IFA
Institut für Arbeitsschutz der
Deutschen Gesetzlichen Unfallversicherung

EMC and functional safety for power drive systems with integrated safety functions

Definition of the test severity levels
Test conditions

1 General

In order to control machine movements, electronic equipment is frequently used which by its nature may be influenced by electromagnetic phenomena. EN 61508 [1] and the machinery sector standard based upon it, EN 62061, make provision for higher immunity to interference for electronic equipment which fulfils safety functions. By contrast, neither EN 61800-5-2 nor EN ISO 13849-1 contain binding provisions requiring higher immunity to interference. Demonstration of higher immunity to interference is therefore necessary only where equipment is certified to EN 61508 or the product is to be used in accordance with EN 62061. The EMC[1] environment in which the product is used must of course be considered. The procedure by which higher immunity to interference may be demonstrated is currently (September 2011) set out normatively in IEC 61508 Ed. 2.0 by a reference to a technical specification in the form of IEC 61000-1-2 Ed. 2. This specification constitutes the basic publication governing EMC and functional safety, and covers the general methods for the attainment of functional safety with regard to electromagnetic phenomena. It also serves as a basis for future EMC standards. Efforts are currently underway within the EMC standards committees to transform these technical specifications into an international standard. The present EN 61800-5-2 product standard governing power drive systems refers only to an old version of IEC 61508. IEC 61000-6-7 (the generic EMC standard governing functional safety in industrial environments), which is currently in preparation, has not yet defined a final test level. The Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA) therefore presents this provision for power drive systems with integral safety function.

2 Power drive systems with integrated safety functions

Power drive systems are drive control devices for regulating the speed of asynchronous and synchronous motors. If safety functions are integrated into these devices, for example for the avoidance of unanticipated start-up or for the safe limiting of speeds, the equipment concerned is described as a power drive system (PDS) with safety-related functions (PDS (SR))[2]. Together with the motor and sensor(s), the power converter then forms part of the PDS (SR), and assumes safety-related functions. During development and application of these products, standards therefore apply which contain requirements concerning the functional safety of safety-related electrical/electronic/programmable electronic systems.

3 EMC requirements of safety technology

The safety-related requirements for PDS (SR) are currently specified in the EN 61508 series of standards. In order for sensitivity to electromagnetic interference to be reduced, Table A.2 of IEC

[1] EMC: electromagnetic compatibility

[2] PDS (SR): Power Drive System (Safety Related)

61000-1-2 Ed. 2 specifies guideline maximum values for interference immunity testing, and sets out additional requirements as a function of the Safety Integrity Level (SIL) in Tables 4 and 6.

A particular deficit of IEC 61000-1-2 Ed. 2 is however the absence of any defined test severity levels. EN 61800-5-2 [2], the product standard for PDS (SR), likewise contains no provisions governing the test severity levels, since PDS (SR) may be used in widely diverse environments. The requirements to be met may differ accordingly. A solution exists in the form of EN 61326-3-1:2008-11 [3]. This standard specifies test severity levels which are intended to demonstrate a higher immunity to interference for the majority of industrial environments. In addition, the IEC 61000-6-7 generic standard (Electromagnetic compatibility (EMC) – Generic standards – Immunity requirements for safety-related systems and equipment intended to perform functions in a safety-related system [functional safety] in industrial environments) is currently (February 2012) in preparation.

This standard is geared closely to the test severity levels set out in IEC 61326-3-1. IEC 61000-6-7 is based upon IEC 61000-1-2.

4 Definition of the test severity levels

Despite the lack of clarity in standards governing EMC and functional safety, PDS (SR) placed on the market at present must satisfy the requirements for higher immunity to interference stated in EN 61508. The IFA has adopted a pragmatic approach to this issue by specifying test severity levels. These are applied during testing and certification of a PDS (SR) for use on machinery. The approach essentially adopts the concept in EN 61326-3-1, which is also applied in part in EN 62061 [4] governing machine controls. Depending upon the necessary Safety Integrity Level, test levels are doubled or the next higher test severity level selected under this concept. If appropriate, the duration of testing or number of interference pulses is increased. Deviation is nevertheless made from EN 61326-3-1:2008-11, since the latter is based upon the generic standards for industrial devices (EN 61000-6-2 [5]). For PDS, however, a product-specific EMC standard (EN IEC 61800-3 [6]) exists which sets out values differing from those in the generic standard for the phenomena of "conducted HF" and "burst and surge". The concept of higher values and the change in the number/duration is therefore applied to the values for EN 61800-3. The individual test severity levels can be found in the annex to this article.

5 Test conditions and test criteria

Satisfaction of the requirements of EN 61508 is intended to ensure that safety-related products do not fail unsafely as a result of electromagnetic influence. No requirements are placed upon the product availability. Consistent with this requirement, the test criterion FS is introduced in EN 61326-3-1 and in the product standard for PDS (SR) (EN 61800-5-2). During the exposure to an influence, the safety function is either retained in full or is impaired temporarily/permanently, a defined safe state is maintained or is attained within the specified fault-response time. The destruction of Type A[3] components is permitted when owing to their type, a safe state is maintained or is attained within the fault-response time.

This criterion is applicable only to the safety function. In the event of higher interference levels, no requirements are placed upon normal functioning of the equipment under test (EUT).

[3] In accordance with [1], Paragraph. 7.4.3.1.2: components the failure modalities of which are adequately defined, the response of which in fault conditions can be completely determined, and for which reliable failure data are available. This applies for example to resistors and transistors, but not to microprocessors, FPGAs and similar complex components.

Should a test result in failure with/without the destruction of components, it is often not possible to demonstrate by analysis that the safe state is always maintained. For demonstration of the observance of the FS criterion, a procedure must be defined in these cases which, on the one hand, provides sufficient confidence, and on the other, limits the consumption of material owing to destruction of components, and the time necessitated by the performance of tests. For this purpose, the following concept is applied in the IFA:

Where an influence is detected, the FS criterion is deemed satisfied when, in three tests at the maximum interference level, the safe state is maintained three times. Destruction of Type A components during this process is permissible.

5.1 Enclosures

In some tests, whether the EUT or the switchgear cabinet into which the EUT is fitted is regarded as the physical boundary of the device is relevant. For a decision in this context, the following must be considered: the Machinery Directive [7] requires of the manufacturer of the machine that it be used without risk to persons throughout its anticipated service life. Reference is made in this context to installing, adjusting and maintaining machinery, in addition to its operation. ISO 12100-1 [8] further supports this requirement, among other things by stating the phases commissioning and troubleshooting. In these phases of a machine's life, it may be assumed that machine movements also occur when the switchgear cabinet is open. The reason for the switchgear cabinet door being opened may also be related to work on other devices located within the same switchgear cabinet. The physical boundary of the device is therefore generally assumed to be the enclosure of the EUT, with the following exceptions:

The switchgear cabinet may be assumed to be the physical boundary of the EUT in cases in which, apart from the EUT, no further devices are located in the switchgear cabinet, and any adjustment work is not sensibly performed with the door open.

Note that the EUT must be set up for the purposes of the test in accordance with the manufacturer's design guidelines. Where PDS (SR) are intended for installation in a switchgear cabinet within which interference is not anticipated, the switchgear cabinet is considered to be the enclosure with respect to conducted interference phenomena.[4]

During testing of the phenomenon of ESD (electrostatic discharge), the higher values apply to the switchgear cabinet as the enclosure. The EUT itself is tested with the values to EN 61800-3.

5.2 Detection and influence

The test arrangement and test procedure must be such that a possible influence can actually be detected. Testing need not necessarily be performed of all, complete safety functions present, provided the hardware to be tested is fully covered.

Memory relays, counter relays and error messages on the equipment under test have proved effective as test equipment. Mechanical aids or a rotary transducer may be employed for monitoring the stationary state of the motor. Excessive speed can be detected reliably by means of an additional tachometer.

[4] For this purpose, assessment of the EMC design guidelines is necessary.

5.3 Cables and supplementary measures employed during EMC testing

If screened cables were used during testing, the user documentation must also prescribe their use for installation. The user documentation must also prescribe the use of mains filters or lightning protection elements, together with any retrofitted screening measures (such as aluminium foil, copper foil, ferrite clamps) which enabled the EMC test to be passed in the first instance.

5.4 Requirements concerning the test plan

The EMC test plan must describe the following:

- Function of the test specimen
- Safety functions
- Operating states
- Monitoring of the test specimen
- Safety-related connections with statement of the maximum permissible cable lengths of the test specimen

The applicable EMC standards must be listed in addition to the test levels of the individual EMC phenomena. Special connecting cables (screened, double screened, twisted) must be described. Description of the signal states, divided into functional/safety-critical, is required for assessment of the test result, as is a listing of the error displays and error codes, and definition of the operating states to be tested.

5.5 Requirements concerning the test report

The EMC test report documents the tests performed and contains the test result. The applicable EMC standards must also be listed in the test report together with the test levels of the individual EMC phenomena. The test arrangement for the individual EMC phenomena and the arrangement for test specimen monitoring must be documented by means of photographs. All influences (functional/safety-critical) upon the test specimen must be documented in a list. A function test of the test specimen must be performed before and after each discrete test. Should the test specimen require modifications in order to pass the test, they must be documented in detail.

6 Literature

[1] EN 61508: Functional safety of electrical/electronic/programmable electronic safety-related systems. Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems (2010)

[2] EN 61800-5-2: Adjustable speed electrical power drive systems, Safety Requirements, Functional Safety (2007).

[3] EN 61326-3-1: Electrical equipment for measurement, control and laboratory use – EMC requirements. Part 3-1: Immunity requirements for equipment performing or intended to perform safety related functions (functional safety) – General industrial applications (2008)

[4] EN 62061: Safety of machinery – Functional safety of safety-related electrical, electronic and

programmable electronic control systems (2005)

[5] EN 61000-6-2: Electromagnetic compatibility (EMC). Part 6-2: Generic standards: Immunity for industrial environments (2005)

[6] EN 61800-3: Adjustable speed electrical power drive systems. Part 3: EMC requirements and specific test methods (2004)

[7] Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast). OJ EC L 157 (2006), pp. 24-86 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:157:0024:0086:EN:PDF

[8] ISO 12100: Safety of machinery – General principles for design – Risk assessment and risk reduction (2010)

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Annex A

A.1 Immunity to high-frequency phenomena for PDS (SR) intended for use on machinery and in the second environment

Coupling	Phenomenon	Basic standard governing the test method DIN EN	Level/criterion to DIN EN 61800-3	Increased immunity to interference (defined by the IFA)	Criterion for operational behaviour	Comment
Enclosure[1]	Electrostatic discharge	61000-4-2	4 kV CD or 8 kV AD if CD is not possible /B	6 kV CD or 15 kV AD if CD is not possible [g]	FS	
	High-frequency electromagnetic field	61000-4-3	80 MHz to 1000 MHz 10 V/m, 80% AM (1 kHz) /A	80 MHz to 1000 MHz 20 V/m, 1.4 GHz to 2 GHz 10 V/m, 2.0 GHz to 2.7 GHz 3 V/m, 80% AM (1 kHz)	FS	See Table 1 for frequency range
Power supply terminals	Fast transients, bursts	61000-4-4	2 kV/5 kHz [a] /B	4 kV/5 kHz [a h]	FS	
	Surge voltage [b]	61000-4-5	1 kV [c]/2 kV [d] /B	2 kV [c]/4 kV [d i] Alternatively: 1 kV [c k]/4 kV [d i]	FS	
	Conducted high-frequency common-mode interference [e]	61000-4-6	0.15 MHz to 80 MHz 10 V, 80%, AM (1 kHz) /A	0.15 MHz to 80 MHz 20 V, 80%, AM (1 kHz)	FS	See Table 2 for frequency range
Power supply terminals	Fast transients, bursts [e]	61000-4-4	2 kV/5 kHz /B	4 kV/5 kHz [h]	FS	

A.1 Immunity to high-frequency phenomena for PDS (SR) intended for use on machinery and in the second environment

Signal terminals	Fast transients, bursts [e]	61000-4-4	1 kV/5 kHz /B	2 kV/5 kHz [h]	FS	
	Surge voltage	61000-4-5	---	0.5 kV [d f i]	FS	
	Conducted high-frequency common-mode interference [e]	61000-4-6	0.15 MHz to 80 MHz 10 V, 80% AM (1 kHz) /A	0.15 MHz to 80 MHz 20 V, 80%, AM (1 kHz)	FS	See Table 2 for frequency range
Terminals for process measurement, control and regulation	Fast transients, bursts [e]	61000-4-4	2 kV/5 kHz /B	4 kV/5 kHz [h]	FS	
	Surge voltage [f]	61000-4-5	1 kV [d f] /B	2 kV [d f i]	FS	
	Conducted high-frequency common-mode interference [e]	61000-4-6	0.15 MHz to 80 MHz 10 V, 80% AM (1 kHz) /A	0.15 MHz to 80 MHz 20 V, 80% AM (1 kHz)	FS	See Table 2 for frequency range

[1] Physical boundary of the device (appliance, installation) through which the electromagnetic fields are dissipated or through which they may enter.

[a] Power-supply terminals with a rated current of < 100 A: direct coupling by means of a coupling and decoupling network. Special agreements must be reached where the rated current is > 100 A.

[b] Applies only to power supply terminals with a power consumption of < 63 A under light-load test conditions as defined in DIN EN 61800-3, 5.1.3.

[c] Phase-to-phase coupling

[d] Phase-to-earth coupling

[e] Applies only to terminals or interfaces with cables the total length of which may exceed 3 m according to the manufacturer's functional specification.

[f] Applies only to terminals with cables the total length of which may exceed 30 m according to the manufacturer's functional specification. Direct coupling of the screen in the case of screened cables.

[g] For SIL 3, the total number of discharges at the maximum interference level must be tripled. These additional discharges must be performed at different points to the previous test points.

[h] For SIL 3, the duration of the test must be multiplied by five.

[i] For SIL 3, the number of pulses must be multiplied by three.

[k] The number of pulses must be multiplied by three.

The terminal markings used are taken from DIN EN 61800-3. The standard also contains a definition of the terminals. A DC supply interface up to 60 V is treated as a signal interface or a terminal for process measurement, control and regulation.

Table 1: Special frequencies for the testing of high-frequency electromagnetic fields

At these frequencies, the test must be performed at an increased interference level. At other frequencies, the interference level need not be increased.

Centre frequency in MHz	Frequency range	Application
84 000	83 996 to 84 004	ISM UK only
	137 to 174	Various Mobile and SRD
168 000	167 992 to 168 008	ISM UK only
	390 to 430	TETRA
	430 to 470	Amateur
433 920	433 050 to 434 790	ISM Region 1 only
896 000	886 000 to 906 000	ISM UK only
897 500	880 to 915	GSM
915 000	902 to 928	ISM Region 2 only
	925 to 960	GSM
1 745 750	1 710 to 1 785	GSM
	1 805 to 1 880	GSM
	1 900 to 2 025	UMTS
	2 110 to 2 200	UMTS
2 450	2 400 to 2 500	ISM
	2 500 to 2 690	UMTS

Table 2: Special frequencies for the testing of conducted high-frequency common-mode interference

At these frequencies, the test must be performed at an increased interference level. At other frequencies, the interference level need not be increased.

Centre frequency in MHz	Frequency range	Application
3 390	3 370 to 3 410	ISM Netherlands only
6 780	6 765 to 6 795	ISM
13 560	13 553 to 13 567	ISM
27 120	26 957 to 27 283	ISM/CB/SRD
40 680	40 660 to 40 700	ISM/SRD

A.2 Immunity to low-frequency phenomena for PDS (SR) with a rated voltage of less than 1000 V and intended for use on machinery and in the second environment

The tests to DIN EN 61800-3 must be performed. No increased requirements apply. The criterion in each case is FS.