is mounted alongside the filter or directly upon it.

6. A shielded cable must be used to connect the drive to motor. The shield must be connected to the enclosure backplate by a good high-frequency connection, for example by direct clamping using a "U" clamp or similar. Multiple zip-ties embracing and pressing the motor cable screen to the drive's optional cable management bracket is an acceptable alternative.



7. The shield of the motor cable must be connected to the ground terminal of the motor frame using a link that is as short as possible, not exceeding 50 mm (2 in) in length. A full 360° termination of the shield to the motor terminal housing (if metal) is beneficial.

8. Where the drive is mounted on DIN rail, a good electrical connection to the backplate is not guaranteed without fitting the additional EMC backplate screw (bottom-centre). If it is not possible to use this screw, then the motor cable screen should be bonded to the optional cable management bracket, or, if necessary, connected using a short pig-tail to the drive's ground terminal screws.

9. Cables carrying the AC supply and the ground to the filter should be at least 100 mm (4 in) from the drive & motor cable (B).

10. Avoid locating sensitive signal circuits in a zone extending 300 mm (12 in) all around the drive (A).

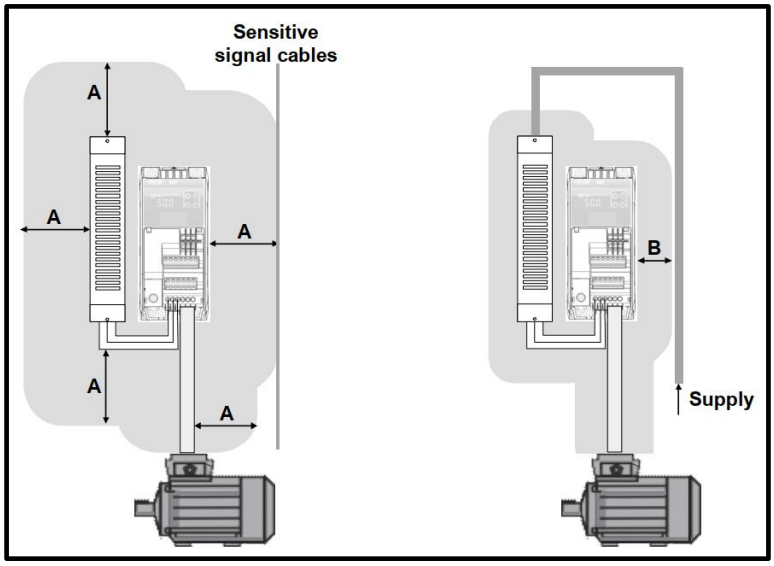


Figure 5 Suitable cable clearances

11. The control circuit 0V of the **Commander S100** family is internally connected to the drive metal grounding bracket and cannot be disconnected. An external controller ground or reference should be connected directly to the drive 0V reference pins {T3, T5, T10 }. If more 0V connections are required a local terminal block placed next to the drive and close to the I/O port should be used. External modules that interact with the I/O of the drive should avoid connecting their references to the cabinet or the ground bar, direct connections should be used instead.

12. A ferrite clamp-on core should be placed over 24 V power supply connections at the input of an external controller or IPC (Industrial PC). These are also recommended over the I/O and control lines to the drives. These always need to fully embrace pairs of signal/power wires with the corresponding return wires.

13. Ideally the cabinet will not be painted on the inside, allowing for a large low-impedance return path for reference potential currents.

5.1.1. Control wiring leaving the enclosure

Control wiring that leaves the enclosure must be carried in shielded cable (one or more cables) with the shield clamped to the enclosure back-plate, or alternatively to the optional drive cable management bracket.

5.1.2. Interruptions to the motor cable

The motor cable should ideally be a single run of shielded cable having no interruptions. In some installations it may be necessary to interrupt the cable, for example to connect the motor cable to a terminal block within the drive enclosure, or to fit an isolator switch to allow safe working on the motor. In these cases follow guidelines given in section 5.1.4.

5.1.3. Terminal block within enclosure

The motor cable shields should be bonded to the back-plate using uninsulated cable-clamps which should be positioned as close as possible to the terminal block. Keep the length of unscreened power conductors to a minimum and ensure all sensitive equipment and circuits are at least 0.3m (12in) away from the terminal block. See Figure 6.

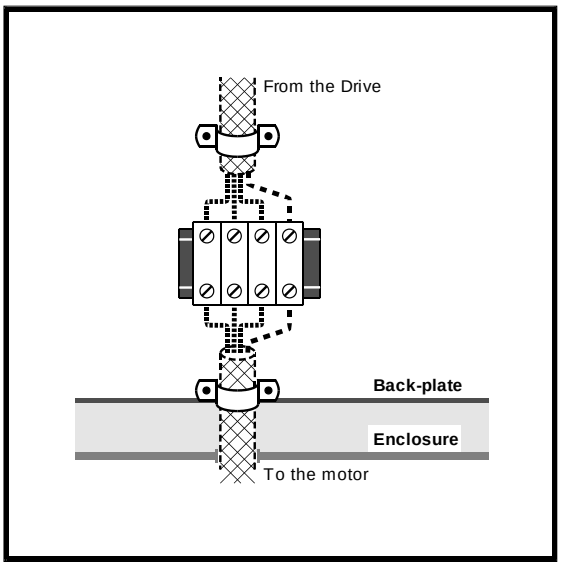


Figure 6 Arrangement for terminal block in motor cable

5.1.4. Using a motor isolator switch

The motor cable shields should be connected by a very short conductor having low inductance. The use of a flat metal bar is recommended; conventional wire is not suitable. The shields should be bonded directly to the coupling bar using un-insulated metal cable-clamps. Keep the length of the power conductors to a minimum and ensure all sensitive equipment and circuits are at least 0.3m (12in) away. The coupling bar may be grounded to a known low impedance ground nearby, for example a large metallic structure which is connected closely to the drive ground. See Figure 7.

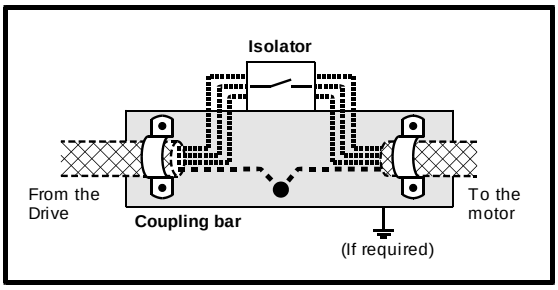


Figure 7 Arrangement for isolator switch in motor cable

5.1.5. Network cabling

In general, Network Cables have good immunity to broadband noise (conducted and radiated), fast transient bursts and surges. CAT 6 or higher-grade cable is recommended.

5.2. Internal EMC Filter

The Commander S100 is available with either C1 or C3 internal filters. It is recommended for the internal EMC filter to be enabled unless there is a specific reason for disconnecting it. The filter may need to be removed if the level of ground leakage current is found to be unacceptable. The internal EMC filter is disconnected by removing the screw shown below.

The internal filter cannot be disconnected on a 200V drive with an internal C1 filter (**S100-xxxx1**)

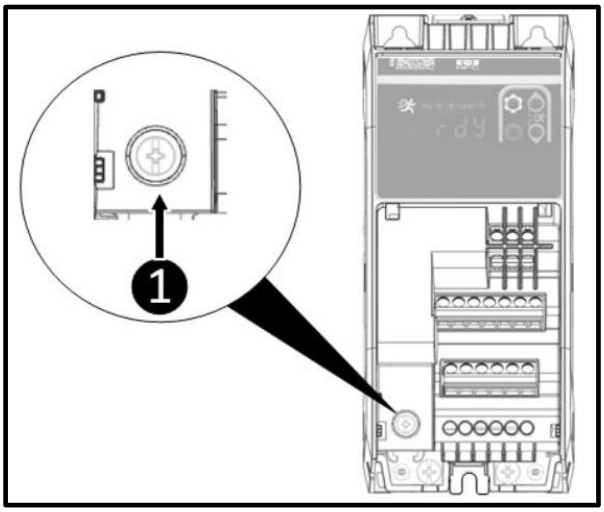


Figure 8 Location of EMC filter disconnect screw

The power supply to the drive must be disconnected for 5 minutes before connecting or disconnecting the internal EMC filter screw.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