17th edition first amendment
Surge protection

Presented by Joe Ellwood
Introduction

Amended section 443 – is surge protection required?

Secondary lightning effects – surges/transient overvoltages
  How do they damage equipment?
  The problems transients cause and why protection is required

Surge protection to BS EN 62305 / BS EN 61643
  Types of SPD / Lightning Protection Zones

Section 534 – Devices for Protection Against Overvoltage
  Selection and installation of SPDs
The following are different consequential levels of protection:

(i) Consequences related to human life, e.g. safety services, medical equipment in hospitals
(ii) Consequences related to public services, e.g. loss of public services, IT centres, museums
(iii) Consequences to commercial or industry activity, e.g. hotels, banks, industries, commercial markets, farms
(iv) Consequences to groups of individuals, e.g. large residential buildings, churches, offices, schools
(v) Consequences to individuals, e.g. small or medium residential buildings, small offices.

For levels of consequences (i) to (iii) protection against overvoltage shall be provided.
Overhead line supplying the building at risk of direct strike - see BS EN62305 (443.1.1)

Consequences related to human life? For example safety/medical equipment (443.2.4)

Consequences related to loss of public service? For example IT centres, museums (443.2.4)

Consequences related to loss of commercial/industry activity? For example hotels, banks, farms (443.2.4)

Consequences relating to groups of individuals or individuals - for example residential buildings (443.2.4)

Lightning current Type 1 SPD or combined Type 1+2 SPD on main switch board to prevent dangerous flashover (534.2.1)

Protection against overvoltages not required (443.2.1, 443.2.2) if equipment withstand voltage to Table 44.3

Coordinated set of overvoltage SPDs for equipment protection e.g. Type 2 or Type 2+3 for distribution boards feeding sensitive electronic equipment (534.2.6)

Protection against overvoltages not required if equipment withstand voltage to Table 44.3

Check if data, signal and telecom lines require protection (443.1.1, 534.2.1)

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Overhead line supplying the building at risk of direct strike - see BS EN62305 (443.1.1)

Consequences related to human life? For example safety/medical equipment (443.2.4)

Consequences related to loss of commercial/industry activity? For example hotels, banks, farms (443.2.4)

Consequences related to loss of public service? For example IT centres, museums (443.2.4)

Lightning current Type 1 SPD or combined Type 1+2 SPD on main switch board to prevent dangerous flashover (534.2.1)

Protection against overvoltages not required (443.2.1, 443.2.2) if equipment impulse withstand voltage to Table 44.3

Coordinated set of overvoltage SPDs for equipment protection e.g. Type 2 or Type 2+3 for distribution boards feeding sensitive electronic equipment (534.2.6)

Protection against overvoltages not required (443.2.4, 443.2.6) if equipment withstand voltage to Table 44.3

Alternative - simplified risk assessment (443.2.4)

Installation presents higher risk (e.g. fire) or requires higher reliability (443.2.2 Note) - see BS EN62305

Consequences relating to groups of individuals or individuals - for example residential buildings (443.2.4)

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Overhead line supplying the building at risk of direct strike - see BS EN62305 (443.1.1)

Consequences related to human life? For example safety/medical equipment (443.2.4)

Consequences related to loss of public service? For example IT centres, museums (443.2.4)

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Check if data, signal and telecom lines require protection (443.1.1, 534.2.1)
Lightning Characteristics

Tendency to preferentially strike taller structures and objects

However ground strikes are common where distance between structures is greater than twice their individual height

The secondary effects of lightning cause transients

Resistive coupling is the most common form of damage

Inductive coupling can also occur
What are Transient Overvoltages (surges)?

Normal mains power supply

Transient overvoltage

Fast

Typically 50 microseconds duration (20,000 transients per second)

Large

Up to 6,000 volts (Almost 20 times mains supply)

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Resistive coupling

Both direct strokes to structure and indirect strokes near structure (up to 1km away)
Inductive coupling

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Lightning Transients

Direct strike to building NOT required

Direct strike to line NOT required

**MISCONCEPTION** –

“I have a structural Lightning Protection System (LPS) fitted – I do not need transient protection for my equipment”

Fitting structural LPS protects the structure NOT the equipment!
Indirect strike to building – with Structural LPS fitted

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Internal - from switching surges (inductive loads)

Motors – lifts, air con

Transformers

Welding Equipment
Direct strike to structure (Source S1)
Direct strike to service line (Source S3)
Direct strike near structure (Source S2)
Lightning flash near service line (Source S4)

1.4 : Lightning Flashes near Connected Services (Source S4)

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The problems that transients cause

Size of transient overvoltage

6000V

Damage

Degradation

Disruption

Downtime

Typical hidden costs of system downtime
Lost business
Delays to customers
Lost productivity
Staff Overtime

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Equipment typically vulnerable to transient overvoltages

- Computers
- Fire and Burglar Alarms
- PABX telephone exchange
- Telecom base stations
- Data communication network
- CCTV equipment

Section 534 focuses on 3 Types of surge protection for mains power but any metallic electrical line (data/telecom) is a path for transients – 534 recommends protection for these services only.
Divert surge currents and limit over-voltages, survive and repeatedly protect personnel, buildings and equipment

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BS EN 62305 and 61643 series

BS EN 62305-1 General principles
BS EN 62305-2 Risk management

BS EN 62305-3
Physical damage & life hazard

BS EN 62305-4
Electrical and electronic systems

Where needed, use SPDs tested and applied in accordance to BS EN 61643 series

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Surge current waveforms to BS EN 61643 series

Surges characterised by standardized waveforms (approx time in µs to peak/half peak)

Direct or partial lightning currents are represented by 10/350 waveform (high energy)
Indirect or induced lightning currents are represented by 8/20 waveform
Type 1 SPDs are tested with 10/350, Type 2 and 3 are tested with 8/20
Surge voltage waveforms (e.g. 1.2/50) are characterized similarly
Complete system used to reduce physical damages to a structure. Consists of external and internal lightning protection systems
- requires use of service entrance Type 1 SPDs for mains
- data, signal and telecom lines also require protection
Type 1 SPDs to protect against damage type D2 – Physical damage (fire, explosion, mechanical destruction etc) due to lightning current effects – including dangerous sparking

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Fire and electric shock hazards from flashover

Service entrance SPDs prevent flashover to preserve life

Used alone, Type 1 SPDs do not protect electronics: An LPS “which only employs equipotential SPDs provides no effective protection against failure of sensitive electrical or electronic systems” BS EN 62305-4 Page 15

Transient overvoltage SPDs (Type 2 and 3) needed to complete a coordinated SPD set for equipment protection
Complete system of protection measures for internal systems against LEMP (surges)

Co-ordinated Type 2 & 3 SPDs, shielding and bonding measures

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BS EN 62305 Damage Type D3 – Failure of internal systems due to Lightning

Damage to electronics occurs from all Sources of Damage S1 to S4

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Zone (area) where lightning electromagnetic environment is defined

- $0_A$: Full current, full magnetic field, $0_B$: partial/induced current full magnetic field
- 1: Limited induced current damped magnetic field
- 2: Limited induced current, further damped magnetic field

Further zones (e.g. LPZ 3) can be created for sensitive equipment.
For LPMS using more than one LPZ, SPD(s) should be located at line entrance into each LPZ for metallic electrical services. The SPD aids to change the zone e.g. from LPZ 1 to LPZ 2.

SPD 0/1 needs to handle higher surge energy than SPD 1/2.

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Principle of co-ordinated SPDs

- **LEMP**
- **Wiring/cable Inductance (L)**
- **Equipment**

\[ U_0, I_0 \]
\[ U_1, I_1 \]
\[ U_2, I_2 \]

Equipment protected against conducted surges
\[ U_2 \ll U_0 \text{ and } I_2 \ll I_0 \]

- **SPD 0/1** - Lightning current protection
- **SPD 1/2** - Overvoltage protection

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### Mains Type, test class and application of SPDs

<table>
<thead>
<tr>
<th>Type of SPD</th>
<th>Description</th>
<th>Test class (Note 1)</th>
<th>Test waveform (µs)</th>
<th>Typical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equipotential bonding or lightning current SPD</td>
<td>I</td>
<td>10/350 current</td>
<td>Mains distribution board</td>
</tr>
<tr>
<td>2</td>
<td>Overvoltage SPD</td>
<td>II</td>
<td>8/20 current</td>
<td>Sub-distribution board</td>
</tr>
<tr>
<td>3</td>
<td>Overvoltage SPD</td>
<td>III</td>
<td>Combination 1.2/50 voltage and 8/20 current</td>
<td>Terminal equipment</td>
</tr>
</tbody>
</table>

Note 1: Test class to BS EN 61643 series
Simplified 10/350 µs current division concept (BS EN 62305)

12.5% of current per conductor

100% of strike to building LPS

50% of current

Electric power line

Equipotential bonding bar

50% of current to earth

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## Relationship between LPL and maximum current handling of mains Type 1 SPD

<table>
<thead>
<tr>
<th>LPL</th>
<th>Maximum current (kA) 10/350 µs</th>
<th>Class of LPS</th>
<th>Maximum Type 1 SPD current per mode* (kA) 10/350 µs</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>200</td>
<td>I</td>
<td>25</td>
</tr>
<tr>
<td>II</td>
<td>150</td>
<td>II</td>
<td>18.75</td>
</tr>
<tr>
<td>III/IV</td>
<td>100</td>
<td>III/IV</td>
<td>12.5</td>
</tr>
</tbody>
</table>

* Based on 3 phase TN-S or TN-C-S system: 4 conductors (L1, L2, L3, N) plus earth – 4 modes to earth

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10/350 current division concept for multiple services (far more realistic in practice)

12.5% of current

100% of strike to building LPS

3.125% of current per conductor

50% of current to earth

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Type 1 SPDs are required as part of BS EN 62305-3

Two peak impulse current levels ($I_{imp}$) of 10/350 mains Type 1 SPD (3Ø supply, 4 wire)

- 25kA Type 1 SPD, for use with LPS Class I & II
- 12.5kA Type 1 SPD, for use with LPS Class III & IV

For structures not at risk of direct strike BUT have overhead lines at risk of direct strike, use 12.5kA 10/350 mains Type 1 SPDs

Type 2 and Type 3 overvoltage SPDs typically have $I_{max}$ 40kA 8/20 and 10kA 8/20 peak current ratings respectively – for durability against typical frequent surge currents ($\leq$3kA 8/20).
Combined Type SPDs

Superior SPDs tested to meet requirements of both lightning current and overvoltage SPDs
  Handle high lightning currents typically seen at service entrance
  Limit overvoltages significantly to even protect electronic equipment

Coordination effectively takes place within the SPD

Creates a safer LPZ environment
  e.g. Can produce LPZ 3 at boundary where line enters from LPZ 0_A

Mains combined Type SPDs e.g. 1+2, 2+3, 1+2+3
Combined Type are more economic
  Less units required than individual Type SPDs
  Single installation saves time, cost over individual Type SPDs

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Lower (therefore better) voltage protection levels $U_P$ (let-through voltage) for a given test surge

Lower value of risk of loss of life and equipment (Table NB.3 BS EN 62305-2)

Allow continuous operation of electronic equipment (full mode protection – protect in both common and differential modes)

Takes account of oscillation effect and additional voltage drop of connecting leads (20% safety margin)

$U_P$ of $\leq 1600V$ for Type 1 and $\leq 600V$ for Type 2 and Type 3 SPDs (tested to 61643, 230/400V system)
The need for protection

Section 534 applies when the need for surge protection is identified by BS EN 62305 and/or Section 443

Section 443 does not consider direct lightning strokes to the structure or line and refers to BS EN 62305

BS EN 62305 replaced BS 6651 in 2008

Protection of electronics now normative part of BS EN 62305 (previously only an informative part (Annex C) of BS 6651)
Section 534

Covers selection and installation of all mains Type of SPDs

- **Type 1**
  - Equipotential bonding or lightning current SPD
  - Main Switch Board
- **Type 2**
  - Overvoltage SPD
  - Sub Distribution Board
- **Type 3**
  - Overvoltage SPD
  - Terminal equipment level

All Types tested to BS EN 61643 SPD product test standards

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Section 534 key areas

Connection of SPDs at or near origin of installation

Transients can exist between any two pairs of conductors

Mode of protection – protection between two conductors

Common mode – protection between each line and protective conductor
Or between each line and main earthing terminal if this distance is shorter

Differential mode – protection between line conductors

Protection of electronic equipment and against switching transients

Full mode protectors are most effective

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Transient overvoltages transmitted by the supply distribution system are not significantly attenuated downstream in most installations (443.1.1 Note 3)

Protection level $U_p$ (sometimes known as let-through voltage of SPD)

It is voltage clamping level (per mode) of the SPD (for a given transient test)

Key parameter, to be sufficiently lower than equipment withstand levels $U_w$

Lower than impulse immunity levels for electronic equipment (61643)

**TABLE 44.3 – Required minimum impulse withstand voltage, $U_w$**

<table>
<thead>
<tr>
<th>Nominal voltage of the installation V</th>
<th>Category IV (equipment with very high impulse voltage)</th>
<th>Category III (equipment with high impulse voltage)</th>
<th>Category II (equipment with normal impulse voltage)</th>
<th>Category I (equipment with reduced impulse voltage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>230/240</td>
<td>6</td>
<td>4</td>
<td>2.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

1 This impulse withstand voltage is applied between live conductors and PE.

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Maximum continuous operating voltage of SPD ($U_c$) shall be sufficiently greater than system voltage
   At least 10% higher than nominal a.c. rms voltage to earth
   In practice SPDs to 61643 allow for this with $U_c$ of 275V or higher

Surge current
   SPD has to be sufficient to survive in the environment where it is located
   Type 1 SPDs (higher surge current handling) for service entrance (lightning - equipotential bonding)
   Type 2 and 3 SPDs provide overvoltage protection (lower surge current capability than Type 1 SPDs)
      Protection against switching transients (differential mode)
Co-ordination of SPD types

SPDs on same installation need to operate together effectively

Ensure Type 1 handles high energy surges and Type 2 & 3 SPDs limit overvoltages respectively

Poor co-ordination could result in damage to SPDs and equipment

Refer to SPD manufacturers guidance

Co-ordination is dependent on technology used within SPD
Fault protection integrity
  Fault protection to remain effective even in case of SPD failure
SPDs in practice should have dedicated OCPD in-line
  The SPD OCPD should discriminate with the upstream OCPD

End of life conditions of SPDs
  OCPD provides protection against SPD short circuits
  SPDs should have internal thermal safety disconnection e.g. for safe disconnection from abnormal supply conditions
Connection of SPDs at or near origin of installation

Protect in common mode as minimum requirement
Configuration determined by supply earthing arrangement – ensure SPD failure do not compromise fault protection integrity
Connection Type 1 (CT 1) typically used for TN-S, TN-C-S systems
CT 2 used for TT systems – known in industry as ‘3+1’ arrangement
  SPD between neutral and main protective conductor handles 4 times surge current – e.g. up to 100kA 10/350
SPDs to 61643 tested to ensure safe disconnection against possible faults

CT 1

CT 2

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Section 534 key areas – selection of SPDs

SPD in conjunction with RCDs

SPDs installed before or upstream of RCD – no tripping problem from overvoltages

SPDs installed load side of RCD – nuisance tripping possible

RCDs to have immunity to surge currents of 3kA (8/20 surge current waveform)

S Type RCDs meet this requirement
Section 534 key areas – installation of SPDs

Correct installation critical for effective protection

Shunt (parallel) installed protection most common - independent of supply load current

However additive inductive voltage drop from connecting leads

Additive voltage also seen by equipment

Connecting leads therefore need to be kept as short as possible

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SPD installation – parallel connection

534 recommends connecting leads \((a + b)\) should not preferably exceed 0.5m

Under no circumstances should leads exceed 1m

In practice, connecting leads should be kept as short as possible (0.25cm if practicable)

Minimum size of connecting leads copper (or equivalent):
- 16mm\(^2\) for Type 1 SPDs
- 4mm\(^2\) for Type 2, 3 SPDs
  
  Or equivalent size to line conductors if smaller

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OCPD  overcurrent protective device
SPD   surge protective device
E/I   equipment or installation to be protected against overvoltages

\(a + b \leq 1.0\) m

Main earthing terminal or connecting conductor bar

IEC 947/02

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Installation effects – parallel protectors
Installation effects – parallel protectors

The connecting leads of a parallel protector have opposing current flows and hence magnetic fields.

Binding connecting leads cancels magnetic fields and hence inductive voltage.

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Installation effects – connecting leads

- Protector with unbound 2m connecting leads (2,300V)
- Protector with tightly bound 2m connecting leads (1,200V)
- Protector with unbound 25cm connecting leads (810V)
- Protector with tightly bound 25cm connecting leads (630V)
- Protector only

Voltage:
- 2,250V
- 2,000V
- 1,750V
- 1,500V
- 1,250V
- 1,000V
- 750V
- 500V
- 250V

Time:
- 2μs
- 4μs
- 6μs
- 8μs
- 10μs

Safe level (700V)

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SPD installation

Key:
1 distribution board
2 main switch
3 main earthing terminals
4 neutral terminals
5 enclosure for SPD
6 first OCPD
7 alternative first OCPD

Protective conductor

L1 L2 L3 N

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Section 534 key areas – selection of SPDs

SPD status indication

SPDs installed in shunt/parallel – if they fail, user unaware, equipment unprotected

SPDs to indicate if they provide limited or no protection

Indication could be visual, audible and/or remote

Remote connection to BMS or external panel light
Where to Protect

In accordance with LPZ concept, each and every incoming and outgoing metallic service line from a building MUST be protected to preserve the required LPZ.

Transients enter buildings via metallic conductors
   Through both underground and overhead cables

Protect all cables which enter or leave the building.

Protect critical equipment locally
   From switching transients created internally

Different systems require different protectors – a mains protector cannot protect a telephone or signal line.

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Mains protection example

<table>
<thead>
<tr>
<th>Main distribution board</th>
<th>Subdistribution board (feeding critical equipment)</th>
<th>Location of critical equipment, e.g. office $&gt;&gt; 10$ m from subdistribution board</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incoming supply</strong></td>
<td><strong>ESP 415 TNS</strong>&lt;br&gt;Type 1 Surge Protector</td>
<td><strong>Risk of switching surges from lift motor etc</strong></td>
</tr>
<tr>
<td>fused F&lt;sub&gt;s&lt;/sub&gt;</td>
<td><strong>F&lt;sub&gt;2&lt;/sub&gt;</strong></td>
<td></td>
</tr>
<tr>
<td><strong>HRC switch fuse</strong></td>
<td><strong>F&lt;sub&gt;PD&lt;/sub&gt; ≤ 0.5 F&lt;sub&gt;2&lt;/sub&gt;</strong></td>
<td></td>
</tr>
<tr>
<td>or MCCB F&lt;sub&gt;2PD&lt;/sub&gt;, where F&lt;sub&gt;2PD&lt;/sub&gt; ≤ 0.5 F&lt;sub&gt;2&lt;/sub&gt;</td>
<td><strong>Critical equipment e.g. computer room</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ESP 415 D1/LCD</strong>&lt;br&gt;Combined Type 1, 2, 3 Surge Protector</td>
<td><strong>ESP MC Series Microconditioner</strong></td>
<td></td>
</tr>
</tbody>
</table>

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Mains protection example

ESP 415 M2
Combined Type 1, 2, 3
Surge Protector at
mains distribution
board directly protects
critical equipment

Incoming supply
fused F3

HRC switch fuse
or MCCB Fsep,
where Fsep ≤ 0.5Fs

Critical
equipment
e.g. computer
room

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Section 534 covers selection and installation of all SPD types
   Type 1 for protection against direct lightning strikes causing flashover
   Type 2 and 3 for equipment overvoltage protection

Section 534 in-line with latest IEC/BS EN 62305 standards
   BS EN 62305 “Protection against lightning” – personnel, structures, systems

Correct selection and installation of SPDs critical for effective protection

Protect data, signal & telecom lines as well as mains power
Questions & Answers