Electronic Systems Protection – Introduction

What transients are and why you need protection

Transient overvoltages are large, very brief and potentially destructive increases in voltage.

Causes

Transient overvoltages can be caused by:

- the secondary effects of lightning strikes (either between clouds or to ground) from a kilometre, or more, away
- the electrical switching of large inductive loads (such as motors, transformers and electrical drives), or capacitive loads (such as power factor correction).

Devastating effects

Although they last only thousandths or millionths of a second, transient overvoltages can devastate modern electronic systems:

- disrupting system operations, through data loss, data and software corruption and unexplained crashes
- degrading equipment components and circuitry, shortening equipment lifetime and increasing failures
- destroying components, circuit boards and I/O cards
- causing costly and unnecessary system downtime.

Transient overvoltage damage to the circuit board, left, is clear to see, but most damage is barely visible, as below.

Growing threat

The miniaturisation of electronic components and circuits makes systems ever more susceptible to damage, and the growing use of electronic systems further increases our vulnerability to the effects of transients.

Most modern electronic systems are at risk:

- **computers**
- **data communication networks**
- **building management systems**
- **PABX telephone exchanges**
- **CCTV equipment**
- **fire and burglar alarms**
- **telecom base stations**
- **uninterruptible power supplies (UPSs)**
- **programmable logic controllers (PLCs)**
- **plant sensors**
- **telemetry and data acquisition equipment.**

Loss of these systems will cripple industrial, commercial and governmental organisations alike.

Risk assessment

Although most of us work in buildings with lightning conductors, these aren't designed to, and won't, stop transient overvoltages from damaging electronic equipment. To prevent lightning damage to electronic systems, this structural lightning protection needs to be complemented with transient overvoltage protection.

Interestingly, if we use the lightning risk assessments in BS 6651, ***the risk of transient overvoltage damage to electronic systems inside a building is greater than the risk of damage to the building itself.***

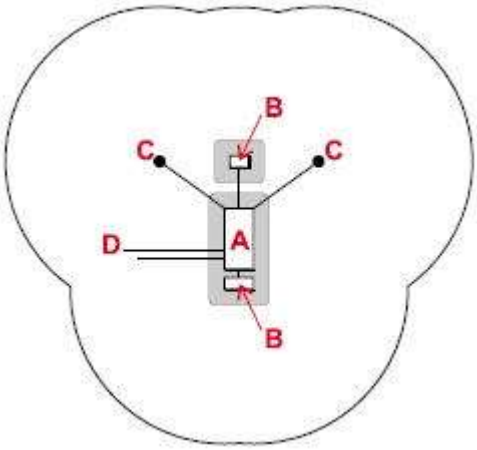
Therefore, if, like most people, you work in a building where structural lightning protection has already been thought necessary, then there is a ready made argument for transient overvoltage protection.

Example: collection area comparison

This site consists of a main building **A**, *auxiliary buildings* **B** *and some ground level sensors* **C**, *which are linked by various underground cables.*

The collection area for this site for a direct lightning strike is a distance equivalent to the height of the structures laid out in plan (shown as the shaded area).

The effective collection area for transient overvoltages is much larger. It includes a collection area associated with the surrounding ground (unshaded), plus additional areas (not shown) for incoming power and phone lines **D**.



Protection benefits

Effective transient overvoltage protection can prevent:

- **lost or destroyed data**
- **equipment damage**
- **repair work - especially costly for remote or unmanned installations**
- **the high cost of extended stoppages - sales lost to competitors, lost production, deterioration or spoilage of work in progress**
- **loss of essential services - fire alarm, security systems, building management systems**
- **health and safety hazards caused by plant instability, after loss of control**
- **fire risks and electric shock hazards.**

When and where to protect

Transient overvoltages are conducted into the sensitive circuitry of electronic equipment on power and data communication, signal and telephone lines. Protection is recommended for:

- all cables which enter or leave the building (except fibre optic)
- the power supply local to important equipment
- electronic equipment outside the main building(s).

Protect incoming and outgoing electrical services

Lightning strikes between clouds or to ground (and objects upon it) can cause transient overvoltages to be coupled onto electrical cables, and hence into the sensitive electronic equipment connected to them.

To protect the electronic equipment inside a building, all cables that enter or leave the building must be protected. Cables leaving the building can also provide a route back into the building for transients.

For each building protect incoming/outgoing:

- mains power supplies (including UPS supplies)
- data communication and local area network cables
- signal, control, instrumentation and alarm lines
- CCTV, satellite, TV and antenna cables
- telephone and telemetry lines.

Protect the power supply locally to important equipment

In addition to installing protection on the mains power supply as it enters/leaves the building, protection should also be installed locally to important equipment. Protection at the main LV (low voltage) incomer(s) is necessary to prevent large transients from entering the building's power distribution system, where they could have far-reaching effects. However, where the cable run to equipment exceeds approximately 20 metres, transient overvoltages may appear on the mains after the protector at the main LV incomer.

These transients can result from:

- the electrical switching of large inductive loads within the building
- a lightning strike to the building - as lightning currents flow through down conductors transient overvoltages can be induced on to nearby power cables
- the natural inductance and capacitance of long cable runs, 'amplifying' the voltage 'let-through' the protector at the main LV incomer.

Additionally, local protection guards against the possibility of a supply which enters/leaves the building being overlooked and left unprotected.

Protect data lines locally

Generally, the biggest risk to data, signal, telecom and network wiring is associated with cables that enter and leave the building. These should always be protected. However, data cables within a building can additionally have transients induced on to them when loops between data and power cables "pick up" voltages from the magnetic field caused by a lightning strike.

BS 6651:1999 Appendix C advocates the use of metal in the structure, and a Faraday cage lightning protection scheme to help exclude magnetic fields. Cable management practices eliminate loops by routeing data and power cables along the same general path.

In these cases, the need for local data line protection is minimal. However, where these steps are not possible, data line protection, local to the equipment requiring protection, should be considered.

Protect electronic equipment outside the building

On-site or field-based electronic equipment with mains power, data communication, video, signal or telephone line inputs will need to be protected against transient overvoltages. It may be helpful to think of each equipment cabinet or cubicle as a separate building with incoming/outgoing cables to be protected.

Complementary techniques

As well as the use of transient overvoltage protectors, BS 6651:1999 outlines additional protection techniques which can be used to help reduce the transient threat. These are described further in the Furse Electronic Systems Protection Handbook. Where these can be used, principally on new build or refurbishment projects, they need to be supported by the use of transient overvoltage protectors.

How to get effective protection

In order to provide effective protection, a transient overvoltage protector must:

- be compatible with the system it is protecting
- survive repeated transients
- have a low 'let-through' voltage, for all combinations of conductors
- not leave the user unprotected, at the end of its life, and
- be properly installed.

Compatibility

The protector must not interfere with the system's normal operation:

- mains power supply protectors should not disrupt the normal power supply or cause high leakage currents to earth,
- protectors for data communication, signal and telephone lines should not impair or restrict the systems data or signal transmission.

Figure 1 summarises potential sources of system impairment.

Figure 1 - General indication of system impairments which manufacturers of transient overvoltage protectors should provide details of

	Protectors for mains supplies		Protectors for data lines		
	Parallel protectors	In-line protectors	Low frequency protectors	Network protectors	Radio frequency protectors
Nominal operating voltage	✓	✓	✓	✓	✓
Maximum operating voltage	✓	✓	✓	✓	✓
Leakage current	✓	✓	✓	✓	✓
Nominal current rating	×	✓	✓	✓	✓
Max continuous current rating	×	✓	✓	✓	✓
In-line impedance	×	✓	✓	✓	✓
Shunt capacitance	×	×	×	✓	✓
Bandwidth	×	×	✓	✓	✓
Voltage standing wave ratio	×	×	×	✓	✓

Survival

It is vital that the protector is capable of surviving the worst case transients expected at its intended installation point. Transient overvoltages caused by the secondary effects of lightning are unlikely to have currents exceeding 10kA. (See section on Location Categories.) More importantly, since lightning is a multiple event, the protector must be able to withstand repeated transient overvoltages.

Let-through voltage

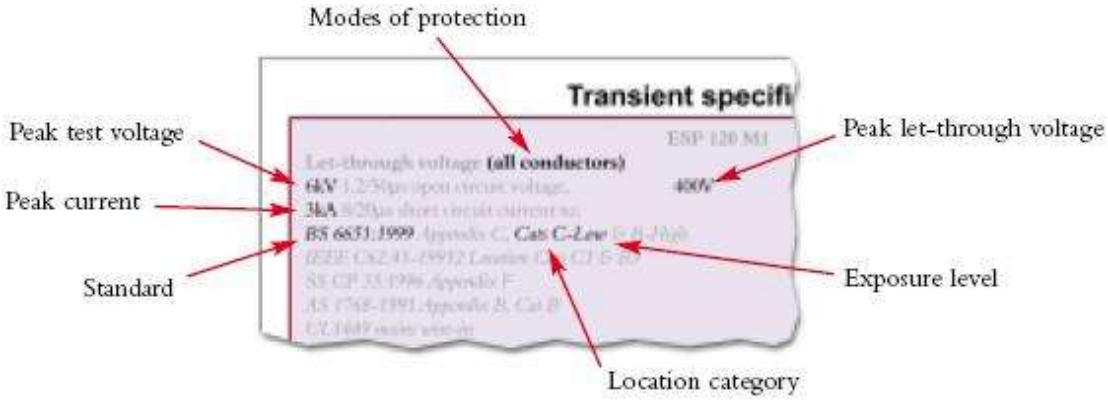
The larger the transient overvoltage reaching the electronic equipment, the greater the risk of interference, physical damage and hence system downtime. Therefore, the transient overvoltage let through the protector should be as low as possible and certainly lower than the level at which interference or component degradation may occur.

Transient overvoltages can exist between any pair of conductors:

- phase to neutral, phase to earth and neutral to earth on mains power supplies,
- line to line and line(s) to earth on data communication, signal and telephone lines.

Thus, a good protector must have a low let-through voltage between every pair of conductors.

Let-through voltage should be quoted for a relevant standard test.



The boxed section outlines location categories, exposure levels and their peak voltages and currents. An explanation of transient testing is given in Appendix C of the Electronic Systems Protection Handbook.

End of life

When the protector comes to the end of its working life it should not leave equipment unprotected. Thus in-line protectors should take the line out of commission, preventing subsequent transients from damaging equipment. Protectors for data communication, signal and telephone lines and protectors for low current mains power supplies are usually in-line devices. Where protectors are installed at mains power distribution boards it is usually unacceptable for these to suddenly fail, cutting the power supply. Consequently, to prevent equipment being left unprotected, the protector should have a clear pre end-of-life warning, which allows plenty of time for it to be replaced.

Installation

The performance of transient overvoltage protectors is heavily dependent upon their correct installation. Thus, it is vital that protectors are supplied with clear installation instructions.

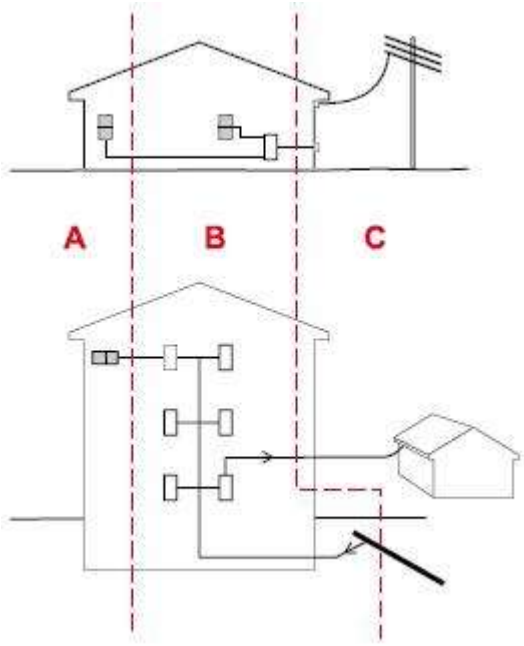
Location categories and exposure levels explained

Standards define location categories and exposure levels for transient overvoltage protectors. This is based on the fact that the likely worst case transient overvoltages the protector must (a) survive and (b) protect against, depend upon where it's installed.

Mains power supplies

The American standard IEEE C62.41, and subsequently BS 6651, SS CP 33 and others, define three location categories for mains power protectors. This is because as a mains borne transient travels through a building, the amount of current it can source becomes smaller (due to the impedance of mains cables and current division). Location Categories A, B and C are defined in Figure 2.

Location Category C is defined as either:



more than a 20m cable run from Category C.

- outside the building, or
- the supply side of the main, incoming, LV distribution board; i.e. the board bringing the power supply into the building from the electricity supply authority, LV transformer or from another building, or
- the load side of distribution boards providing an outgoing power supply to other buildings or to on-site equipment.

Location Category B is defined as either:

- on the power distribution system, between the load side of the incoming distribution board and the supply side of a socket outlet or fused spur, or
- within apparatus which is not fed from a wall socket, or
- sub-distribution boards located within a 20m cable run of Category C, or
- plug-in equipment or a fused spur located within a 20m cable run of Category C.

Location Category A is defined as:

- plug-in equipment or a fused connection located

Data communication, signal and telephone lines

Following on from work by the ITU, BS 6651 defines a single location category for data communication, signal and telephone line protectors. This is because transient overvoltages on data communication, signal and telephone lines are not significantly attenuated by the cable. Regardless of where protectors are installed in the building, the worst case will be similar. Consequently, all data communication, signal and telephone line protectors fall within Location Category C.

Exposure levels

The probable worst case transient overvoltage expected at each location category depends upon the probable number of lightning strikes, the vulnerability of the system and its consequential loss rating. Together, these factors determine whether electronic equipment is in a high, medium or low transient exposure level. This can be calculated from the risk assessment procedure in Appendix C of BS 6651:1999 (this is explained in Section 3 of the Furse Electronic Systems Protection Handbook). If the transient exposure level for the system is not known it is prudent to assume a high exposure level. Figures 3, 4, 5 and 6 show probable worst case transients for location categories and exposure levels.

Figure 3 - Mains power supply - Category C

System exposure level	Peak voltage	Peak current
High	20kV	10kA
Medium	10kV	5kA
Low	6kV	3kA

Derived from original work in IEEE C62.41-1991 and reproduced from BS 6651:1999

Figure 4 - Mains power supply - Category B

System exposure level	Peak voltage	Peak current
High	6kV	3kA
Medium	4kV	2kA
Low	2kV	1kA

Derived from original work in IEEE C62.41-1991 and UL 1449 and reproduced from BS 6651:1999

Figure 5 - Mains power supply - Category A		
System exposure level	Peak voltage	Peak current
High	6kV	500A
Medium	4kV	333A
Low	2kV	167A

Derived from original work in UL 1449 and reproduced from BS 6651:1999

Figure 6 - Data lines - Category C		
System exposure level	Peak voltage	Peak current
High	5kV	125A
Medium	3kV	75A
Low	1.5kV	37.5A

Derived from original work in CCITT IX K17 and reproduced from BS 6651:1999

How to apply protection and what to use

We've seen how protection should be installed on:

- all cables which enter or leave the building (except fibre optic)
- the power supply local to important equipment
- electronic equipment outside the main building(s)

With the aid of the illustration we can see how this might be applied in practice.

Protect incoming and outgoing electrical services

We'll start by considering the main (office) building in isolation.

Incoming mains power supplies

Install protection on the incoming mains power supply at the incoming distribution board(s).

If, as in this example, there are any other power supplies entering the building install protection on these near where they enter the building.

Outgoing mains power supplies

Outgoing supplies can provide transient overvoltages with a route back into the building's power distribution system.

Install protection on supplies to other buildings. (Note how, if correctly positioned, the protector at the incoming distribution board (1), also protects against transients from the outgoing supply to the UPS building.)

Install protection on outgoing supplies to site services, such as CCTV systems and site lighting.

Protect all incoming/outgoing data communication, signal and telephone lines (unless fibre optic).

Telephone lines

Incoming telephone lines and extensions that leave the building have protectors installed on them at the PBX's distribution frame.

In our example, there is a direct (i.e. not via the PBX) telephone line to an alarm panel, which also needs protecting.

Signal and data communication lines

Protectors are installed on CCTV video cables from outdoor cameras to prevent damage to the control desk.

A protector is installed at the network hub to protect it from transients on the between building data link.

Equipment such as our RF receiver, with antenna (or satellite) links will also need protecting.

Protect the power supply locally to important equipment

Within the building transient overvoltages can be injected on to the mains power supply (downstream of the protector at the incomer). Consequently, protectors should be installed close to important pieces of equipment.

Protection is installed on the local distribution board feeding the servers and network hub. (Note how the top floor PC network and RF receiver is protected by the protector on the distribution board (2).)

The telephone PBX is protected locally by a plug-in protector.

Protect electronic equipment outside the building

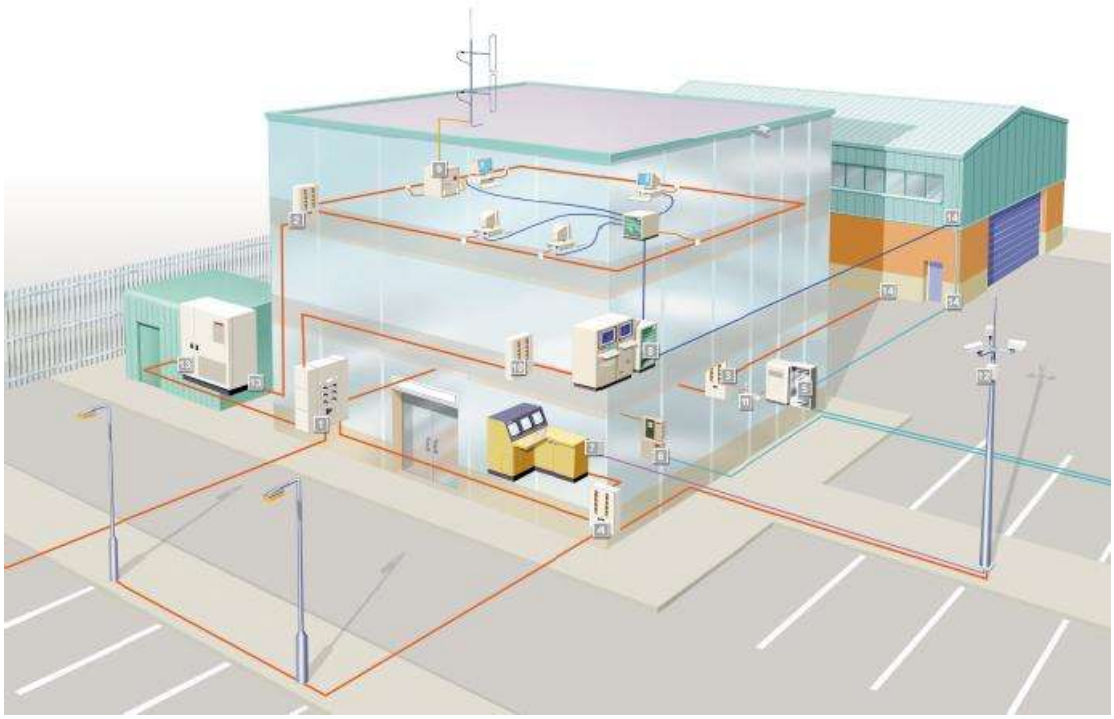
Electronic equipment outside the main building in ancillary buildings, on site or in the field should also be protected.

Protect outdoor CCTV cameras with protectors on the power supply, and video cable (and, if relevant, telemetry control line).

If the UPS is housed in a separate building with a separate earth, incoming and outgoing supplies will need to be protected. This is because most modern UPS systems contain electronics that makes them vulnerable to being disabled by transient overvoltages. To prevent transient overvoltage damage to the UPS it must have a protector

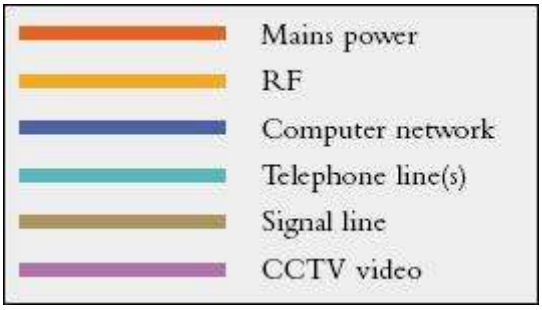
installed on its input and (because its outgoing supply leaves the building) on its output. A protector will also need to be installed on the power supply into the main building (2).

Protection is also installed on mains power, data communication and telephone lines entering the neighbouring building. Additional protection (not shown) may be required within this building (whether it's a computer-controlled warehouse or automated manufacturing operation with PLCs, drives and computer controls).



Protector selector

(1) (2) (3) (4) Mains wire-in protectors
(5) PBX telephone/ISDN line protection
(6) Plug-in telephone line protection, or
Wire-in telephone line protection
(7) CCTV video protectors
(8) Computer network protector
(9) RF signal protector
(10) Mains wire-in protector
(11) Plug-in mains protector
(12) Protectors for low current mains power supplies,
CCTV video and
telemetry lines
(13) Mains wire-in protectors
(14) Mains wire-in protectors
Computer network protector
PBX telephone/ISDN line protection



General points of installation

The following is intended to supplement the guidance given with each product entry in order to give a general overview of installation. This should not be viewed as a substitute for the Installation Instructions supplied with the protector. Copies of these are available separately on request.

Installing parallel connected protectors for mains power supplies

- Protectors should be installed very close to the power supply to be protected, either within the distribution panel or directly alongside it (in an enclosure to the required IP rating).
- Connections between the protector and the phase(s), neutral and earth of the supply should be kept very short.
- Protector performance is enhanced by tightly binding connecting leads together, over their entire length.
- On supplies rated over 100 amps the phase/live connecting leads should be fused with suitably rated HRC fuses or switchfuse, MCCB or MCB.

Installing in-line protectors for data, signal, telephone or power

- Protectors are usually installed between where cabling enters or leaves the building and the equipment being protected (or actually within its control panel).
- The installation position should be close to the system's earth star point (usually the mains power earth) to enable a short and direct connection to earth.
- In-line, or series, connected protectors generally have connections marked line and clean. The line end of the protector should be connected to the dirty, incoming line (from where the transient is expected). The clean end of the protector should be connected to the line or cable to the equipment.
- Cables connected to the protector's clean end should never be routed next to dirty line cables or the protector's earth bond.
- Unless ready boxed, protectors should be installed either within an existing cabinet/cubicle or in an enclosure to the required IP rating.

What every Furse protector gives you

Furse protectors are probably the best engineered transient overvoltage protectors on the market today.

Furse protectors have been designed by a dedicated in-house team to provide maximum protection, reliability and ease of use - wherever they are installed.

Furse protectors have been tested to relevant standards, including:

- BS 6651:1999 Appendix C
- IEEE C62.41-1991
- SS CP 33:1996 Appendix F
- AS 1768-1991 Appendix B
- UL1449
- IEC 1000-4-5:1995
- ITU (formerly CCITT) IX K17

Furse protectors are manufactured to the highest standard and have undergone stringent testing, both during and after manufacture.

Each Furse protector gives you:

- Let-through voltages below the level where equipment could be damaged
- Low let-through voltage between all sets of conductors
- Repeated protection in lightning intense environments
- Robust housings
- Different mounting options
- Clear, comprehensive installation instructions supplied with each protector
- Maintenance free
- 5 year warranty against faulty components and manufacturing defects

What our customers say about us

"The cost of lightning damage to system hardware and software is just the tip of the iceberg. This is usually dwarfed by consequential losses, the 'hidden costs' of losses that emerge after an incident however well insurance covers are arranged. This can result in downtime, lost business and opportunities and possibly lost customers."

John Whittall, Manager Risk Improvement
Zurich Commercial Insurance, Britain

"Furse lightning protection units have been used on Vodafone base stations for over 10 years. These units have proved to be very reliable and complement the technical support and after sales service Vodafone have received from Furse."

Stephen Williams, Senior Engineer
Vodafone, Newbury, Britain

"We were using some very expensive surge suppressors for our TV and Radio Broadcasting facilities, only to find they were not effective. I came across Furse ESP products in an IEEIE journal sometime back. About five years back, the first Furse ESP purchase was tried out at a transmitting station, at a hilltop, which is prone to lightning. It was terribly effective and since then Furse products have come to stay with us. Now we are using them in all our six repeater stations."

Nimal P Gooneratne, Director of Broadcast Engineering Services
MTV Channel, Sri Lanka

"I hadn't been involved with transient protection before, but every time I contacted Furse there was an engineer on hand. He was knowledgeable, helpful and friendly and gave good quality customer service."

Richard Mynott, Property Services Engineer
Castrol, Reading, Britain

"We are very satisfied with the performance of Furse ESP protectors, as are our customers. Previously we had used other products, but these didn't give as effective protection as Furse ESP. Although it increases the overall cost of the system, it is a justifiable expense. Because of the confidence we have in Furse we recommend use of Furse ESP to our customers."

Peter Chin Hon Ming, Sales Manager
Lucent Technologies, Kuala Lumpur, Malaysia

"As electrical consultants we have for many years realised the importance of protecting electronic equipment from lightning. It is one of the first things we specify and we specify Furse ESP for the quality of the product and the technical support we receive."

K L Ng, Director
Jentrik, Malaysia