Power Quality what is it?

In Europe at least, single phase power is nominally 230V, having changed from the 240V system in January 2003. The applicable harmonised standard is EN 50160:2000. Power standards in the UK are defined by OFGEM the electricity regulator. See: http://www.ofgem.gov.uk/ofgem/shared/template2.jsp?id=1274

However, if you read the fine print you will discover that the 240V system was ± 6% while the 230V system is ±10% for 95% of the time (- 15% allowed at other times). In other words, we now have a lower quality of supply than we had before.

We also tend to assume that being an industrialised country our power generation and grid is delivering what we as consumers would call "quality" power. However a brief look at OFGEM's 2003 annual report shows that, not only is the power supply network filled with problems, but an ever more demanding customer base and intense price competition are actually making the problem worse. So what does OFGEM regard as unacceptable power quality?

When is a power cut a Power Cut?

The most obvious form of disruption is of course loss of power. According to the report there were 12 loss of supply incidents in the year (April 2002 - March 2003) the highest recorded number since 1998. That may seem like fantastic news, but these statistics ONLY apply to faulty equipment in the National Grid itself, human error or "protective" disconnection is not considered to be the fault of the Grid and is unmeasured. However it does include storm related damage which was responsible for 5 of the 12 incidents.

Also from the report there were "no reportable voltage or frequency excursions". Again this sounds remarkable, however to be reportable a "voltage excursion" has to be greater than 6% (BEYOND ±10%) and be continuous for 15 minutes. In other words 400V is fine as long as it lasts less than a quarter of an hour, but even 267V would have to be continuous and recorded to be an "excursion".

Frequency excursions are extremely rare in a system as large as the National Grid mostly because of the number of sources and their inherent slow speed of frequency change. Frequency in the UK is nominally 50Hz ±1% and almost always better.

We are left therefore with no suitably independent definition of a power problem or of "quality power."

When Problems Occur

Of course when problems do occur you can claim compensation from your supplier, but do you realise how little this compensation is?

Private Consumers can claim £100 if a power cut lasts more than **18 hours**, or £50 for 4 or more cuts each longer than 3 hours in a 12 month period. Furthermore the supplier can claim exemption for "extreme weather", even from the 18 hour rule, by demonstrating to OFGEM that "everything reasonable was done."

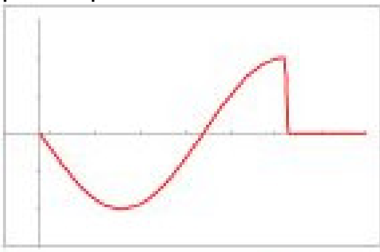
Although some large commercial contracts negotiated directly with the supplier call for other forms of compensation, if a company doesn't have a specific contract, the above rules are applied.

In over 20 years of Power Quality consulting and manufacturing, Advance has never known of a successful claim against the supplier on "unacceptable power quality". Therefore, the clear message is "Protect Your Own".

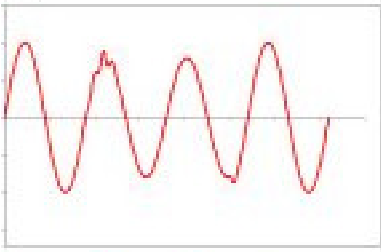
Advance defines Power Quality

Over the years this question has led Advance to define every different power problem.

- Power Cut / Black out / Loss of Supply / Supply Interruption
  Complete loss of power (voltage less than 1% of nominal) i.e. no current flowing for greater than 20ms. Power cuts can be prearranged or accidental. “Long” cuts are more than 3 minutes, and EN 50160 “expects” up to 50 annually depending on area

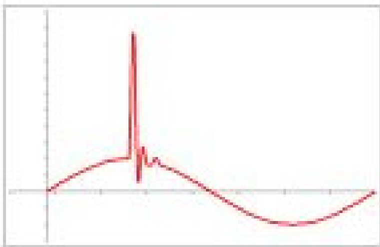


- Power Sag / Brown out / Supply fade / Voltage Dip
  A reduction in voltage greater than 10% for longer than 10ms. According to EN 50160, dips last between 10ms and 1 minute. However Advance’s experience is that a dip can be hours in duration, e.g. during a substation fault



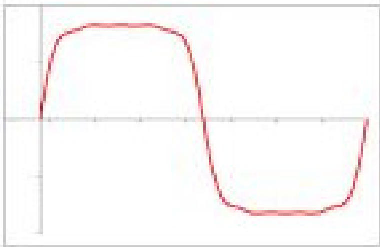
- Power Swell / Supply Surge
  An increase in supply voltage greater than 15% for longer than 100ms. Shorter version shown

- Transient / Spike / Impulse
  A sharp increase in supply voltage (high dv/dt) with an amplitude greater than 50% of nominal supply. Frequently followed by a decaying oscillation. Spike induced by photocopier shown

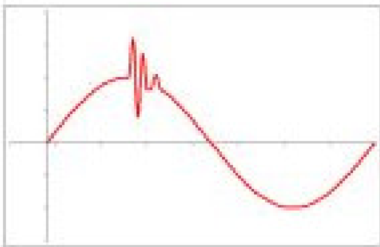


- Lightning Transient / E M P
  A series of high energy repetitive spikes with an interval between spikes less than twice their duration. Spike from local area ground strike shown

- Harmonics / Waveform Distortion
  A voltage variation from the ideal sine wave caused by harmonics of the prime frequency. (150Hz superimposed on 50Hz is third harmonic - illustration from rail site with THD 20%) EN 50160 quotes a Total Harmonic Distortion (THD) of less than 8%. Most Harmonics are internally generated rather than supply borne.



- Normal mode Noise / Radio Frequency Interference (RFI)
  A variation of the waveform caused by a superimposed frequency that is non-harmonic. Frequently this waveform decays or rings. Fluorescent tube switch-on shown



- Common mode Noise / Radio Frequency Interference (RFI)
  As normal mode noise, but where the return or source path is the earth conductor.

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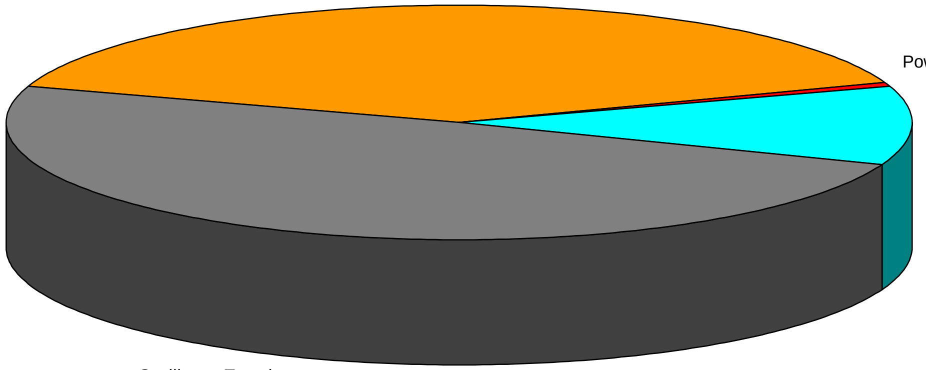
These definitions are further confused by the fact that they normally occur in groups, often with one disturbance cascading several others. In addition, natural impedances and inductances in the supply wiring and equipment cause ringing or "echoes" of a power problem, further confusing the demarcation.

Three phase power can also suffer from unbalance (rms values of phases more than 5% different and/or phase angles not equal)

Quality Power can be defined as Power without any of these defects.

How common are the problems

Figure 1 Allen & Segall "Monitoring of Computer Installations for Power Line Distrurbances"



There are lies damn lies and statistics. However, several major studies have been carried out to record the types of disturbance and their frequency.

George W Allen and Donald Segall of IBM System Development Division conducted one of the most respected studies and, although based in the USA in 1974, their report is still quoted today. They monitored AC power to IBM equipment at 200 locations in 25 cities across the United States, and recorded the various AC power anomalies that disrupted the equipment operation during a two-year time span.

In other words their criterion for quality power was whether IBM equipment was disrupted.

In 1974 most ICT equipment used linear power supplies which are largely unaffected by small transients and completely immune to most forms of noise. Today most ICT equipment uses switch mode power supplies whose susceptibility to transients and common mode noise is far greater.

The Allen-Segall study concluded that 88.5% of AC power problems were transient related.

Allen and Segall found that the most disruptive (49%) of power problems stemmed from oscillatory, decaying transients. These are examples of long duration, non-lightning related, transients. Lightning induced voltage spikes or impulse transients were the next most frequent, representing 39.5% of the total number of AC power problems.

Although the USA has a higher incidence of lightning than in the UK, we are still subjected to an average of 0.3-1 lightning strikes per square kilometre per year

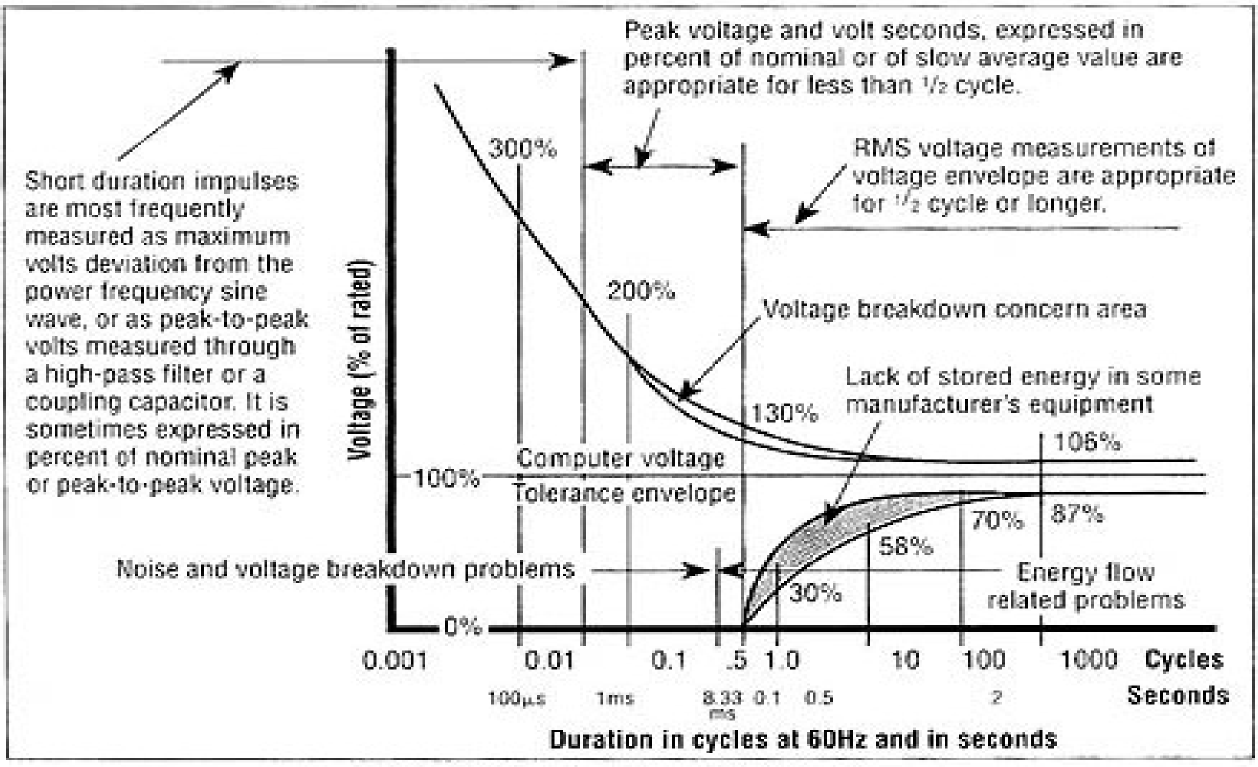
See:http://www.met-office.gov.uk/climate/uk/averages/lightning.html

In contrast, power outages accounted for only 0.5% of equipment disruptions, whereas sags and swells were responsible for 11% of AC power problems.

Electrical distribution systems have not changed significantly from the mid-seventies while electrical and electronic equipment has become much more sophisticated. Now, although power outages are becoming more infrequent, harmonic distortion has become a major concern for equipment users. Transient activity has also become increasingly more threatening to modern state of the art electrical and electronic load devices.

Other studies include:
M Goldstein and P Speranza "The Quality of US Commercial AC power" 1982, which records nearly double the frequency of disturbances at Bell Telephone sites.

TS Key "Diagnosing Power Quality-related Computer Problems", which leads to the development of the CBEMA curve detailing recommended immunities for a computer power supply.



The CBEMA Curve from FIPS No. 94.

What are the symptoms of these Power Problems?

Power Problem		Incandescent Light Bulb	Fluorescent tube	Switch Mode Power Supply (SMPS) - the usual power supply in PCs, Servers and telephone switches	Hard disk (Main storage medium in PCs and Servers)	PC / Server memory	Network infrastructure (PC Network Cards, Hubs, Routers, Switches etc)
Noise	Common Mode Noise	N/A	N/A	Short life	Occasional data errors or in extreme cases disk failures (more common in RAID arrays - Disk 0)	N/A	Communication errors, occasional data errors or in extreme cases hub failures
	Normal Mode Noise	"flicker", filament burn outs, shorter life	some flicker	design dependant in extreme cases mystery resets	Data errors, bad sectors	design dependant in extreme cases mystery resets	SMPS dependant in extreme cases mystery resets
Transient	Small Spike	filament burn outs	Capacitor failure	design dependant in extreme cases mystery resets	Data errors, bad sectors	Memory failures	Data errors, communication errors
	Large Spike / EMP	Filament "pops"	Tube burns out with distinctive corona at one end	SMPS failure	Disk corruption or failure, usually unrecoverable	Mainboard flashover, memory failure	Flashover failures
Harmonics	Small <8% THD	N/A	N/A	SMPS overheating	N/A	N/A	N/A
	Larger THD	Shorter life due to thermal "ageing"	Shorter life of capacitor and tube	SMPS failure	N/A	N/A	N/A
Voltage Variation	Brownouts / Dips	reduction in brightness	possible switch off depending on levels	Reset / switch off	Data errors disk corruptions	Reset / switch off data errors	Reset / switch off data errors
	Surge / Swell	increase in brightness filament burn outs	occasional tube burn outs	SMPS failure / overheating failures	Disk motor failure	Reset / switch off data errors	Reset / switch off data errors
	Blackouts / Power Cuts	No light!	No light!	Short life	Incorrect shutdowns lead to corrupted files or even unbootable operating systems	Memory failures	Data error / loss reboot times

What Protection is available?

ADVANCE	TDA, TSB, TDC	AIT	AGT / ATS	Elite
Power Solution	Transient Voltage Suppression System (TVSS)	Ultra Isolation Transformer	Constant Voltage Transformer (CVT)	Uninterruptible Power Supply (UPS)
Common Mode Noise	-	✓	✓	✗[1]
Normal Mode Noise	-	✓	✓	✓[2]
Small Spike	✓	✓	✓	✓
Large Spike / EMP	✓	✓[3]	✓	-
Small Harmonics <8% THD	-	-	✓	✓
Larger Harmonics	-	-	✓	✓[4]
Brownouts / Dips	-	-	✓	✓
Surge / Swell	✓[5]	✓[6]	✓	✓[7]
Blackouts / Power Cuts	-	-	✓[8]	✓

Adapted from a similar table in IEEE std 1100:1992

[1] UPS are frequently a source of common mode noise due to their output filters. For a true noise free UPS fit an AIT to the output
[2] UPS contain output filtering to reduce normal mode noise. For zero noise fit a CVT to the output
[3] AIT's will attenuate a large spike or EMP by approx 10,000:1
[4] Elite UPS recreate the sine wave but are susceptible to large amounts of harmonic on the input, to protect the UPS fit a CVT
[5] TVSS will clamp a surge above their clamping voltage but will not correct long term swells
[6] AIT's will attenuate a rising surge but not correct the over voltage
[7] Elite UPS will correct a swell but are susceptible to surges to protect the UPS fit TVSS/CVT
[8] Single phase CVTs will bridge short power cuts up to 100ms. The ATS three phase input CVT is unaffected by single phase failures

Transients and EMP

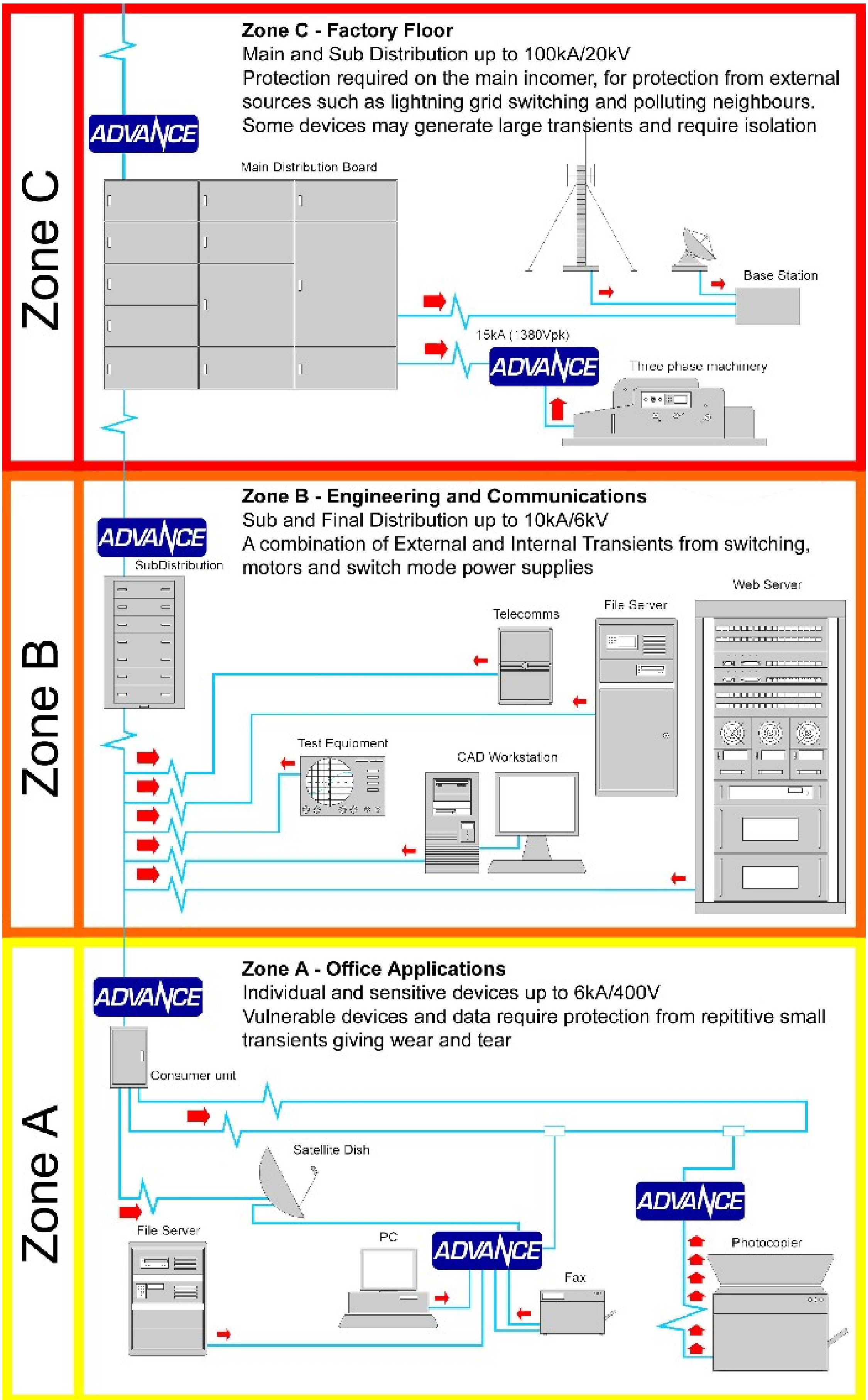
The IEEE Emerald Book recommends applying surge protection devices in a cascaded or two stage approach – at the service entrance and then downstream at the panel boards and critical loads. This comprehensive installation creates an effective shield from high-energy transients.

The IEEE Emerald Book recommends the use of surge protection devices as a part of a building's transient protection system. Because the service entrance device can only reduce and not completely eliminate the high-energy transient, a second device must be applied to protect critical equipment.

The Zone Approach

By placing a surge protection device (SPD) at the service entrance or main incomer (Zone C http://www.strikesafe.co.uk/htm/tdc.htm) and branch panel boards that feed external equipment like HVAC units, the building has an effective shield from high energy transients trying to make their way in from the outside. A second layer of SPDs sited at key branch locations (Zone B http://www.strikesafe.co.uk/htm/tsb.htm) provides effective protection against internally generated disturbances, which are prevented from feeding back within the electrical system. The bi-directional nature of parallel SPDs allows one unit mounted at the panel board to protect all circuits within the panel board – a very cost-effective application.

Finally, point-of-use series suppressors are placed at critical loads and delicate equipment (Zone A http://www.strikesafe.co.uk/htm/tda.htm) like the fire alarm system, security systems, and in computer rooms.



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