ENA Customer Guide to Electricity Supply

Energy Networks Association Limited

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August 2008

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Published by the Energy Networks Association, Level 3, 40 Blackall Street, Barton, ACT 2600.

Contents

The Purpose of this Guide

This Guide has been produced by the Energy Networks Association (ENA), the peak national body representing electricity Network Service Providers[1] throughout Australia.

Its purpose is to provide information on how electricity is supplied, the quality and reliability of electricity supply that can be expected from an electricity network, and steps that customers should take when they lose supply or believe that the quality of their supply is below an acceptable level.

This document is one in a series of three and relates to all customers but primarily to larger commercial and industrial customers having access to technical specialists to assist in dealing with electricity supply issues. ENA also has 'plain English' publications to assist smaller industrial and commercial customers, and residential customers.

This Guide is intended to provide an introduction to the issues. Where it is necessary to gain greater insight, the Guide provides references to documents such as relevant Australian and International Standards.

The Guide has the following structure:

Introduction

This is an overview that describes the structure of the Australian electricity supply industry and the regulatory framework in which it operates.

PART 1 – Electricity Supply

This section describes in general terms the way in which electricity is supplied to customers and the roles of generators, transmission companies, distribution companies and retailers.

PART 2 – Understanding your Load and Needs

This section describes the key items that customers need to understand about their load when negotiating a new or upgraded connection to a Network Service Provider (NSP).

PART 3 – Network Reliability

This section describes how despite suppliers' efforts to optimise the reliability of their power systems, customer interruptions to electricity supply are inevitable and customers need to identify and manage the associated risks.

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[1] Under National Electricity Law, organisations that transmit and distribute electricity are referred to as Transmission Network Service Providers and Distribution Network Service Providers. The more traditional term for the latter is "distributor". With the separation of retail and network functions, the new term more accurately reflects the functions that members of the ENA perform, and we have used it throughout this document.

PART 4 – Network Power Quality

This section describes how the quality of the electricity provided to customers is not always suitable for use by all customer equipment. The major power quality disturbance types are identified and discussed and the importance of purchasing electrical equipment with sufficient levels of power quality immunity is highlighted.

Introduction

A Changed Industry

Since the early 1990's, there have been significant changes in the structure and regulation of the electricity industry as part of the national competition policy reforms. There has been a move away from state based vertically integrated organisations, to a clear separation between regulated network service provision and competitive retail and generation. Customer choice in the selection of their retailer has been facilitated by the introduction of laws to regulate access to distribution and transmission networks. Electricity Network Service Providers have clear targets for the level of reliability expected of their network, and there is transparency in the development of network plans and performance reporting. This information is publicly available, and adds significantly to the material available to assist you in managing your electricity needs.

Electricity the Product

Electricity is a unique product with a number of unusual attributes. Unlike fuels such as gas or petrol, which can be stored, almost all electricity is produced and delivered the instant you use it. It typically has to be transported a considerable distance over a highly interconnected transmission and distribution system. Because of the complexity of the system, and the fact that thousands of other customers are taking electricity from it at the same time, there are a great many factors that influence the reliability performance and power quality of the electricity supply delivered. Apart from the obvious impacts of weather and equipment performance, what you do in your premises can affect the quality of supply received by neighbouring electricity customers (and vice versa). Electricity Network Service Providers strive to provide a network that meets reasonable quality and reliability standards for all users at an affordable cost. This means that they must not only adhere to standards on their network, but also impose standards on users of electricity.

Quality and Reliability of Supply

Historically, the needs of an electricity network were relatively simple. Most applications centred on lighting, heating and motive power. Technological and lifestyle changes, especially the widespread use of electronics and microprocessors, have introduced a myriad of new benefits for business and the community at large and with it increased expectations relating to reliability and quality of electricity supply. Modern electronic equipment is sensitive to variations and disturbances in electricity supply that had previously been ignored. Issues include logic errors, loss of data, and unscheduled shutdowns to actual component damage. Customer loads can generate unwanted harmonic currents, flicker, voltage sags and high levels of voltage regulation in the supplying network. These effects via the network can, in turn, cause severe disturbance to other electricity customers.

Customers generating excessive disturbance to the network can have adverse impacts on:

- the operation of other equipment in the customer's own installation.
- the operation of equipment in other customers' installations.
- the operation of the electricity supply network.

Environmental factors, such as storms, lightning or other forms of damage to the power supply network (eg vehicle accidents) can also generate disturbances that adversely impact on customer installations.

Most variations and disturbances are caused by environmental factors, especially where supply is provided by overhead power lines. They are a normal part of the operation of a complex public supply system and electrical equipment needs to be designed to tolerate a reasonable range of variation and disturbances.

No "Disturbance-free" Guarantee

It is impossible to provide or guarantee a completely disturbance-free and uninterrupted electricity supply. The reliability and quality of supply varies in different parts of the distribution network. Individual customers may experience more or fewer than the average number and duration of interruptions and disturbances. In most cases, equipment and appliances will function as you would expect. However, if there are supply conditions that might cause problems or unsatisfactory performance, it is essential that you are aware of and respond to these factors before you make commitments to purchase equipment or make alterations to your installation.

Your local electricity Network Service Provider can provide reliability and power quality information. They are continually striving to improve the overall performance of their network, but improvements may be required that specifically relate to you. The feasibility and cost of any specific improvements should be discussed with your local electricity Network Service Provider.

Customer Needs

Each customer's needs and requirements for electricity vary but here are some examples of how you might be affected by some typical supply factors:

(a) The *Quantity* of electricity you require …

While most loads are supplied at low voltage, major industrial and commercial loads are supplied at medium and high voltage in some cases. The optimal voltage is a function not only of the size of the load, but the availability and capability of the local network to supply that load. It is important that if you are planning a new business or increases to your existing loads, that a dialogue be established with your electricity Network Service Provider. It is recommended early in your planning cycle that you determine feasible supply arrangements, and the infrastructure development required to meet your needs.

(b) The *Reliability* of supply you require …

Electricity Network Service Providers have different planning standards for different parts of their network. Redundancy exists in some parts of the network that enables supply to be maintained, or restored quickly, in the event of an item of plant being taken out of service. The level of redundancy depends on the total amount of load being serviced, and the geographic locality of the load. As a general rule, most transmission and subtransmission parts of the network have redundancy, but there is often less redundancy in the medium and low voltage parts of the network. There are also other factors. For example, an underground cable supply would typically be expected to suffer less outages than an overhead power line, but may take longer to repair if there is a cable failure.

In most cases, the network in the immediate vicinity of your premises is unlikely to have redundancy meaning that supply would be lost in the event of equipment failure or maintenance requiring an outage. For the majority of customers, whilst less than perfect, this is an acceptable arrangement providing the right balance of cost and reliability. In some businesses this may not be acceptable and a higher reliability standard is required. If the impact of a supply interruption is particularly high, you may need to consider having an alternative source of supply or a backup generator. You should discuss your reliability needs with your electricity Network Service Provider early in your planning cycle to determine what solutions are technically and economically feasible.

(c) The *Quality* of supply you require …

When building or expanding your business with sensitive automatic electronic equipment including variable speed drives, programmable logic controllers or computers then careful consideration needs to be given to the quality of electricity supply provided. The overall quality of supply that you will receive is very much dependent on where you are connected into the network. As a general rule the quality of supply is improved by connecting to the network at higher voltage levels and by connecting to networks with lower network exposures. If your business has a continuous process or is very vulnerable to voltage sags, you should consult your Network Service Provider for advice on the suitability of particular locations.

Power quality performance of networks can and do vary greatly from location to location. Are you in a rural area with long lengths of overhead line or are you in a very heavily loaded CBD area of a major city?

Careful planning of installations at the design stage can vastly improve the immunity of plants and installations to voltage sags and other disturbances. Often the most economic way of providing adequate plant immunity involves the use of simple strategies that involve providing Uninterruptible Power Supplies (UPS), specific phase connections for control equipment and/or special switch mode power supplies to low power control devices such as computers, PLC's and motor controls.

Electrical Safety

The safety of people and property is of paramount importance to everyone involved in the electricity industry. Strict legislative requirements apply to electrical installations that directly impact both you, as the customer, and your electricity Network Service Provider. However, this Guide is only concerned with factors affecting the availability, reliability, and quality of electricity supply.

Electrical safety information is available from a number of national and jurisdictional sources including:

- Electricity Network Service Providers
- Electricity retailers
- Technical and safety regulators
- Australian Standards and guidelines
- Service and Installation Rules

It is imperative that you have access to resources, such as specialist engineers, consultants or electrical contractors to assist in the management of your safety, and safety obligations.

Connecting to the Supply Network

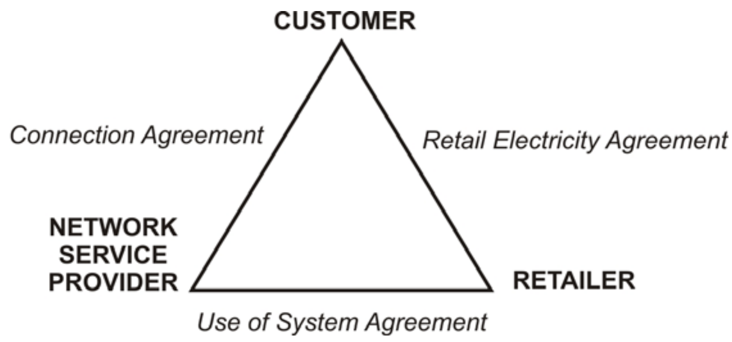
The vast majority of large industrial and commercial electricity users in Australia can now choose their electricity retailer. Electricity networks have a so called natural monopoly and whereas competition is practical in the generation and retailing sectors, it is not practical in transmission and distribution networks.

Electricity Network Service Providers must observe state, territory and national codes, licences and statutes that specifically deal with the performance and nature of an electricity supply network. These are designed to minimise the risk of unsafe conditions, interruption to supply, and poor quality of supply, and to ensure fair and open competition in generation and retailing activities. There is a combination of state and federal regulators who monitor and enforce both the technical and commercial aspects of these codes. At the highest level, the operation of the electricity industry is governed by the National Electricity Law.

As a consequence, most customers now have two contracts relating to their electricity supply:

- a Connection Agreement with the Network Service Provider
- a Retail Electricity Agreement with their retailer of choice.

There is also usually a Use of System Agreement managing the relationship between the Network Service Provider and the retailer. As a consequence, the relationship is often referred to as a "triangular" contractual arrangement.



Your electricity Network Service Provider provides connection and supply services under conditions usually contained in a Connection Agreement. If you wish to connect an installation to a distribution network, you must first complete an application for connection and provide sufficient detail of the proposed installation to enable the Network Service Provider to determine its suitability for connection. In parallel, you should select an electricity retailer.

Your installation must comply with relevant Australian legislation and standards, the Network Service Provider's Service and Installation Rules, and other connection policy documents specific to the Network Service Provider such as supply quality standards. These standards require your installation to be capable of coping with the routine variations and interruptions to supply discussed in this Guide.

Ensuring Customer Satisfaction

Electricity Network Service Providers are continually striving to improve the reliability and quality of electricity delivered from their network. In many instances, their licence conditions now set specific targets for improvement in reliability. The factors affecting electricity supply to individual customers vary widely from place to place. Installations need to be designed to take into account local supply conditions. Your electricity Network Service Provider will offer assistance, including providing information about local factors, to help you make appropriate decisions.

Early advice from your Network Service Provider can help minimise any future concerns or problems. This guideline provides background information to help with this communication.

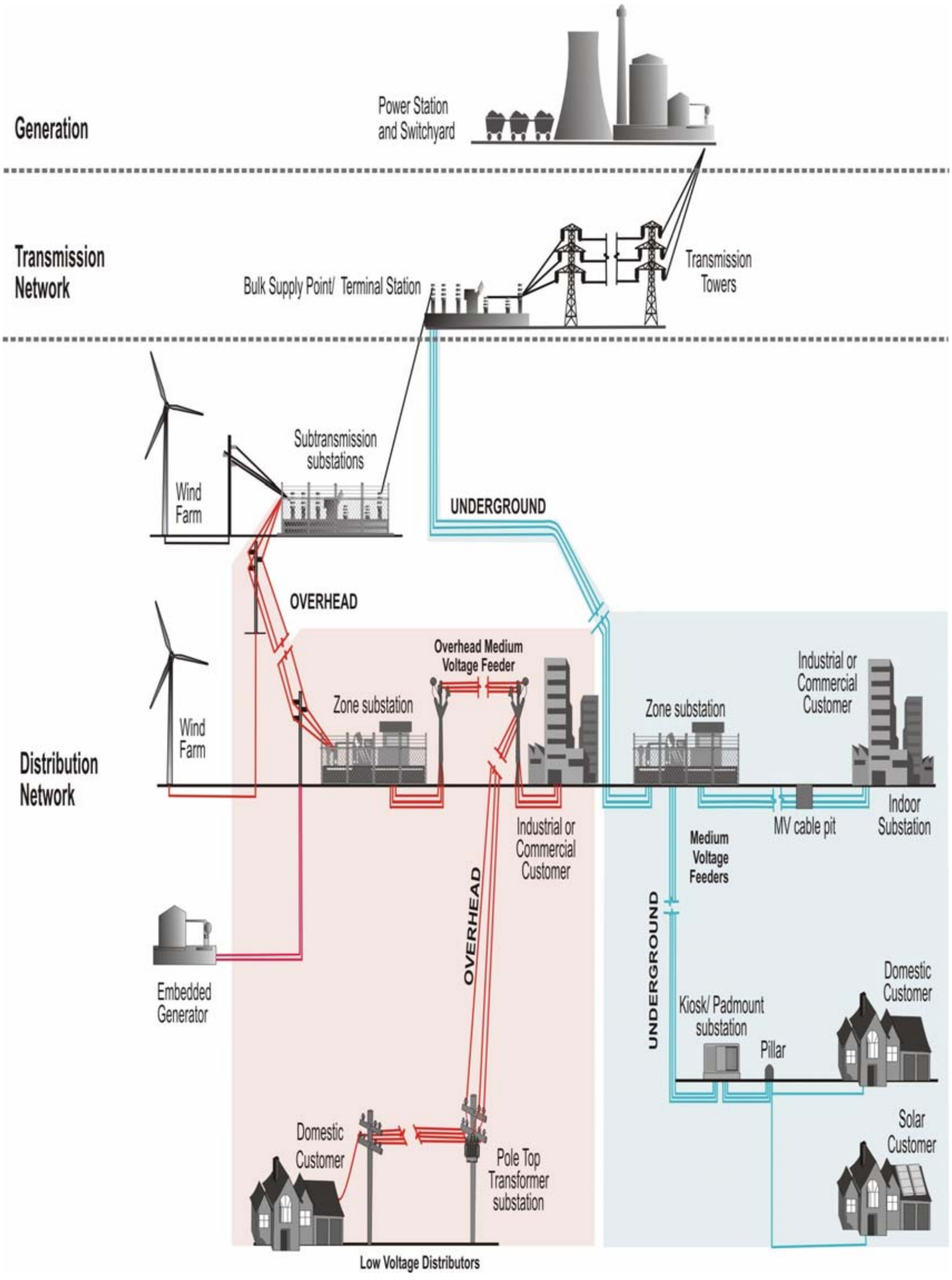
Once you are connected to the network, your electricity Network Service Provider is committed to assisting you operate in a safe and effective manner.

If you suspect a power supply quality problem from outside your installation, you should contact your Network Service Provider. In most cases, your Network Service Provider will be able to help you determine whether the problem is being experienced by other customers as well or is confined to your installation. If other customers are similarly affected, the problem could be transferred from some other installation or the source could be the supply system itself. If the problem is confined to your installation, further investigation will most likely be needed within your premises. Also, the customer may have to submit a safety plan.

Many Network Service Providers offer power quality services to identify problems and provide solutions. You may also need to seek expert advice and assistance from equipment suppliers, engineering consultants and/or electrical contractors.

PART 1: Electricity Supply

The Electricity Supply System



Electricity Supply

The physical process of electricity supply is divided into three broad stages; generation, transmission, and distribution. In addition to the physical aspects, there is a commercial overlay involving the trading of electricity between generators and retailers or, in some circumstances, generators and large electricity users.

Generation

Most electricity is generated at large scale conventional power stations from various natural resources such as coal, natural gas and hydro. In most of Australia, generators can competitively bid to have their output dispatched into a "pool" such as the National Electricity Market in the eastern and southern states, or the Wholesale Electricity Market in Western Australia. These markets are administered by an independent market operator.

In addition to conventional large scale generators, there is increasing use of distributed generation within networks. These generators are typically cogeneration plants located in factories producing and utilising steam, coal seam methane installations associated with coal mining, wind farms, biogas and solar installations.

Transmission

Many large conventional power stations are located at or close to the fuel resource which is often a considerable distance from where the major demand for electricity is located. Large quantities of electricity are therefore transported over the transmission network to major substations located in key areas. Transmission lines typically operate at voltages ranging from 132kV to 500kV, and may link states.

High voltages are needed for the economic transport of large quantities of electricity but are far too high for most customers to use. Terminal or Bulk Supply Substations transform these voltages to lower voltages used in the subtransmission and distribution network. These substations also contain switchgear to control the flow of electricity.

Distribution

Distribution is a generic term that usually encompasses both subtransmission and distribution functions. Voltages such as 132kV, 66kV and 33kV are commonly used in the subtransmission system to distribute large blocks of power. Zone substations then transform from subtransmission voltages to medium voltages (MV) such as 22kV or 11kV. Many large industrial and, to a lesser extent, commercial customers take supply at these voltages. Subtransmission and medium voltage feeders could be overhead power lines or underground cables. Distribution transformers transform high voltage to the low voltage (230/400V) that is reticulated for general use within households, shops, businesses, factories, hospitals, schools and other smaller customer installations.

Retail

Retailers aggregate the electricity requirements of large numbers of customers and purchase energy from the wholesale market. Due to changes in supply and demand, the price in the wholesale market changes frequently. Retailers enter into contracts with generators to enable stable prices to be offered to customers. As well as performing this function, retailers co-ordinate the billing of network service and market administration charges, and provide a single point of contact for the majority of issues faced by customers. Retailers and Network Service Providers work closely together to ensure that any technical or commercial issues customers may have are dealt with efficiently and promptly.

System Operation

The transmission and distribution systems are provided with protection systems that serve two purposes:

(a) Under normal conditions, they maintain the continuity of the network and allow continuity of supply for all customers.

(b) Under fault conditions, they can disconnect supply to certain sections of the network to assist in isolating or removing faults to minimise risks to the safety of people or equipment, and to limit the number of customers affected by the fault.

With the exception of rural localities, the transmission and subtransmission distribution systems generally have a degree of interconnection. This means that supply can usually be provided from more than one source.

At the medium voltage distribution level, there is a mixture of so-called ring and radial systems. Ring systems have more than one source of supply, and after a fault, supply can be restored to most affected customers by switching the network without the need to be affected by the repairs. Radial systems have a single source of supply, and after a fault, usually require lengthy repairs to be effected before supply can be restored.

Classifying Networks

At any point throughout the supply chain, from large generators through the transmission and distribution systems to the customer's own installation, there are factors that can influence the amount of power available, reliability and quality of supply.

The nature of the supply system and the location of the customer both have a significant effect on quality, reliability and supply restoration times.

Overhead power lines are a widely used and economic way of transmitting and distributing electricity. They are vulnerable to a variety of environmental and third party influences such as storms, lightning strikes, vandalism, and vehicle accidents. If network faults or damage occur, the problems can usually be found by visual inspection and repaired reasonably quickly.

Underground cables are considerably more expensive than overhead lines and are often installed for aesthetic, load density or safety reasons (eg avoiding the need to have overhead power lines close to multi-storey buildings in city streets). They are more complicated in construction but are also protected from most of the problems encountered by overhead power lines. However, if they are damaged or develop faults, the time taken to locate problems and carry out repairs can be much greater.

There are three broad location classifications (these areas may be defined in more specific terms by your jurisdictional electricity regulator):

Central Business Districts (CBD)

The central business district and commercial centres of major cities will have the highest reliability because of the greater use of interconnected underground distribution, both medium and low voltage, and the relatively shorter lengths of these lines, reducing their exposure to environmental problems. These areas can usually be supplied from a number of different substations and with remotely controlled switchgear. This system can achieve higher levels supply continuity and better than average restoration times in the event of failures.

Urban

The residential and commercial areas in cities and major towns will have a mixture of medium voltage underground cables and overhead power lines. These areas are often supplied from an interconnected network with at least one alternative source of supply. In the event of a failure, line crews can usually restore supply to most customers by field switching within an hour or two. After network faults there will often be a small set of customers that cannot have their electricity supply restored until repairs are completed.

Rural

Areas outside the CBD and urban areas, such as rural regions and associated small towns, are usually supplied by overhead medium voltage lines with limited or no interconnections to alternative sources of supply. Lines are categorised as "Short Rural" where lines are up to 200 km long, and "Long Rural" where lines may be many hundreds of kilometres in length. As a general rule, as line length increases, the incidence of faults increases due to greater exposure to weather, vegetation and other environmental factors that cause faults and disruptions. Repairs can also take longer because of the time involved for response crews to travel and then find and repair the damaged parts of the system.

Isolated Networks

The terms CBD, Urban and Rural apply to the vast majority of customers connected to large interconnected networks. In some remote locations, a small network connected to one or more generators (usually a diesel generator at a single locality), may be used to supply a community or group of communities. These are commonly termed Isolated Networks.

PART 2: Understanding your Load and Needs

To gain the greatest benefits from your electricity supply, it is essential that you have a thorough understanding of your electrical load. An electricity supply requires a partnership that matches the requirements of electricity customers with the capability of the supplying network.

Due to geographic and economic factors, the capability of networks varies substantially from location to location. When negotiating connection arrangements it is essential that you have a detailed understanding of your load and business requirements so that satisfactory network performance can be provided at the lowest possible costs.

Some customer installations are simply unsuited to connection to a network in some locations because reliability and power quality can be predicted by your Network Service Provider to be unsuitable for some customer applications. For example, it simply may not be feasible to construct an industrial plant incorporating sensitive continuous processes in some rural or remote areas and achieve long term satisfactory operation.

Some proposed new or upgraded customer connections are unsuitable because the customer's load may interfere with the network and cause disruption to other customers. In fact, every customer connected to a network has an impact on the supply to all other customers. The role of the Network Service Provider is to manage these impacts to ensure that standards of supply are maintained for the benefit of all customers. This is why a Network Service Provider may place strict supply conditions on your electrical load and installation.

Electricity customers need to balance the network connection costs for an extra high reliability/power quality supply against the costs of installing more power quality disturbance immune equipment and systems. It is the aim of each Network Service Provider to assist customers in achieving a suitable balance that will satisfy the customer's long term needs.

When negotiating your new or upgraded connection to the network with your Network Service Provider, as a minimum you need to have a thorough understanding of your installation's load and operating requirements including the following:

1. Maximum demand
2. Motor starting
3. Nominal supply voltage
4. Designing and preparing for power interruptions
5. Immunity to power quality disturbances
6. Load fluctuations and flicker
7. Harmonic emissions into the network
8. Power factor correction
9. In plant generation

You may need to seek expert advice and assistance on these issues from consulting engineers, electrical contractors and/or equipment suppliers.

Maximum Demand

The load current drawn from the network by a customer's installation varies continuously throughout the day. The predicted maximum current drawn from your new or additional load is a major consideration in determining the capacity required of both your own installation and your connection to the supply network.

The maximum demand of your installation is usually calculated by your electrical contractor or consulting engineer. Basically it involves adding up the contributions of individual pieces of plant and equipment. This process takes into account the diversity of operation between individual pieces of equipment.

A key consideration is whether or not the network has the capacity to supply your expected load. Just because you're already connected to the supply system or you can see there's a distribution network near your premises or property, you should not assume that connecting is a simple and straightforward matter.

Just as you had to consider the electrical loads and current-carrying capacity of your own installation, your electricity Network Service Provider has to take similar factors into account when connecting your installation to the network. Your electricity Network Service Provider will need details of the loads you propose to connect to the system. You should be aware that alterations to the network will require lead times which will vary depending on the nature of the load and the capacity of the system. The capacity of the existing network may already be close to its maximum. To connect your installation, your Network Service Provider may have to increase the capacity of the network. The work involved could range from replacing the distribution transformer with a larger one to rebuilding the distribution system with larger conductors, transformers and switchgear.

In most cases, connection will be straightforward and it will just be a matter of making application, providing the necessary details about what you require, and allowing sufficient time for the connection to take place. In some cases, depending on the extent of changes to the network needed to supply your installation, you may be required to contribute towards the capital cost.

Discussion Points with your Consultant or Network Service Provider

What is your maximum demand and load pattern?

What are your future capacity needs and expansion plans?

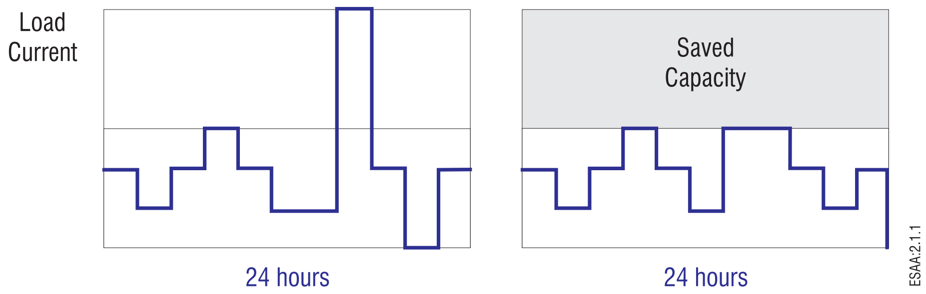
What are the applicable network service charges?

Does the existing supply network have the capacity to supply your load? Is a network augmentation required?

Are there any demand management opportunities to reduce the maximum demand?

Demand management is the management of the loads within your installation to meet objectives for maximum and average demand.

Peak Load Reduction by Load Management



The difference between maximum and average loads can have a significant impact on the current-carrying capacity required. In the example above, both installations take the same amount of electrical energy from the supply but the one on the left has to have twice the current-carrying capacity. By using demand management techniques to even out the demand for electricity and, in particular, to reduce peak loads, the required capacity has been halved. This means either a saving in cost by installing a smaller cable in the first place or having spare capacity for expansion or load growth without the expense or disruption of replacing existing cables. Electricity tariffs for large customers commonly include a charge based on maximum demand. This may be measured in kilowatts (kW) or kilovolt amps (kVA) and is typically based on the highest demand over a 15 or 30 minute average during the month. Demand charges may also vary on a seasonal basis. Demand management can lead to significant savings on these forms of tariff.

Nominal Supply Voltage

The supply voltage is the voltage existing at any time, from phase to neutral or phase to phase, at your installation terminals. The Nominal Supply voltage is the voltage by which a system is designated or identified and to which certain operating characteristics are referenced.

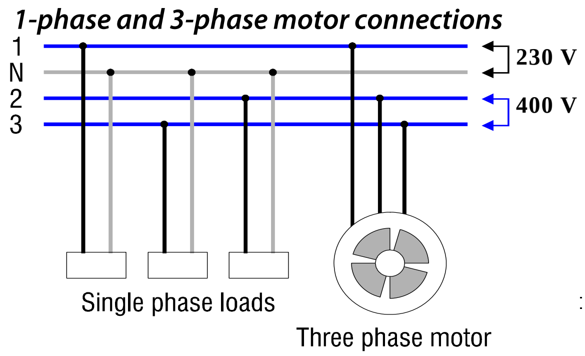
Most Australian electricity customers take supply from their Network Service Provider at low voltage. The nominal voltage for the low voltage system is 230 volts phase-to-neutral and 400 volts phase-to-phase. Depending on your load and availability in your area you may have an option to take one of supply options below.

- 230V 1-phase 2 wire
- 230V/400V 2-phase 3 wire
- 230V/400V 3-phase 4 wire
- 230V/460V 2 x 1-phase 3 wire

If your load is too large for a low voltage supply or you wish to take advantage of the reliability and power quality benefits of supply at higher voltages then supply options need to be discussed with your Network Service Provider. Common medium and high voltage nominal voltage levels used in Australia are 11kV, 12.7kV, 19.1kV, 22kV, 33kV, 66kV, 132kV, 220kV, 330kV and 500kV.

Most industrial/commercial customers take supply at low voltage. Some large customers take supply at medium voltage from the distribution network. A few very large customers take supply at subtransmission or transmission voltages.

Supply can be single or three phase. Single phase is restricted to very small loads. The supply consists of two wires – an active and a neutral. Larger industrial and commercial installations have a three phase supply consisting of three active wires and a neutral. The big advantage with three phase systems is that large motors are significantly smaller, more efficient, and run more efficiently compared to single phase motors with the same power.



Single phase equipment can be connected between any one of the three active phases and the common neutral. However, it is important to have loads connected equally to the three phases otherwise the supply voltages become unbalanced and voltage drops and power losses in the distribution system increase.

The "Steady State Voltage" section in Part 4 (Network Power Quality) provides important information on low voltage system characteristics in Australian networks.

Discussion Points with your Consultant or Network Service Provider

Do you have any special loads like three phase motors, welders, etc. within your installation that requires a 3-phase or 2-phase supply?

Is my load sufficiently large or does it have special power quality needs? I Should I consider a medium voltage or high voltage supply?

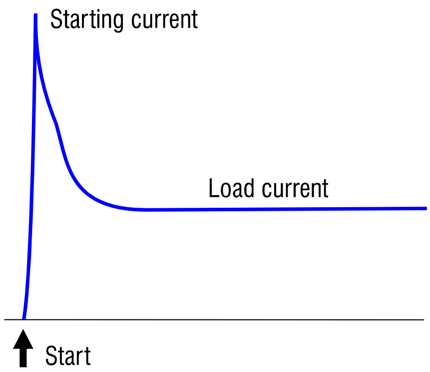
If a medium voltage or high voltage supply is to be considered what network service charges will apply? What special operating and maintenance requirements will apply? What additional network connection costs will apply?

Motor Starting Currents

The sudden increase in electric current caused by starting motors can cause severe short duration voltage sags that can adversely impact on other equipment within your installation. In addition these voltage sags can be transmitted through the network and cause adverse impacts on other customers. Impacts can include maloperation of computers and sensitive electronic equipment and tripping of electric motors. Voltage sags caused by frequent motor starting can also create annoying levels of light flicker.

In general terms, most loads such as heating elements and incandescent lamps draw a steady current from the supply. Electric motors, however, are different. When they start, they have to overcome inertia and accelerate the mass of their rotors and directly-coupled equipment. To do this, they draw large amounts of current from the supply – anything up to nine times the normal full load current during the motor start. The starting process can take a few seconds up to a minute.

Motor Stating Characteristics



Discussion Points with your Consultant or Network Service Provider

What large motors are being planned for the installation?

What methods of starting are being proposed?

How much current will your motor draw when it starts?

What is the anticipated voltage drop on start at the motor terminals, main switch board and point of supply?

How frequently will large motors be started (starts/day)?

Does the existing supply network have the capacity to supply this current?

Will the voltage drop have any adverse impacts on your other plant equipment?

Do you need to reassess your proposed method of motor starting? Is a lower current starting method needed?

Suggestions

If the existing supply system has the capacity to start your motor Direct On Line (DOL) and other customers will not be adversely affected, your connection will probably be approved subject to Service and Installation Rules requirements. Service Rule limits on motor starting are primarily designed to protect other existing and future customers from voltage sag and flicker problems.

If the network hasn't sufficient capacity for DOL motor starting you will need to consider alternative methods of starting such as:

- **Soft Starters:** These devices use power electronics to cut out part of the voltage sine wave to apply a reduced voltage. The fundamental frequency of supply to the motor supply remains unchanged. Motor current is reduced because of the reduced motor supply voltage. Care needs to be taken to ensure the motor has sufficient starting torque to meet your starting needs.

- **Autotransformer Start:** These devices use an autotransformer with bypass contactors to generate a reduced voltage. Motor current is limited and care needs to be taken to ensure the motor has sufficient starting torque to meet your starting needs.

- **Variable Speed Drives**: These devices normally use inverter technology to produce a variable voltage, variable frequency supply. With suitable control systems these devices can start motors with very modest starting currents. After motor starting, these devices may or may not be bypassed depending on the design and the application.

- **Star-Delta Starters**: The motor is first connected in "star" which applies phase to neutral voltage to the windings, reducing starting current to about one-third of the DOL value. As the motor comes up to speed, it is switched to "delta" which applies the normal phase-to-phase voltage. The transition can also produce a current peak.

- **Liquid resistance starters also have a place in industry**

Designing and Preparing for Power Interruptions

Power interruptions to your installation are inevitable. The duration and frequency of future power interruptions is very difficult to predict. Some network connection points however can be predicted to provide superior long term performance because of network configuration, network exposure and protection schemes.

There is considerable benefit in designing your installation to cater for power interruptions. The aim is to be able to withstand power interruptions with the least possible disruption to the business. For example, computer data loss may be prevented by incorporating a UPS system. Other processes may require special design considerations to minimise disruptions.

Customers need to design for and anticipate the impact of both planned and unplanned power interruptions.

Discussion Points with your Consultant or Network Service Provider

How vulnerable is the installation to power interruptions? What will the cost and disruption impact be for a 1 minute, 1 hour or 10 hour supply interruption to supply?

What level of reliability can I expect from my connection point? Will it be adequate for my needs?

Are there alternate network connection points or network options to improve my reliability? What would be the cost of a more reliable arrangement?

Voltage Fluctuation and Flicker

Large fluctuating loads can cause annoying flicker to electric lighting within your installation or externally in the power network and impact on other electricity customers. When flicker reaches a certain level it can be detected by the human eye and can reach levels that cause annoyance. Common disturbing fluctuating loads causing light flicker are arc furnaces, welding machines and frequently starting electric motors as used in air conditioning equipment.

Discussion Points with your Consultant or Network Service Provider

Do you propose to connect any large fluctuating loads within your installation? If so what impact will they have on my installation and the supplying network?

In some cases modelling by electrical engineering consultants will be required to assess the impacts on the installation and the supplying network. Will the fluctuating loads meet the flicker limits detailed in the relevant standards?

Early identification of large fluctuating loads and clarification of requirements with the Network Service Provider is very important at the design process. Your Network Service Provider can provide you with network electrical characteristics that can assist you with flicker modelling.

Harmonic Current Emissions into the Network

Almost all electricity customers generate harmonic currents that are injected into and absorbed by the supplying network. Harmonic currents are non 50 Hz AC currents. The most common sources of harmonic currents are non-linear electronic devices including computers, variable speed drives and discharge lights.

Harmonic currents can have very adverse impacts both on your installation and the supplying network. Harmonic currents have no useful application and use up valuable current carrying capacity of your installation and the supplying network. In this way they adversely impact on the true power factor of the power system and cause unwanted additional network losses. In extreme cases harmonics can cause significant heating in power cables (especially neutrals) and transformers.

Depending upon the network source impedance at the point of supply, customer generated harmonic currents will cause harmonic voltages that will be reflected across to other electricity customers. With all customers generating harmonic currents, there is a net effect whereby unwanted harmonic voltages are generated and reflected across the entire network. The resulting network wide harmonic voltages need to be kept within limits specified in AS61000.3.6 for the benefit of all customers. Customer generated harmonics are a form of electrical pollution that needs to be minimised for the benefit of all customers.

Discussion Points with your Consultant or Network Service Provider

Do Variable Speed Drives (VSD) or other large power electronic loads make up more than 40% of your total load? Is the largest VSD more than 20% of your load?

Are your VSDs designed to minimise their harmonic current injection into your installation and the network?

Do you need to conduct a harmonic study to ensure compliance with the requirements of AS61000.4.30?

What is the minimum, maximum and prospective fault level at the point of supply?

Suggestions

Be very conscious of the harmonic currents generated by your new and existing load. Neutral conductors are particularly prone to heating by some harmonic currents. In four wire low voltage systems, never use reduced size neutral conductors and consider larger neutral conductors where harmonic currents are anticipated. In cases where neutrals will carry large harmonic currents, be cautious of hazardous voltage differences between neutral and earth conductors. Also be careful to ensure that the cable geometry of the low voltage conductors is optimised to minimise the adverse impacts of harmonic currents.

When purchasing new VSDs and other power electronic equipment, specify low harmonic current generating equipment.

If your installation is experiencing overheating cables, excessive neutral to earth voltage, unexpected circuit breaker tripping or unexpected fuse operation, then load generated harmonics may be the cause.

Where harmonic currents are going to be significant, ensure that the ratings of cables, transformers and switchgear are adequate for the harmonic conditions.

Power Factor

Power factor measures the electrical efficiency of loads.

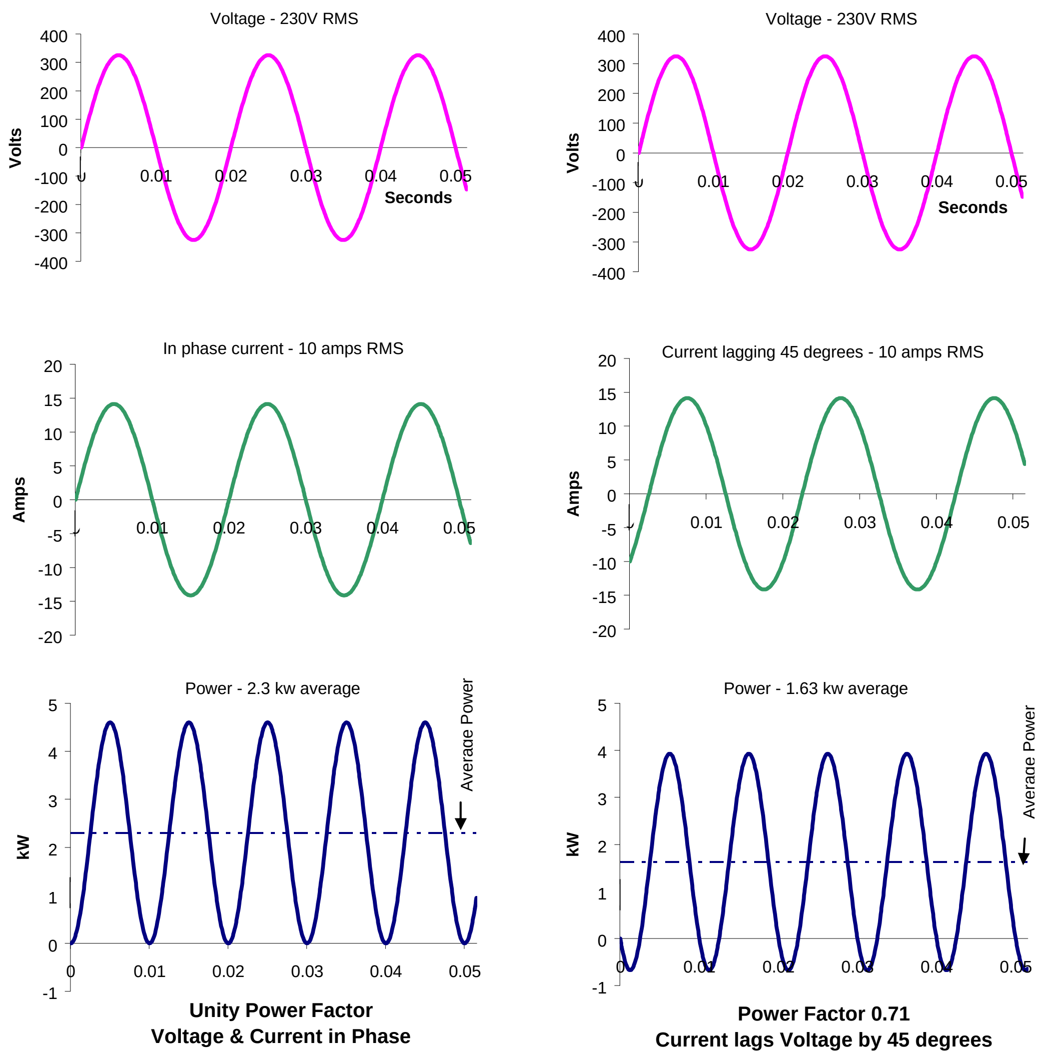
Displacement power factor is a measure of the degree to which fundamental 50 hertz voltage and current are in phase with each other.

True power factor is the ratio of electrical power (measured in watts) to the product of RMS voltage and RMS current in an AC circuit.

As well as minimising the load current required by a given load, maintaining a good power factor may also be a requirement of your Network Service Provider's Service and Installation Rules.

In simple electrical circuits, electric power = voltage x current. This assumes that the voltage and current are in phase with each other – which is only the case with purely resistive loads such as heating elements. In most installations, equipment such as motors and discharge lamps cause the current and voltage to become out of phase. When this occurs, less power can be transferred because the maximum values of the voltage and current no longer coincide.

Examples and illustration of Displacement Power Factor



In the example above, note that in both cases the size of the current is unchanged. This means that the same current-carrying capacity is required in both cases. As power factor gets progressively worse, less and less real power is delivered to the load. Low power factor loads require more electric current to get the same power transfer as high power factor loads. More electric current means bigger and therefore more expensive cables and more unwanted voltage drop. Having a "good" (i.e. high) power factor means that you will get the most value out of the current-carrying capacity of your installation and the supplying network.

Power factor equals 1.0 when the voltage and current are in phase. The power factor for typical installations can vary from 0.85 - 1.0. Installations with large inductive loads can have a power factor lower than 0.5. Installations with low power factor are a major concern of Network Service Providers because they cause inefficient use of the supplying network.

Your electricity Network Service Provider may also have requirements for you to ensure the power factor of your installation does not fall below certain limits. Electricity tariffs based on kVA rather than kilowatts provide financial incentives to maintain a high power factor.

In most installations, power factor can be improved by the installation of capacitor banks.

Discussion Points with your Consultant or Network Service Provider

What is the power factor of your installation? Will the power factor meet the requirements of the Service and Installation Rules?

Are power factor correction capacitors required?

Suggestions

Power factor is usually a problem with inductive loads such as motors (especially when they run at light loads) and some lighting installations. The presence of inductive elements (motor windings and iron ballasts in fluorescent lamps) causes the current to lag behind the voltage.

Power factor can be "corrected" by use of capacitors; These devices can be installed alongside items of equipment such as motors or installed at switchboards to correct the overall power factor of the entire installation. They need to be selected with care and matched to the load.

Being of fixed value, power factor correction capacitors can only provide an adjustment for one set of conditions. If your load and power factor varies significantly with time, you may need automatically controlled switched capacitor banks to maintain the power factor within predetermined limits.

When installing capacitor banks, caution needs to be exercised to ensure that the capacitors do not resonate with existing or future harmonics. Detuning blocking inductors are always recommended for capacitor banks to eliminate the possibility of resonances at harmonic frequencies.

In some situations capacitor banks may need filter circuits to prevent attenuation of Network Service Provider audio signal frequency injections used for load control (e.g. off peak hot water control). Your Network Service provider can advise on ripple frequencies used in your supply area and any requirements for blocker circuits.

Customer Electricity Generation

Electricity customers are increasingly taking advantage of opportunities to generate electricity within their installation. Some installations require back up supply in case of a loss of network supply while others wish to take advantage of process steam, renewable or other energy source. Customers can arrange their generation such that it never runs in parallel with the grid network supply or run as an island independent of the grid.

Generation that runs in parallel with the grid can be designed to meet the installation's total load requirement with excess generation being exported into the grid. Alternately, grid connected generators may be designed to also run below the installation's load, thereby ensuring there is never export into the grid. The full range of options should be discussed with your Consultant or Network Service Provider.

Discussion Points with your Consultant or Network Service Provider

What is the purpose of the in-plant generation? Backup supply for essential services, exploitation of a fuel source or plant process opportunity?

Is the network capable of absorbing the capacity of the generation?

What protection is required for the generation system?

What will the impact be on plant and network fault levels?

What will be the impact on plant reliability?

What are the safety implications of in-plant generation?

Is there a demand management opportunity using this generator?

Suggestions

Installing generation within an installation is one of the most complex things an electricity customer can do. The level of complexity increases with island operation, parallel grid connection with no export or parallel grid connection with export. The best choice for a customer depends on the purpose of the generation, the nature of the fuel, the economics of generator operation and the technical requirements for grid connection. Your Network Service Provider can assist you in making the best choices.

PART 3: Network Reliability

Reliability refers to how certain you can be of having continuous supply – modern electricity supply systems are generally very reliable that it's often easy to overlook the fact that they can and will be interrupted from time to time. Interruptions can be of varying duration from fractions of a second to several hours, depending on the cause and what has to be done to restore supply.

Whilst considerable effort goes into maximising the reliability of the network, interruptions are inevitable. As a consequence, you should identify the risks of supply interruptions so you can take appropriate steps to manage their impact. You need to consider:

- Do you have any equipment or processes that could be affected by momentary or extended interruptions?
- What would be the cost and consequences of these interruptions?
- What stand-by or backup measures do you need for your installation?

A number of loads are particularly important to consider when an electricity interruption occurs. These may include:

(a) Lighting

Premises with no natural lighting or occupied at night should have appropriate emergency lighting, including exit lights.

(b) Access and exits

Automatic doors and gates will need to be bypassed; people will need to use adequately-lit stairwells as an alternative to lifts.

(c) Data

Prudent computer users will have backup and records management procedures, and UPS to permit a managed shut down of system.

(d) Critical processes

Manufacturing processes need to be shut down in an orderly fashion. Continuous processes, especially those involving materials which have to be maintained at high temperatures (eg plastic extrusion), will need special measures. Commercial premises have particular problems – will you be able to keep trading if supply is interrupted (eg barcode scanning, electronic funds transfer)?

(e) Perishable product

Food, pharmaceuticals, etc, that need to be kept at low temperatures will need to be protected; well-insulated storage areas will maintain their low temperatures for a reasonable period of time, provided that doors are not opened or higher temperature product added.

Clearly, there are solutions that assist in mitigating interruptions that you should implement within your own business. However, to assist in the analysis of the risks of electricity interruptions, there are benefits in understanding the inherent reliability of the electricity network that you are connected to, or proposing to connect to. The following sections describe how reliability is measured, and how the design of the network impacts on the level of reliability you receive.

Reliability Indices

In order to provide meaningful comparisons of reliability performance, the measures used by Network Service Providers and regulators to track reliability focus on how often and for how long electricity is interrupted. An interruption of 1 hour per annum equates to a reliability level of 99.989%. If this were to increase to 1½ hours, the reliability would still be 99.983% – a barely noticeable change. This measure in itself does not provide the focus on reliability performance that Network Service Providers and regulators need to monitor the performance of the network. As a consequence, a range of specific indices have now become part of the "jargon" of the industry. These are referred to as SAIDI, SAIFI, CAIDI and MAIFI.

(a) **SAIDI - System Average Interruption Duration Index** – the total number of minutes, on average, that a customer on a distribution network is without electricity supply in a year.

(b) **SAIFI - System Average Interruption Frequency Index (SAIFI)** – the average number of times a customer's supply is interrupted in a year.

(c) **CAIDI - Customer Average Interruption Duration Index (CAIDI)** – the average duration of each customer interruption. This index represents the average length of time a customer has to wait before electricity supply is restored after an interruption.

(d) **MAIFI – Momentary Average Interruption Frequency Index (MAIFI)** – the number of momentary (less than 1 minute) interruptions experienced by an average customer in a year.

Total loss of supply voltage for intervals exceeding one or two seconds are regarded as 'interruptions' to supply. Very short term voltage excursions (known as voltage dips or voltage sags) lasting only one or two seconds are categorised as "quality" issues. These events are not classed as interruptions even though they may cause similar problems to customers. The "Voltage Sag" section of Part 4 "Network Power Quality" provides more information on the characteristics of voltage sags.

Interruptions may be temporary or sustained:

(a) **Momentary** interruptions are caused by faults such as a branch hitting a power line which cause no permanent damage. If the fault has cleared, supply is usually restored by the operation of automatic reclosing circuit breakers. Supply is usually interrupted for no more than 15 seconds although it could be as long as 30 to 40 seconds before supply is restored. There might also be two or even three attempts to automatically reclose before the fault is cleared and supply is finally restored. MAIFI measures the number of interruptions less than 1 minute in duration.

(b) **Sustained interruptions** are caused by significant damage or other incidents on the system requiring the attendance of a line crew. Supply is interrupted until the problem can be found and attended to, depending on the nature and location of the problem and the distance the crew has to travel. This could take a few hours or significantly more in some country areas. If there is no permanent damage to the power line and emergency personnel report that there are no safety problems, supply could be switched back on after about 15 minutes. Sustained interruptions of greater than 1 minute are included in SAIDI, SAIFI and CAIDI indices.

It is not practical for Network Service Providers to measure and record these indices on an individual customer basis. As a compromise, most distribution Network Service Providers keep records at a high voltage feeder level (generally 11kV or 22kV), which they can then aggregate on a feeder type (CBD, Urban, Short Rural or Long Rural), regional or company basis. Not all distributors record MAIFI.

Planned and Unplanned Interruptions

Interruptions can be planned or unplanned. Planned interruptions occur when Network Service Providers need to interrupt supply to connect new customers or carry out planned maintenance or repairs to network equipment. Network service providers are generally required to provide two days notice of their intent to conduct planned maintenance. This is intended to assist you in managing the impact of these necessary interruptions. In recent years, Network Service Providers have developed techniques that enable them to do an increased amount of work live. These so-called “live line” techniques help reduce the incidence of planned outages, but are not always economic or practical. Above all, safety cannot be compromised. Unless the Network Service Provider is totally satisfied that live line techniques can be safely applied, a planned interruption will be arranged.

Unplanned interruptions generally occur without warning or in an emergency such as a fire or vehicle accident. They may be due to environmental causes such as storms, lightning or birds, animals or vegetation touching mains, equipment failure, or other causes largely outside the Network Service Provider’s control such as vehicle accidents, cable dig-ins and vandalism. Environmental causes are the greatest contributor to unplanned interruptions.

Interruptions also occur when it is necessary to carry out emergency work to eliminate the risk of injury to people or damage to property. For example, if there has been an accident involving a power line, supply will need to be switched off at the nearest switching point to the accident – this could affect customers not in the immediate vicinity of the accident. It is also sometimes necessary to interrupt supply to prevent the risk of fire when conditions reach fire danger levels in high bushfire risk areas.

There are also circumstances where the market operator, or the transmission Network Service Provider, may need to interrupt supply to protect the overall security of the power system network (this is called “load shedding” and may be required if there has been a significant loss of generation or transmission capacity). These events are rare, but a necessary part of operations to avoid large parts of the system shutting down.

Reliability Reporting

Depending on the jurisdiction in which they operate, Network Service Providers are required to report either quarterly or annually on the reliability performance of their network. These reports are generally available on the web.

As well as providing insight to the overall trend in each Network Service Providers' reliability performance, these reports are a useful source of information to you, the customer, as to the frequency and duration of outages that are typical in your locality.

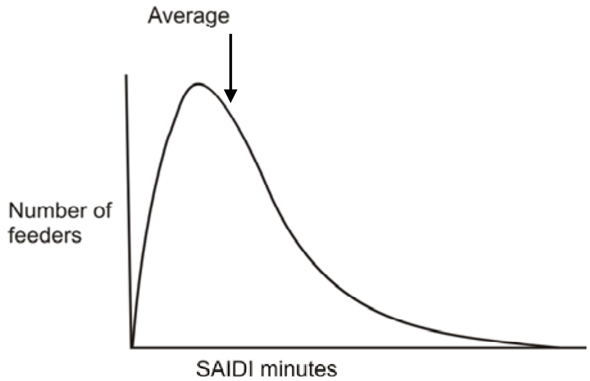
SAIDI, SAIFI and CAIDI are almost universally reported at both Network Service Provider level, and by feeder type – that is, CBD, Urban, Short Rural and Long Rural. In addition, planned and unplanned outages are reported separately. MAIFI may also be reported on this basis.

It is also common to provide information on a "normalised network" basis. Normalisation removes events over which the Network Service Provider has no or very limited control. This includes outages due to load shedding by the market operator or transmission Network Service Provider. It also includes some exclusions relating to major events that impact on large sections of the network These could include major storms, cyclones and bushfires. The rules for exclusion are set by regulators.

The "normalised network" basis of reporting is intended to provide a guide to the underlying trend in the performance of the network over time, removing some of the volatility that occurs from year to year.

Reliability Measure	***Indicative Range for Australian Distributors (Average across all customers)***
SAIDI	15 to 500 minutes per year
SAIFI	0.4 to 5 interruptions per year
CAIDI	30 to 300 minutes
MAIFI	0.1 to 15 interruptions per year

Whilst providing a useful guide to the performance of the network in your locality, care needs to be exercised in interpreting the results. Results vary significantly between Network Service Providers because of the different conditions under which they operate. Even at a feeder category level within the one Network Service Provider, there can be a wide variation in the performance of individual feeders (both in comparison to each other, and from year to year). Typically, the spread of individual feeder performances within a feeder category may be distributed around the average as shown in the following diagram.

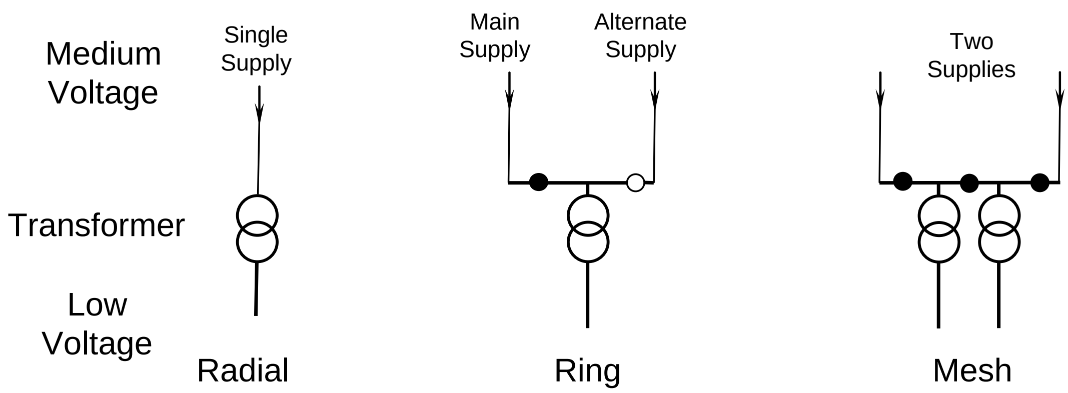


In recent times, a number of governments have introduced licence conditions requiring Network Service Providers to maintain or improve the average performance of their high voltage network, and to target improvement programs at the worst performing feeders. If reliability is crucial to your business, you should discuss with your Network Service Provider the nature of the network that you are connected to, whether any improvements or changes are planned, and what mitigation strategies you may need to implement to achieve the optimal reliability for your business.

Reliability by Design

Electricity networks have developed over many years, and their design is often a function of the load density being serviced. The inherent design of the network affects the reliability that you receive.

Commonly used Medium Voltage / Low Voltage combinations



- **Radial line –** Single MV supply only with no alternative supply from network. Customers have to wait for detection, repair, and restoration after a network fault. Customers need to be able to manage interruptions for many hours. Backup or emergency supply probably justified for important loads. This method of supply is very common in rural and remote areas.

- **Ring –** After a fault on the main MV supply, the supply needs to be manually changed over to the alternate source by field crews operating disconnect switches. Customers need to be able to manage interruptions of at least several hours. Backup or emergency supply may be justified for important loads. This method of supply is most common in urban, residential, shopping centre and light industrial areas.

- **Meshed system –** Failure of supply from one source is catered for by automatic switching and changeover to another source of supply. Some customers probably won't notice the transition while others will detect a brief voltage sag. Your equipment needs to be robust enough to ride through a second or more of disturbance. Backup or emergency supply may still be justified for critical loads. This method of supply is rare and is generally restricted to CBD areas of large capital cities.

Information on each Network Service Provider's design philosophy for the level of redundancy in their zone substations and subtransmission system is usually published in their Network Management Plans. This can also provide a valuable source of information on the inherent reliability of the network, and the levels of redundancy that exists in particular geographic locations.

In some areas, your Network Service Provider may be able to offer a second point of supply from a different part of the medium or high voltage network. If a problem occurs on one section of high voltage network, supply can be taken from the second point. Circuit breakers at the supply points must be interconnected so that changeover can take place safely and effectively. Because of the high cost involved, this is usually only justified for major installations such as hospitals and large manufacturing enterprises.

Where high levels of reliability are important for a customer, optimising electricity arrangements by using a range of solutions within the customer's own installation should always be considered. These solutions may include;

- **Emergency Power Supplies -** Certain premises are required to have emergency power supplies to ensure public safety – eg lighting and exit lighting in public buildings. In hospitals, life-critical equipment will be supplied from a dedicated emergency circuit, usually battery-based, and with a seamless changeover from normal to emergency supply.

- **Uninterruptible Power Supplies -**Computing and electronic equipment can be provided with a battery-based uninterruptible power supply (UPS).

- **Backup or Stand-by Generator Power Supplies -** Your installation can have its own emergency or backup generator. Usually it will just have the capacity to maintain supply to important circuits rather then the entire installation. Loads are normally divided into essential and non-essential and supplied from separate circuits. The automatic start-up and changeover will take time and a UPS may be needed to maintain supply to critical circuits and equipment until the generator comes on line. Where customers have their own generators, appropriate measures are needed to ensure that their installations are isolated from the network so that people working on power lines, and expecting them to be de-energised, are not exposed to danger.

- **Battery Powered Notebook Computers –** Use of battery powered computers in lieu of desk top computers may be an option for some applications.

In many cases an installation solution will be more cost effective than a network solution.

No matter what method of supply is used to service your area, supply interruptions are inevitable. The method of supply has a bearing on the long term average of power interruption frequency and duration that can be expected.

Restoring Supply

Restoring supply is the process of re-energising power lines once the source of interruption has been identified and removed. Restoring supply can be an automatic or manual process.

In order to restore supply as quickly as possible after temporary faults, Network Service Providers make extensive use of automatic circuit breakers and reclosers, but there are still many circumstances where field inspection, repairs and switching are required.

Restoring supply can have the same effect as switching on all your equipment and appliances at once – overloading circuits and causing its own set of problems (especially if you are trying to start large motors).

Many devices, especially larger equipment in industrial or commercial installations, will disconnect themselves from the supply when it is interrupted (eg through the operation of no volts or under-voltage relays). This prevents them starting with mechanical loads still connected (and producing even higher starting demands). Because of the obvious safety and process issues, an orderly restarting sequence is essential.

In commercial and industrial installations, under-voltage or "no volt" relays should operate to disconnect equipment from the supply so that correct starting procedures can be followed when supply is restored. Speed controls on motors should "fail safe" and disconnect the motor if supply is lost while contactors will drop out.

Contact phone numbers for your Network Service Provider can generally be found in a telephone directory. However, a good source of information is your electricity account, particularly if you have changed retailer. This will list the correct numbers to call for various issues, such as accounts, service difficulties or emergencies.

PART 4: Network Power Quality

The quality of supply is a more complex and subtle matter compared to reliability. It is not about whether supply is available but rather, if electricity supply is suitable and compatible for use by customer equipment.

In Australia, electricity supply is often simply described as nominally a 230 volt RMS alternating current supply consisting of a 50 Hz sinusoidal waveform. This does not mean that customers should expect a constant perfect 230 volt sinusoidal supply. In fact the supply voltage is never a perfect 50 Hz 230 volt sinusoidal supply. Variations in supply voltage, frequency and wave shape occur with the supply to all installations and these variations are normal and are generally not a problem for customers.

Factors which affect quality of supply include:

1. Steady state voltage
2. Supply frequency
3. Voltage sags
4. Voltage swells
5. Voltage transients
6. Harmonic distortions
7. Radio frequency inference

Many of these factors are difficult to identify and observe, and their measurement usually requires the use of special test equipment with the analysis being carried out by experienced technicians or engineers.

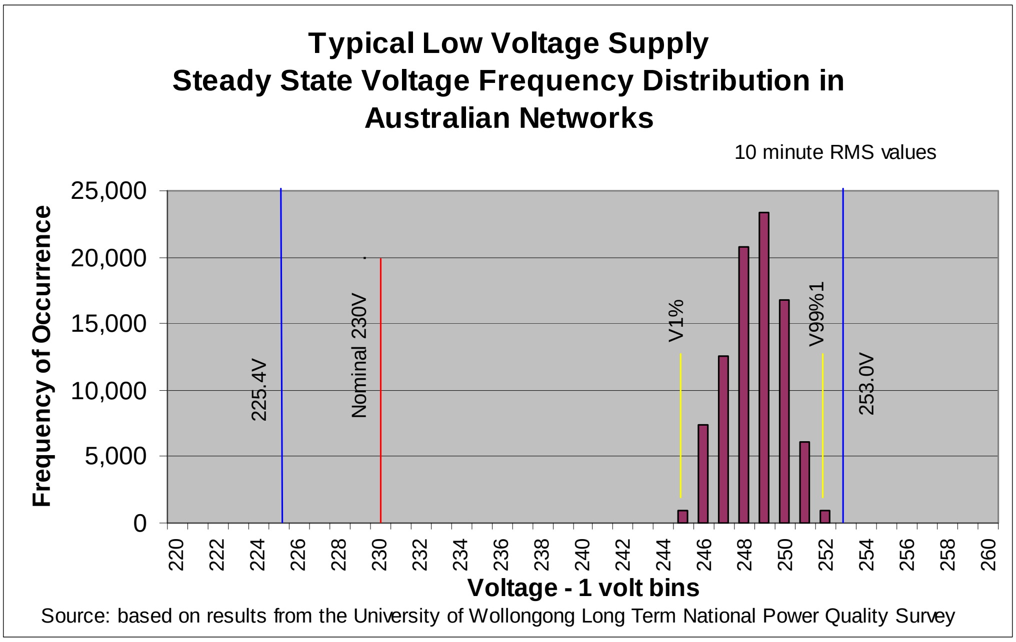
Steady State Voltage

Steady state voltage levels in networks are constantly changing in response to load variations and other networks events. In general terms, as loads increase, voltage levels tend to drop. Similarly, when load is switched off, voltage levels tend to rise. Automatic voltage regulation equipment on the distribution network compensates for longer term voltage variations but it is not designed to react to short term events. These are all normal variations which your electricity Network Service Provider takes into account in designing and managing the network.

Steady State Voltage Range

The supply voltage range made available by Network Service Providers is specified to be within a range which varies from state to state and is set by either state government regulation, code or by Australian Standard AS 60038.

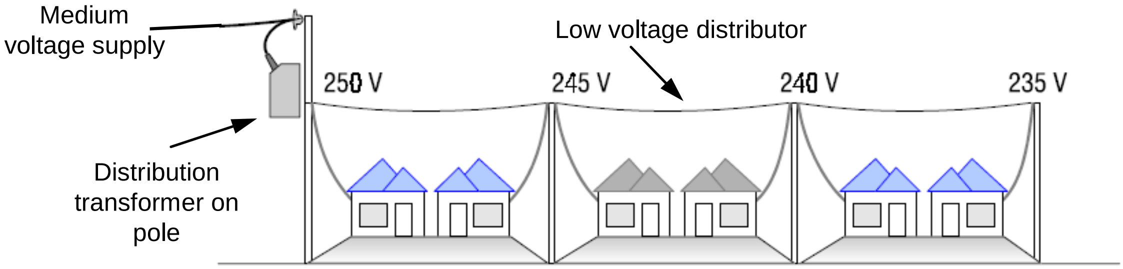
Most Australian distributors aim to control phase to neutral steady state voltage at the point of supply to LV customers in the range equivalent to 230V +10% to 230V -2% based on 10 minute RMS average measurement of voltage. Variations larger than this are not excluded under AS 60038 and should be expected and planned for by customers. Voltage variations outside these ranges can and do occur, especially during abnormal network conditions.



The figure above shows the typical voltage range experienced at a single site near a distribution transformer. It should be noted that the voltage remains at the top part of the 230V +10% to 230V -2% voltage range most of the time. Despite the nominal voltage being 230V, the voltage is close to 248V most of the time. Note that V1% and V99% show percentile voltage measures at this site.

The voltage range at the distribution transformer in combination with voltage drop along low voltage distributors and service mains is designed to provide steady state voltage within the required range to all low voltage customers.

Voltage Drop in Low Voltage Distributors



Low voltage supplies in Australia have higher steady state voltage levels than many other countries with 230V nominal systems. For example, New Zealand operates a 230V ±6% system and many parts of Europe operate in the 230V +2% -10% range. This means that some voltage sensitive electrical equipment labelled 230V may not operate effectively and provide long life in different countries (including Australia). Customers need to ensure that when purchasing electrical equipment that it is compatible with the Australian environment.

Although the nominal voltage in Australia is 230V, the voltage range used in Australia is very similar to the 240V ±6% range used under previous voltage standards and regulations.

Surveys of multiple sites from the University of Wollongong Long Term National Power Quality Survey shows a wide range of voltage levels can be expected at sites. Based on these surveys, the table below shows the wide range of steady state voltage conditions that low voltage customers can expect at the point of supply.

Voltage Measure	*Target Minimum Value*	*Target Maximum Value*	*Indicative Range found in Australian LV Networks*
$V_{1\%}$	230V-2% (225.4V)		216V to 245V
$V_{99\%}$		230V+10% (253.0V)	238V to 264V

Additional voltage drop also occurs within your own installation, between the point of supply and your equipment. AS/NZS 3000 (Wiring Rules) sets a limit on the voltage drop within customer installations at 5%.

Suggestions

Many countries throughout the world use a nominal 230V system. Within the 230V nominal system practical upper and lower voltage limits vary greatly but are generally within the range of 230V ±10%. Voltage sensitive equipment such as lighting, fixed resistive devices such as heaters and some electronic equipment may be designed to operate only over part of the full 230V ±10% range. This means that not all 230V equipment will achieve optimum performance and long life under Australian steady state voltage conditions. When purchasing voltage sensitive equipment, customers need to be conscious of the Australian steady state voltage conditions to achieve optimum equipment performance and long life. The indicative voltage range found in Australian LV networks in the University of Wollongong Long Term National Power Quality Survey is 240V ±10%.

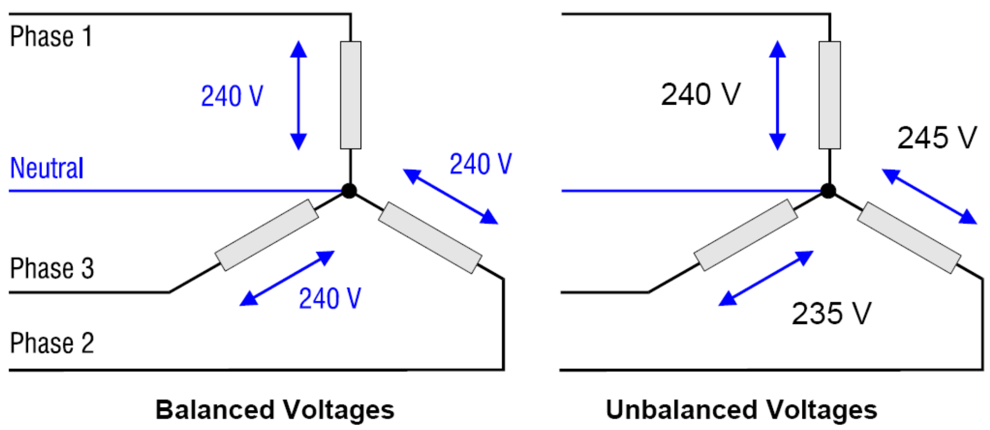
Some large customers take supply at medium voltage (typically 6.6kV, 11kV, 22kV and 33kV) and High voltage (typically 66kV, 110kV 132kV, 220kV, 330kV and 500kV). Customers who take supply at these voltage levels also experience variations in steady state voltage levels. The steady state voltage range varies from site to site and the Network Service Provider should be consulted to determine the likely range.

Voltage Unbalance

Voltage unbalance is a difference in the value of each of the three phase voltages and/or phase angle displacement. In technical terms, voltage unbalance is the ratio of the –ve sequence voltage to the +ve sequence voltage.

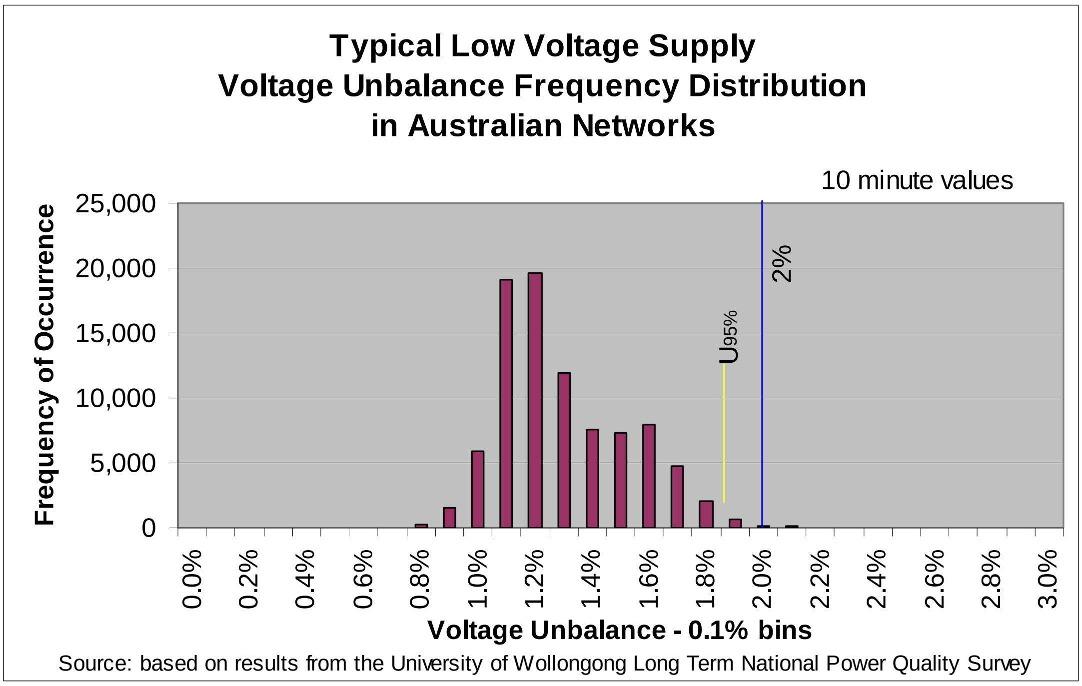
In three phase low voltage systems, unbalanced voltages can result from either unbalanced network impedances and/or unbalanced loads. Under normal operating conditions, both the supply network and three phase equipment are designed and built to have balanced impedances. The challenge for Network Service Providers and customers is to balance the connection of individual single phase loads to achieve a balanced three phase system. In practice, this is a very difficult result to achieve and some degree of unbalance will always result.

Unbalance is mainly a concern for customer installations with three phase supplies that contain three phase equipment. An unbalanced supply can cause unwanted heating and loss of efficiency of three phase motors. Unbalance can also cause maloperation of motor and variable speed drive protection schemes.



Example of Voltage Unbalance

Electricity Network Service Providers endeavour to manage the operation and loading of the distribution system so that the level of voltage unbalance is less than 2% for most of the time.



The figure above shows the typical voltage unbalance range experienced at a single site. Note that $U_{95\%}$ shows the 95th percentile of unbalance at this site.

Surveys of multiple sites from the University of Wollongong Long Term National Power Quality Survey shows a wide range of unbalance can be expected at sites. Based on these surveys, the table below shows the wide range of voltage unbalance that low voltage customers can expect at the point of supply.

Voltage Unbalance Measure	*Target Maximum Value*	*Indicative Range found in Australian LV Networks*
$U_{95\%}$	2.0%	0.3% to 3.0%

Discussion

Do you have an unbalanced three phase supply? Can your equipment (mainly motors and VSDs) tolerate this unbalance? Do your three phase motors have phase unbalance protection?

There are limits to the amount of unbalance that three phase motors can tolerate. Australian Standard AS 1359.31 provides more information about the effects of voltage unbalance on certain types of motor.

Unbalanced voltages within your installation may be the result of unbalanced loads within your installation. Ensuring that single phase loads are connected equally across the three phases is good practice for any installation.

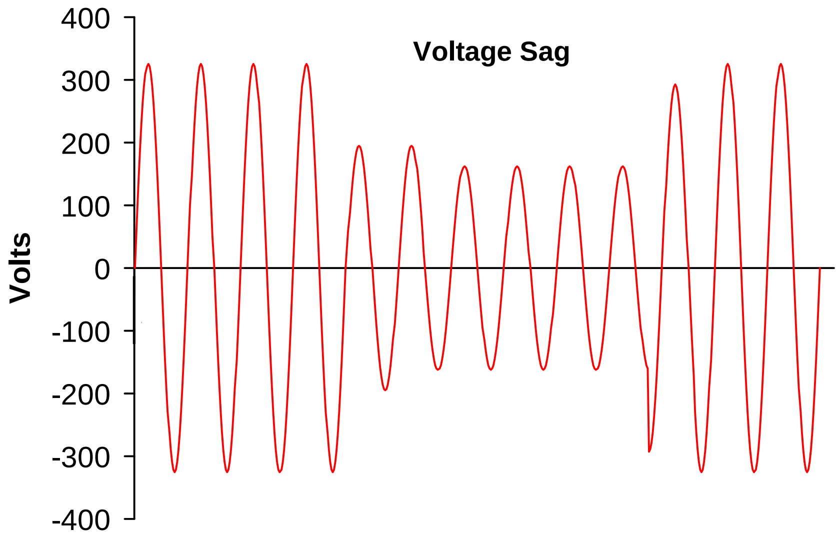
Voltage unbalance can cause the incorrect operation of protection relays and voltage regulation equipment. Unbalance can also generate non-characteristic harmonics from three phase electronic loads.

Unbalanced loads in your installation can affect other customers. Your electricity Network Service Provider's Service and Installation Rules will usually require that your installation be balanced over the three phases so that other customers are not affected.

If you experience unbalanced voltages outside the allowable limits and your own load is balanced, your electricity Network Service Provider may be able to assist by making adjustments to the network.

Voltage Sags

Voltage sags are short-term reductions in the RMS supply voltage of duration 0.5 cycles up to one minute.



The most common cause of voltage sags are faults in the distribution and transmission systems and the starting of large motors. Other causes of voltage sags are electrical faults in customer installations and transformer energisation inrush currents.

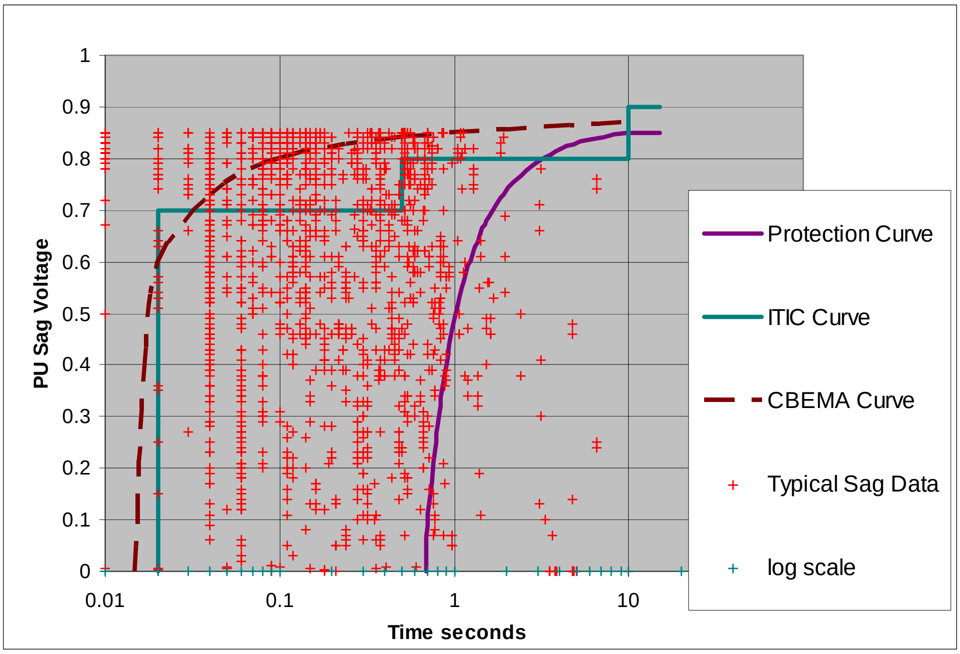
Voltage sags are common unavoidable events on distribution networks. Most voltage sags are shallow and are not noticed by most customers. However some voltage sags are deep enough and long enough to cause disruption to sensitive electronic equipment such as computers, variable speed drives, programmable logic controllers and motor control systems.

Voltage sags are generally more common during storm events with the frequency of voltage sags increasing during times of high lightning activity.

Because of differing network configuration arrangements, some supply areas are more vulnerable to voltage sags than others. Due to network exposure issues, rural areas tend to experience higher frequencies of voltage sags than city areas. Network Service Providers may be able to provide some indication of the severity of voltage sag performance at a particular location.

The voltage sag performance of the network generally improves with higher supply voltage. That is the customers that take supply at the transmission level (eg 330kV) will generally receive improved voltage sag performance compared to the subtransmssion connected customer (eg 33kV and 66kV), who in turn will generally received improved voltage sag performance compared to distribution supplied customers (eg 11kV, 230V and 400V).

Typical Voltage Sag Distribution on Australian Networks



Source: Electric Power Consulting Pty Ltd & University of Wollongong

The above diagram shows a typical distribution of voltage sags on Australian medium voltage and low voltage networks. The diagram shows that many of the voltage sags are below and to the right of the Information Technology Industry Council (ITIC) curve and the Computer and Business Equipment Manufactures Association (CBEMA) curve. These curves are equipment immunity curves. Hence equipment that is designed to be immune to ITIC and CBEMA levels can expect to suffer many voltage sag initiated maloperations. The frequency of these maloperations will depend on the voltage sag performance of the network at the point of supply. ITIC and CBEMA immunity levels are totally incompatible with normal network voltage sag performance and are more indicative of the quality of supply that could be expected from the output of a well designed Uninterruptible Power Supply.

The Protection Curve shown on the diagram is a curve based on typical protection characteristics of distribution networks and provides a boundary from which most (but not all) voltage sags will be above and/or to the left. Equipment designed to this level of voltage sag immunity can be expected to operate successfully through most (but not all) voltage sag disturbances.

Suggestions

Electricity customers need to assess their sensitivity and vulnerability to voltage sags. Customers with major computer systems or continuous processes are often the most vulnerable to voltage sags. While there have always been voltage sag events on power systems, the growing use of computers and other electronic equipment has made many installations more susceptible to these events.

When a customer is considering a location for a large voltage sag sensitive plant, it is suggested that the predicted relative voltage sag performance be discussed with the Network Service Provider.

There are many steps a customer can take to improve the immunity of equipment to voltage sag maloperation. It is suggested that customers identify and focus on the key essential parts of their entire process. These are the process parts that have the potential to cause serious disruption to the plant or process.

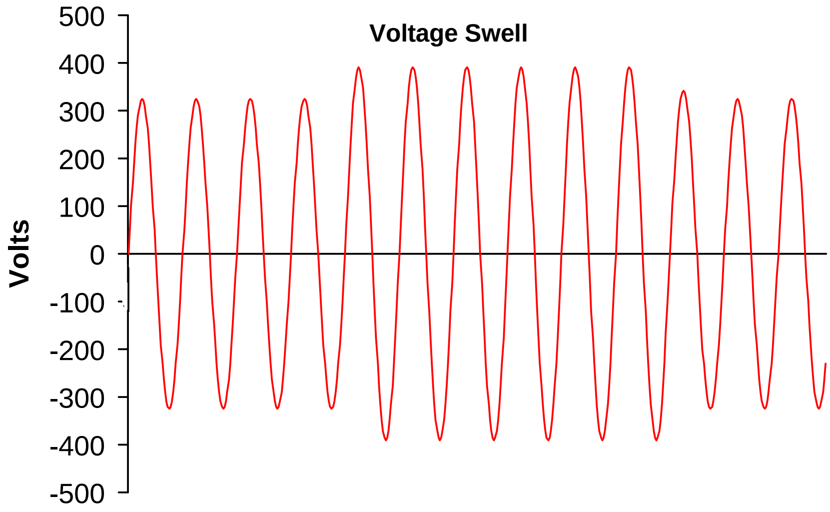
Common measures available to customers for minimising the impact of voltage sags are:

1. Use of uninterruptible power supplies
2. Use of batteries (D.C. systems)
3. Use of high energy storage/ wide input voltage range switch mode power supplies
4. Use of phase to phase (400V) circuits for control purposes
5. Maintaining all plant control circuits on a common phasing (e.g. red phase)
6. Careful setup of variable speed drive and motor protection systems
7. Use of D.C. contactors and A.C. contactors with low drop out voltage levels
8. Careful selection of all electrical equipment

Voltage Swells

Voltage swells are a short term increase in the RMS supply voltage above a threshold level of duration 0.5 cycles up to one minute. In the Australian low voltage system, the threshold or swell limit is commonly set at 264 volts.

Voltage swells are generally infrequent on distribution networks. When they do occur they are most often caused by capacitor switching or maloperating On Load Tap Changing transformers. Most electrical equipment is designed to withstand the normal range of swells a customer is likely to experience.



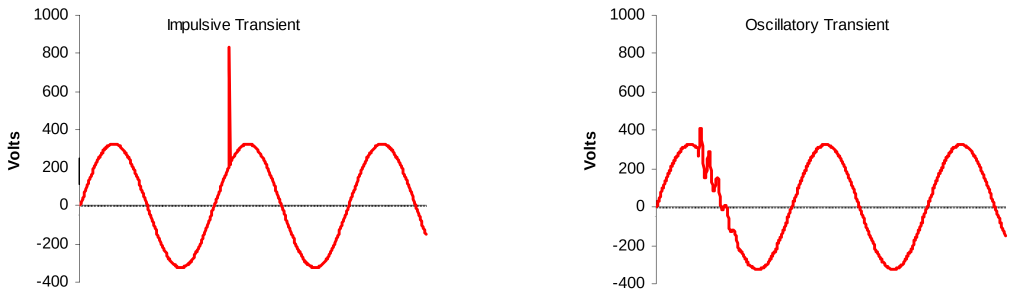
Suggestions

When purchasing expensive sensitive equipment, ensure the equipment is capable of sustaining reasonable swell levels without damage, loss of life or maloperation.

If swells are occurring at the point of supply to your installation, they should be reported to your Network Service Provider for investigation.

Transients

A transient is a sudden non-power frequency change in the steady state condition of voltage or current. There are two basic types of transient, impulsive transients and oscillatory transients.



Types of Voltage Transients

Impulsive Transients

The most common cause of an impulsive transient is lightning. The intermixing of medium voltage and low voltage conductors can also be a cause of impulsive transients. Impulsive transients are often characterised by their maximum voltage, rise time and decay time. Lightning generated transients in distribution networks can have a magnitude of many thousands of volts and have a very short duration typically in the range of 1 nanosecond to 1 millisecond.

Oscillatory Transients

An oscillatory transient consists of a voltage or current whose value rapidly changes polarity (i.e., positive to negative). Oscillatory transients can be caused by capacitor switching in a resonant circuit environment. Such resonance can be the result of switching either within a Network Service Provider's network or within a customer's installation. Resonant circuits and commutation in power electronic devices can also be the cause of oscillatory transients.

Suggestions

High energy impulsive transients can damage customer installations and electrical equipment. Customers can mitigate the risks of damage and maloperating equipment by paying particular attention to:

- Earthing
- Strategic installation of surge diverters/lighting arrestors
- Bonding
- Shielding

If an installation has experienced lightning related failures, has expensive or critical equipment then special mitigation attention is recommended. Lightning protection of installations is a very specialised area and customers should consider seeking expert advice.

In most cases oscillatory transients do not cause problems for customers. In some case oscillatory transients can cause maloperation of sensitive electric equipment including computers and variable speed drives. In rare cases oscillatory transients can damage sensitive electronic equipment. Customer experiencing problems with oscillatory transients should consult their Network Service Provider.

Voltage Fluctuations and Flicker

Flicker is the impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.

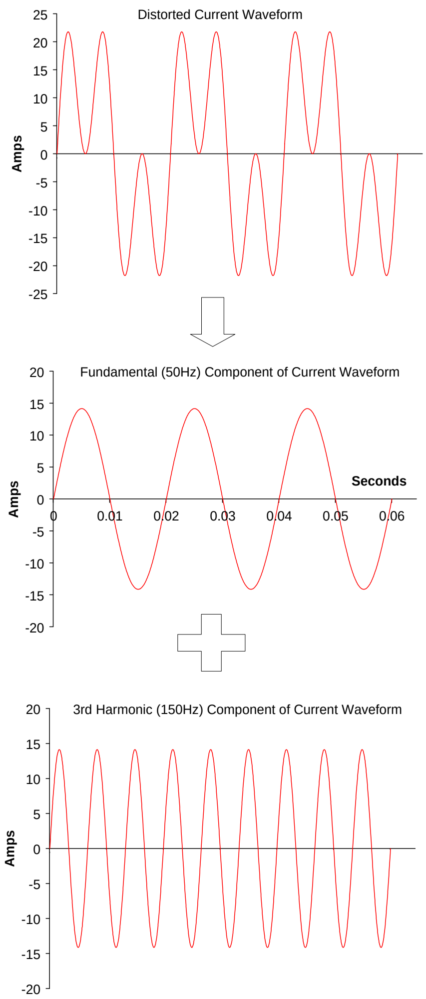
Large fluctuating customer loads can cause annoying flicker via electric lighting. Where a customer load causes voltage fluctuation at the point of supply with the network, the voltage fluctuations may cause excessive flicker on the electricity supply to other customers. Common disturbing fluctuating loads causing light flicker are arc furnaces, welding machines and frequently starting electric motors.

Discussion

If you experience flicker problems that are not caused by your own disturbing load, then consult your Network Service Provider.

Harmonic Distortion

Harmonic distortion is a regular, repetitive distortion of the basic voltage or current sine wave pattern.



Example of a Distorted Current Waveform

Harmonic distortion results from the operation of appliances or equipment that generate non-sinusoidal currents. Most modern day loads including computers, variable speed drives, fluorescent lighting are electronic in nature and inject unwanted harmonic currents into the network that must be absorbed by the supplying network. Injected harmonic currents combine with the impedance of the network to create unwanted harmonic voltages.

It is the aggregation of the injection of harmonic currents into the network from all non-linear loads that cause harmonics. These non-linear loads include all switch mode power supplied devices (e.g. computers, televisions, microwave ovens etc.), arc furnaces, thyristor switched motor controls, variable speed drives and discharge lighting.

In power systems, voltage or current distortions consisting of regularly repeating symmetrical waveforms are common. When analysed these distortions are found to be made up of the summation of pure sine wave components of varying magnitudes which have frequencies that are integer multiples (harmonics) of the fundamental frequency (50 Hz). For example, a waveform of 150 Hz is the third harmonic.

Where the voltage or current distortion is regularly repeating over one cycle and the distortion is non symmetrical, even harmonic components are generated. Where the voltage or current distortion repeats over a number of complete cycles e.g. 40 msec or 60 msec then subharmonics are generated.

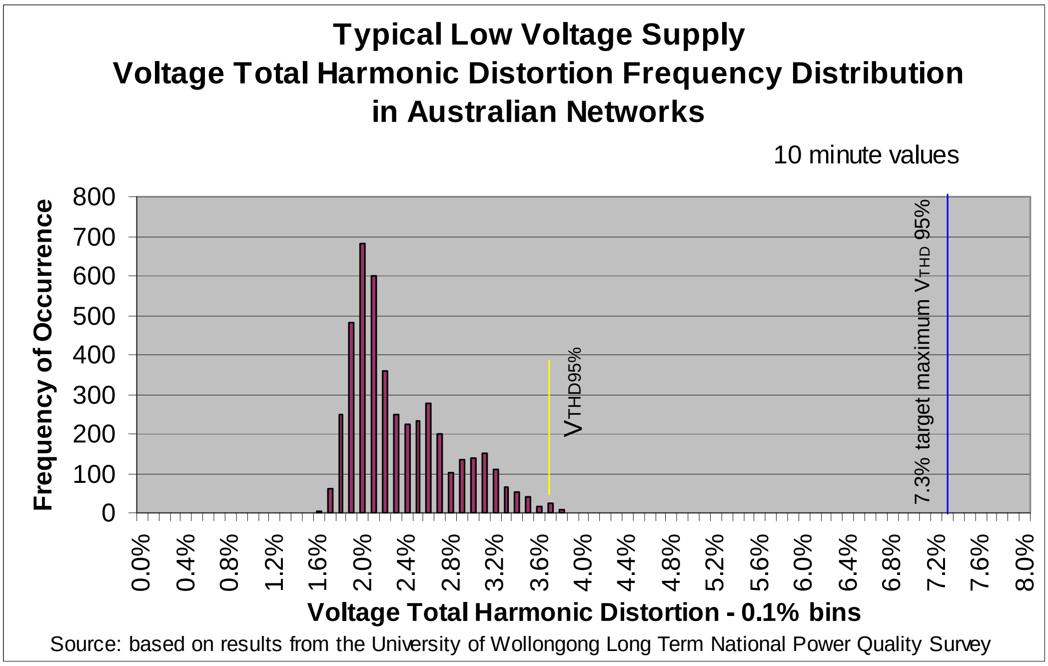
Interharmonics are created by some customer loads and are generated when the voltage or current distortion is irregular and or has a repeating time that is not an integer number of cycles.

Harmonic currents and voltage are undesirable but an inevitable part of electricity supply systems. High levels of harmonics cause additional heating losses in cables and transformers and may require such equipment to be derated. Third and other triplen harmonic currents in low voltage systems are a particular concern because they can cause neutral conductor overheating and excessive neutral to earth voltages.

Interharmonics can cause problems such as light flicker, maloperation of ripple control receivers, audible noise in audio equipment and vibration in induction motors.

Harmonic levels in networks and customer installations can be magnified by resonance associated with capacitor banks.

With regard to customer equipment, excessive harmonic voltages can cause additional losses in electric motors and poor performance of sensitive electronic equipment.



The chart above shows the typical voltage Total Harmonic Distortion experienced at a single site. Note the $V_{THD95\%}$ percentile voltage measures at this site.

Surveys of multiple sites from the University of Wollongong Long Term National Power Quality Survey shows a wide range of voltage total harmonic distortion be expected at low voltage sites. The table below shows the wide range of steady state voltage conditions that low voltage customers can expect at the point of supply.

Harmonic Measure	*Target Maximum Value*	*Indicative Range found in Australian LV Networks*
$V_{THD95\%}$	7.3%	1.5% to 7.3%

Discussion

Electricity Network Service Provider's need customers to satisfy their responsibilities to maintain harmonic currents to within the limits set out in standards to ensure that network harmonic voltage are kept within set limits.

If a customer experiences excessive harmonic voltage at the point of supply that is not caused by the customer load, the Network Service Provider should be consulted.

Supply Frequency

Supply frequency is the rate at which the voltage of the electricity supply alternates. Supply frequency is measured in Hertz (cycles per second). The normal frequency of the voltage in Australia is 50 Hz.

Electricity Network Service Providers do not control the supply frequency and do not undertake that the frequency will meet a particular standard. Within the National Electricity Market, setting frequency standards is a matter for NEMMCO, the National Electricity Market Management Company. Outside the National Electricity Market, setting frequency standards is a matter for the local generating authority.

Frequency control is a function of the generation process. Supply frequency is determined by the speed at which synchronous generators rotate. In turn the supply frequency determines the speed at which induction and synchronous motors operate.

Large load increases across the network tend to slow down the generators which decrease frequency. Large load decreases across the network cause generators to speed up which increases frequency. Load changes are continually occurring and generators are always adjusting their output to maintain frequency within set limits.

For most of the time, frequency is maintained to within the range of 49.75 Hz to 50.25 Hz with a time accumulation error of up to 5 seconds. Under rare multiple contingency events the frequency can vary in the range 47 Hz to 52 Hz. For more detail on expected frequency variations and characteristics, refer to the NEMMCO document titled "Control of Frequency and Time Accumulation Error".

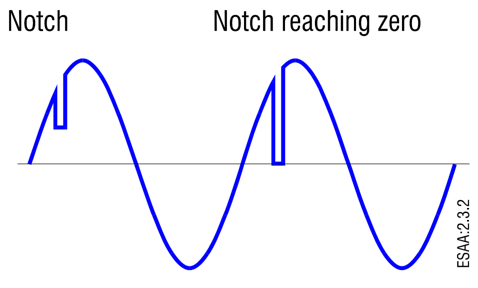
Discussion

Most customer equipment is not affected by normal variations in supply frequency.

Other Waveform Distortions

Notching

Notching of the supply system voltage waveform can occur when silicon controlled rectifiers (SCRs) are used in three phase control equipment (e.g. DC motor speed controls or induction heating equipment). When the SCR in one phase is turning on and the SCR in the next phase in turned off, momentary short circuits may occur. The resulting sudden increase in current flow can cause the voltage to drop. In severe cases the voltage can pass zero.



Some clocks, counting devices and other sensitive devices use the zero crossing point of the waveform as a timing signal. If severe notching occurs (e.g. if the notch depth passes zero), the equipment may operate or run twice as fast as it should or simply maloperate.

Direct Current

Direct current is current which only flows in one direction as opposed to alternating current which reverses its direction of flow during a cycle. Direct current is not necessarily a steady current; it can change in magnitude but not reverse its direction.

A direct current component in the neutral conductor has the effect of offsetting the waveform and can be caused by equipment that has different operating characteristics in each half of the voltage cycle. In effect, it is another form of waveform distortion. The direct current voltage component of the neutral conductor with respect to earth can reach levels in the order of ±10 volts.

Even a small amount of direct current is undesirable as it can result in transformer saturation and corrosion of the network and customer's earthing systems, possibly leading to unsafe operating conditions. No major item of equipment that is known to cause direct current to flow, can be connected directly to a supply network, and an isolating transformer designed to 'block' the direct current component may need to be installed between the equipment and the network.

It is not possible to completely eliminate the presence of direct currents from the network as these will occur in small quantities from some appliances. The direct current contribution from these sources is limited by Australian Standards.

In addition, direct current components in the neutral conductor can be influenced by such variables as proximity to large direct current traction motors and cathodic protection schemes. The Wiring Rules, AS3000 and other related Standards specify earthing requirements for customers' electrical installations, and there are stringent network earthing requirements.

Mains Signalling

Network Service Providers may inject signalling voltages onto the network to switch customers' time controlled tariff equipment (eg off peak water heaters). Commonly used frequencies are 492, 750 and 1050 Hz. Other frequencies may also be used.

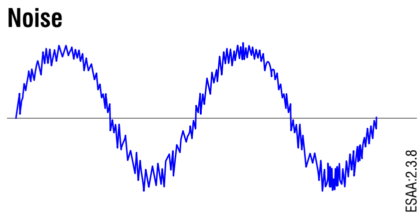
The signals may cause interference to sensitive equipment such as PA systems if they are not designed to block the signals. In addition some signals can cause unwanted audible noise in some electrical equipment. The optimum signalling voltage is a compromise to ensure effective operation of the load control relays without causing significant interference. If mains signalling causes problems within your installation then consult your Network Service Provider.

Noise

Electrical noise is a persistent oscillatory disturbance of the waveform. Noise can also refer to the audible sounds produced by some power lines and electrical equipment.

Electrical Noise

Electrical noise is a waveform disturbance with a broad frequency distribution which could be up to about 200 000 Hz. If it is of sufficient magnitude, it can cause similar problems to notching.



Electrical noise can be carried by the conductors of the customer's installation or the network (mains-borne) or it can be induced by electromagnetic fields. Mains-borne noise is similar to harmonic distortion but consists of a mixture of higher frequencies (not necessarily harmonics of 50 Hz).

Mains frequency electromagnetic fields (50 Hz) are more likely to produce specific problems with audio circuits and computer screens than interfere with the normal operation of electrical equipment. If audio circuits are not adequately shielded, nearby electrical cables can induce 50 Hz signals. This problem is made worse if the noise signal is then amplified. Strong electromagnetic fields can also deflect the path of the electron beam in computer screens, distorting the display or causing it to jitter.

Audible Noise

Audible noise includes the 50 Hz hum normally produced by electrical equipment such as transformers and the crackle of electrical discharges from insulators and other high voltage equipment. This latter noise can be persistent or intermittent.

(a) Intermittent discharges are usually related to weather conditions. Partially loose connections can be disturbed by winds while damp or humid conditions can result in electric currents tracking across the surface of dirty insulators. A good shower of rain will probably wash the insulators clean and stop the discharge. In coastal or industrial areas, electricity Network Service Providers may have a program of insulator washing to manage this problem.

(b) Persistent discharges are due to damaged equipment (eg, cracked insulators or loose connections).

These discharges can, in turn, produce radio frequency interference that affects communications equipment. (Radio frequencies range from 10 kilohertz to 100 000 megahertz.)

Discussion

Do you have equipment likely to produce noise or electromagnetic interference within your own or neighbouring installations?

Do you have equipment susceptible to noise or interference?

What measures do you need to take to protect your equipment against noise or interference?

Electrical Noise

Mains-borne noise can be introduced by electronic control devices which work by reshaping the supply waveform – e.g. dimmers or speed controllers, especially those using thyristors to "chop" the sine wave. These disturbances are similar to harmonic distortion, differing only in their frequency. Small motors, particularly those in some portable appliances, are often a source of noise (most home owners are familiar with drills, mixers or hair dryers interfering with the television picture). Loose connections, inadequate earthing, or low manufacturing standards can contribute to noise problems.

Suggestions

Electrical Noise

The same measures which protect against transients and harmonic distortion can also be applied where electrical noise is a problem.

Power filters are usually used to minimise the effect of rapid voltage changes but they can also remove or attenuate electrical noise. A line conditioner can also protect against electrical noise and voltage transients.

Audio circuits and computer screens affected by mains frequency electromagnetic fields (50 Hz) need to be adequately shielded or separated from the noise source.

Audible Noise

Your electricity Network Service Provider will comply with noise abatement legislation and other relevant regulations. This legislation is usually contained in Environmental Protection area. Network service providers are conscious of potential noise problems and employ a variety of techniques to address them. These include the purchase of special low noise transformers and the use of low vibration mountings. A satisfactory outcome is often achieved by ensuring adequate separation between the equipment and any customer or public locations.

The source of noise caused by electrical discharges may be harder to locate, especially if it is an intermittent fault. Insulator pollution problems can be addressed by various methods while damaged equipment, once found, can be repaired or replaced.

Radio Frequency Interference

Complaints about radio frequency interference with radio, television and other communication equipment can be referred to the Australian Communications and Media Authority (ACMA).

The ACMA has publications and technical advisory staff to assist customers in determining the likely cause of reception interference. If the problem is identified as being caused by the distribution system, your electricity Network Service Provider will address the problem in consultation with the ACMA.

Glossary

Alternating Current (AC)	Current which regularly reverses its direction of flow; the number of complete cycles of flow and reversal per second determines the AC frequency.
Ampere (A)	Unit of electric current.
Australian Communications and Media Authority (ACMA)	Agency responsible for investigating interference with radio and television reception.
Backup Power Supply	A power source or generator installed by a customer to take over supplying the installation if the main supply is lost.
Interruption (Blackout)	Total loss of electricity supply affecting one or more customers and persisting for some time.
Brownout	An abnormal low supply voltage condition lasting more than 1 minute.
Computer and Business Equipment Manufactures Association (CBEMA) curve	A voltage sag equipment immunity curve produced by the Computer and Business Equipment Manufactures Association.
Customer Average Interruption Duration Index (CAIDI)	The average duration of interruptions experienced by customers in a year (total duration of interruptions divided by the average number of interruptions); also known as the "average restoration time" – i.e., the average length of time a customer has to wait before supply is restored.
Capacitance, capacitor, capacitive	An electrical load characterised by the voltage waveform lagging behind the current.
Circuit breaker	An electrical switch able to interrupt a flow of current under both normal and fault conditions.
Cogeneration	The combined production of useful heat and electricity from the combustion of a fuel.
Consumer's Main	The electrical conductors connecting the customer's main switchboard to the Point of Supply.
Current	Rate of flow of electric charge through a conductor.
Customer	The end user of electricity supplied through a network.
Direct Current (DC)	Current which only flows in one direction (this does not necessarily mean that the current remains at a steady value).

Delta Connection	The connection of three phase equipment using just the three active conductors; each phase operates at phase-to-phase voltage (eg 400 volts).
Demand Management	The management of the loads within a customer's installation to meet objectives for maximum and average demand.
Direct On Line (DOL)	A motor starting method which connects the motor directly to the supply, usually resulting in a large peak starting current as the motor comes up to speed.
Disconnect Switch	Device used to open or close contacts in a distribution system circuit.
Distribution System	The network of switchgear, conductors, transformers and other equipment which transmits electricity from the transmission system and supplies it to customers.
Distribution Transformer	Transformer which reduces high distribution voltages to low voltage – usually 230/400 volts nominal for supply to customers.
Disturbance	A short term change in supply characteristics such as those caused by large motors starting or stopping.
Electricity Regulator	An office established by each jurisdiction to ensure compliance with relevant legislation, Codes, and Regulations.
Emergency Power Supply	A power source or generator installed by a customer to take over supplying the installation if the main supply is lost.
Fault current	The amount of current flowing in a circuit under short circuit fault conditions.
Feeder	A section of the distribution network.
Flicker	Fluctuations in light output of electric lighting detectable by the human eye.
Fluctuations	Irregular changes in supply characteristics such as rises and falls in supply voltage and/or current. Usually associated with rapidly changing loads.
Frequency	The number of cycles occurring in a unit of time (usually a second); in the case of AC electricity supply, the number of cycles per second. In Australia, the nominal supply frequency is 50 Hz.

Generator	Source of electric power in a power system.
Harmonic	Integer multiples of a base frequency (eg, the third harmonic of 50 Hz is 150 Hz).
Harmonic	
Harmonic Distortion	A distortion of the sinusoidal waveform that can be expressed as the compound effect of a number of underlying harmonics.
Hertz (Hz)	A measure of frequency; one hertz equals one cycle per second.
High Voltage (HV)	Voltages in excess of 36,000 volts AC.
HV/MV Injection	The introduction of high voltage or medium voltage into the low voltage system through accidental connection (eg, a broken MV conductor falling across a low voltage feeder).
IEC	International Electrotechnical Commission; the international body responsible for developing safety and technical standards.
IEEE	The Institution of Electrical and Electronic Engineers.
Immunity (equipment)	The ability of electrical equipment to operate satisfactorily despite certain variations in the electricity supply.
Impedance	A property of electric circuit components (eg, conductors, transformers, capacitors and inductors) which restricts the flow of AC electric current.
Incandescent Lamp	A lamp in which light is emitted by a filament heated to high temperature by an electric current.
Induction, inductor, inductive	An electrical load characterised by the current waveform lagging behind the voltage; usually associated with devices containing an iron core and windings (eg, motors, ballasts).
Information Technology Industry Council (ITIC) Curve	A voltage sag equipment immunity curve produced by the Information Technology Industry Council.
Interconnector	A transmission line connecting the transmission networks in adjacent states or territories.
Interruption	A loss of supply usually lasting for more than one or two seconds; interruptions of less than one second or involving less than a 100% drop in supply voltage are classified as disturbances.
Kilovolt (kV)	One thousand volts.

Kilowatt (kW)	One thousand watts.
Kilowatt hour (kWh)	One thousand watt hours.
Kilovolt-amp (kVA)	One thousand volt amps.
Line Conditioner	A device which filters out fluctuations and provides a stable output voltage over a wide range of input voltages.
Load current	The amount of current flowing in a circuit or drawn by equipment when operating under normal conditions.
Load Factor	The ratio of the average load to the maximum load.
Load Shedding	The systematic disconnection of customer loads to protect the security of the transmission network during periods of significant system overload or loss of generation capacity.
Momentary Average Interruption Frequency Index (MAIFI)	The number of momentary interruptions (less than 1 minute) experienced by an average customer in a year.
Low Voltage (LV)	Voltages greater than 50 and less than 1000 volts AC; generally refers to the 230/400 volt supply taken by most customers.
Maximum Demand	The highest load occurring over a period of time.
Medium Voltage (MV)	Voltages greater than 1000 volts AC and less than 36000 volts AC.
Megawatt (MW)	One million watts.
Meshed System	A distribution system with a number of interconnection points so that failure at one point can be isolated and supply maintained to other customers from elsewhere in the network.
Microsecond (μsec)	One-millionth of a second.
Millisecond (msec)	One-thousandth of a second.
Motor Starting Current	The electric current drawn by a motor during the starting process.
NEMMCO	The National Electricity Market Management Company: the body responsible for operating and administering the National Electricity Market.
Network	The structures, conductors and other electrical equipment which conveys electricity to customers.
Network Service Provider	An entity licensed to provide connection to the electricity distribution network and associated

	services.
Noise (Electrical)	Small persistent distortions of the voltage waveform, usually at higher frequencies.
Notching	A distortion of the waveform which can occur during the rectification process when two phases of the supply are effectively short-circuited for a brief time.
Nominal Voltage	The voltage by which a system is designated or identified and to which certain operating characteristics are referenced. (eg 230V)
Nuisance Tripping	Unnecessary operation of protective equipment in response to changes in voltage or current which are within reasonable limits.
Over-Voltage	Persistent condition in which supply voltage is greater than the upper limit.
Point of Supply	The boundary point between the electricity supply network and the customer's installation.
Point of Common Coupling	The first point on the network at which disturbances from a customer's installation may impact on other network users. This is usually the point where the service main is connected to the distribution network.
Power	Rate at which energy is used. Units are in kWhr. .
Power Factor (True)	True power factor is the ratio of electrical power (measured in watts) to the product of RMS voltage and RMS current in an AC circuit.
Power Factor (Displacement)	Power factor is the cosine of the angle between the fundamental of the voltage and the fundamental of the current.
Power Filter	A device which smooths out or filters the effect of rapid voltage surges; it can also remove or attenuate electrical noise.
Power Quality	Any voltage, current or frequency deviations that results in failure or maloperation of customer equipment.
Protection Curve	A Voltage Sag curve based on typical protection characteristics of distribution networks. Provides a boundary from which most (but not all) voltage sags will be above and/or to the left.
Radial Feeder	A distribution line supplied from only one end.

Recloser	A reclosing circuit breaker. Many faults which trip circuit breakers are only temporary; a recloser automatically switches back on after a short period. If the fault has gone, supply is automatically restored.
Rectifier	A device which converts AC into DC.
Reliability	A measure of the continuity of supply (i.e., how long supply is interrupted).
Retailer	An entity that purchases electricity in the wholesale electricity market and on sells the electricity to large numbers of customers.
Ring Main	A distribution system with a number of interconnection points and therefore multiple directions from which supply can be maintained to a given point.
Service Main	The electrical conductors connecting the Point of Supply to the distribution network; these may be overhead or underground.
Signalling	A control technique used by electricity authorities to control certain equipment by injecting voltages of distinctive frequency.
Silicon Controlled Rectifier (SCR)	Solid-state control device; effectively acts as a heavy-duty switch when its "gate" connection is triggered by a control signal.
Single Phase	Electrical circuit with a single current path (one active and one neutral conductor in low voltage systems or two active conductors in some high voltage systems – see SWER).
Single Wire Earth Return (SWER)	A high voltage single phase distribution system using only one conductor; the circuit is completed through earth connections (much like the wiring in a car uses the body and chassis as a return path to the battery "earth".
Sinusoidal	A waveform shape which follows a sine curve (sine wave).
Star Connection	A connection of three phase equipment using the three actives and the neutral; each phase operates at phase-to-neutral voltage (eg, 230 volts).
Starting current	The amount of current flowing in a circuit or drawn by equipment under starting conditions.

Steady State Voltage	The RMS voltage measured over a length of time (usually 10 minutes).
Substation	An installation comprising of switchgear and transformer(s). Used to control the flow of electricity and transform the voltage from one level to another.
Surge Diverter	A voltage-sensitive device such as a metal oxide varistor (MOV) which restricts incoming voltages to predetermined levels, directing the associated fault current to earth.
Sustained Interruption	An interruption caused by an incident or damage to a power line requiring manual switching to effect restoration of supply.
System Average Interruption Duration Index (SAIDI)	The total average duration of interruptions experienced by customers in a year (total number of interruptions multiplied by the average duration of interruptions); also referred to as the "average customer minutes off supply".
System Average Interruption Frequency Index (SAIFI)	The average number of times a customer loses supply in a year.
Taps	Connections to the windings of a transformer.
Tap-changing	Automatic or manual process of connecting to different taps to change the output voltage of a transformer; usually performed in response to changing loads in order to maintain supply voltages within limits.
Temporary Interruption	An interruption caused by a fault which leaves no permanent damage to the power line. Supply is usually restored automatically.
Three Phase	An electrical distribution system using three active conductors separated by 120 degrees.
Thyristor	A solid-state device used to control current flow; also known as a silicon-controlled rectifier (SCR).
Time Accumulation Error	The time error in seconds a synchronous clock would measure due to variations in mains frequency.
Total Harmonic Distortion	A measure of distortion applicable to repeating waveforms. Used commonly as a measure of harmonic distortion for voltage and current. It is the RMS value of the non fundamental components of the waveform.

Transformer	A device which changes AC voltages; step-up transformers increase voltage while step-down transformers decrease them.
Transient	A sudden short duration change in voltage and/or current.
Transmission system	The network of structures, conductors, and equipment which transports large quantities of electricity from power stations to major substations; usually operates at voltages of 220 kV and above.
Under-Voltage	Persistent condition in which supply voltage is less than the lower limit.
Uninterruptible Power Supply (UPS)	A device to provide protection against supply interruptions as well as against voltage fluctuations. A UPS incorporates an energy source such as a battery and supplies AC equipment through an inverter. UPS systems vary greatly in performance and cost. The more expensive double conversion types are capable of filtering out some disturbances. UPS systems are often used in conjunction with a stand-by generator to provide supply during extended outages.
$U_{95\%}$	95^{th} percentile of voltage unbalance. That is the voltage unbalance calculated from a set of voltage unbalance readings (usually 10 minute) of a site during a survey period that is greater than 95% of the readings and less than 5% of the readings.
Volt (V)	Unit of electrical pressure.
Voltage	Electrical pressure which causes current to flow in a circuit.
$V_{1\%}$	1^{st} percentile of steady state voltage. That is the voltage calculated from a set of steady state voltage readings of a site during a survey period that is greater than 1% of the readings and less than 99% of the readings.
$V_{99\%}$	99^{th} percentile of steady state voltage. That is the voltage calculated from a set of steady state voltage readings of a site during a survey period that is greater than 99% of the readings and less than 1% of the readings.

Voltage Regulation	Variations in voltage with changing load conditions.
Voltage Sag	A short duration reduction in supply voltage where the RMS voltage of a ½ cycle falls below a threshold limit (e.g. below 216V RMS in a 230V system). Voltage sags can last from ½ cycle through to 60 seconds.
Voltage Swell	A short duration increase in supply voltage where the RMS voltage of a ½ cycle increases above a threshold limit (e.g. above 264V RMS in a 230V system).
Voltage Unbalance	The ratio of -ve sequence voltage to +ve sequence voltage. It is a measure of the unevenness of phase voltages in a three phase system.
Volt-Amp (VA)	The product of the voltage and current in a circuit.
$V_{THD95\%}$	95^{th} percentile of voltage total harmonic distortion. That is the total harmonic distortion calculated from a set of steady state voltage readings of a site during a survey period that is greater than 95% of the readings and less than 5% of the readings.
Watt (W)	Unit of power.

Standards and References

AS/NZS 3000 – “Wiring Rules”

AS 60038- “Standard Voltages”

AS/NZS 61000.3.6- “Limits – assessment of Emission limits for distorting loads in MV and HV power systems”

AS/NZS 61000.3.2- “Limits for harmonic current emissions (equipment input current less than or equal to 16 A per phase)”

HB 264 – Power Quality. “Recommendations for the application of AS/NZ 61000.3.6 and AS/NZ 61000.3.7”

AS/NZS 61000.3.3 - “Limitation of voltage fluctuations and flicker in low voltage supply systems for equipment with a rated current less than or equal top 16A”

AS/NZS 61000.3.5 - “Limitation of voltage fluctuations and flicker in low voltage supply systems for equipment with a rated current 16A to 75A”

AS/NZS 61000.3.7- “Limits – Assessment of emission limits for fluctuating loads in MV and HV power systems”

AS/NZS 61000.3.11- “Limits—Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems—Equipment with rated current less than or equal to 75A and subject to conditional connection”

AS/NZS 61000 2.2 – “Environment – Compatibility levels for low frequency conducted disturbances and signalling in public low voltage power supply systems”

AS/NZS 61000 2.12 – “Environment – Compatibility levels for low frequency conducted disturbances and signalling in public medium voltage power supply systems”

IEEE Std 519 – “IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems”

IEEE Std 1159 – “IEEE Recommended Practice for Monitoring Electric Power Quality”

IEEE Std 142 – “IEEE Recommended Practice for Grounding in Industrial and Commercial Power Systems”

IEEE Std 1100 – “IEEE Recommended Practice Powering and Grounding Sensitive Electronic Equipment”

IEEE Std 446 – “IEEE Recommended Practice Emergency and Standby Systems for Industrial and Commercial Applications”

IEEE Std 1366 – “IEEE Guide for Electric Power Distribution Reliability Indices”

CENELEC EN 50160 – “Voltage Characteristics of electricity supplied by public distribution systems”

Essential Services Commission of Victoria – “Distribution Code”

“Service and Installation Rules of New South Wales”

“Victorian Service and Installation Rules”

“ActewAGL Service and Installation Rules for Connection to the Electricity Distribution Network”

Power and Water Corporation – “Installation Rules”

NEMMCO – “Control of Power System Frequency and Time Error”

National Electricity Rules

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August 2008