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Problems with the EMC requirements in BS7671

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Problems with the EMC requirements in BS7671
(the IEE/IET Wiring Regulations, amended 17th Edition)

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1 Summary

New requirements on Electromagnetic Compatibility (EMC) were been added to the 17th Edition [1], and have been in force since January 2012.

The new Clause 332.1 added some requirements that go beyond those in the EMC Regulations [2] and could increase that cost of some equipment, and the new Clause 444 does not provide sufficient practical guidance.

This brief article discusses these issues, and shows where to find well-proven practical guidance.

2 Introduction

EMC is the engineering discipline of ensuring that – when installed and operated – all electrical, electromechanical and electronic equipment, system and installations:

- Do not emit such high levels of electromagnetic (EM) disturbances that they cause too much electromagnetic interference (EMI) to other equipment
- Are sufficiently immune to the EM disturbances in the operating environment that they function well enough

The above bullets paraphrase the *Essential Requirements* for compliance with the EMC Regulations [2], which implement the European Commission's (EC's) Directive on EMC [3].

In some installations EMI can cause functional safety or financial risks that are not covered by complying with [2] or [1], see the IET's guides [4].

The EC apparently decided that all EU national electrical codes should provide guidance on designing electrical installations to comply with the EMC Directive – so they specified that they all add Clauses 332 and 444.

Amendment No. 1: 2011 added these to the 17th Edition [1], and they came into force on 1 January 2012 [5]. Geoff Cronshaw of the IET described these new requirements in [6], [7] and [8].

Please do not take this article to imply any criticism of the IET's Working Group that added these EMC clauses to the 17th Edition – they were hamstrung by having to use text mandated by the EC. I was a member of that group, but when I was told that we could only make cosmetic changes to existing IEC text that I considered to be completely unsuitable for purpose, I ceased to play an active part.

I officially raised the issues discussed in this article with the relevant IET committee in 2012, but as far as I am aware nothing at all has been done to address them. So I thought it was time that I went public with them.

First, some background….

3 EMC "Responsible Persons"

Since the 20th of July 2007, [2] has required that the owner or operator of a building or site appoint and name a "Responsible Person" for each "Fixed Installation" in their building or site.

The Responsible Person must ensure that their Fixed Installation meets [2]'s Essential Requirements – plus keep documentation showing that it has been constructed using good EMC engineering practices ready for inspection by the EMC enforcement authorities.

[2] defines the Responsible Person as: "*…the person who, by virtue of their control of the Fixed Installation is able to determine that the configuration of the installation is such that when used it complies with the Essential Requirements.*"

Therefore, a Responsible Person is the only person who has authority (control) over all EMC aspects of the design, construction, maintenance, upgrades and modifications to their Fixed Installation, including all of its electrical installations and their items of equipment; AC or DC power supplies; wiring and cabling, etc.

[9] says that a Responsible Person does not have to be an EMC expert, and can seek appropriate advice in fulfilling their obligations, *but he or she cannot delegate their responsibility*, for example to the designer of an electrical installation or an M&E contractor.

4 "Fixed Installations"

[2] requires the owner or operator of a building or site to define its Fixed Installations. (Note that a Fixed Installation cannot be supplied to an end-user – this legal concept applies to owners/operators only, see [10] and Chapter 2 of [11] for details.)

A typical building or site has many different types of electrical installations, such as: computer networks; HVAC; access control; smoke and fire alarms; elevators; lighting; production lines, etc., all designed in accordance with the IET Wiring Regulations by different electrical engineers working for different companies.

Each single electrical installation *could* be designated as a "Fixed Installation" with its own Responsible Person. More likely, a Responsible Person will have authority over a Fixed Installation comprised of any number of electrical installations, perhaps all of the electrical Installations in a particular building, some (or all) of the buildings on a site or campus, even a national network such as the UK's telephone system, with its millions of miles of wire and thousands of telephone exchanges.

5 Clause 332.1 goes beyond the requirements of the EMC Regulations

Clause 332.1, new in [1] and in force since 1st January 2012, says: "*All electrical installations and equipment shall be in accordance with the EMC Regulations and with the relevant EMC standard.*" Let's consider this in two parts.

"*All electrical installations and equipment shall be in accordance with the EMC Regulations….*"

[2] only requires an electrical installation to comply with its Essential Requirements when it has been, on its own, designated as a Fixed Installation by the owner or operator of the building or site and its Responsible Person appointed.

Where an electrical installation is just part of a Fixed Installation, as will usually be the case, [2] does not require it to meet the Essential Requirements. Instead, it applies other requirements.

A very important issue is that [2] only applies to products, systems or installations at the point where their ownership transfers to their end-user (i.e. the owner or operator of a building or site).

Where an electrical installation is supplied to a main contractor (or a subcontractor), who then sells it to the end-user (or the main contractor), [2] applies to the main contractor and not to the supplier of the electrical installation.

So we can see that, in most cases, the designer or installer of an electrical installation need do nothing to comply with Clause 332.1.

Of course, EMC technical specifications should always be "flowed down" the supply chain to each installation's designer and/or installer, and it is important to be aware that these could be very different indeed from what might be expected from the EMC standards. But this is a contractual matter and nothing to do with [1] or [2].

For complete details on the requirements of [2] for Fixed Installations, and its very different requirements for a) standard products supplied to an end-user, and b) custom-engineered products, equipment, systems or electrical installations, supplied to an end-user, see [10] and Chapter 2 of [11] respectively.

"*….. and with the relevant EMC standard.*"

[2] has no mandatory requirements for *anything at all* to meet any EMC standards (although many people mistakenly think it does), and anyway there are no EMC standards for installations. See [10] and Chapter 2 of [11] for details.

But the above requirement in Clause 332.1 is that *all electrical installations and equipment* must be in accordance with *the relevant EMC standard*.

This goes well beyond the requirements of the EMC Regulations and could add costs to some suppliers of electrical equipment, systems or installations, most likely manufacturers of custom instrumentation/control cubicles, and system integrators.

I am sure that the authors of Clause 332.1 thought they were interpreting the EMC Directive correctly, but it seems to me that they made the common mistake of assuming that defined terms in the EMC Directive (e.g. 'fixed installation') had their common, everyday meanings – which of course they don't.

The result is something that is frequently unworkable, and when workable increases costs by more than is necessary to comply with the EMC Directive and its corresponding UK Statutory Instrument (the 2006 EMC Regulations).

I would not be at all surprised to learn that Clause 332.1 is routinely ignored, both by practitioners and independent inspectors.

6 CE + CE does not equal CE

It would be a mistake to think that all that was needed for a Fixed Installation comprising two or more electrical installations to comply with [2]'s Essential Requirements, was for its electrical installations to comply individually.

Whilst the emissions from each individually-compliant electrical installation should be below the levels of EMI that could (for example) cause digital TVs to blank, DAB radio reception to stop, or GPS navigational systems to lose sight of enough satellites – two or more such electrical installations operating at the same time might exceed those levels, causing their Fixed Installation to fail to comply with [2]. There are also problems for immunity.

Assuming (incorrectly) that all that is necessary to create a compliant control cubicle, system, electrical installation or Fixed Installation, is to construct it from parts that are individually compliant, is unofficially called the CE + CE = CE approach.

This approach has no legal or technical justification and [12] includes a specific warning not to use it: "*It should be noted that combining two or more CE-marked finished appliances does not automatically produce a "compliant" system e.g.: a combination of CE-marked Programmable Logic Controllers and motor drives may fail to meet the Essential Requirements.*"

7 What is required in practice to achieve EMC compliance?

For an ordinary dwelling (or similar) in the 1990s, i.e. without significant electronic content, it was generally considered sufficient for compliance with [2] to use equipment that was CE marked and declared EMC compliant with [2] (or [3]), and to install it in accordance with the EMC installation instructions that [2] requires all manufacturers to provide.

However, ordinary dwellings are increasingly seeing Personal Computers connected to telephone lines for broadband Internet, and connected to one or more televisions by long Ethernet cables. These are not the "*simple installations containing equipment that is not interconnected by signal cables*", which A.444.1 in [1] says can be dealt with by single-point earthing.

The only low-cost alternative to Ethernet cables at the time of writing, that is guaranteed to work throughout a building, is to use powerline telecommunications, unfortunately these emit signals onto mains cables that are equivalent to the mains conducted noise power of more than 1000 just-barely-legal other types of CE marked computer equipment, so their use could not be called good EMC engineering.

For the designer/installer of electrical installations for buildings or sites more complex than a typical 1990s household, how far to go with EMC engineering techniques depends on:

a) The aggregated conducted and radiated EM emissions of all of the items of equipment

b) The conducted, induced and radiated EM disturbances that can occur in the operational environments of the individual items of equipment, and their wiring, due to the aggregated emissions from:

   - all other installations in the same and neighbouring buildings
   - portable or mobile equipment, such as motor vehicles, aircraft (fixed wing and rotorcraft), marine vessels, railway systems and rail vehicles, walkie-talkies, cellphones, Wi-Fi, Radio Frequency Identification (RFID), etc.
   - natural EM disturbances, e.g. lightning, personnel electrostatic discharge, etc.

c) The susceptibility to EM disturbances of each item of equipment in the installation, and the possible consequences if they suffer excessively from EMI

d) For the greatest cost-effectiveness – the likely future developments of the installation, and of all the issues listed above.

To be able to quote a price for the design/installation of an electrical installation it is necessary to establish its EMC characteristics – its EM performance specifications. In the absence of a specification from the Responsible Person or the next-contractor-up-the-supply-chain, it is necessary to determine what is the operational EM environment that could interfere with the equipment in the installation, and what especially sensitive equipment might be nearby that could be interfered with.

Determining the EM environment usually involves on-site EMC measurements at several locations, using expensive test gear operated by EMC measurement experts, generally taking a few days (sometimes a week or more) and typically costing at least several thousand GB Pounds.

For example, an industrial site might already have a number of similar electrical installations, and want to add more of the same to increase production rates. However, the site's total level of emissions might already be close to (for example) interfering with the checkouts at a nearby supermarket.

Adding the extra production lines could cause the site to stop the supermarket from working, probably triggering an official investigation that could result in shutting down the new lines – possibly the whole site – until the problem is fixed.

Such shut-downs do not require court hearings, merely a decision by an EMC enforcement officer, and has occurred more than once in the UK [13]. The officer's decision can stand for 6 months, and could then be extended by the Secretary of State.

However, at the time of writing it appears that very few buildings or sites in the UK have appointed Responsible Persons, despite it being a legal requirement since 20th July 2007.

Where no Responsible Person has been appointed, a supplier of electrical installations who wishes to trade legally will generally suffer significantly increased costs. Where such illegally-operating customers choose the suppliers who quote the lowest prices, they would need to take great care if they want their installations to comply with the Wiring Regulations, and/or with the EMC Regulations.

8 Clause 444 lacks practical guidance

According to [2] a wiring/cabling installation *in itself* (i.e. with no equipment connected) is "EMC benign". So, *in themselves*, wiring/cabling installations have no technical requirements or standards to meet to comply with [2].

However, there are many EMC design and construction techniques that should be applied to wiring and cabling, for all Fixed Installations more complex than a typical 1990s household.

Clause 444 in [1] covers the EMC design of a building's AC mains power supplies very thoroughly, but then fails to provide any *practical* guidance for anything else. Here are some examples:

- Most of Clause 444 is concerned with Information Technology Equipment (ITE) installations, with a few nods towards telecoms.

  How to deal with other applications, such as medical, scientific, industrial, entertainment, sport, etc., is not mentioned.

- Figure 44.3 shows a "Bypass Conductor" – a simple and effective good EMC engineering technique that would have benefitted hugely from a reference to the sections in [14] or other publications that provide practical guidance, including how to design for different frequency ranges and how to save cost by using existing metalwork such as support structures.

- Figure 44.3 also shows a cable screen terminated at both ends – another simple and effective good EMC engineering technique – that contradicts decades of installation industry dogma that cable screens should only be terminated at one end.

  It has been known for over 30 years that terminating cable screens at one end only is bad EMC practice for controlling high frequencies – but Clause 444 does not even mention it, and neither does it refer to the sections in [14] or other publications that describe how to design and install it in practice.

  [14] and other publications also explain why "pigtailed" cable screen terminations should not now be used – another example of installation industry dogma known to be bad EMC practice for decades, but not mentioned in Clause 444.

- Clause 444.5.2 (iii) states: "*The impedance of equipotential bonding connections intended to carry functional earth currents having high frequency components shall be as low as practicable and this should be achieved by the use of multiple, separated bonds that are as short as possible.*"

  I have never before read a sentence that was so very correct *in principle*, and yet so very unhelpful *in practice*! It provides no guidance on what it means by:

  - "*high frequency components*" (up to 10MHz, 100MHz, more? And how to find out what they are?)
  - "*as low as practicable*" (less than 1Ω, 0.1Ω, 10mΩ, less ? And over what frequency range?)
  - "*multiple separated bonds*" (how many, what spacing?)
  - "*as short as possible*" (1m, 100mm, 10mm, less?).

  Without this detailed information for each part of an electrical installation, risky under-engineering or costly over-engineering should be expected.

- Equipotential bonding is often mentioned, without it being made clear that it means something very different from what is normally understood.

  Electrical installation designers/installers generally assume that it means ensuring people cannot come into contact with more than 50V AC rms. (Of course, the 17th Edition has a lot more detail on this very important issue.)

  But in EMC engineering it means designing each part of the bonding network to have an electrical impedance (not mere resistance) of much less than 1 Ohm at the highest frequency of concern to the designer; and also have its first "accidental antenna resonance" at a frequency at least 10 times higher than the highest frequency of concern.

  The highest frequency of concern to a designer is the highest frequency at which it could cause troublesome emissions for the intended application, or the highest frequency at which it could suffer from troublesome susceptibility in the intended application. Note that either of these frequencies may be significantly different (higher or lower) to the highest frequency that the most relevant EMC product or generic standards test to.

Many more practical shortcomings in Clause 444 are not discussed here, due to space constraints. In fact, it is difficult to find anything in Clause 444 that is of practical utility – in marked contrast to the rest of the Wiring Regulations, which are nothing if not practical.

9 Practical, well-proven good EMC engineering techniques do exist

Happily, good EMC engineering techniques for the design and construction of electrical installations are well-proven in practice, not difficult to understand or employ, and can often use existing metalwork to reduce costs.

Discussing them even briefly would require several articles the size of this one, but one and two-day training courses are available, as are a number of publications, including: [15], [11], [16], [14], [17], [18], and [19]. Technical Guidance Notes [20] and [21] from the EMC Test Labs Association may also be useful.

10 Conclusions

The EMC requirements in BS7671, the IET Wiring Regulations, are either impractical, unhelpful, or go way beyond what is required to comply with EU and UK Law. I doubt that anyone in the UK actually complies with them, and I feel sorry for anyone who tries.

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