ELECTRICAL POWER RELIABILITY IN THE WATER INDUSTRY

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ABSTRACT

Electrical power reliability is one of many factors that are necessary for the ongoing successful operation of water industry facilities. Electricity is a utility that the customer generally takes for granted, assumes that it will be available 24x7 and with properties that are 'fit for the purpose'. However the practical reality can be somewhat different. The continuing growth in the use of power electronics and electronic controls in all facets of society has placed new emphasis on the importance of creating and maintaining an environment in which electrical equipment will operate reliably.

This paper discusses some aspects of electrical reliability that can impact on the reliable and repeatable operation of electrical and electronic equipment. All examples are taken from assignments that the author has performed in the Victorian water industry.

1.0 TERMINOLOGY

Electrical power reliability, from an end user perspective, is a combination of:

- Continuity of supply – interruptions and outages
- Quality of supply – deviations of voltage and current from "ideal" characteristics that may impact on the operation and/or life expectancy of electrical equipment
- Electromagnetic compatibility or EMC – the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment. (IEC and AS/NZ definition).

EMC is part of the title of many IEC and Standards Australia standards that cover electrical emissions and immunity of equipment, test methods, limits and product standards.

1.1 Key Attributes of Electricity

Electricity, unlike water, cannot be stored. The supply of electricity to customers is a delicate balance between generation (e.g. coal, hydro etc) and the load taken by customers with the interconnection via the transmission (high voltage towers) and distribution (poles and wires) networks. Any significant perturbation due to a large load change, lightning strike etc will be felt as a disturbance by many customers.

The magnitude of the ideal alternating voltage and current moves between maxima and minima in a sinusoidal manner. Each cycle ideally takes twenty milliseconds giving fifty cycles per second and is called a frequency of 50Hz.

The electrical industry fathers found that alternating current could be generated and transferred over larger distances more cost effectively than direct current. In addition the alternating cycles could be shifted in time by 120 electrical degrees or 6.6666 milliseconds to create a 3-phase supply.

Typical 3-phase voltage and current waveforms are shown below in Figure 1. One phase has been highlighted for clarity and while the voltage waveform is very close to an ideal sine wave, the current waveform is not i.e. the current waveform is distorted.

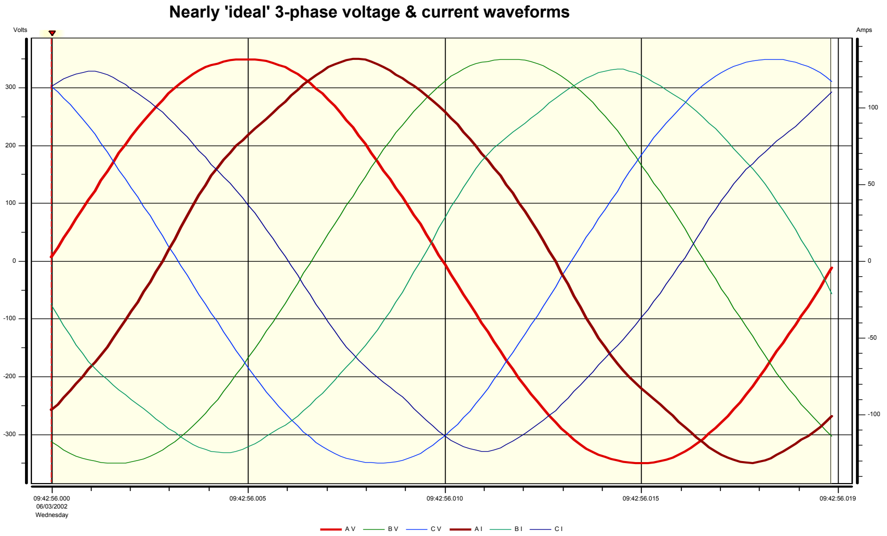


Figure 1: ***Nearly 'Ideal' voltage and current waveforms***

Electrical and electronic equipment are designed and tested using close to ideal waveforms. The ability of equipment to correctly and predictably operate when exposed to non-ideal waveforms is a function of the equipment design and usually equipment capital cost.

2.0 CAUSES OF 'NON-IDEAL' ELECTRICAL CONDITIONS

Non-ideal electrical conditions can be due to disturbances originating externally or internally to the site.

2.1 External Disturbances

External disturbances are from events on the electricity distribution system that are propagated from the source to other customers. The severity of the disturbance at a customer location is a function of the distance from the source of the event.

The source of external disturbances includes:

- Network equipment failures
- Storms, lightning strikes etc
- Animals, birds etc
- Network switching operations
- Vehicle-pole accidents
- Other customers

External disturbances will always occur and the plant must be designed and operated to safely accommodate them.

2.2 Internal Disturbances

Internal disturbances are events that result from the operation or malfunction of equipment within the site.

The source of internal disturbances includes:

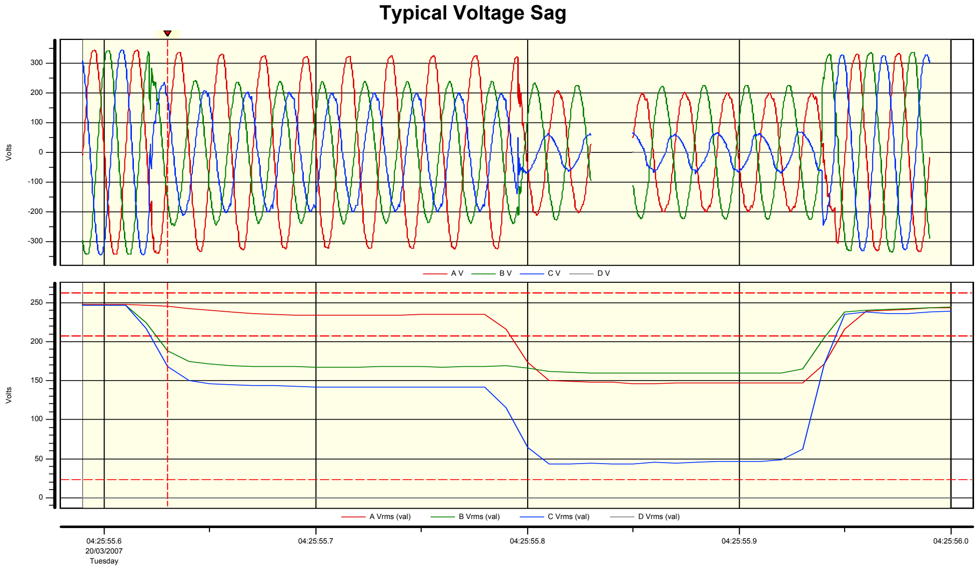
- Motor starting currents
- Variable speed drives or VSD's, discharge lighting
- Equipment earthing and shielding
- Inability to appropriately handle external disturbances

Internal disturbances are a function of the plant electrical design, specification and selection of equipment, installation techniques and maintenance practices.

3.0 EXAMPLES OF DISTURBANCES

Figure 1 shows 'nearly ideal' voltage and current waveforms.

Voltage sags or dips are the most commonly experienced disturbance. Sags usually are due to external events but can be produced from internal motor starting and equipment failures. Figure 2 shows a sag on two phases that developed into a sag on all three phases. The total duration of the event is 0.32 seconds. Sag durations are typically in the range of 0.1 to 1 seconds.



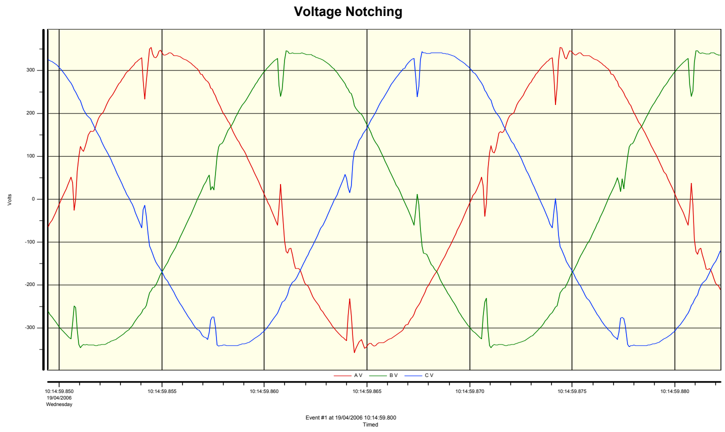
CATEGORY: Short Duration Instantaneous Sag

	BV	CV
Threshold crossed (Volts)	207.0	207.0
Magnitude (Volts)	159.4	42.72
Duration (sec.)	0.32	0.32

<u>Figure 2:</u> ***Typical voltage sag***

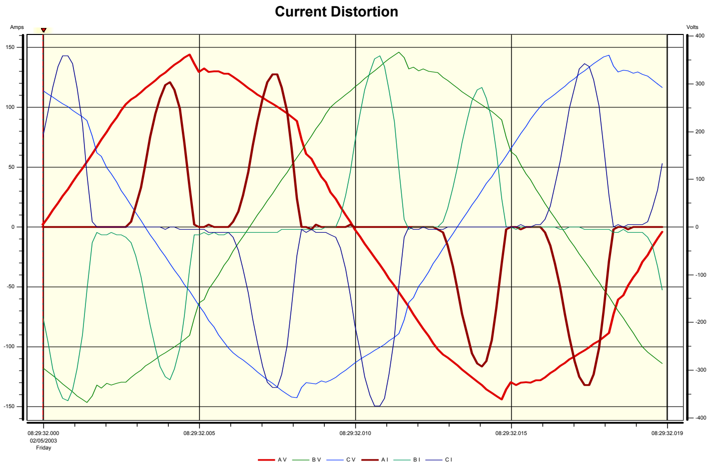
Voltage waveshape distortion can take several forms.

Figure 3 is an example of voltage notching produced by a VSD.
Note that there are additional crossings of the zero axis produced by some notches. These additional zero crossings can result in malfunctions of some electronic devices that use the voltage waveform for timing and frequency control e.g. digital clocks, generator controls.



<u>Figure 3:</u> ***Example of voltage waveform distortion***

Current distortion is produced by customer equipment e.g. VSD's, discharge lighting, PC's, etc. Figure 4 shows an example of current distortion. The distorted current flows through the electrical system resulting in voltage distortion that is propagated to all items of equipment. Voltage distortion is also transferred to other customers through the supply transformers and the network.



<u>Figure 2:</u> ***Current distortion***

Transients or spikes take many forms and Figure 5 shows one example.

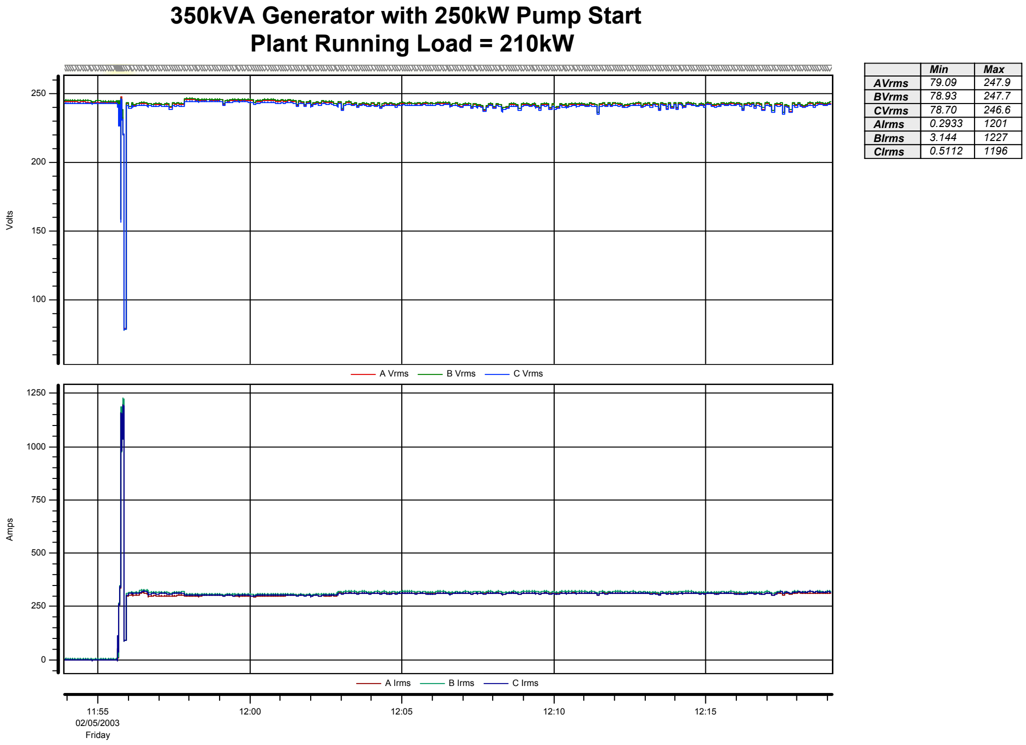
<u>Figure 5:</u> ***Oscillatory transient***

4.0 INCOMPATIBILITY EXAMPLES

Some examples from the water industry that have resulted in disturbance problems include:

- Voltage sag resulting from motor starting currents
- VSD's are disturbance generators and hence must be designed, selected and installed correctly. Malfunctioning electronic equipment can result from incorrectly installed shielded cables to motors and high levels of voltage distortion produced by the operation of VSD's. Radiated interference to neighbouring properties is also possible.
- Generator supply – plant produced disturbances are often 'amplified' when the site is operated on generator supply. Motor starting and VSD's are common sources of excessive disturbances that result in equipment malfunctions.
- Design and commissioning considerations – equipment specification and set-up e.g. VSD configuration settings; earthing of equipment; layout and adequate separation between 'dirty' power cables and control cables; detailed commissioning testing; compliance with the Electricity Distribution Code (Victorian sites) which sets limits at the network interface. The customer is responsible for internal criteria.

Figure 6 shows the start-up of a 250kW pump on a 350kVA generator where the voltage dropped to 78V during the start. The voltage sag caused some other equipment to trip.



	Min	***Max***
AVrms	*79.09*	*247.9*
BVrms	*78.93*	*247.7*
CVrms	*78.70*	*246.6*
AIrms	*0.2933*	*1201*
BIrms	*3.144*	*1227*
CIrms	*0.5112*	*1196*

Figure 6: ***Pump start on generator supply***

Figure 7 shows the impact that one 90kW VSD had on the voltage distortion of a 190kW generator. The excessive voltage distortion caused a new technology electronic controller to malfunction and shutdown the generator.

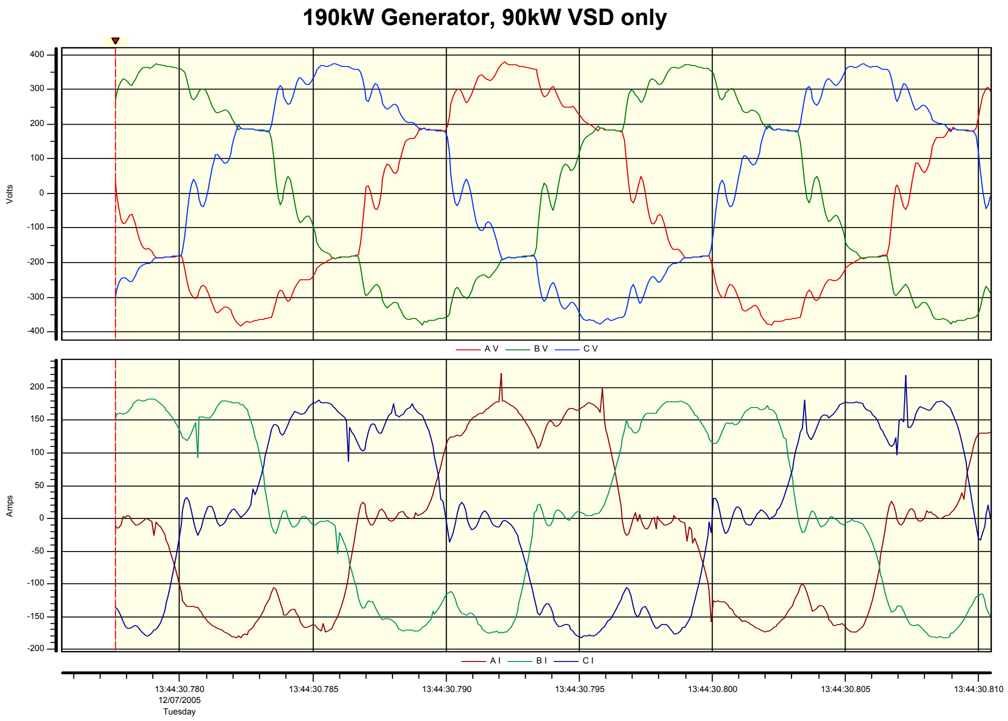


Figure 7: ***VSD operation on generator supply***

5.0 CONCLUDING COMMENTS

Power Quality disturbances will always be present both from external and internal sources. While it is technically possible to prevent nearly all disturbances from adversely impacting the operation of plant and equipment, the required level of immunity is a trade-off between capital cost and business interruption cost.

Design and installation decisions can have a significant impact on the immunity of a plant to disturbances. Plant upgrade projects can unintentionally lower the immunity level of a plant unless the impact of disturbances is considered. It is usually cheaper to make changes at the design stage rather than perform modifications to a site facility.

There are several Standards Australia standards and other Codes that can assist in the specification of equipment and acceptance testing of electrical facilities.

Power quality disturbances can be measured, analysed and their impact on plants predicted. There are many steps that can be taken during design and commissioning to improve the electrical operating reliability of a facility.