CitiPower and Powercor Grid -Connected Renewable Energy Systems

TECHNICAL GUIDELINES

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HEALTH AND SAFETY

The implementation of this Technical Guideline shall be undertaken with due consideration to Health, Safety and Environment, relevant Statutory and Regulatory requirements and Codes of Practice as applicable.

1 PURPOSE

To improve the environment by reducing greenhouse gas emission, CitiPower and Powercor are keen to promote the use of renewable energy sources such as solar and wind. With the advanced technologies in electronics, photovoltaic cell and battery developments, a grid-connected renewable energy system (via inverters) is feasible. This document highlights the technical requirements associated with these “Inverter Energy Systems” and provides some guidelines for CitiPower and Powercor’s customers when dealing with the inverter energy systems.

In general, CitiPower and Powercor adopts the Australian Standard AS 4777 Parts 1, 2 and 3 for the requirements of the customer’s Inverter Energy Systems. The purpose of this Standard is to highlight the salient points in AS 4777 and CitiPower and Powercor’s specific requirements (such as metering arrangements and protection settings) with the aim to ensure that both the safety and the reliability of the distribution network are not jeopardised.

2 SCOPE

This document applies to the renewable energy systems which are connected to CitiPower and Powercor’s Low Voltage Distribution Network (the **grid**) (240 volts single phase or 415 volts three-phase) through DC-AC inverters (excluding motor-driven inverters) or AC voltage regulators (for AC generators, such as wind turbines or micro hydros) of rating up to 10 kVA (single Phase) or 30 kVA (three-phase).

3 REFERENCES

Australian Standard AS4777 Grid Connection Of Energy Systems Via Inverters Part 1: Installation Requirements

Australian Standard AS4777 Grid Connection Of Energy Systems Via Inverters Part 2: Inverter Requirements

Australian Standard AS4777 Grid Connection Of Energy Systems Via Inverters Part 3: Grid Protection Requirements

4 DEFINITIONS

Islanding – in this document means any situation where the **grid** fails or is tripped and one or more inverters maintains a supply of any description (be it stable or not) to any section of the distribution network outside the consumers installation (i.e. on the distribution network side of the point of connection).

Point of Connection – in this document means the first point where CitiPower and Powercor's aerial or underground service cable is connected to the customer's property.

Inverter Energy System – in this document means an energy system consists of a DC energy source (such as the Solar (PV) array or a DC generator) and a DC-AC Inverter (a device to transfer the DC energy source to an AC load).

Regulated Energy System – in this document means an energy system consists of an AC generator (such as a wind / hydro generator) and an AC voltage regulator (if necessary) to provide a steady voltage output to an AC Load.

5 CONNECTION REQUIREMENTS

5.1 GENERAL

The DC-AC inverter / AC voltage regulator must comply with the appropriate electrical safety requirements of, including but not limited to, AS/NZS 3100.

The DC-AC inverter / AC voltage regulator shall have AC voltage and frequency ratings compatible with AS 60038.

In additional to the above general requirements, a **grid**-connected inverter / regulated energy system must fulfil the following:

5.2 IMPULSE WITHSTANDING VOLTAGE

The DC-AC inverter / AC voltage regulator, or other equipment directly connected to the **grid**, must withstand Standard Lightning Impulse of 0.5 Joule, 5kV, 1.2/50 waveform to AS1931 Part 1 or in accordance with IEC 60255-5.

5.3 HIGH FREQUENCY NOISE / ELECTROMAGNETIC COMPATIBILITY (EMC) OF THE INVERTER

All equipment in the inverter / regulated energy system must comply with the Radio communications Act.

5.4 POWER FACTOR

The inverter / regulated energy system shall have a power factor between 0.8 leading and 0.95 lagging for outputs from 20% to 100% of rated VA, or as agreed between CitiPower and Powercor Network (Technical Standards) and the customer.

Note: Lagging power factor is defined to be when VAR flows are from the **grid** to the inverter, when the inverter acts as an inductive load from the perspective of the **grid**.

5.5 VOLTAGE FLUCTUATIONS AND FLICKER (INVERTER SYSTEM)

Equipment in the system must conform to the voltage fluctuation and flicker limits as per:

- AS/NZ 61000.3.3 for equipment rated less than or equal to 16A per phase, ***or***
- AS/NZ 61000.3.5 for equipment rated greater than 16A per phase.

5.6 HARMONICS (INVERTER SYSTEM)

The DC-AC inverter / AC voltage regulator system shall have harmonic currents (at full load) less than the limits specified in table below:

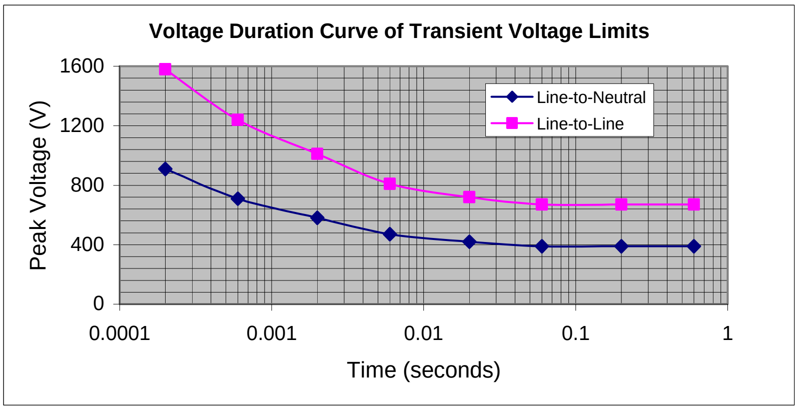
Current Harmonic Number	**Limit based on % of fundamental**
3 – 9th	<4%
11 – 15th	<2%
17 – 21st	<1.5%
23 – 33rd	<0.6%
above 33rd	<0.3%
Even harmonics	< 25% of equivalent odd harmonics
Total Harmonic Distortion (THD)	<5%

5.7 TRANSIENT VOLTAGE LIMITS (INVERTER SYSTEM)

The DC-AC inverter shall be tested in accordance with the transient voltage limit test described in Appendix C of AS 4777.2 (Similar tests apply to AC voltage regulators).

The voltage-duration curve derived from measurements taken at the AC terminals of the inverter / regulator shall not exceed the limits as detailed below:

Duration (Seconds)	Instantaneous Voltage	
	Line-to-Neutral (Volts)	Line-to-Line (Volts)
0.0002	910	1580
0.0006	710	1240
0.002	580	1010
0.006	470	810
0.02	420	720
0.06	390	670
0.2	390	670
0.6	390	670



To prevent the possible destruction of expensive electronic equipment, such as television sets and computers (within the customer's installation and also other customers connected to the same LV Network), it is desirable for **the customer to have a Surge Protection device (with operation indicator / target) installed at the Switchboard where the inverter output is connected**. This Surge Protection device will act as a backup protection against mal-functioning of the "Voltage Limiting" device in the inverter.

Once the Surge Protection device has operated (as shown by the indicator / target), the customer shall immediately arrange a qualified person to check / replace the Surge Protection Device as per the manufacturer's recommendation.

If additional Surge Protection device is to be installed, it shall operate at 275 volt r.m.s. (phase to neutral) with a minimum impulse rating of 80 kA (20 kA 10/350 μS).

5.8 DIRECT CURRENT (DC) INJECTION PREVENTION (INVERTER SYSTEM)

CitiPower and Powercor's preference is to have a mains-frequency isolating transformer installed at the point of connection on the AC (output) side of the DC-AC inverter to prevent the DC component from entering the **grid**.

If the isolating transformer is not incorporated with the DC-AC inverter, the DC-AC inverter shall be type tested to ensure the DC output current at the AC terminals of the inverter is below the limits as detailed below:

- For a single phase inverter, the DC output current of the inverter at the AC terminals shall not exceed 0.5% of its rated output current or 5 milli-amperes, whichever is the greater.
- For a three phase inverter, the DC output current of the inverter at the AC terminals, measured between any two phases or between any phase and neutral, shall not exceed 0.5% of its rated output current or 5 milli-amperes, whichever is the greater.

5.9 DATA LOGGING AND COMMUNICATION DEVICES

Any electronic data logging or communications equipment incorporated in the DC-AC inverter or the AC regulator shall comply with the appropriate requirements of AS/NZS 60950, especially the requirements for electrical insulation, creepage and clearance distances.

5.10 CONNECTIONS WITHIN CUSTOMER'S INSTALLATION

For customers directly connected to CitiPower and Powercor's network, the inverter / regulated system shall be connected to the main switchboard, or to a distribution board, via an isolating switch or lockable circuit breaker. If the inverter is connected to a distribution board then all switchboards between the inverter energy system and the main switchboard including the main switchboard shall be labelled (see Clause on labelling).

For other customers, it is preferable that the inverter / regulated energy system(s) be connected directly to the main switchboard. In installations where this is not possible/desirable the nearest distribution board shall be used and all switchboards between the inverter energy system and the main switchboard including the main switchboard shall be labelled (see Clause on labelling).

The inverter / regulated energy system must be connected to a dedicated circuit. The rating of the inverter / regulator circuit cables and all the cables between any distribution boards and the main switchboard which carry inverter / regulator output must be rated for at least the full output of the inverter / regulator as per the Wiring Rules (AS/NZS 3000).

When Residual Current Devices (RCDs) are used in the customer's installation, the inverter / regulated energy system shall be connected to the electrical installation which is on the **grid** side of any RCDs.

5.11 GENERAL TESTING (EQUIPMENT AND WIRING)

All relevant equipment shall be tested as per AS3100, or other relevant Australian Standards dealing with the specific features of the design, construction and testing of the equipment.

All wiring and earthing arrangements within the installation shall be tested and verified as per AS/NZS 3000.

5.12 PROTECTION REQUIREMENTS (INVERTER SYSTEM)

5.12.1 Devices

If the inverter / regulator is not in close proximity to the switchboard into which it is feeding, some form of over-current protection shall be provided to prevent excessive current flowing through the cable feeding into the switchboard unless the inverter / regulator is supplied from a current limited source, e.g. the Photovoltaic (PV) cells.

The **grid** protection device shall incorporate a **grid** disconnection device which shall prevent both AC and DC from the inverter / regulated energy system entering the **grid** when the disconnection device operates.

The **grid** disconnection device shall incorporate an electro-mechanical switch (i.e. a switch that provides a physical separation of conductors in the OFF state) if:

- There is no isolation transformer between the energy source and the **grid**; ***or***
- The inverter / regulated system continues to provide electrical power to any portion of the electrical installation, i.e. it operates as an uninterruptible power supply (UPS) system in the event of the disruption of the **grid** supply.

The **grid** disconnection device may incorporate semi-conductor devices if isolation transformer exists between the energy source(s) and the **grid** and the system does not operate as an UPS system.

5.12.2 Grid Protection Schemes

The **Over-Current Protection** shall have an interrupting capacity adequate for the prospective short circuit current at the switchboard where the output of the inverter / regulator is connected. If the inverter / regulator is connected to the customer's Main switchboard, the prospective fault current will be 3 kA single-phase or 6 kA three-phase (from CitiPower and Powercor's distribution network) plus the contribution from the inverter system.

The Over-Current Protection shall operate when the output from the inverter / regulated energy system is greater than 100% of the inverter rating.

The inverter / regulated energy system protection shall operate and isolate the inverter / regulated energy system from the **grid** if:

- The supply from the grid is disrupted;
- The system voltage (the **grid**) is greater than 265 volts (phase-to-neutral) or 458 volts (phase-to-phase) **(Over-Voltage Protection)**;
- The system voltage (the **grid**) is less than 195 volts (phase-to-neutral) or 337 volts (phase-to-phase) **(Under-Voltage Protection)**;
- The system frequency (the **grid**) is greater than 51.5 Hz **(Over-Frequency Protection)**; ***or***
- The system frequency (the **grid**) is less than 48.5 Hz **(Under-Frequency Protection)**

In addition to the above protection, the inverters must have at least one of the "active" methods of "islanding detection" **(Anti-Islanding Protection)**, as listed below, following a **grid** failure.

Examples of the "active" methods of Anti-Islanding Protection include:

- Frequency Shift – shifting the frequency of the inverter away from normal conditions in the absence of a reference frequency;
- Frequency Instability – allowing the frequency of the inverter to be inherently unstable in the absence of a reference frequency;
- Power Variation – periodically varying the output power of the inverter; ***and***
- Current Injection – monitoring for sudden changes in the impedance of the **grid** by periodically injecting a current pulse.

All the above mentioned methods shall cause the protection to operate and disconnect the customer's Inverter Energy System from the **grid**.

If the inverter / regulated energy system does not have the above mentioned features in the protection, the inverter / regulator manufacturer must demonstrate an alternative anti-islanding feature that is acceptable to CitiPower and Powercor (Network – Technical Standards). Otherwise other forms of external protection relaying are required which have been type tested for compliance with these requirements and approved by CitiPower and Powercor (Network – Technical Standards).

The total protection operation and disconnection time shall not exceed 2 seconds after **grid** failure.

The inverter / regulated energy system must remain disconnected from the **grid** until the reconnection conditions are met (see Clause 8 below).

5.12.3 Security Of Protection Settings

Where the inverter / regulated energy system has protection settings that may be changed via a keypad or switches, adequate security must be employed to prevent any tampering or inadvertent / unauthorised changing of these settings. A suitable lock or password system shall be used.

All settings and setting changes must be approved by CitiPower and Powercor.

6 DISCONNECTING SWITCH(ES)

Lockable Disconnecting Switch (appropriately labelled as per Clause 7 below) must be provided on the switchboard to which the inverter / regulator is directly connected. This Disconnecting Switch shall be lockable in the OFF position and operation of this switch shall isolate the inverter / regulated energy system (all active conductors) from that switchboard.

Locking facility of the Disconnecting Switch shall be suitable for the Victorian Power Industry 2147 Padlock lock which has a 5.5mm hasp. Commercially available locking devices can be used to take this lock if the disconnect Switch is not fitted with the ability to lock off.

The disconnecting switch shall be installed to the requirements for main switches, as specified in AS/NZS 3000.

In installations where the inverter / regulated energy system is connected at a distribution board other than the main switchboard, then two (or more) lockable switches must be provided:

1) The disconnecting switch, located on the main switchboard which controls the sub-circuit of the distribution board to which the inverter / regulated energy system is connected, must be lockable – This switch is to be used as an alternative isolation for CitiPower and Powercor personnel working on the **grid**.

2) Other lockable switch(es) must be provided on the distribution board(s) to which the inverter / regulated energy system(s) is directly connected – This switch provides isolation for electrical contractors working on the customer's installation.

7 LABELLING / SIGNAGE

For label details and installations information refer to the Victorian Service and Installation Rules.

8 RECONNECTION

Automatic reconnection of inverter / regulated energy system(s) onto the **grid** shall only occur if:

- the **grid** voltage is within the range of 200 to 260 volts (phase-to-neutral) or 346 to 450 volts (phase-to-phase);
- the **grid** frequency is within the range of 49 Hz to 51 Hz;
- the above conditions have been maintained for a minimum duration of 1 minute; ***and***
- the inverter / regulated energy system and the **grid** are synchronised and in-phase with each other.

9 COMMISSIONING TESTS

The customer shall ensure the inverter / regulated system installer does complete all the necessary tests and proves the correct operation of the **grid** protection device(s) prior to making final connections to the **grid**.

CitiPower and Powercor may arrange representative(s) (CitiPower and Powercor's Customer Service Representative) to witness the tests being carried out on site.

Section 10 of AS 4509.3, as shown in B can be used as the testing guidelines for the inverter / regulated energy system.

10 SYSTEM MAINTENANCE

Since the inverter / regulated energy system and the associated protection devices are owned by the customer, it is the customer's obligation to ensure that the system (equipment and installation) is safe and the protection is at all time effectively coordinated with CitiPower and Powercor's distribution network (as defined in the Electricity Distribution Code).

The customer shall therefore be responsible to arrange the necessary system maintenance on a regular basis.

Section 11 of AS 4509.3, as shown in

APPENDIX C can also be used as the maintenance guidelines for the inverter / regulated energy system.

11 METERING

CitiPower and Powercor is not directly involved in the establishment of the Supply Contract / Agreement between the customer and the Electricity Retailer. However, CitiPower and Powercor shall arrange to install an appropriate meter (or meters) which shall:

- Register the import energy (kWhr) to the customer
- Record the export energy (kWhr) either in a separate register or directly subtracting the import energy reading (as for the electro-mechanical energy meters, with a minimum value of zero)

The customer's energy usage shall be calculated based on the net metering data (as per the Supply Contract / Agreement between the customer and the Electricity Retailer) for that billing period.

For all customers, the "Inverter Energy System" shall be connected directly to the switchboard, or distribution board, on a dedicated circuit via an isolating switch or lockable CB.

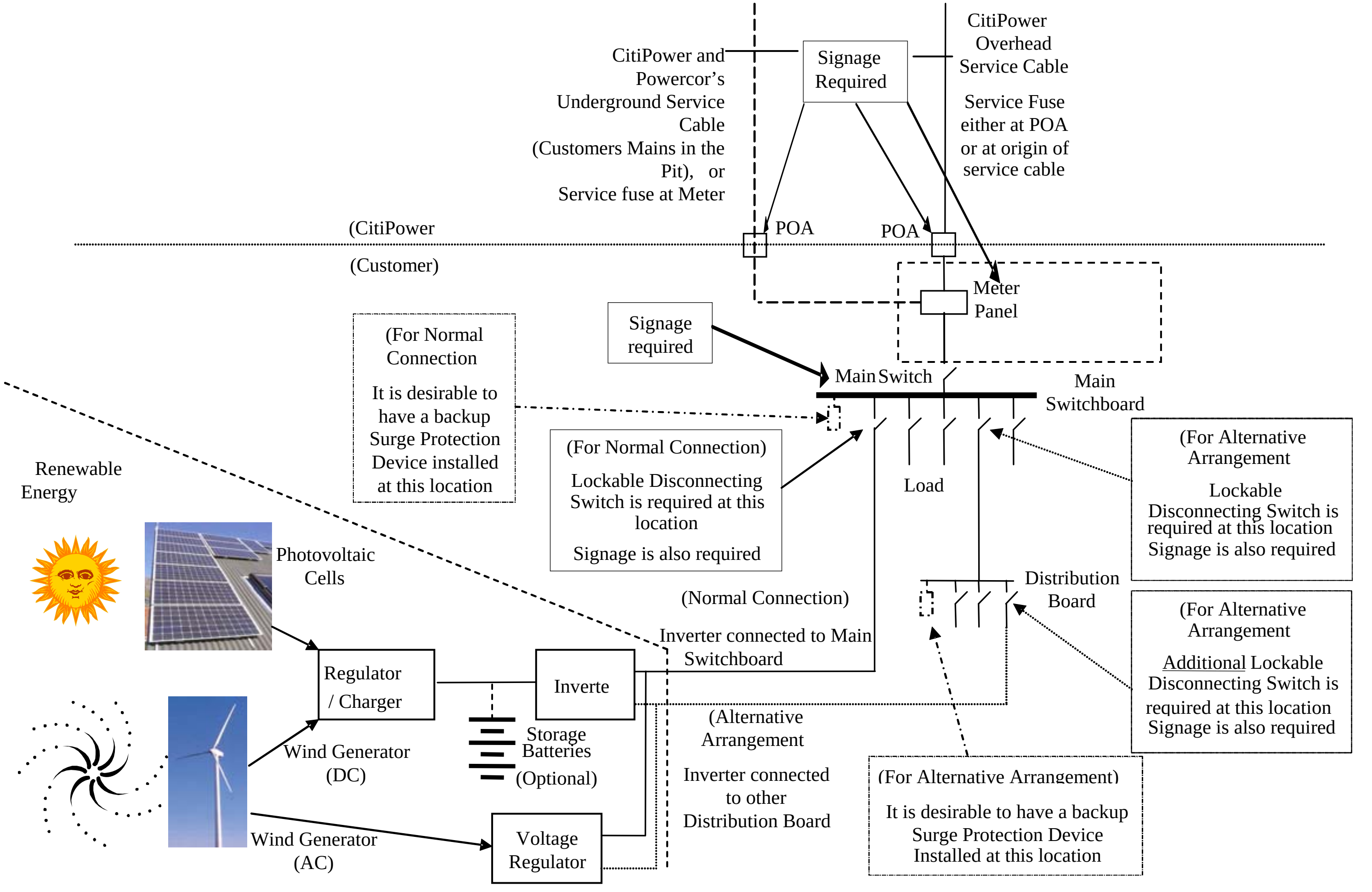
12 ATTACHMENTS

Appendix A – Single Line Arrangement For a Typical Grid Connected Inverter System

Appendix B – Extracts (Section 10) of Australian Standard AS4509.3 Stand-alone Power System, Part 3: Installation and Maintenance

Appendix C – Extracts (section 11) of Australian Standard AS4509.3 stand-alone power system, part 3: Installation and Maintenance

APPENDIX A – SINGLE LINE ARRANGEMENT FOR A TYPICAL GRID CONNECTED INVERTER SYSTEM



APPENDIX B – EXTRACTS (SECTION 10) OF AUSTRALIAN STANDARD AS4509.3 STAND-ALONE POWER SYSTEM, PART 3: INSTALLATION AND MAINTENANCE

SECTION 10 TEST AND COMMISSIONING

10.1 GENERAL At the completion of the installation, but before any energy source is applied to the system, the test procedures of Clauses 10.2 and 10.3 shall be completed to ensure that on connection of power, the system is connected properly, no damage is caused to electrical equipment and all system components operate normally.

10.2 WIRING All wiring shall be tested for continuity and short circuits.

10.3 POLARITY Before the power is connected the battery bank, polarity shall be checked at the main fuses and then progressively out to the ELV circuits furthest from the battery bank (where necessary).

After the initial polarity check, the battery bank main fuse shall be connected. A voltmeter shall be used to confirm voltage and polarity, while circuit protection and equipment are being connected.

10.4 CHARGING SOURCES Before connection, the following should be carried out:

(a) The PV array should be checked for correct wiring and operation by measuring the open-circuit voltage and short-circuit current of each series-connected string.
(b) Wind and micro-hydro generators should be checked for correct wiring and operation in accordance with the manufacturer's instructions.
(c) Generating set output voltage and frequency should be checked.
(d) PV regulators should be checked for correct operating voltages and currents. Any low and or high volt disconnect/alarms circuitry should be checked for correct operation.
(e) Battery chargers should be checked for correct operating voltages and currents. Any low and/or high volt disconnect/alarms circuitry should be checked for correct operation.

All measurements should be recorded as initial operating parameters as part of the commissioning records, for future reference (see Section 12).

10.5 SYSTEM FUNCTIONAL TEST The overall function of the complete system should be tested and the results documented. All input sources should provide charge to the battery bank and, where applicable, power should be available to any connected ELV appliances.

APPENDIX C – EXTRACTS (SECTION 11) OF AUSTRALIAN STANDARD AS4509.3 STAND-ALONE POWER SYSTEM, PART 3: INSTALLATION AND MAINTENANCE

SECTION 11 SYSTEM MAINTENANCE

11.1 GENERAL Before maintenance is carried out on any equipment, the system shall be made 'safe'. When the system needs to be shut down, the shutdown procedures of AS 4509.1 shall be followed.

11.2 MAINTENANCE OF THE ELECTRICAL WIRING A correctly installed electrical wiring system normally needs infrequent maintenance, but periodic inspection of cabling security, electrical connections and mechanical protection should be performed.

11.3 MAINTENANCE OF THE PV ARRAY The PV array should be the subject of regular maintenance inspection, as follows:

(a) Carry out the following actions at least quarterly:
- (i) Clean PV modules surface, (if required).
- (ii) Adjust array tilt (where necessary) seasonally, and, for tracking arrays, check array orientation is consistent with the time of day.
- (iii) Check array mounting security.
- (iv) Check for damage to mechanical cable protection.

(b) Check the following items at least annually:
- (i) The electrical integrity (connection security and absence of corrosion) of the array connection system.
- (ii) PV array charging voltage and current is consistent with prevailing weather conditions and battery voltage.

11.4 MAINTENANCE OF WIND TURBINE GENERATORS The maintenance on the wind turbine generators and associated equipment should be carried out in accordance with the manufacturer's instructions.

11.5 MAINTENANCE OF MICRO-HYDRO GENERATORS The maintenance of the micro-hydro generator equipment should be carried out in accordance with the manufacturer's instructions.

11.6 MAINTENANCE OF GENERATING SETS Maintenance of the engine and alternator, including routine maintenance requirements such as oil and filter changes and adjustments, tune-ups and overhauls, should be carried out in accordance with the manufacturer's instructions.

Generating set operation (including auto start and remote start, where fitted) should be checked at the completion of any engine maintenance.

11.7 MAINTENANCE OF THE BATTERY BANK

11.7.1 General The battery bank should be subject to regular maintenance inspection and checks.

(a) Before carrying out maintenance the following precautions should be taken:
- (i) Isolate the battery bank so that no charge or discharge currents flow.
- (ii) Use only insulated tools while working on the battery system.
- (iii) Take care to prevent shorting battery terminals.
- (iv) Ensure that any hydrogen build-up has been thoroughly expelled, in accordance with Clause 11.7.2.

(b) The following actions should be performed at least quarterly:
- (i) Check battery connections for corrosion and tightness.
- (ii) Clean battery bank, especially the battery tops between cell terminals.
- (iii) Check battery electrolyte level.
- (iv) Check and record battery voltage and cell specific gravity, voltage and temperature.

11.7.2 Safe entry to battery area Where the battery enclosure is suspected of having high concentrations of hydrogen (e.g. ventilation fan is not operating or ventilation openings are blocked), the enclosure should be fully cleared of hydrogen gas before entry or performance of any maintenance.

All charging sources should be disconnected, any blockages cleared and the enclosure opened as far as possible. Mechanical means should be used to force several air changes through the area. If a portable fan is used, it should be ensured that it is running and facing the enclosure before any doors or covers are opened.

11.8 MAINTENANCE OF OTHER ITEMS Regular maintenance checks should be performed in accordance with manufacturer's instructions. If no recommendation is available, annual checks should be carried out, including the following:

(a) Check that battery charger operation is correct and that the current supplied is consistent with battery state of charge.
(b) Check that regulator/controller operation is correct.
(c) Check that meter readings are consistent with system parameters.
(d) Check that inverter operation is correct.
(e) Check that the operation of isolating devices (e.g. circuit-breakers and residual current devices) is correct.