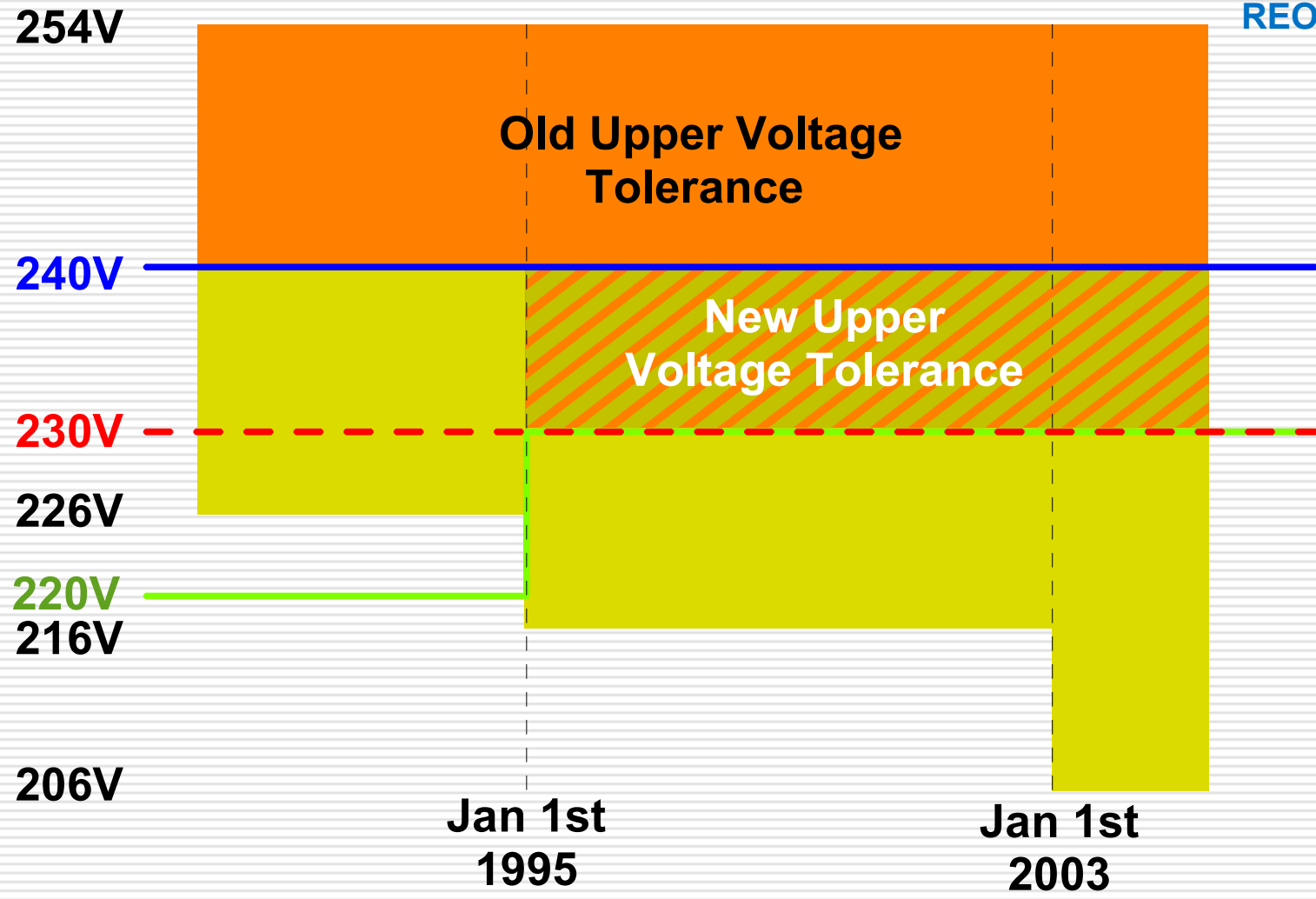


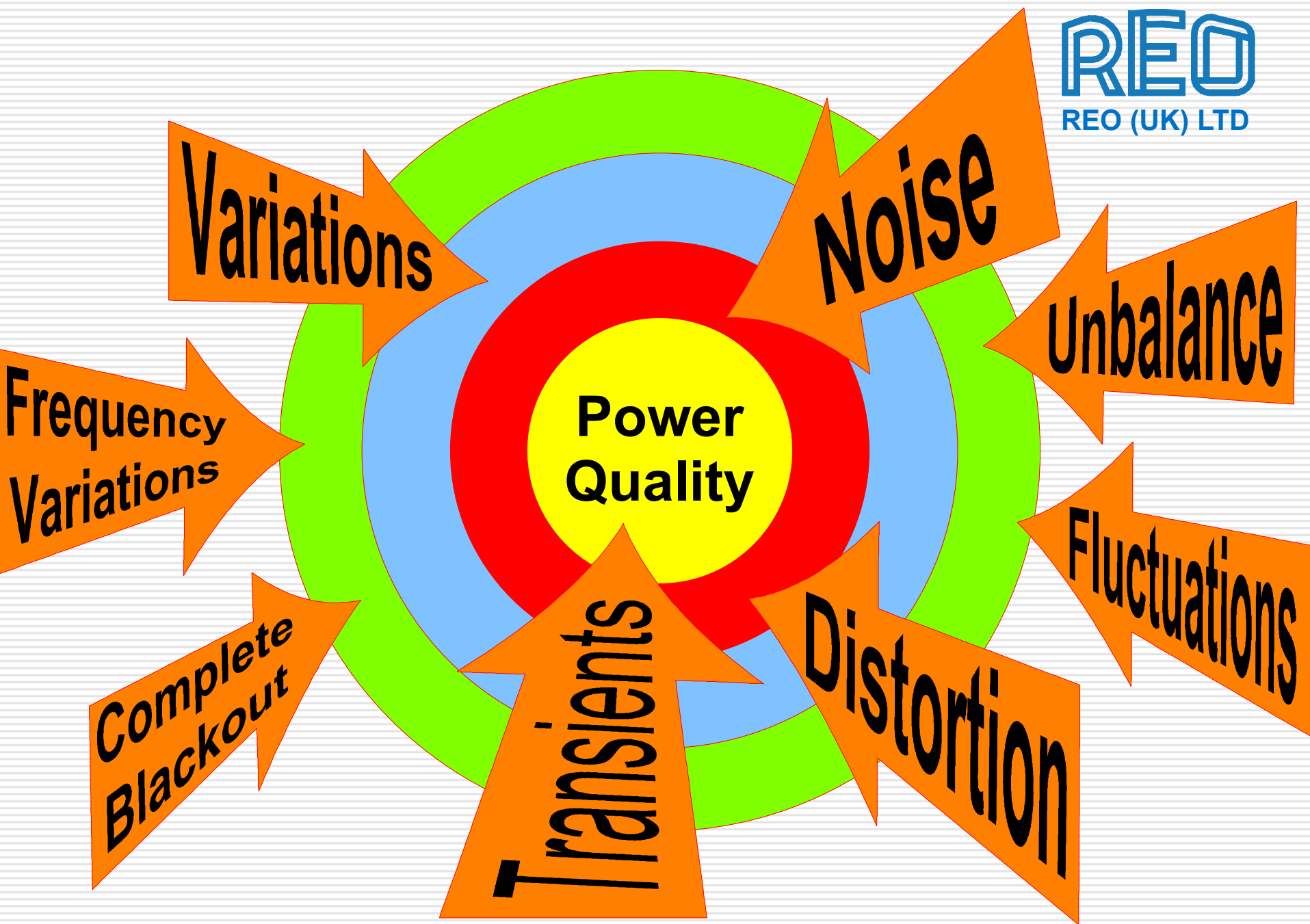


Power Quality

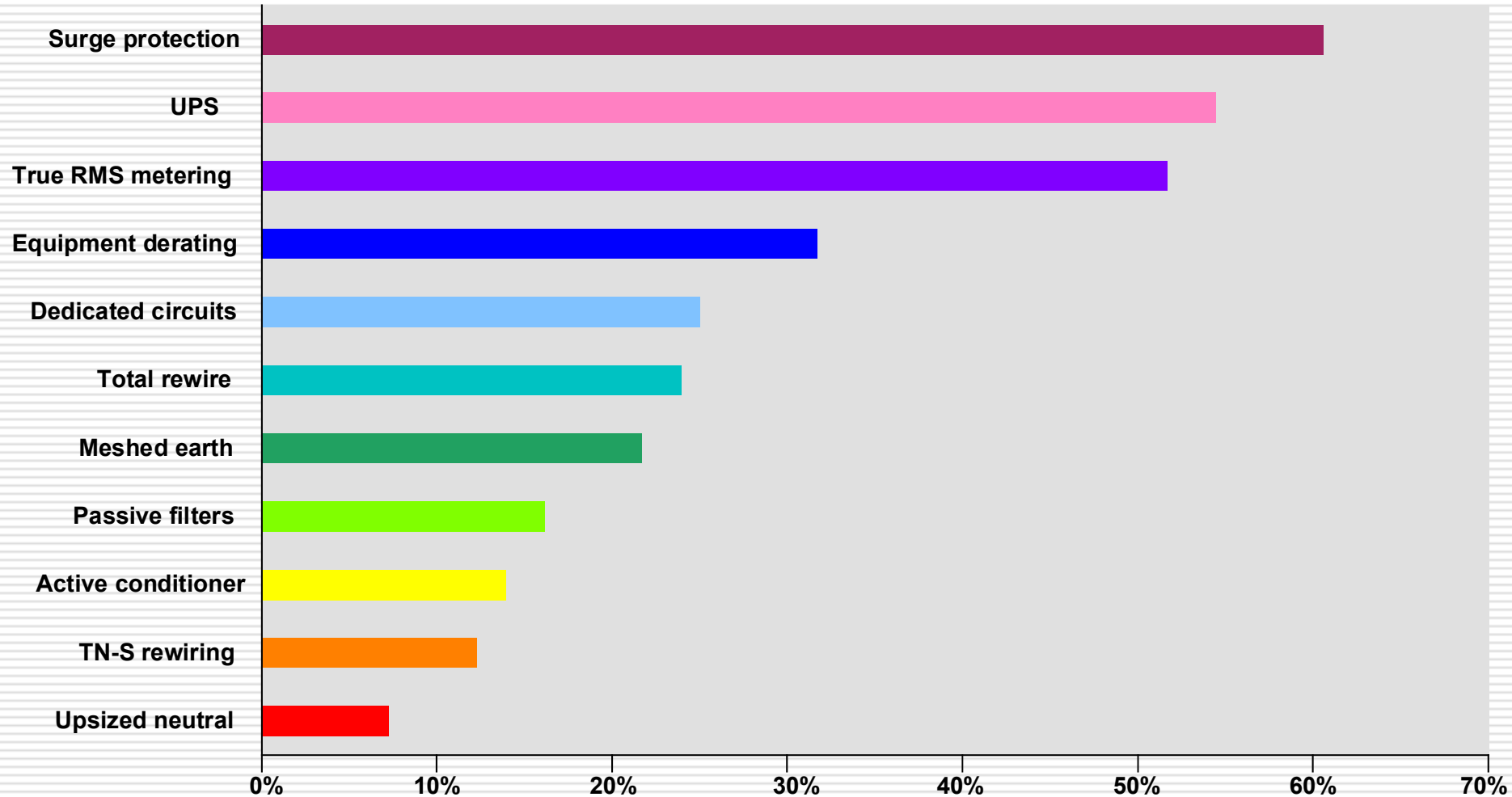


Moving the supply voltage goalposts

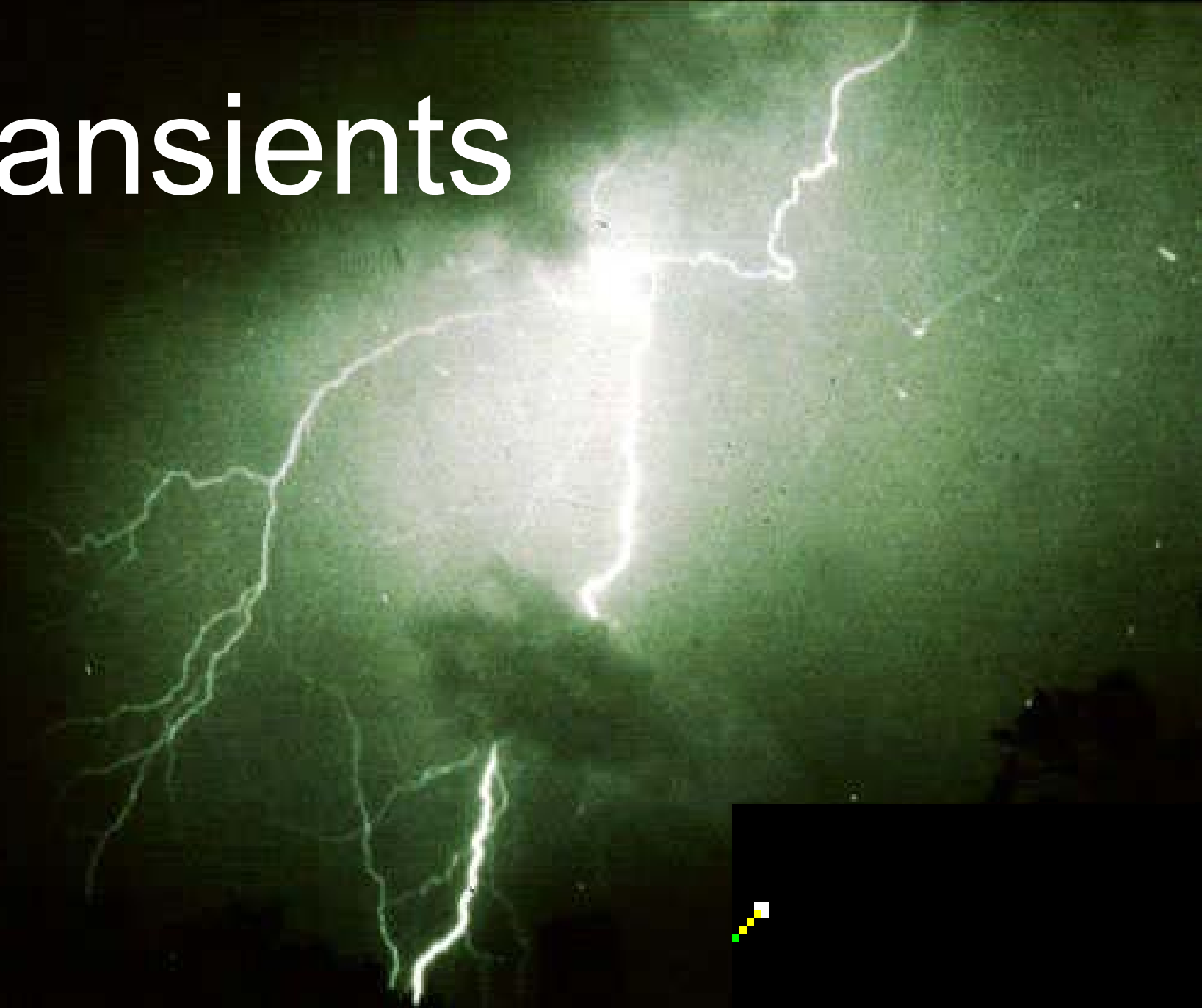




The most widely used Power Quality Solutions from a survey of 1400 sites in 8 countries



Transients

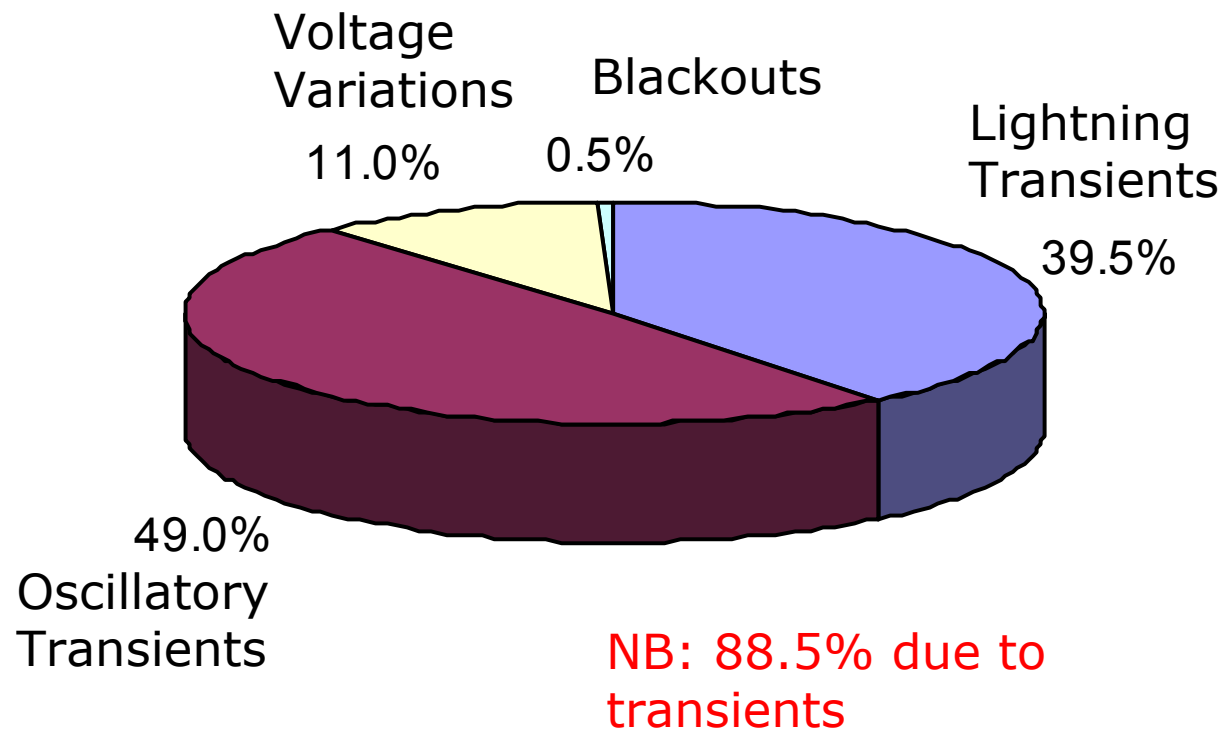


Transients can be caused by:-

- Lightning
- Switching on the mains supply network
- Switching of any load (even relays !)
- Sags
- Arc welding

Transients are often referred to as surges, particularly in standards

IBM Survey of incidence rates of harmful power disturbances causing computer equipment failures (Allen & Segall)



Some interesting facts about lightning

- ❑ There are about 300,000 ground strikes every year in Britain
- ❑ 30 – 60 people are struck by lightning each year and on average 3 may be killed

Source: Tornado and Storm Research Organisation www.torro.org.uk

- ❑ The Met Office monitors radio waves emitted from lightning flashes. These have a frequency of about 50 kHz and in principle can travel from the other side of the World with very little loss in strength.

Source: www.met-office.gov.uk

EN 61000-4-5: Testing and measurement techniques-Surge immunity test

- ❑ This standard defines the test levels for various classifications of equipment. The most stringent test (interconnections through outdoor cables) calls for a 4kV surge test.
- ❑ In reality surges in excess of 10kV can be expected, particularly in North and South America and the Pacific Rim.



Locations near to power lines are particularly vulnerable to transients, typically 10kV ten times a year. Whereas an office in town could expect up to 3kV ten times a year.

Source: Manufacturing Systems Magazine

Last Updated: Tuesday, 29 April, 2003, 13:31 GMT 14:31 UK

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Power cut hits commuters

Power cuts in Belfast have caused disruption for road and rail travellers.

It follows a serious fire at an electricity substation on the Glen Road in west Belfast.



Supplies were affected after the substation fire

The power failure hit about 0700 BST on Tuesday, causing problems for commuters as traffic lights and train signals were also affected.

Northern Ireland Electricity said major customers were affected but its domestic customers still had power.

An investigation is under way to find out what went wrong at the Hannahstown substation.

There may have been a power surge caused by a fault in the voltage switching system overnight.

The fire service was called to the scene and on arrival they found ceramic insulators still smouldering.

Home next to the substation were unaffected but the power

WATCH AND LISTEN
BBC NI's Rosy Billingham:
"The power surge caused considerable disruption right across Belfast"
▶ VIDEO

SEE ALSO:

- ▶ Electricity attacks warning
24 Apr 03 | Northern Ireland
- ▶ Power restored to NI homes
24 Feb 02 | Northern Ireland
- ▶ Storms cut power supplies
20 Feb 02 | Northern Ireland

RELATED INTERNET LINKS:

- ▶ Northern Ireland Electricity
- ▶ Translink

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TOP NORTHERN IRELAND STORIES NOW

- ▶ Efforts intensify to break impasse
- ▶ UDA's 'spokesmen vendetta'
- ▶ Man killed in road accident
- ▶ Partygoer in arson inquiry

TOP UK STORIES NOW

Transients can cause:-

- ❑ Equipment failure
- ❑ Premature ageing of components e.g semiconductors (especially power components such as rectifiers)
- ❑ Disruption of a process
- ❑ Fire

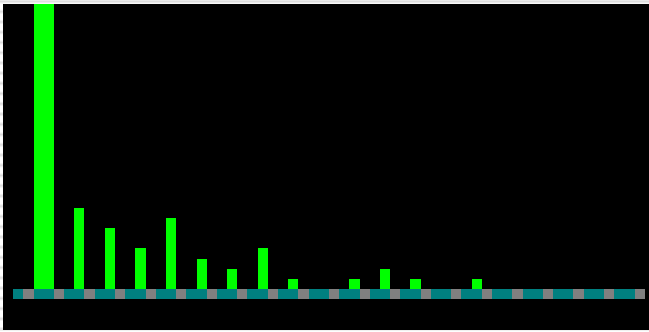
Some devices for protection against transients

Gas discharge tube, essentially just a spark-gap, slow but very high power and negligible leakage



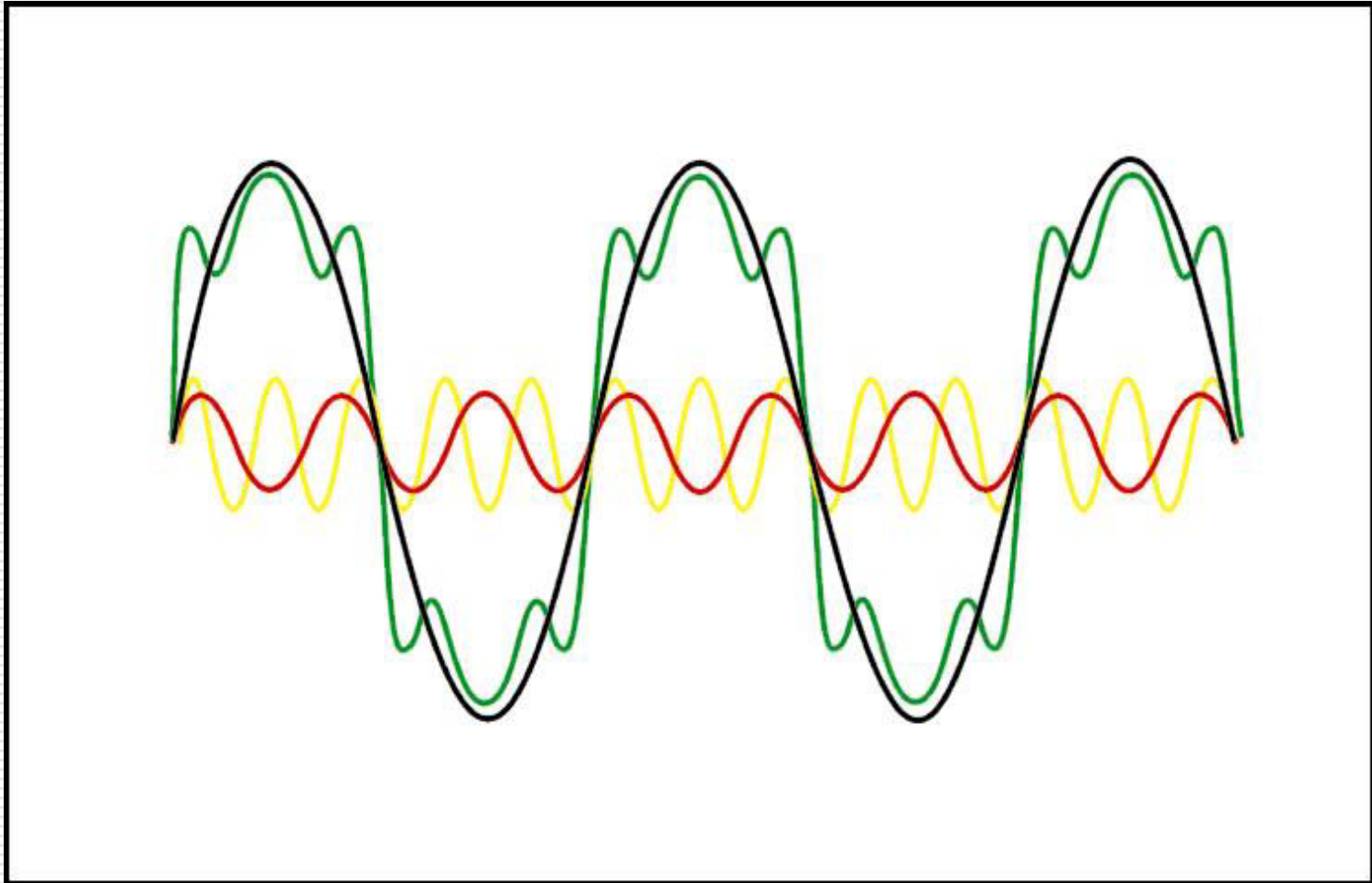
Metal-oxide varistor, a bulk semiconductor, fast and less rugged than a GDT

Also avalanche devices (zener type action) and thyristor devices



Harmonics

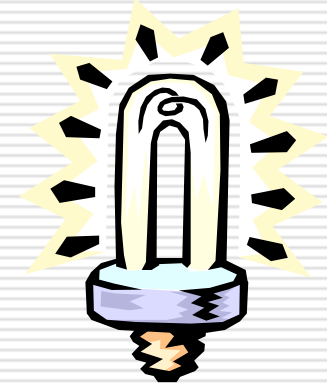
- Sinusoidal components of a non-linear periodic waveform with a frequency that is a whole multiple of the fundamental frequency
- Symmetrical waveforms – odd harmonics only
- Asymmetrical waveforms – both odd and even harmonics

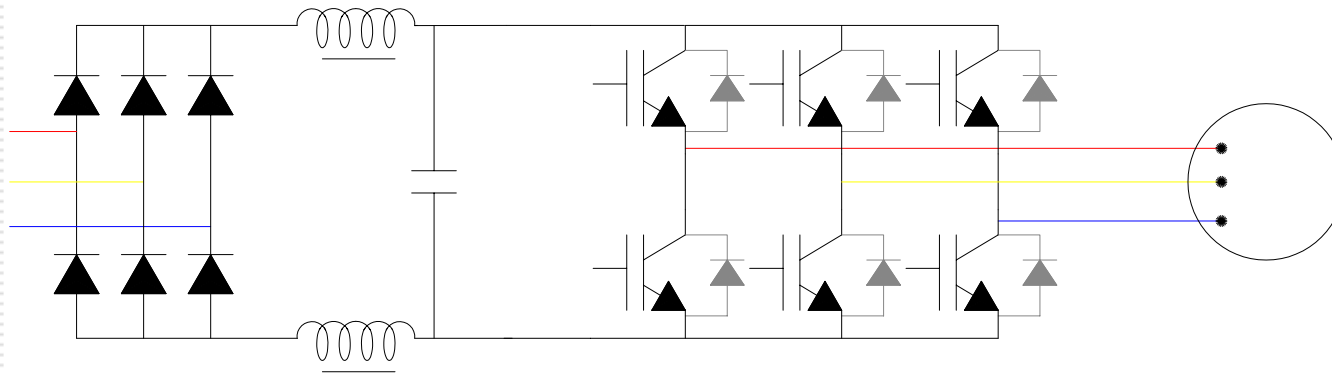


A sine wave distorted by third and fifth harmonics

Harmonics are caused by:-

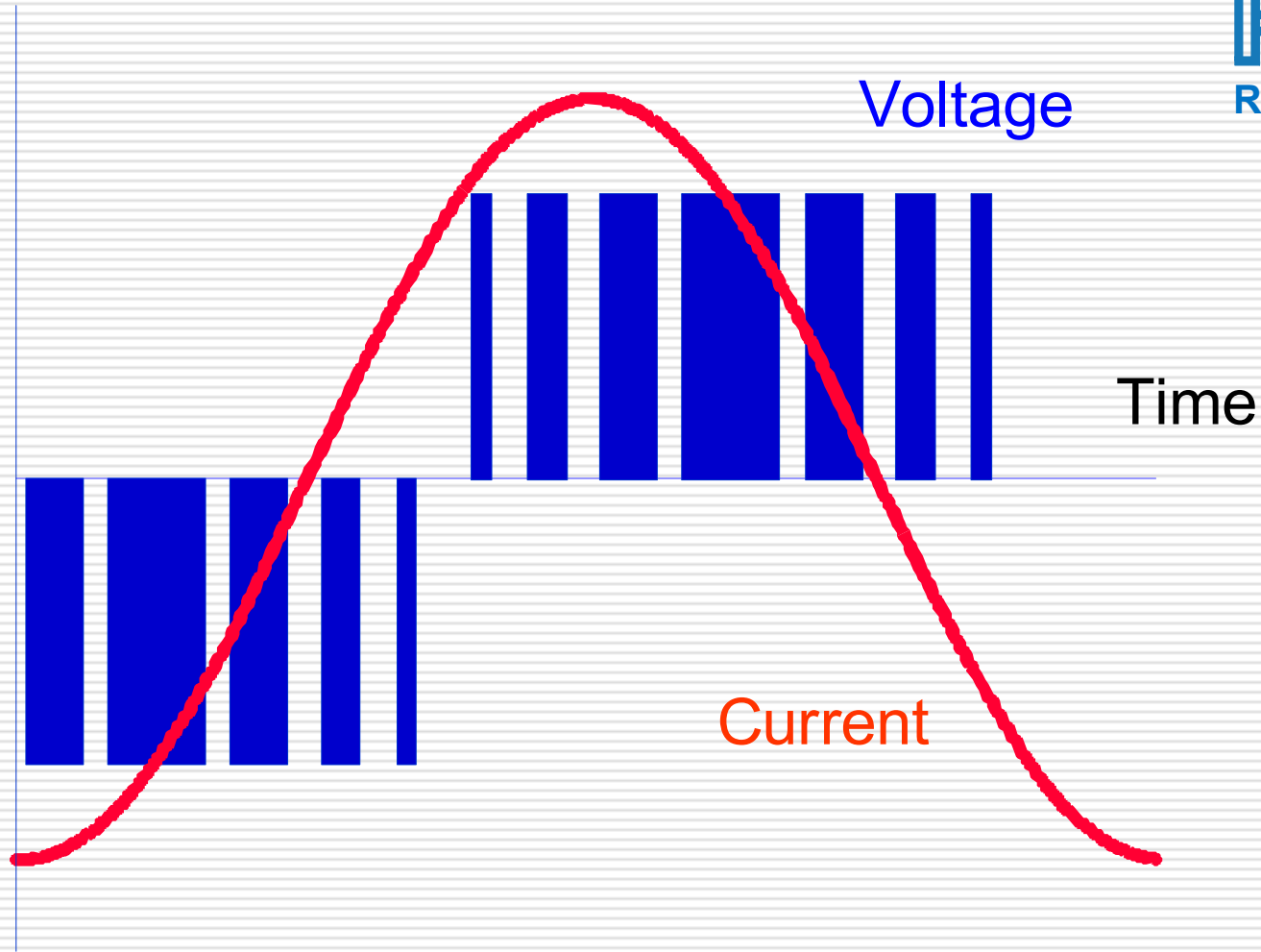
- Fluorescent Lighting (energy saving bulbs)
- Televisions and computers
- Switch mode power supplies
- Variable speed drives
- Air conditioning equipment
- IT equipment
- Phase-angle power controllers



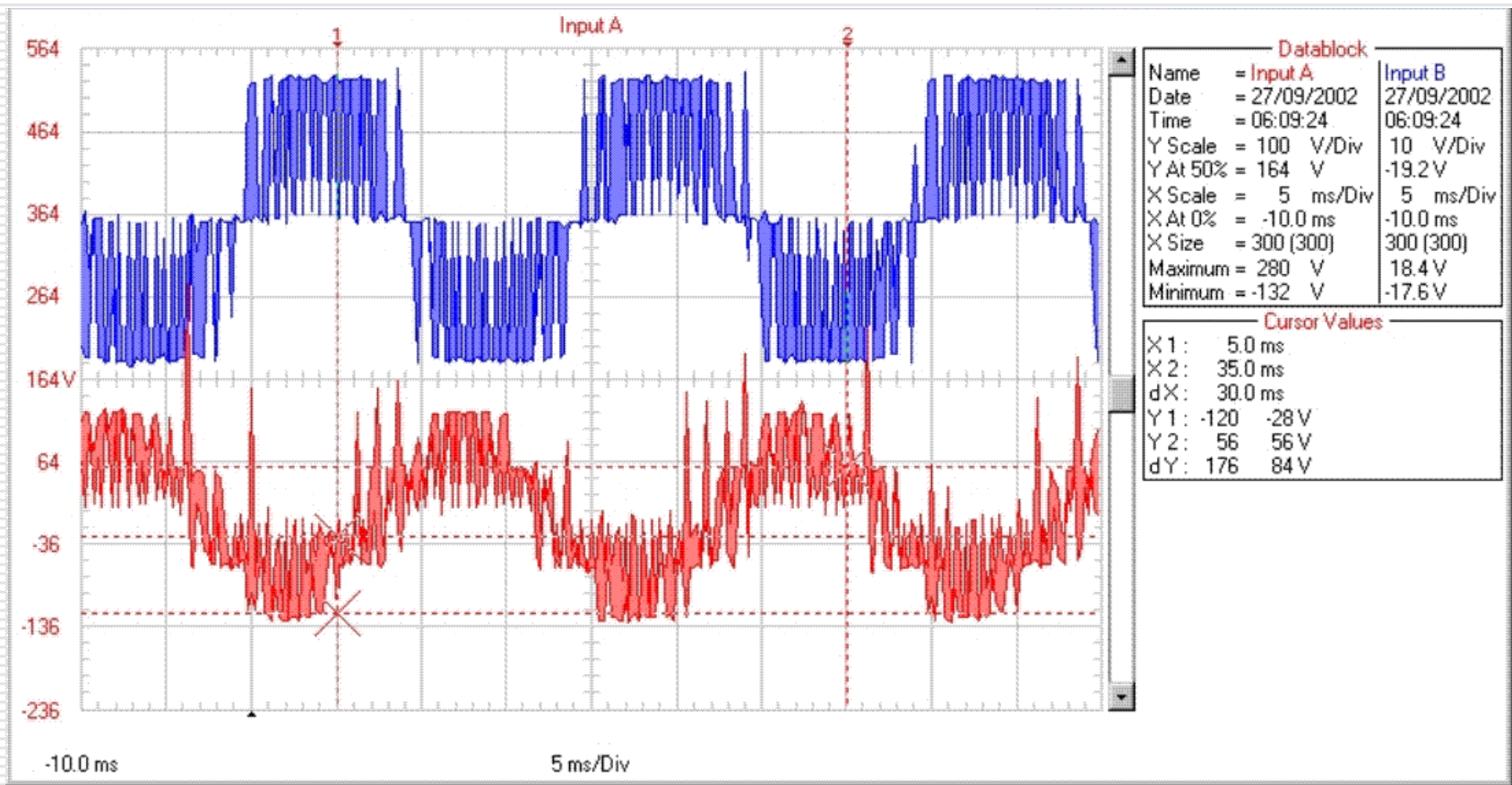


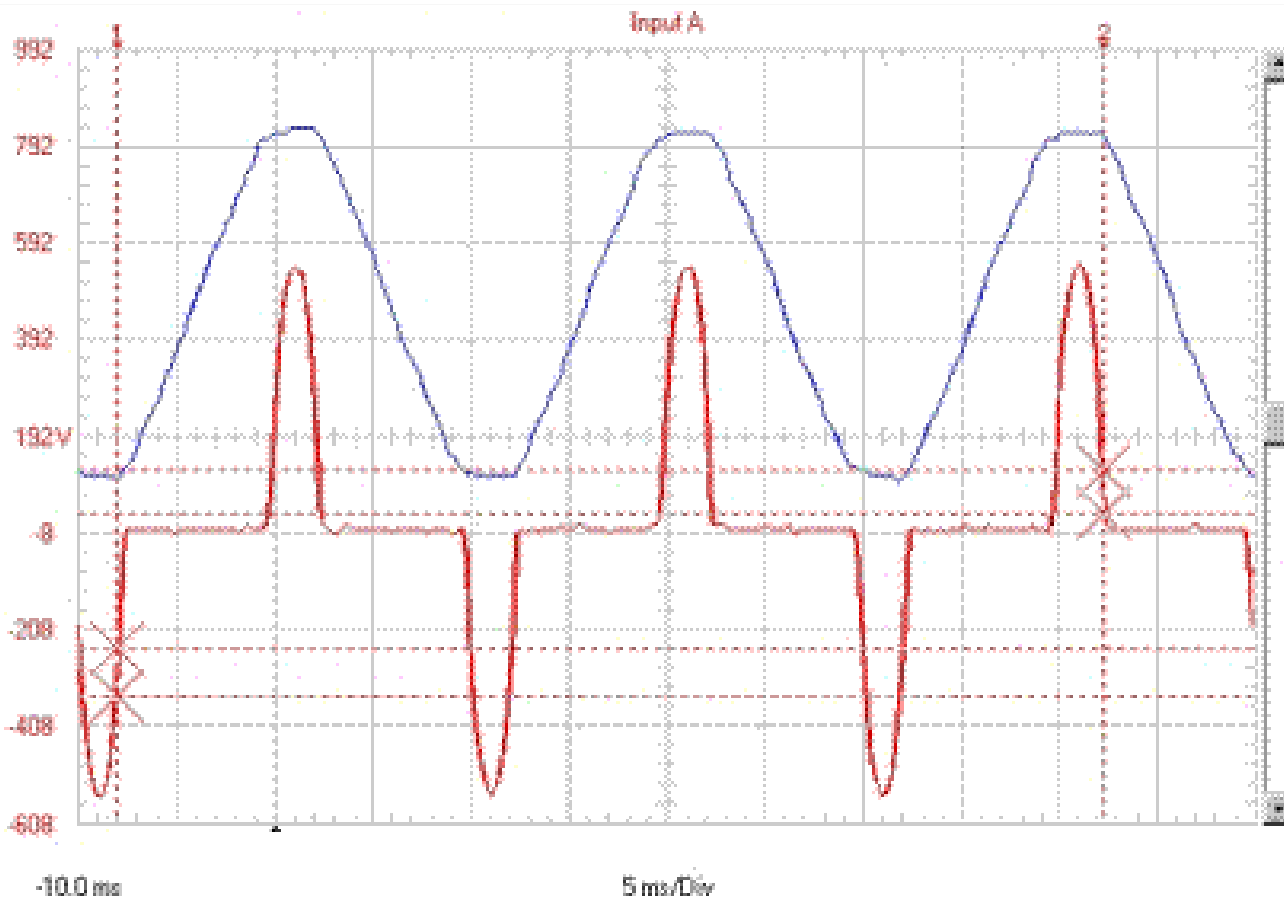
A Variable Speed Drive (VSD) comprises three main components:-

- ❑ A RECTIFIER to convert the mains supply into DC
- ❑ The DC LINK incorporating chokes and capacitors for maintaining a steady DC voltage
- ❑ An OUTPUT STAGE using Insulated Gate Bipolar Transistors (IGBT's) for generating a 3-phase, variable frequency output to control the motor



Simplified diagram showing the pulse width modulated output from an inverter drive.



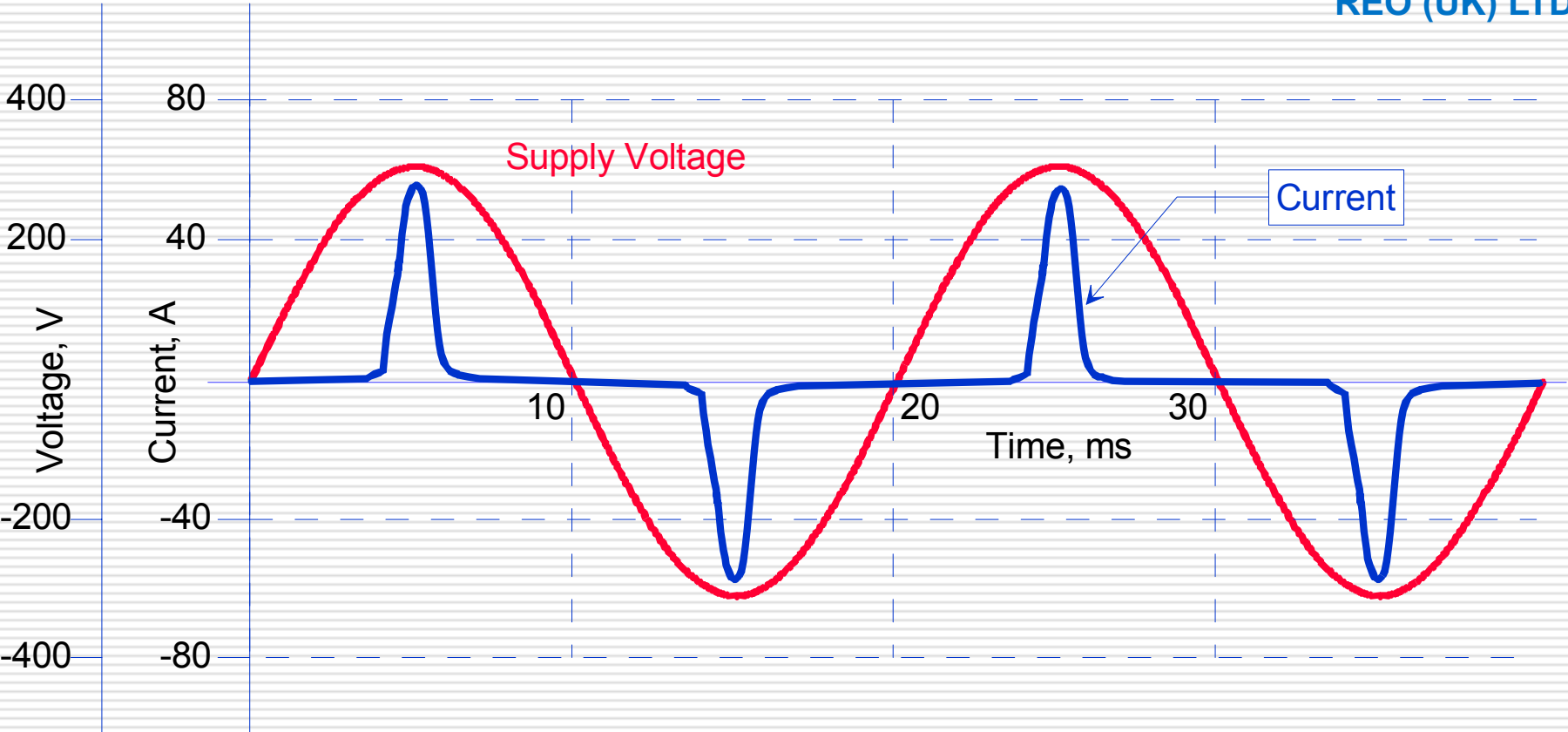


Datablock:

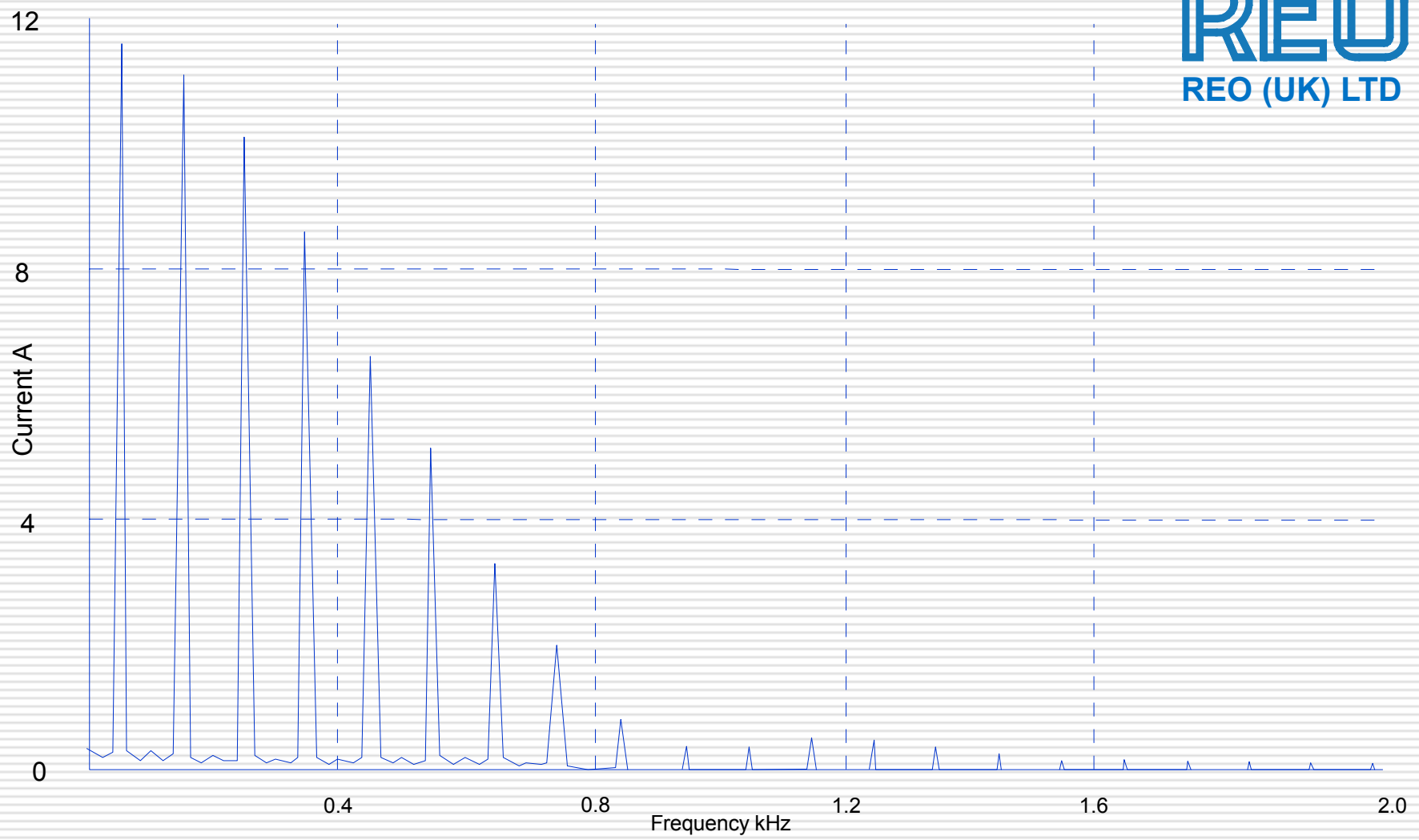
Name	Input A	Input B
Date	27/09/2002	27/09/2002
Time	00:56:54	00:56:54
Y Scale	200 V/Div	10 V/Div
Y At 50%	192 V	-13.6 V
X Scale	5 ms/Div	5 ms/Div
X At 0%	-10.0 ms	-10.0 ms
X Size	300 (300)	300 (300)
Maximum	552 V	18.4 V
Minimum	-552 V	-18.4 V

Cursor Values:

X1:	-8.0 ms
X2:	42.2 ms
dX:	50.2 ms
Y1:	-344 -248 V
Y2:	32 120 V
dY:	376 368 V



Typical input current waveform for a 1.5 kW PWM drive



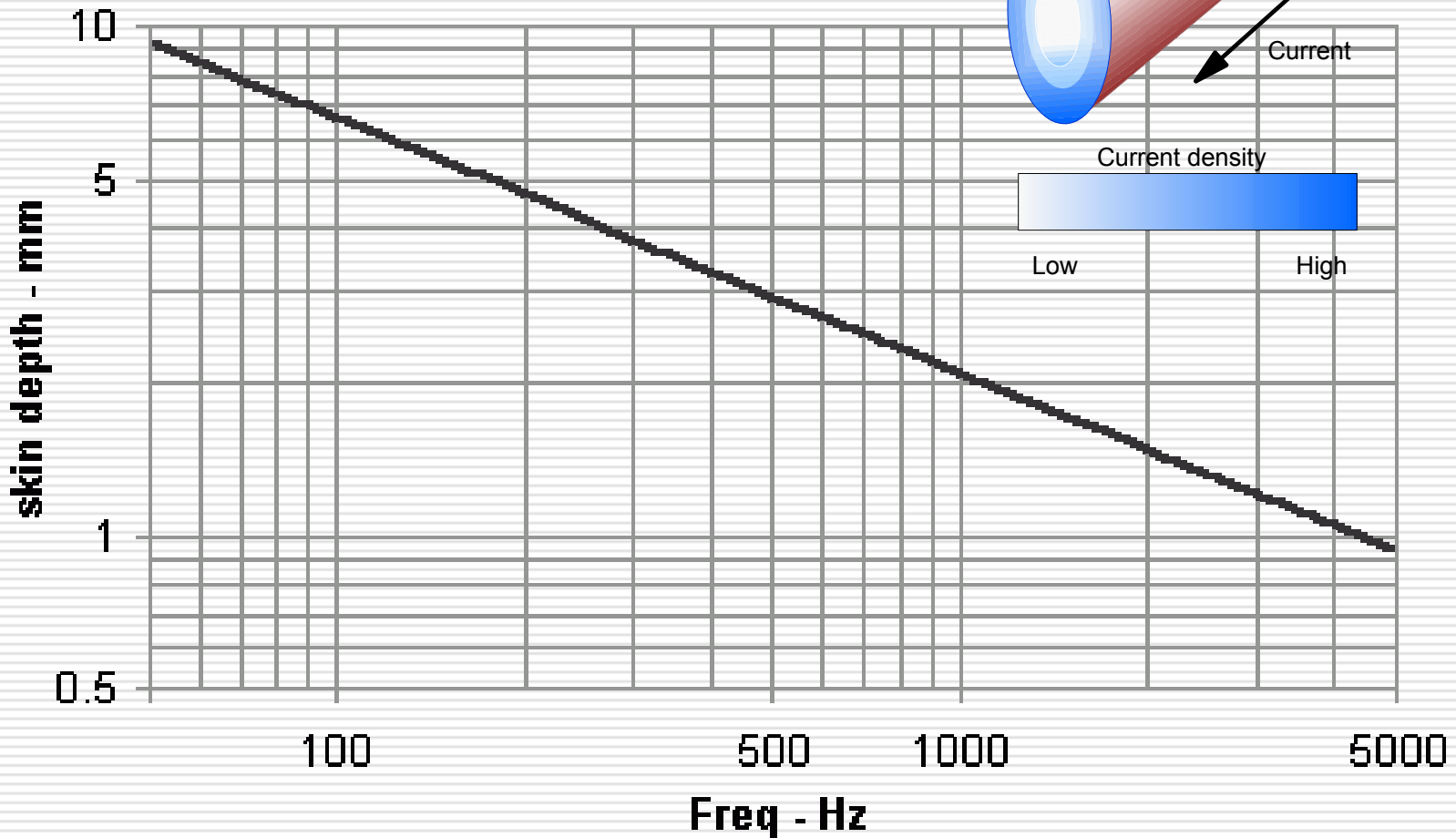
Spectrum showing harmonic content of current waveform for 1.5kW PWM drive

Harmonics can cause:-

- ❑ High neutral currents i.e can be $1.7 \times$ phase current when there are a lot of single phase loads because triplens are additive
- ❑ Problems with half-size neutrals in older buildings
- ❑ Nuisance tripping
- ❑ Overheating and fire hazards
- ❑ Overheating of Power Factor Correction Capacitors
- ❑ Extra losses in transformers
- ❑ Losses in power cables (skin effect)

The formula for the depth of skin effect in copper is:-

$$\text{Depth (mm)} = \frac{66.04}{\sqrt{f}}$$



Standards and Recommendations

- ❑ EN 61000-3-2
 - Up to 16A/phase
 - For Lighting Equipment > 25 W
 - For Other Equipment > 75 W

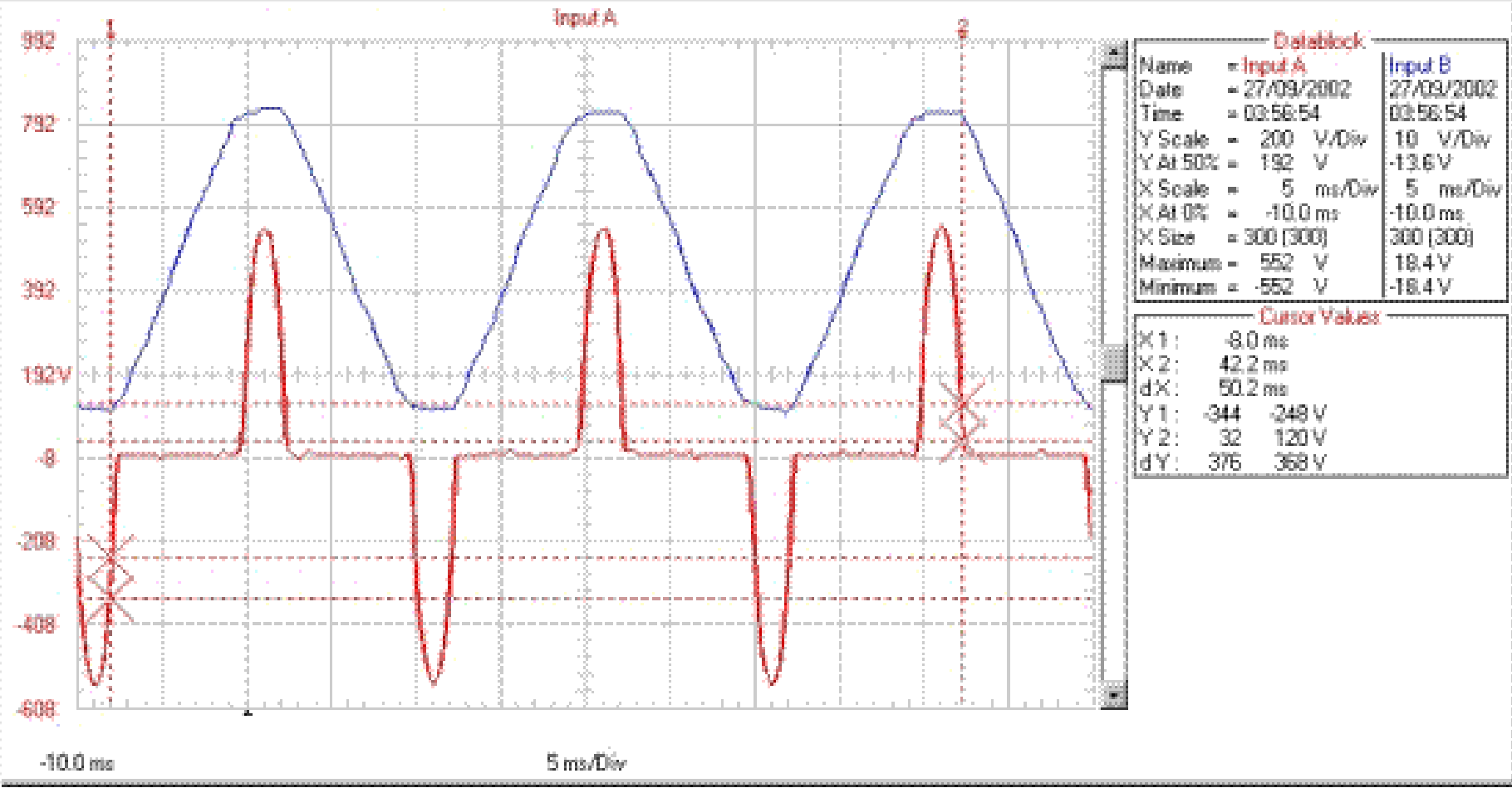
- ❑ G5/4 Recommendations

Harmonic distortion reduction techniques (medium power range)

- Line reactors or DC link reactors
- Star/Delta 12 pulse systems
- Active PFC
- PWM control of power transistors instead of using rectifiers
- Transformers with a high leakage inductance
- UPS that doesn't generate harmonics
- Dedicated LV transformer



The effect of adding a 4% line reactor

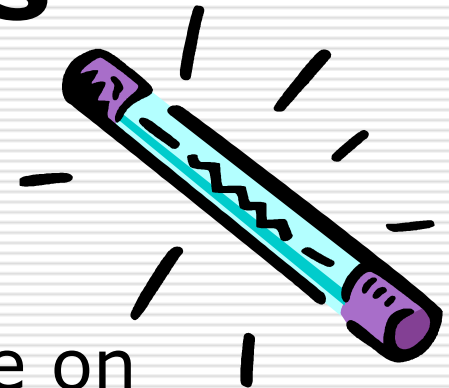


Voltage variations

Dips, dropouts and interruptions (short duration of less than 1 min)

These are caused by:-

- ❑ Load switching and fault clearance on the mains network
- ❑ Switching to emergency power supplies such as a UPS
- ❑ Starting of large loads (motors can draw up to six times their full load current))

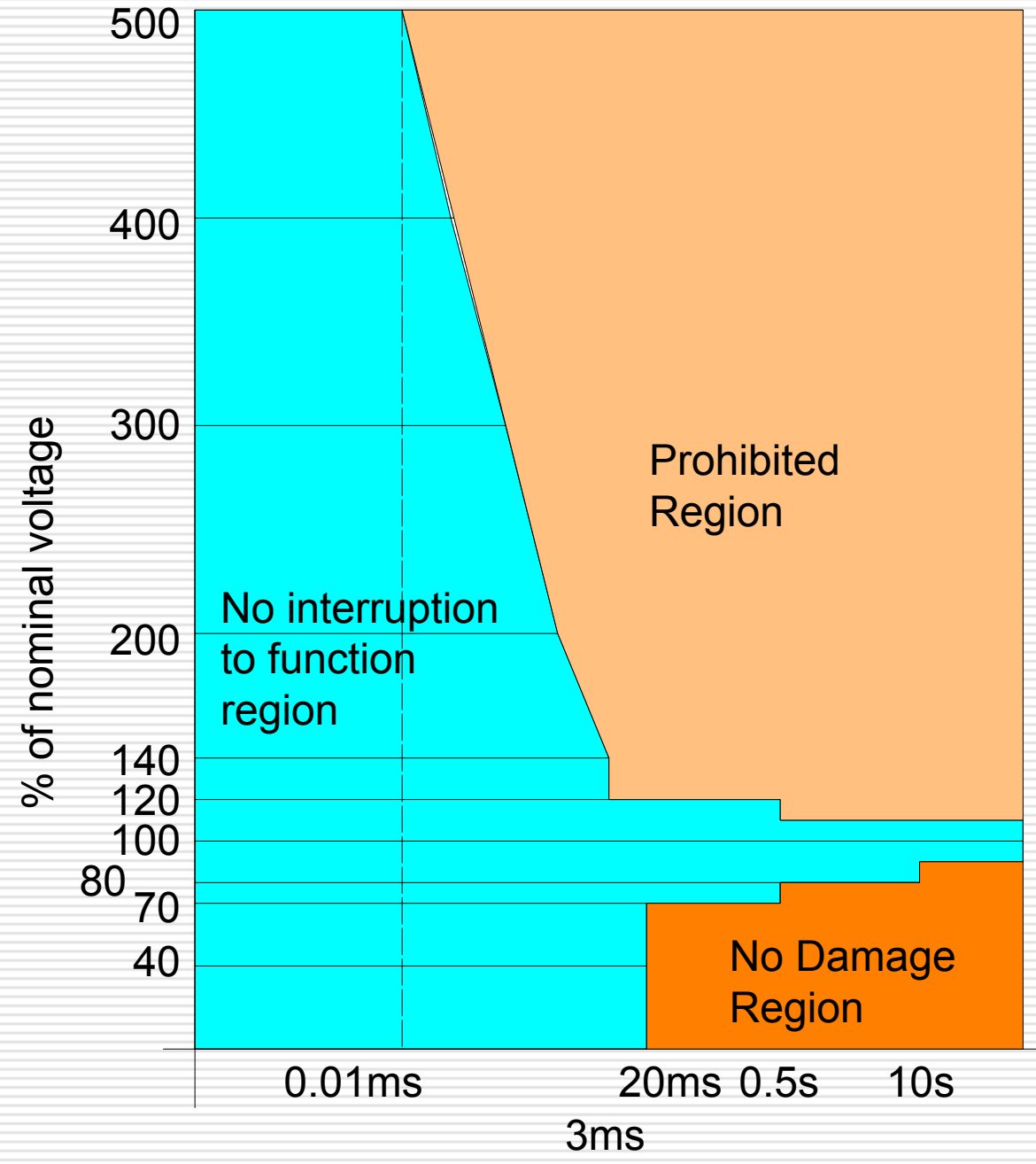


Dips, dropouts and interruptions can cause:-

- ❑ Domestic timers to stop
- ❑ Electromechanical devices, relays, contactors and solenoids to malfunction
- ❑ Protective circuits to close down
- ❑ Data loss on IT equipment

CBEMA Curve

Reproduced with permission from the Information Technology Industry Council (ITI)



Number of disturbances per annum caused by faults or switching operations in the public supply systems

(Source: International Union of Producers and Distributors of Electrical Energy (UNIPEDE): 1991, No. 50.02.)

Depth %	Duration			
	10 ms to <100 ms	100 ms to <500 ms	500 ms to <1s	1s to < 3s
10 to < 30	61	66	12	6
30 to < 60	8	36	4	1
60 to < 100	2	17	3	2
100	0	12	24	5

BS EN 50160:2000 Voltage characteristics of electricity supplied by public distribution systems - permits

- ❑ Short term dips under 85% and less than 1 minute = 10 to 1000 times/year
- ❑ Interruptions under 1% and longer than 3 minutes = 10 to 50 times/year
- ❑ Transients up to 6 kV Line to Earth

swells

Not so common but can be caused by:-

- ❑ Temporary voltage rise on non-faulty phases during a single line-to-ground fault
- ❑ Energising of a large capacitor bank

Over and under voltages (long duration)

- ❑ Can affect the performance of equipment
- ❑ Relays and contacts can drop-out
- ❑ Equipment can shut-down for protection
e.g drives
- ❑ Can shorten the life of electrical goods
- ❑ More critical where supplies are less reliable
or in remote areas.

Solutions for voltage variation problems

- ❑ Voltage stabilisers
- ❑ Constant voltage transformers
- ❑ Uninterruptible Power Supplies
- ❑ Multi-tapped transformers
- ❑ Switch-mode power supplies use their mark-space ratio to hold up the voltage but draw more current.

Blackout

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Last Updated: Saturday, 18 October, 2003, 09:32 GMT 10:32 UK

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Trains back after power surge

Rail services in the West Midlands are returning to normal after a power surge caused chaos for passengers at Birmingham New Street station.



The incident caused disruption to commuters.

Passengers faced major delays for several hours after the surge caused a power failure and disrupted signals just after 1330 BST on Friday.

Thousands of homes were briefly affected and some city centre shops had to move customers out when their lights failed.

An investigation has been launched into the incident.

A Network Rail spokeswoman said on Friday: "It affected the whole of Birmingham. Shops like Rackhams had to throw everyone out because they had no lights.

"There was a fluctuation that knocked out quite a lot of our equipment including the signalling which is the most important aspect.

WATCH AND LISTEN
The BBC's Peter Lane reports from Birmingham
"It hasn't been a good day for passengers"
▶ VIDEO

BBC Birmingham
Travel, sport, webcams and more from the BBC website for Birmingham

BBC Travel News
Updated traffic and travel information, around the clock, around the country

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Last Updated: Saturday, 16 August, 2003, 00:08 GMT 01:08 UK

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Firms struggle to resume business

Financial markets have recovered quickly from the effects of widespread power blackouts in the US and Canada, but transport problems still hit factories and offices.



The daily commute proved tricky

Many companies have been disrupted, especially in the vulnerable aviation sector.

Airlines have cancelled hundreds of flights and analysts say this may cost the industry tens of millions of dollars.

The New York Stock Exchange opened as usual on Friday, although trading was light as many people struggled to get into work.

In New York, Mayor Michael Bloomberg urged non-essential workers to take the day off, warning that the subway system

WATCH AND LISTEN

The BBC's John Terrett

"In the business and financial hub of the United States people have been jumpy ever since 9/11"



NORTH AMERICA BLACKOUT

KEY STORIES

- Blackout 'originated in Ohio'
- Bush urges US grid upgrade
- Firms struggle to resume business
- Net survives power outage

EYEWITNESS REPORTS



Homeward struggle

A young British intern describes her experiences in New York's blackout

- Toronto's novel ways to cope
- Initial fears of terror in New York

Stand-by power

- Uninterruptible Power Supplies
- Flywheel Generators
- Fuel Cells
- Diesel Generators

In conclusion

- ❑ If you design electrical equipment it is not adequate to rely purely on standards
- ❑ It is very likely that power quality (reliability) will worsen
- ❑ The authorities will continue to tighten-up on voltage distortion limits
- ❑ There are many power quality issues that engineers may not be aware of

Examples of items that are susceptible to external magnetic fields

Cardiac pacemakers, medical monitors, etc using CRT display



PC monitors (including CRT type and PC monitors using PC floppy disc drives)



Handy cell telephones in airports



Video & tape recorders and players



Loudspeakers

At the time of writing, the EMC Directives generic and product-family immunity standards that call up EN 61000-4-8 only apply to products that contain magnetically sensitive components, such as cathode-ray

tubes (CRTs, e.g. computer monitors, TVs), electron-multipplier tubes, moving-coil microphones, microphone transformers, half-etched sensors, magnetic recording/playback, loudspeakers and the like.

But it is not only magnetically sensitive parts which can suffer interference from power-frequency magnetic fields. All signal current loop inductors, and these loops enclose an area which will pick up magnetic fields in their environment to create interfering voltage.

An important example concerns printed circuit board (PCB) layouts. For example, if the current path of a weaker signal enclosed a loop area of 10cm² (e.g. a square 10cm on one side) exposure to a 50Hz magnetic field will add a noise voltage to the wanted signal which is enough to prevent recovery.

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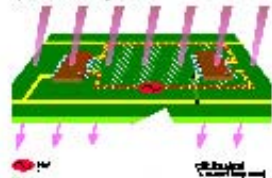
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Diagram illustrating magnetic field interference on a PCB layout



Statements about both of these are required on the Declaration of Conformity which is signed by a company's Technical Director (or someone with similar authority).

The EMC conformity assessment is usually achieved by applying all of the relevant standards listed under the EMC Directive. A listing under the EMC Directive means that complying with that standard provides a presumption of conformity for the EMC issues it covers.

But a presumption of conformity is only a presumption and not a guarantee of conformity. The EMC Protection Requirements require that a product does not cause or suffer from unacceptable interference when used in its intended environment. EMC standards only cover a limited range of interference types and typical environments, and some of the standards are well-known to be inadequate for the modern environment, so there is always the possibility that simply meeting all the relevant standards will not create a compliant product. This issue is specifically recognized in the upcoming 2nd Edition of the EMC Directive, which will require manufacturers to perform an EMC risk assessment to determine what EMC standards are relevant for each of their products.

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