Guidance Note Addresses Surge Test Problems

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A new guidance note provides advice for dealing with some key issues that have surfaced with the increasing use of the IEC 61000-4-5 surge test.

The use of the surge test required by IEC/EN 61000-4-5 is becoming more commonplace as the newer product and generic standards refer to it as a matter of course. With this more frequent use, its shortcomings have become more apparent. The basic standard includes some requirements that are not well defined and for which the product standards give no additional guidance.

Some time ago, the EMC Test Laboratories Association (EMCTLA) published a technical guidance note (TGN 39) addressing one of the issues. The guidance is in the process of being updated to cover other issues as they are raised. In addition, IEC subcommittee (SC) 77B, the International Electrotechnical Commission (IEC) committee responsible for the standard, is looking at updating IEC 61000-4-5 in the framework of the normal maintenance cycle. This update, however, will take several years.

EMCTLA

EMCTLA is a grouping of UK EMC test laboratories, organized to promote the interchange of information on technical and regulatory issues in EMC testing. Members of the association request guidance from the appropriate panel via the secretary of the working group. The panel considers the request, together with any additional information, and reports to the secretary any guidance to be given. The panel's recommendations are distributed to members and are also freely available via the EMCTLA Web site.

Once published, the technical guidance notes (TGNs) are not only sent to the UK Department of Trade and Industry (DTI), but also to the European Commission in Brussels. Currently there are 42 TGNs, with further notes in process. Although TGNs are widely used as a source of guidance within the UK, it should be noted that they have no legal standing and are not necessarily recognized across Europe.

Each TGN carries a legal disclaimer. They are not intended to conflict with the instructions in standards, but rather should offer a particular interpretation whenever necessary. Other countries that apply CE marking may have different interpretations of some of the issues raised in a particular guidance note.

TGN 39: Addressing the Issues

This article discusses the issues in the context of the new version of the EMCTLA TGN and provides some reasoned guidance to address some of the problems that are being encountered. One particular product standard, the recently published second edition of IEC 60601-1-2 on medical electrical equipment, does recognize some of the major problems and attempts to resolve them. This standard is referenced where relevant. EN 50270, EMC of gas detectors, is another European product standard that provides a specific modification to the surge test application.

Applying the Surge Voltage in Increasing Steps. Testing to IEC/EN 61000-4-5 requires that the disturbing signal be applied to the equipment under test (EUT) at levels up to and including the maximum level specified for the apparatus. Clause 8.2 states,

> The test procedure shall also consider the non-linear current-voltage characteristics of the equipment under test. Therefore the test voltage has to be increased by steps up to the test level specified in the product standard or test plan. All lower levels including the selected test level shall be satisfied. For testing the secondary protection, the output voltage of the generator shall be increased up to the worst-case voltage breakdown level (let-through level) of the primary protection.

This statement raises a number of questions. The basic test standard is nearly always used by reference from a product or generic standard. It would be open to these standards to give some explicit instructions as to the choice of levels, but in general they do not provide any guidance. Therefore, it should be clear that a manufacturer could not declare compliance based on a test at the compliance levels only. But, if a manufacturer is required to test in increasing steps up to the compliance level, what steps should be used? The basic standard defines severity levels, but it does not explicitly link these to the required steps. A specific test plan could do so, but most clients rely on a test house to advise them on a test plan.

The EMCTLA view is that all lower severity levels as specified in the standard should be tested up to the maximum

specified by the product committee or test plan. The specified levels are 0.5, 1, 2, and 4 kV and x (special). For products specified to 0.5 kV maximum, a lower level of 250 V may be used to test protection let-through.

For the higher final-test levels, multiple steps contribute to an excessively long test, but reliance on testing to the maximum level alone is not what the standard specifies. IEC 60601-1-2, ed. 2, has considered the question and places an explicit requirement on the levels to be tested. The standard specifies that if the equipment has no surge protection device, then only the highest levels need be tested. It justifies this requirement as follows:

> **The surge test is mainly a test for the ability of the power supply to withstand this high-energy pulse.** If no surge protection device is installed ... a test at only the highest immunity test level specified, ±2kV for ac power lines to ground and ±1 kV for ac power line to line, will be the worst case. In that case, testing at lower immunity test levels is not useful and would provide no additional information. If a surge protection device is installed ..., testing at lower immunity test levels is necessary to verify proper operation of the surge protection device.

Although this advice may be helpful to medical device manufacturers, there is no immediate way to apply such guidance more generally. A similar specification could be put into other product standards, and the fact that it hasn't suggests that the authors of those standards do not see the issue as worthy of their concern.

The TGN states that, when applying tests for CE marking, the maximum level of surge to be applied should be that given in the product specific or generic standard. All lower severity levels shall be tested up to the maximum specified, as IEC 61000-4-5 mandates. On the other hand, applying additional investigative tests or examining immunity up to the primary protection level, as is implied by the first and last sentences of the paragraph quoted above from IEC 61000-4-5, should be part of the manufacturer's design-proving work and not part of a compliance test.

Number of Surge Pulses versus Phase Angle. The basic standard requires at least five positive and five negative tests at the selected points and, if not otherwise specified, the surges must be applied in synchronization with the voltage phase at the zero-crossing and the peak value of the ac voltage wave (positive and negative). This could be interpreted as requiring either:

- Five pulses at each of four phase angles (0°, 90°, 180°, and 270°), giving a total of 20 pulses for each polarity at each voltage level; or,
- Five pulses distributed between each of the four phase angles, requiring only five pulses for each polarity at each voltage level; or,
- Some number in between.

Naturally, the second of these options is most attractive to test house customers because it requires only a quarter of the time of the first interpretation, but this option fails to indicate how the pulses might be distributed in phase. However, the EMCTLA view is that, for ac power ports (input or output), the surges shall be applied synchronized to the ac voltage phase at 0° or at 180°, 90°, and 270°. Product committees may select different phase angles as appropriate to the product. Although testing at both 0° and 180° is allowed, testing at only one zero-crossing point is considered to be necessary.

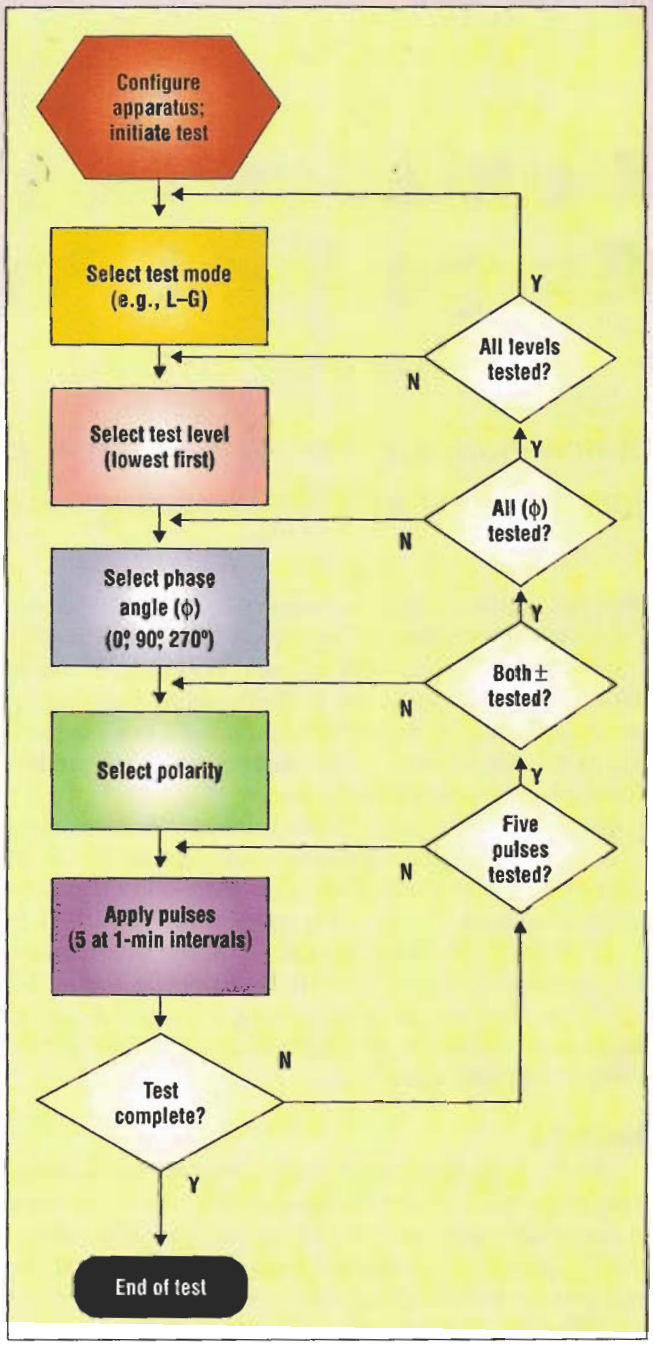

Figure 1. The flowchart represents the intended test sequence for the application of surges.

This interpretation requires a total of 15 pulses for each polarity at each voltage level. It is consistent with the requirement laid down explicitly in Clause 36.202.5 of IEC 60601-1-2.

Time between Pulses. The normal minimum period as specified in the standard is 1 minute, although the standard also states, "The maximum repetition rate depends on the built-in protection devices of the EUT." EMCTLA suggests a shorter

period may be agreed between test laboratory and manufacturer, but it also recommends that this be not less than 20 seconds to avoid undue component heat stress.

The concerns over the potentially excessive test time and possible component stress are not fully addressed in this TGN. These are matters that need consideration at the international level and may be the subject of a request for new work initiated through IEC SC 77. The flowchart in Figure 1 represents the intended test sequence for the application of surges. Exceptions would be noted in the test plan or test report, with reasons for departure.

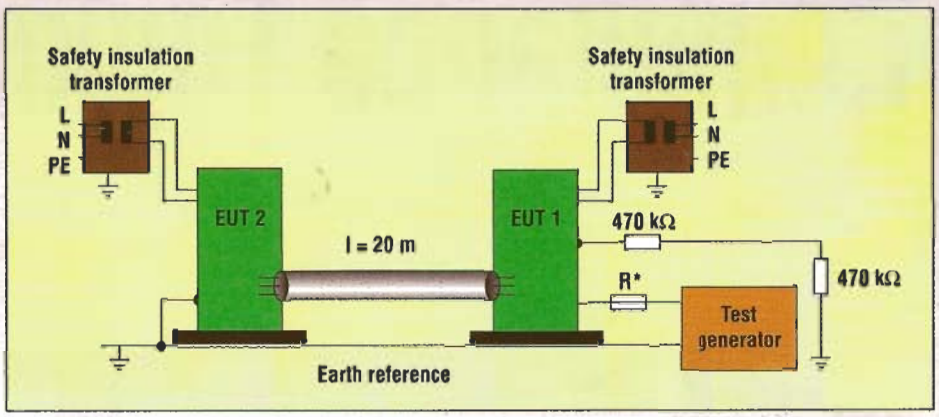

Figure 2. Test operators should be aware of a possible safety hazard when applying surges to shielded cables in accordance with Clause 7.5 (Figures 13 and 14 of the standard). This shows a modified Figure 13 (Figure 14 is similarly modified).

Set-up for Tests Applied to Shielded Lines. There are other difficulties with the standard that are addressed in EMCTLA's TGN.

Test operators should be aware of a possible safety hazard when applying surges to shielded cables in accordance with Clause 7.5 (Figures 13 and 14 of the standard). Figure 2 illustrates Figure 13 of the standard. A faulty shield connection, resulting in a high impedance to the ground reference, could cause a dangerous charge to build up on the EUT (shown as EUT 1 in the figures). To ensure the safety of the operator, it may be necessary to allow discharge of the cabinet between pulses.

The best way of achieving a repeatable test is to apply the surge at the usual earthing point of the chassis.

This discharge can be achieved by the connection of 2 × 470-kΩ high-voltage-rated resistors between the chassis of EUT 1 and the ground reference (similar to the ESD coupling-plane discharge network). Because the surge generator is not designed for continuous operation and considering the maximum rate of application to be 1 pulse per 20 seconds, the resistors can safely be rated at 0.5 W each. It is unlikely that the high value of resistance introduced between chassis and ground will have a detrimental effect upon the waveform of the generator.

The value R* in the test generator output for this screened-cable interface test is uncertain from the standard (0, 10, or 40 Ω). Annex B.1 definitions, which state that 42 Ω applies to all lines other than low-voltage power supply network lines, appear to conflict with the wording in Clause 7.5. This clause itself states, "The test level applied on shields is the 'line-to-earth value' (2-Ω impedance)"; in fact, the line-to-earth source impedance is 12 Ω. It is recommended that until the standard is more clearly worded, that R* be 0 Ω (i.e., no additional resistor), leaving the output impedance of the generator as 2 Ω (value as given in Clause 7.5).

Clause 7.5 does not clarify where the surge is to be applied. If a handheld probe is in use, this surge can be applied to the metalwork of the cabinet. However, this method may limit repeatability. Suggested guidance is to simulate real-world conditions in which a surge appears between the grounds of the two interconnected systems. Therefore, the best way of achieving realistic conditions and a repeatable test is to apply the surge at the usual earthing point of the chassis or to a metallic connector shield.

Other Considerations

When applying surges in line-to-line mode to a three-phase ac port, testing can be restricted to the combination, $^{3}C_{2}$ (e.g., L1–L2, L1–L3, L2–L3, not L1–L2 and L2–L1, etc.). This restriction is justified because both polarities are tested on the lines under test.

Figures 6 and 7 in the standard do not clearly differentiate connections or feedthrough of the L, N, and E wires of the mains supply to the decoupling network. Test operators should ensure that the decoupling network case is connected both to protective earth (PE) and to the test system ground reference as is shown in Figures 8 and 9 in the standard.

Conclusion

The advice given in this article is based on engineering judgment, comments from sources within EMCTLA, and IEC SC 77B Working Group 11's draft working document. The authors welcome additional comments that may be used to further improve the published EMCTLA TGN. The text of the TGN can be found on the EMCTLA's Web site, http://www.emctla.org, and comments can be made via the secretary, dave.imeson@btinternet.com.

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