# LOW VOLTAGE CAPACITORS - CUSTOMER INSTALLATION

## Foreword

This Standard sets out the minimum requirements for customer installation of low voltage capacitors. This Standard is extracted for customer installations from the broader standard for low voltage capacitor installation found in the ENERGEX Supply and Planning Manual.

## Contents

# Section 1 - General

## 1.1 Scope

This technical standard covers the requirements for the installation of capacitors for the purpose of Power Factor Correction.

## 1.2 Application

Unless specified otherwise, all capacitors and installations will comply with all relevant Queensland Safety Acts/Regulations, Australian/International Standard and ENERGEX requirements, in particular:

| | |
|---|---|
| ANSI/IEEE C37.99 | Guide for protection of shunt capacitor banks |
| IEEE 18 | Standard for Shunt Power Capacitors |
| IEEE 1036 | Guide for Application of Shunt Power Capacitors |
| IEC 61921 | Power-Capacitors – Low Voltage power factor correction banks |
| IEC 60831-1 | Shunt Capacitors of the self-healing type for A.C. systems having a rated voltage up to and including 1000V |
| IEC 61642 | Industrial A.C. Networks affected by Harmonics – Application of Filters and Shunt Capacitors |
| AS 1028 | Power reactors and earthing transformers |
| AS 1013 | Shunt Capacitors for connection to Power Frequency Systems (Superseded Standard) |
| AS 2897 | Power Capacitors-Shunt-Rated Voltages above 660V A.C. (Withdrawn Standard) |
| AS/NZS 3000 | Wiring Rules |
| AS 3017 | Electrical Installations Testing and Inspection Guidelines |
| AS/NZS IS0 9001 | Quality systems model for quality assurance design, development, production, installation and servicing. |
| AS/NZS 61000.3.6 | Electromagnetic compatibility (EMC) - Limits - Assessment of emission limits for distorting loads in MV and HV power systems |
| AS/NZS 61000.3.7 | Electromagnetic compatibility (EMC) - Limits - Assessment of emission limits for fluctuating loads in MV and HV power systems |
| AS 4681 | The storage and handling of Class 9 (miscellaneous) dangerous goods and articles. |
| ENERGEX Supply and Planning Manual | |

## 1.3 Object

### 1.3.1 Power Factor Requirements

In accordance with Section 36 of the Electricity Regulation 2006 (Electricity Act 1994), ENERGEX may require the customer (by notice in writing) to maintain a power factor at their installation of at least 0.8 lagging, and except by agreement with ENERGEX, not greater than unity. Contestable customers operating under the NEC are required to maintain power factor within the range 0.9 lagging to unity.

If the power factor falls outside agreed limits, the customer must take action to ensure compliance as soon as reasonably practicable.

This may be achieved by installing additional reactive plant or reaching a commercial agreement with ENERGEX to install, operate and maintain equivalent reactive plant as part of the connection assets.

Additional reactive plant in the form of capacitor installations should be designed to avoid a number of potential problems, including:

- Producing leading power factor
  (refer Section 1.3.3, Types of Capacitors and Section 1.3.5, Sizing of Capacitors).
- Amplifying harmonic currents flowing into other parts of the network
  (refer Section 1.3.6, Harmonics).
- Causing large inrush current or voltage transients upon switching
  (refer Section 1.3.7, Switching).
- Attenuating audio-frequency signals used for load control
  (refer Section 1.3.8, Load Control).

### 1.3.2 Design Requirements

Construction of capacitors should comply with the standards listed, primarily AS 2897 *Power Capacitors-Shunt-Rated Voltages above 660V A.C.* and IEEE Std 18 *Standard for Shunt Power Capacitors.*

### 1.3.3 Types of Capacitors

Capacitors are either switched or fixed, i.e. not switched. Generally, in determining the type required, the following guidelines are considered:

a) Fixed capacitors are sized for minimum load conditions and for network installation.

b) Switched capacitor banks are designed for load levels above the minimum condition up to peak load.

Switched banks provide greater control over the amount of reactive power supplied. This can bring about a number of benefits including greater loss reduction and control over excessive voltages.

#### 1.3.3.1 Customer Requirements for Type

Regardless of the method chosen, the capacitors used should never create a leading power factor through the reactive power they deliver.

Switched banks must adequately switch so that the reactive power on the system does not become capacitive. Leaving a capacitor on too long will create a leading power factor which can cause significant problems with transformers, electronic equipment and the voltage at terminals. Switched capacitor banks hence require a controller which ensures the power factor of the respective system stays between the pre-determined lagging value and 0.99.

Switched banks should also use adequately sized steps to ensure smooth correction of power factor. The number and arrangement of steps should suit the profile of the load.

### 1.3.4 Location of Capacitors

#### 1.3.4.1 Customer Installations

The capacitor/bank needs to be located near the respective load. For customer installations this may take one of three mains forms:

1) Individual Compensation
2) Sector Compensation
3) Group compensation at the main switch board of the designated location.

The method employed will depend on the electrical apparatus being operated at the facility and the load profile. A manufacturer should be consulted in order to determine the most effective form of compensation.

#### 1.3.4.2 Climate Consideration for ENERGEX

Capacitors should be so placed that there is adequate dissipation of the heat produced by the capacitors. Overheating shortens capacitor life. The ventilation of any enclosure and the arrangement of the capacitor units shall provide good air circulation around each unit. Depending on the ambient temperature in which the capacitor has to operate, it may be necessary to use one or more of the following remedies identified by AS2897:

(a) To choose a capacitor designed for a higher ambient air temperature (e.g. category –5/B instead of –5/A, which is otherwise suitably designed).
(b) To employ capacitors with rated voltage higher than that resulting from Paragraph A2.
(c) To employ forced air cooling.

### 1.3.5 Sizing of Capacitors

#### 1.3.5.1 Requirements for Customer Sizing

The sizing of capacitors depends on the required power factor. At minimum, capacitors should be sized to ensure the power factor at the desired location meets ENERGEX's power factor requirements (0.8 or 0.9). It should also be ensured that they do not create a leading power factor at any time.

For capacitors being used on individual apparatus, generally they should not be rated greater than 30% of the motor rating. This should be verified with a consultant or manufacturer.

In terms of global compensation (main switchboard), if fixed capacitors are used, they should be sized no greater than 85% of the minimum kilovar required, i.e. 85% of the lowest kilovar recorded for any time of day.

The sizing of a switched bank will depend on the type of control used and the power factor required. They should however be programmed to ensure the reactive power supplied does not create a power factor above 0.99.

The sizing decision should also consider any further correction which may be required.

### 1.3.6 Harmonics

#### 1.3.6.1 Harmonics on the network

Harmonic distortion is produced by any non-linear load connected to the network. The most common and increasing cause of this distortion is the use of electronic power converters to supply and control loads.

#### 1.3.6.2 Harmonics, Resonance and Capacitors

The principle effect of harmonic currents flowing in the network is that they create harmonic voltage drops across the various circuit impedances. The impedance of any point of the network depends on the frequency, circuit components and their configuration.

The series connection of inductance and capacitance can result in a very low impedance in a certain frequency range. This low impedance is known as series resonance and can lead to multiple increases in the current of the capacitors. It also can prohibit the successful operation of communication signals, cause excessive voltage distortion at capacitors or conductor heating. The loss of communication signal will be further discussed in Section 1.3.8, Load Control.

A parallel combination of inductance and capacitance can result in a very high impedance in a certain frequency range. This very high impedance is known as parallel resonance and leads to a very high voltage and high circulating currents in the respective inductive and capacitive circuit. These magnified currents and voltage can have a number of negative consequences on plant equipment, which include:

| **Equipment** | **Consequences** |
|---|---|
| Current harmonic distortion problems | |
| Capacitors | Blown fuses, reduced capacitor life |
| Motors | Reduced motor life, inability to fully load motor |
| Fuses/Breakers | False/spurious operation, damaged components |
| Transformers | Increased copper losses, reduced capacity |
| Voltage Harmonic Distortion Problems | |
| Transformers | Increased noise, possible insulation failure |
| Motors | Mechanical fatigue |
| Electronic Loads | Mal-operation |

The addition of capacitors to a network hence establishes conditions from which resonance can develop.

1.3.6.3 Parallel Resonant Frequency

A capacitor will be in resonance with a harmonic in accordance with the following equation in which n is an integer:

$$n = \sqrt{\frac{S}{Q}}$$

Where

S is the short circuit power (MVA) where the capacitor is installed;
Q is the capacitor output, in megavars
n is the harmonic number

1.3.6.4 General requirements for Harmonic Suppression

ENERGEX's policy is to keep harmonic levels to within the limits set out in AS/NZS 61000.3.6 Electromagnetic compatibility (EMC) - Limits - Assessment of emission limits for distorting loads in MV and HV power systems.

For installations, it is strongly recommended that the customer engages a consultant to ensure harmonic levels will be satisfactory. ENERGEX will normally supply network impedance, loading and configuration details upon request. The consultant is encouraged to perform the calculations for the PCC also, for review by ENERGEX.

In some cases restrictions will be placed on the type, size, design and operation of equipment to be connected. Alternatively or in combination with, the network arrangement must be chosen appropriately. In most cases, the customer will be expected to contribute to any additional costs incurred on the network to reduce harmonic levels.

1.3.6.5 Methods to alleviate harmonics

There are a number of methods which can be used to alleviate harmonics problems. These are identified by the IEEE as:

a) Ungrounding grounded-Wye capacitors
b) Changing capacitor bank sizes and/or locations
c) Adding a reactor to an existing capacitor/bank
d) Adding a filter capacitor
e) Controlling the capacitor switching scheme to avoid resonance.

Of those identified, the principal method to prevent harmonic problems involves item (c) above, application of a reactor in series with the capacitor/bank to avoid the resonance condition causing the harmonic amplification.

1.3.6.6 Reactors

The introduction of a reactor, depending on its type, can bring about a number of beneficial outcomes:

- Dampening the effect of capacitor switching
- Controlling the natural frequency of capacitor banks to avoid resonance or capacitors sinking current.

Reactors can take three main forms. These include inrush limiting, detuned or tuned reactors. AS 1028 *Power Reactors and Earthing transformers* and Appendix G of AS 2897 *Power Capacitors-Shunt-Rated Voltages above 660V A.C* detail the requirements for the use of reactors. For information which is not addressed in these Australian standards, IEC 61642 *Industrial A.C. networks affected by harmonics – Application of filters and shunt capacitors* should be consulted.

1.3.6.7 Inrush Limiting Reactor

Inrush limiting reactors are designed to avoid the large, high frequency current which flow when a capacitor/bank is energised.

1.3.6.8 Detuned Reactor

Detuned reactors are designed to limit the inrush current and to ensure that the capacitor/bank does not resonate with the network impedance.

1.3.6.9 Tuned Reactor

Tuned reactors are designed with a number of purposes. In conjunction with limiting inrush current and preventing resonance, they are also intended to filter specific harmonics from the system.

Reactors, as detailed by AS1028, may have tolerance levels. Variations in the permissible tolerances for capacitors and reactors can result in differences in the tuned frequency. This may mean that the capacitor is not tuned exactly to the intended frequency, which could result in the amplification of harmonics or sinking of signals. The manufacturer should be consulted to ensure reactors are specifically configured to meet the requirements of the particular situation.

1.3.6.10 Reactor considerations

It should be known that the use of a reactor in series with a capacitor results in a voltage rise at the capacitor terminals, and changes the effective kvar output of the bank. These should be considered when rating a capacitor bank and can be determined using the formulae:

$$V_{CAP} = \left(\frac{n^2}{n^2 - 1}\right) \times V_{SYS}$$

Where

$n$ is the tuned harmonic of the filter ($n > 1$)
$V_{sys}$ is the system line-to-line voltage, in volts
$V_{cap}$ is the capacitor line-to-line voltage, in volts

$$k\,\text{var}_{FIL} = \frac{(V_{SYS})^2}{(X_C + X_L)\times 1000}$$

Where

$k\,var_{FIL}$ is the effective reactance of the bank, kilovars
$V$sys is the system line-to-line voltage, volts
$X_C$ is the capacitive reactance at the fundamental frequency, ohms per phase
$X_L$ is the inductive reactance at the fundamental frequency, ohms per phase

1.3.6.11 When a reactor is required

Three basic conditions can be used to determine whether harmonic filters (tuned reactors) are required. These **act as a guide only**, and the need for a reactor will **depend on the result of the harmonic analysis**:

1. If the customer's total 3-phase non linear load (in kVA, 1hp = 1kVA) is more than 25% of the main transformer capacity, tuned reactors will be required.
2. If the plant's total 3 phase non-linear load is less than 15% of the main transformer capacity, capacitors can usually be applied without problems from harmonics.
3. If the plant's total non-linear load is between 15% and 25%, a detuned reactor bank will usually be applied, however other factors should be considered.

1.3.6.12 Which loads are non linear?

The following list consists of a number of the larger contributors to harmonic distortion:

General:
- Transformers and chokes
- Electronic power converters
- Rectifiers and converters, especially when controlling variable-speed induction motors
- Induction and electric arc furnaces, welding equipment
- Uninterruptible power supplies (UPS Systems)
- Single – phase switch mode power supply units for modern electronic loads such as televisions, VCRs, computers, monitors, printers, telefax machines, ballasts, compact energy saving lamps

Specific:
- DC Motor Drives (ac/dc)
- AC Motor Drives (ac/dc/ac)
- Variable frequency drives
- Programmable controllers
- Induction furnaces
- Solid state Uninterruptible Power Supplies
- Arc Furnaces
- Arc Welders
- 3 Phase Full Wave Rectifiers
- 3 Phase Full Wave Converters
- 6 Pulse Converters

#### 1.3.6.13 Harmonic Analysis

The magnitude of harmonic currents and voltages at any point in a distribution system can be predicted using accepted harmonic modelling techniques that consider the frequency dependence of circuit components and loads. In the majority of cases, non-linear devices or harmonic sources may be considered a constant current source independently injected into the system at the point of generation, at each harmonic independently. The overall response of the network is then assessed in terms of individual harmonic values and the total harmonic distortion.

#### 1.3.6.14 Requirements for Harmonics Analysis: Customer installations

Before a capacitor/bank is connected to a distribution system, the supplier will need to ensure harmonic distortion following installation will be within the limits outlined in Section 1.3.11. This may require harmonic analysis, which will be dependant on the capacitor/bank being used.

If a detuned capacitor/bank is being used, no harmonic analysis will be required if the bank is detuned to a frequency which is below the first prevalent harmonic. ENERGEX should be contacted to obtain this harmonic limit.
Note: As there is no need to perform harmonic analysis, provided that the bank is detuned to a frequency which is below the first prevalent harmonic, a detuned capacitor bank is the preferred method.

If a tuned bank (or harmonic filter) is being used, a harmonic analysis will be required to determine the prevalent harmonics. This analysis will be used to design the bank.

Any other type of capacitor/bank (fixed, switched or transient reduced) will require a harmonic analysis to be performed prior to installation. This will also be accompanied by before and after measurements at the point of common coupling to check background levels pre-existing before connection of the new load, and compliance with limits imposed following connection. It should be noted that in a distribution system, the background readings may be high due to other distorting loads connected to the network and may vary considerably over time due to differing load duty cycles, system configuration, load level and resonant conditions.

#### 1.3.6.15 Requirements for Harmonic Protection: Customers

If the installation of the capacitor/bank causes amplification of harmonics outside the limits specified by ENERGEX, measures must be taken to reduce this effect. The methods to achieve this will depend on the number and magnitude of harmonics present. A consultant/ manufacturer should be employed to determine a suitable method.

### 1.3.7 Switching

#### 1.3.7.1 Inrush Current

Energizing a capacitor/bank will result in a transient inrush current. The magnitude and frequency of this inrush current are a function of the point on the voltage wave at closing, the capacitance of the circuit, the inductance of the circuit, the initial charge of the capacitor bank at the instant of closing, and the damping of the circuit due to closing resistors or other resistance in the circuit. This effect is magnified when a capacitor/bank is energised close to a capacitor/bank which is already connected. During the closing operation or a restrike between parallel capacitors/banks, the transient inrush current through the switching device between that energized and the one being switched can be very large.

In-rush current of large magnitudes and high frequency cause damage to circuit breakers, contactors and capacitors. AS2897 requires capacitors to be able to withstand currents up to 100 times the nominal current. It also however recognises that it may be necessary to reduce these transient overcurrents to acceptable values in relation to the capacitor and to other equipment by switching through resistors or reactors in the supply circuit.

1.3.7.2 Inrush Limiting Mechanisms

The magnitude and frequency of the inrush current should be minimised to ensure the proper operation of the switching device as well as relays, fuses, etc. Where inrush currents are excessive, one or a combination of the following steps is taken:

a) Add current limiting reactors (identified in Section 1.3.6.6) to decrease the peak current and frequency of the oscillatory inrush transients
b) Add switch pre-insertion resistors. These resistors are designed to over-damp the circuit, preventing oscillations and allowing the capacitor to become essentially charged to line potential before the main contacts of the switch close.
c) Switch the capacitor in smaller var increments.
d) Control the switching device to close on zero voltage difference across the switch.

1.3.7.3 Recommendations for Inrush Currents – Customers

- Fixed Isolated Capacitor Banks

Generally no action will be needed to protect fixed, isolated capacitor banks from inrush current. This should be verified by calculating the peak inrush current.

The peak inrush current and its frequency can be calculated by:

$$I_S = I_N \sqrt{\frac{2S}{Q}} \quad \text{and}$$

$$f_s = f_N \sqrt{\frac{S}{Q}}$$

Where:

$I_S$ = peak inrush bank current, in kiloamperes
$I_N$ = rated capacitor bank current (r.m.s.), in kiloamperes
S = the 3-phase short-circuit (MV.A) at the point where the capacitor is to be connected, in megavolt amperes
Q = the capacitor output, in megavars
$f_S$ = the frequency of the inrush current, in hertz
$f_N$ = the rated frequency of the capacitor, in hertz.

If the inrush current is greater than that which the proposed capacitor bank can handle, an inrush limiting mechanism will be required.

Note: AS 2897 requires capacitors to be capable of being energised 1000 times per year assuming that the associated peak switching current may reach 100 times the rated current of the capacitor.

- Back-to-back Capacitor Banks

For a fixed capacitor bank which shares a feeder with other fixed banks, an evaluation will need to be completed to ensure these banks are not too close together. In this situation the inrush current is only limited by the impedance on the line between the two banks.

The peak inrush and its frequency are calculated from:

$$I_S = \frac{U\sqrt{2}}{\sqrt{X_C X_L}} \quad \text{and}$$

$$f_S = f_N \sqrt{\frac{X_C}{X_L}}$$

Where:

Is = peak inrush bank current, in kiloamperes
U = the phase-to-earth voltage, in kilovolts
$X_C$ = the series-connected capacitive reactance's per phase, in ohms
$= 3U^2\left(\frac{1}{Q_1} + \frac{1}{Q_2}\right)$
$X_L$ = the equivalent inductive reactance per phase between the banks already energized and the bank to be switched, including the internal inductive reactance of the capacitors, in ohms
$f_S$ = the frequency of the inrush current, in hertz
$f_N$ = the rated frequency of the capacitor, in hertz
Q1 = the output of the bank to be switched, in megavars
Q2 = the sum of the outputs of the already energized bank(s), in megavars.

Where it is concluded that the inrush current is too large, one of the capacitors/banks will need to be moved or the use of an inrush limiting mechanism as described above will need to be employed to reduce the inrush. The manufacturer should be notified where required.

Note: AS 2897 requires capacitors to be capable of being energised 1000 times per year assuming that the associated peak switching current may reach 100 times the rated current of the capacitor.

- Switched Capacitor Banks

Switched capacitor banks provide vars in stages. The inrush current can be determined using the provided formulae. At minimum there should be inrush limiting mechanisms between the stages. This should be included by the manufacturer in the switched bank. A detuned or tuned bank may be used if harmonic or resonance conditions also are prevalent (see Section 1.3.6.2). It is stressed the manufacturer is consulted to ensure reactors are specifically configured to meet the requirements of the particular situation.

#### 1.3.7.4 Voltage transients

Following the closing of the switching device to energise a capacitor/bank, the voltage of the capacitor/bank bus collapses to the level of the voltage of the capacitor/bank, which is usually zero. In attempting to return to its nominal voltage, the bus overshoots this value and oscillates about it until the oscillations are damped.

Capacitor energising transient can produce high phase-to-phase over-voltages on terminating transformers, excite circuit resonances resulting in transient voltage magnification in secondary voltage networks or cause problems with sensitive electronic equipment.

#### 1.3.7.5 Voltage Magnification

Where there are capacitors/banks situated at the high and low voltages of power systems, voltage magnification can occur. This results from the switching of the high voltage capacitor and creates severe over-voltages due to magnification at the low voltage capacitors at the remote locations.

#### 1.3.7.6 Voltage transient / magnification limiting mechanisms

Voltage transients can be limited using the same methods detailed for limiting inrush current. These were detailed in Section 1.3.7.2, Inrush Limiting mechanisms.

#### 1.3.7.7 Customer requirements for voltage transients

Before ordering capacitors/banks, customers should contact ENERGEX to determine the location of other capacitors which may affect their installation. The location, sizing and switching information for these capacitors should be forwarded to the manufacturer and/or consultant.

A transient limiting mechanism should be used, as it will maximise the lifetime of the capacitor/bank, reducing replacement costs.

### 1.3.8 Load Control

#### 1.3.8.1 What is load control

Load control, or Audio Frequency (AF) Load Control is the means whereby loads at the customer's premises are controlled (turned off and on) from a few remote sources for the purpose of reducing system demand.

The types of load targeted for load control applications are primarily energy storage devices such as hot water systems, air conditioning systems etc.

#### 1.3.8.2 How are loads controlled

ENERGEX generates, by the use of motor generator sets or solid state electronic units, a signal at the zone substation which is injected into the supply system. This signal is a sine wave of 1050 Hz which is superimposed on the 50 Hz power wave and is carried throughout the distribution system. Receivers are installed at each house tuned to 1050 Hz which can "read" the signal and determine if they are to operate.

#### 1.3.8.3 How capacitors affect load control

Section 1.3.6.2, Harmonics, Resonance and Capacitors introduced the concept of series resonance. The capacitance of the power factor correction installation can form a series resonant circuit with the inductance of the distribution transformer. This creates a very low impedance in a certain frequency range. If this range occurs at the frequency in which a load is controlled it can:

- Lead to an overloading of the ripple control generator.
- ‘Sink’ the control signal, causing a loss of control over the designated load.

#### 1.3.8.4 Requirements for load control: Customer Installations

It should be ensured that all installed capacitors/banks are blocked to limit the absorption of ENERGEX mains signals (audio frequency injection at 1050 Hz, and future supervisory systems). The manufacturer and/or consultant should be notified on necessary blocking requirements.

The blocking mechanism will depend on the capacitor/bank being used.

Detuned Bank: A detuned bank should provide adequate rejection of ENERGEX mains signalling of 1050Hz. This should be verified with the manufacturer.

Tuned bank: A tuned bank should provide adequate rejection of ENERGEX mains signalling of 1050Hz. This should be verified with the manufacturer.

Any other bank: Requires a blocking mechanism designed to reject the mains signalling at 1050Hz. The manufacturer should determine the best method for the particular situation.

### 1.3.9 Wiring and Protection

#### 1.3.9.1 Requirements for wiring and protection: Customer installations

The installations shall comply with the wiring and protection requirements of AS 3000 *Wiring Rules*. In AS/NZS3000:2007 the corresponding Section for CAPACITORS is Section 4.15. Full reference to the Wiring Rules must be made

### 1.3.10 Inspection and Maintenance

All capacitors should be inspected upon installation and periodically throughout service life.

#### 1.3.10.1 Initial Energisation

Testing should adhere to AS 3017 *Electrical Installations Testing and Inspection Guidelines*. AS 3017 sets out some of the common inspection and test methods required to check that a low voltage electrical installation complies with the safety requirements for the prevention of fire or a person or livestock from sustaining an electric shock. The inspection and test methods described in AS 3017 are provided for guidance and are quite general though, citing that alternative methods are acceptable. For this reason, the process provided in IEEE 1036 *Guide for Application of Shunt Power Capacitors*: may be found useful to be considered.

1.3.10.2 Clearance and Grounding

Following de-energisation, the capacitor should not be approached for a time period to allow the voltage across the unit to reduce to 50V or less as required by AS 3000.

1.3.10.3 Maintenance

Maintenance should be carried out to meet the requirements of AS 3017 *Electrical Installations Testing and Inspection Guidelines.* It should only be performed by qualified personnel. AS 2897 has certain specific recommendations for power capacitor maintenance.

Leaking Capacitor Units:
Handling and disposal of capacitor insulating fluid should follow the methods required by AS 4681 *The storage and handling of Class 9 (miscellaneous) dangerous goods and articles*.

Bulged Capacitor Units:
This indicates excessive internal pressure as a result of overheating and/or creation of gases. The manufacturer should be contacted in regards to the process of handling the unit in this situation.

1.3.10.4 Re-Energisation

Re-energisation should not take place until its terminal voltage has decayed to $0.1U_N$ (0.1 x rated voltage).

Following maintenance, all shorts and ground which were used should be removed before re-energisation.

1.3.10.5 Customer Requirements for Inspection

Inspections should only be completed by qualified personnel. Contact should be made with the manufacturer to determine the required rate of inspection. At minimum this should be annually. Any problems or service requirements should be reported to the manufacturer for further investigation and repair.

### 1.3.11 Compliance with Limits and Requirements

Prior to connecting the capacitor/bank at the customer point, customers are required to inform ENERGEX to obtain network data and any limitation existing at the point of connection.

ENERGEX will advise the disturbance emission limits at the customer's point of connection, system fault level, and the customer will require to conduct a supply quality and load assessment in order to verify the compliance with the specified limits.

To ensure compliance with these limits, ENERGEX will conduct measurements before and after the commissioning of the capacitor/bank. If the capacitor/bank does not comply with the required limits, or causes, or is likely to cause, undue interference with the supply to other customers, ENERGEX may direct the customer to modify the capacitor/bank or its operation to avoid such interference. The customer is responsible for such modifications which are at their own expense.

Notwithstanding any of the requirements set out in this document, if the operation of the customer's capacitor/bank causes undue interference to a third party, ENERGEX may invoke Section 36 of the Electricity Regulation 2006 (Electricity Act 1994) to disconnect the offending equipment.

## 1.4 Referenced Documents

| | |
|---|---|
| ANSI/IEEE C37.99 | Guide for protection of shunt capacitor banks |
| IEEE 18 | Standard for Shunt Power Capacitors |
| IEEE 1036 | Guide for Application of Shunt Power Capacitors |
| IEC 61921 | Power-Capacitors – Low Voltage power factor correction banks |
| IEC 60831-1 | Shunt Capacitors of the self-healing type for A.C. systems having a rated voltage up to and including 1000V |
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| AS/NZS 3000 | Wiring Rules |
| AS 3017 | Electrical Installations Testing and Inspection Guidelines |
| AS/NZS IS0 9001 | Quality systems model for quality assurance design, development, production, installation and servicing. |
| AS/NZS 61000.3.6 | Electromagnetic compatibility (EMC) - Limits - Assessment of emission limits for distorting loads in MV and HV power systems |
| AS/NZS 61000.3.7 | Electromagnetic compatibility (EMC) - Limits - Assessment of emission limits for fluctuating loads in MV and HV power systems |
| AS 4681 | The storage and handling of Class 9 (miscellaneous) dangerous goods and articles. |

ENERGEX Supply and Planning Manual

## 1.5 Definitions For This Document

**Capacitor unit (capacitor)** - An assembly of dielectric and electrodes in a container (case), with terminals brought out, that is intended to introduce capacitance into an electric power circuit.

**Capacitor bank** - An assembly of capacitor units connected so as to act together.

**Fixed capacitor bank** - A capacitor bank that does not have a capacitor control and must be manually switched.

**Isolated capacitor bank** - A capacitor bank that is not in parallel with other capacitor banks.

**Switched bank** - A capacitor bank designed for controlled operation.

**Capacitor inrush current** - The transient charging current that flows in a capacitor when a capacitor bank is initially connected to a voltage source.

**Back-to-back switching** - The switching of a capacitor bank that is connected in parallel with one or more other capacitor banks.

**Rated output of a Capacitor ($U_N$)** - r.m.s value of the alternating voltage for which the capacitor has been designed.

## 1.6 Enquiries Regarding This Document

Please direct any queries in relation to this document to Roy English, Network Engineering Standards Manager via email to royenglish@energex.com.au

## 1.7 Amendments

Version 2 – minor corrections to formulae and spelling throughout. Preference for a detuned capacitor solution added into Section 1.3.6.14.