INTEGRAL energy

Power Quality Centre

University of Wollongong

Technical Note No. 1 **June 1998**

UNDERSTANDING POWER QUALITY

This Technical Note describes the range of power quality problems, what causes them, what they affect and what could be done to manage them. Integral Energy, your local Network Operator or the Integral Energy Power Quality Centre can give you advice if you have particular concerns with these issues.

Summary

The ideal power supply to a low voltage customer is 240/415V at 50 Hz with a sinusoidal waveshape. Integral Energy or your local Network Operator cannot keep the supply exactly at the ideal due to a range of disturbances outside its control and attempts to maintain its voltage within specified ranges. Power quality problems arise when these ranges are exceeded and this can occur in three ways:

1. Frequency events: change of the supply frequency outside of the normal range
2. Voltage events: change of the voltage amplitude outside its normal range; this can occur for very short periods or be sustained
3. Waveform events: distortion of the voltage waveform outside the normal range.

Actual voltage varies from the normal range because of disturbances on the supply system, within customer's plant and/or within nearby plants. These disturbances can:

1. damage sensitive data processing, control and instrumentation equipment
2. interrupt supply
3. trip out variable speed drives
4. cause data processing, control and instrumentation equipment to malfunction
5. cause capacitors, transformers and induction motors to overheat
6. cause annoying light flicker.

Your local Network Operator has the responsibility of keeping the power supply voltage within specified limits. Customers have two responsibilities:

1. To ensure that their equipment is able to tolerate the normal range of supply disturbances
2. To ensure that their equipment does not cause disturbances which will propagate into the supply system at an excessive level.

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1. Introduction

Power quality problems evidence themselves in a variety of ways such as:

(i) computer shut down, malfunctions or errors
(ii) PLC (programmable logic controller) malfunction or errors
(iii) variable speed drives tripping out
(iv) racing or blinking digital clocks.

These can give problems ranging from inconvenience to loss of manufacturing capability with substantial loss in income. Why are these problems increasing? Who is responsible? What can be done to minimise their effects within your plant?

We will first consider the ideal power supply, then what prevents this ideal state from being reached and how it affects your equipment.

Electric power can be received at low voltage (240/415 V) or medium voltage (1 kV to 35 kV), one phase or three phase, but the power quality problems are similar in all these cases. To keep the discussion focussed, we shall consider a three phase 415 V system. This is provided by four wires, three of which have significant voltage and are called a, b, and c. The fourth has an ideally zero voltage and is called the neutral, symbol n. The Network Operator provides a voltage at 50 Hz frequency. Your equipment draws current depending on its rating (see text in box on next page). For example a 415 V, 7.5 kW induction motor requires 415 V between each of the three active conductors at a frequency of 50 Hz (cycles per second). It draws a current which depends on how much power it has to supply at the shaft, usually about 14 A at full load. The voltage is not constant as is the DC voltage of a battery. It is AC, that is it pulsates at a frequency of 50 Hz (cycles per second). If a graph was drawn of the shape of the voltage waveform versus time, it would be seen to be sinusoidal as shown in Figure 1.

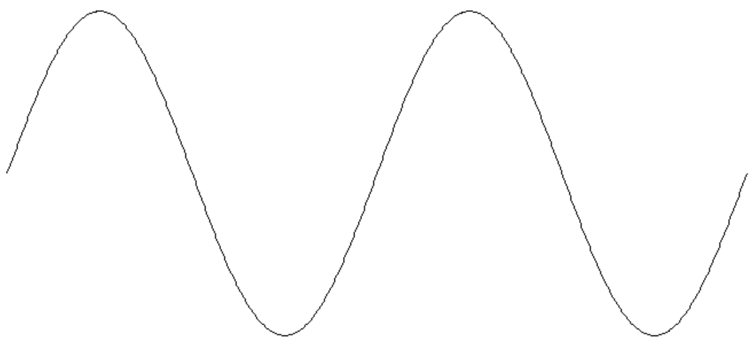

Figure 1. The ideal mains voltage waveform

The reasons for the choice of a sinusoidal voltage at 50Hz are:

1. It is the only shape which can be reasonably guaranteed to stay unchanged from the power station generator to the customer load, provided customer loads are non-distorting (heaters, induction motors, incandescent lights).

2. It minimises the losses in the transmission and distribution system, and in customer equipment.

3. It minimises the risk of introducing an interference voltage in nearby telecommunications equipment.

Power is roughly proportional to voltage times current.

Current causes heating of electrical equipment and degradation of the insulation system.

2. Types of power quality disturbances

There are three general types of power quality disturbances.

2.1 Frequency events

The frequency of the power system is established by the rotational speed of the power station generators. It is very rare that this frequency is varied significantly and consequently this type of event will not be considered further in this technical note.

2.2 Voltage events

If the supply voltage became much higher than 415 V (overvoltage) then the motor insulation would become overstressed and the motor would suffer loss of life. Normally 20 years of service can be expected from an induction motor. If the voltage became much lower than 415 V (undervoltage) then the motor would draw more current in an attempt to take the same power from the supply as for the normal voltage (415 V). This would increase the motor temperature and lead to loss of service life.

The voltage is normally held in the range ±6% at the customer's point of connection.

Voltage variations can be divided into several categories:

a) Long term variations lasting more than 1 minute. These are called undervoltages (if less than 90% of nominal voltage) or overvoltages (if greater than 110% of nominal voltage).
b) Short term variations of duration less than 1 minute. These are called sags (voltage between 10% and 90% of nominal) or swells (voltage greater than 110% of nominal). These are illustrated in Figure 2.

c) Voltage unbalance where the voltage on each phase conductor is different (also shown in Figure 2).
d) Continuous or random fluctuations that are observed as light flicker (see Figure 3).
e) Interruptions where supply is lost completely.
f) Neutral-ground voltage rises that are usually associated with poor grounding/earthing practices.

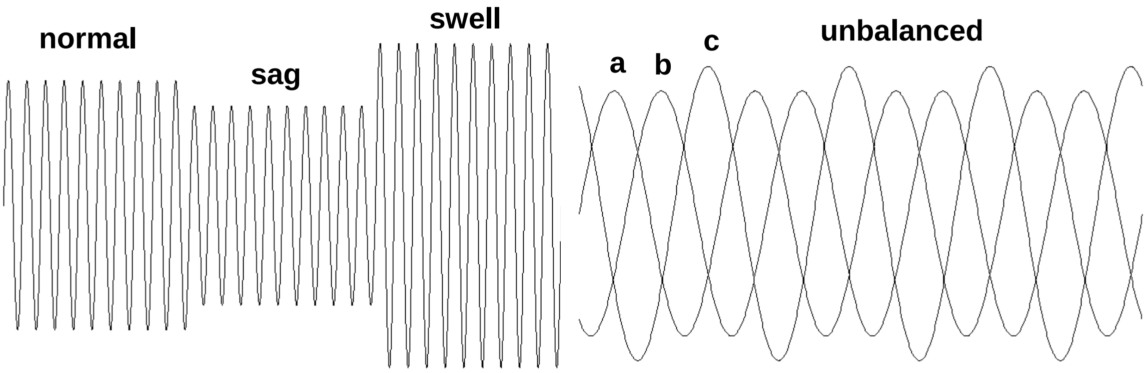

Figure 2. Voltage sags, swells and unbalance.

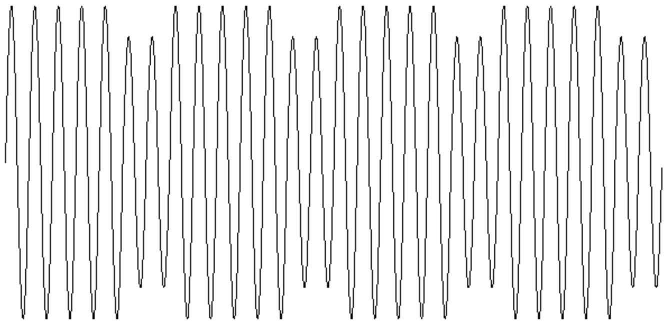

Figure 3. Voltage fluctuations.

2.3 Waveform events

These events result in distortion of the normal sinusoidal waveshape of the mains voltage. Several categories of waveform events can be identified:

a) Harmonics are additional frequencies present in the mains voltage or current that are integral multiples of the mains frequency. Their effect can be seen in Figure 4. Each cycle is distorted but identical.
b) Interharmonics are additional frequencies that are non-integral multiples of the mains frequency, also shown in Figure 4. Neighbouring cycles are not identical.
c) Notching results from the normal operation of 3-phase electronic switching devices such as AC to DC converters. This is illustrated in Figure 5 and is present on many consecutive cycles.
d) Transients are generally large, short duration voltage changes usually resulting from lightning strikes or switching operations on the network. They last for less than one half cycle of the mains voltage as shown in Figure 6.
e) Noise is a disturbance with a broad frequency distribution up to about 200,000 Hz. Its effect on the voltage is illustrated in Figure 7.

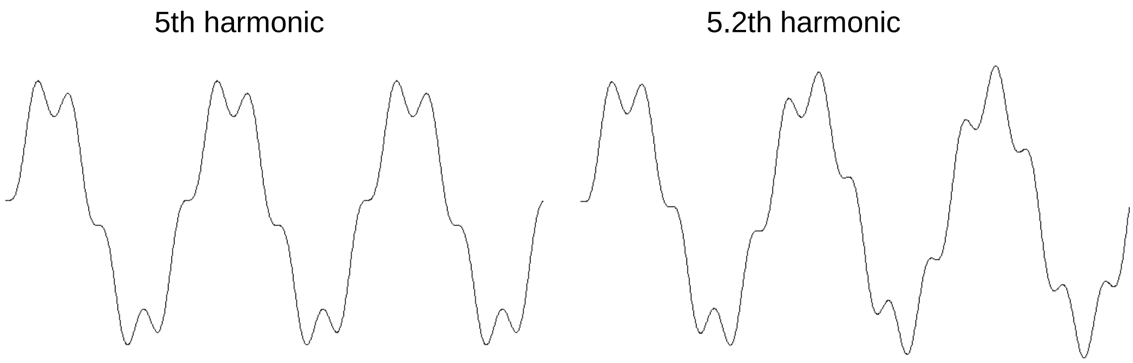

Figure 4. Harmonic distortion.

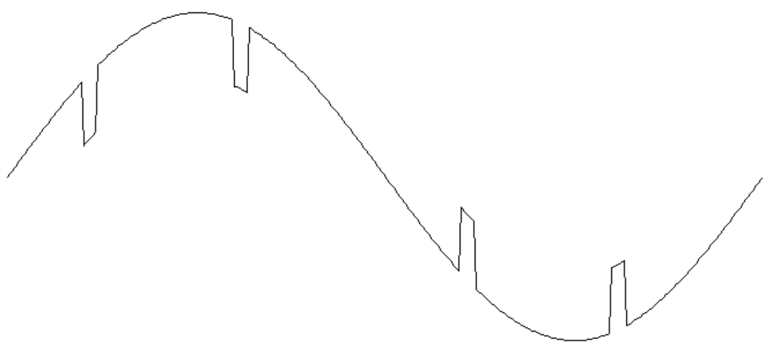

Figure 5. Notching.

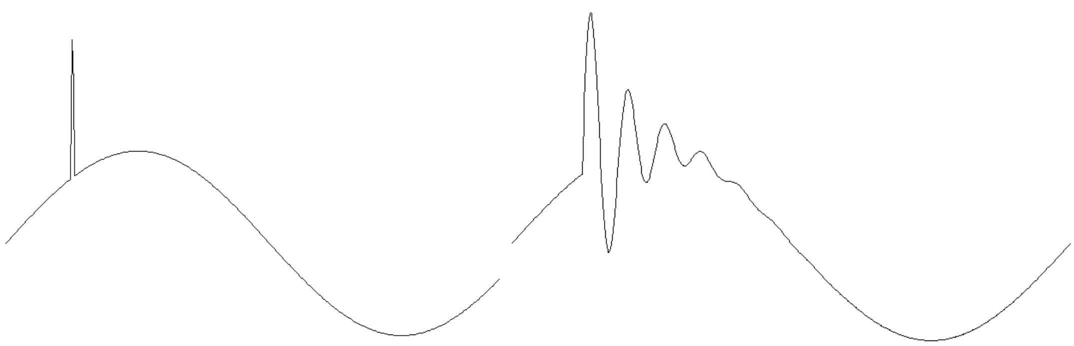

Figure 6. Typical transients from lightning (left) and system switching (right).

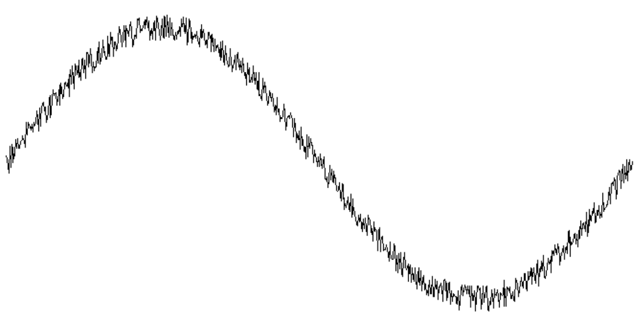

Figure 7. Noise.

3. Causes of power quality problems

Power quality problems can originate in:

1. The supply system.
2. The customer's plant.
3. A neighbouring installation and propagate via the supply.

The electricity supply system is an electric circuit that is spread over the countryside and is vulnerable to all sorts of natural hazards. This includes lightning strikes, faults caused by animals, cars, and the breakdown of equipment. High reliability is achieved by the provision of overhead earth wires to reduce lightning strikes and sensitive protection equipment that detects faults and rapidly switches out the affected part. In many cases this action is sufficient to remove the fault and bring the supply back to normal within a few seconds. In the supply system the following events can occur:

1. Lightning strikes can cause transients. They can also cause voltage breakdown and a fault that gives rise to a sag or possibly an interruption to some customers.
2. Line and capacitor switching can give oscillatory transients.
3. The asymmetrical nature of transmission lines and transformers can lead to unbalance.
4. Faults on your feeder or an adjacent feeder can lead to voltage sags or swells, or a complete loss of supply.

Disturbances originating in customer's plant and nearby installations can be caused by:

1. Sudden connection of large loads, especially motors, can lead to voltage sags.
2. The unequal distribution of single phase loads across the three phases can give unbalance.
3. Cyclic loads such as cranes and frequent motor starts can give light flicker.
4. Poor wiring or grounding within an installation can give high neutral to ground voltages.
5. Power electronic loads such as computers, office equipment, fluorescent lamps, high efficiency lights, variable speed drives (used in manufacturing and some heating and air conditioning) can lead to harmonic distortion and in the case of single phase loads high neutral currents. DC motor drives and AC phase control (light dimmers, heaters) can lead to notching. Poorly designed power factor correction capacitor installations can amplify all these effects.
6. Faulty SMPS (switch mode power supplies) such as in older TV sets give high frequency noise.
7. Switching of contactors and relays gives transients.
8. Malfunction or inappropriate operation of UPSs (uninterruptible power supplies) can lead to transients, sags or interruptions.

4. Some effects of power quality disturbances

4.1 Voltage Events

Disturbance	Effect
Overvoltage	Overstress insulation
Undervoltage	Excessive motor current
Unbalance	Motor heating
Neutral-ground voltage	Digital device malfunction
Interruption	Complete shut-down
Sag	Variable speed drive & computer trip-out
Swell	Overstress insulation
Fluctuations	Light flicker

4.2 Waveform Events

Harmonics	Motor, transformer & neutral conductor overheating, instrumentation malfunction
Notching	Zero-crossover device malfunction
Transients	Electronic device failure or malfunction; drive trip-out
Noise	Fast-running clocks; zero-crossover device malfunction

5. Relative importance of power quality issues

Based on a combination of overseas experiences reported in journals and anecdotal reports, it appears that the most important power quality problems, in terms of the cost to industry, are:

1. Sags
2. Transients
3. Neutral-ground voltages
4. Harmonics
5. Noise

6. What you can do to manage your power quality problems

Control of power quality problems involves co-operation between network operator, customer and equipment manufacturer. The following principles can be used as a guide:

a) Identify weaknesses in your present supply power quality. This can be done by monitoring the supply and/or contacting Integral Energy or your Network Operator to see what information/services are available.
b) Identify critical components in your installation and ascertain their susceptibility to power quality events.
c) Specify all new critical equipment to withstand worst case supply conditions. Your Network Operator should be approached to give you

details of the worst case supply conditions for your point of connection to the network.

d) Seek assurances from equipment manufacturers that their equipment meets your power quality specifications.

e) Ensure that equipment purchased does not cause further degradation of the supply power quality. Not only should susceptibility of equipment be considered but also its potential for emission.

f) Advice regarding power quality investigations may be obtained through Brian McDonald, Quality of Supply Manager, Integral Energy Networks. Ph: 131 081

7. Integral Energy Power Quality Centre

In July 1996, Integral Energy set up Australia's first Power Quality Centre at the University of Wollongong. The Centre's objective is to work with Industry to improve the quality and reliability of the electricity supply to industrial, commercial and domestic users. The Centre specialises in research into the control of distortion of the supply voltage, training in power quality issues at all levels, and specialised consultancy services for solution of power quality problems. You are invited to contact the Centre if you would like further advice on quality of supply.

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