Energy Efficiency EMSD

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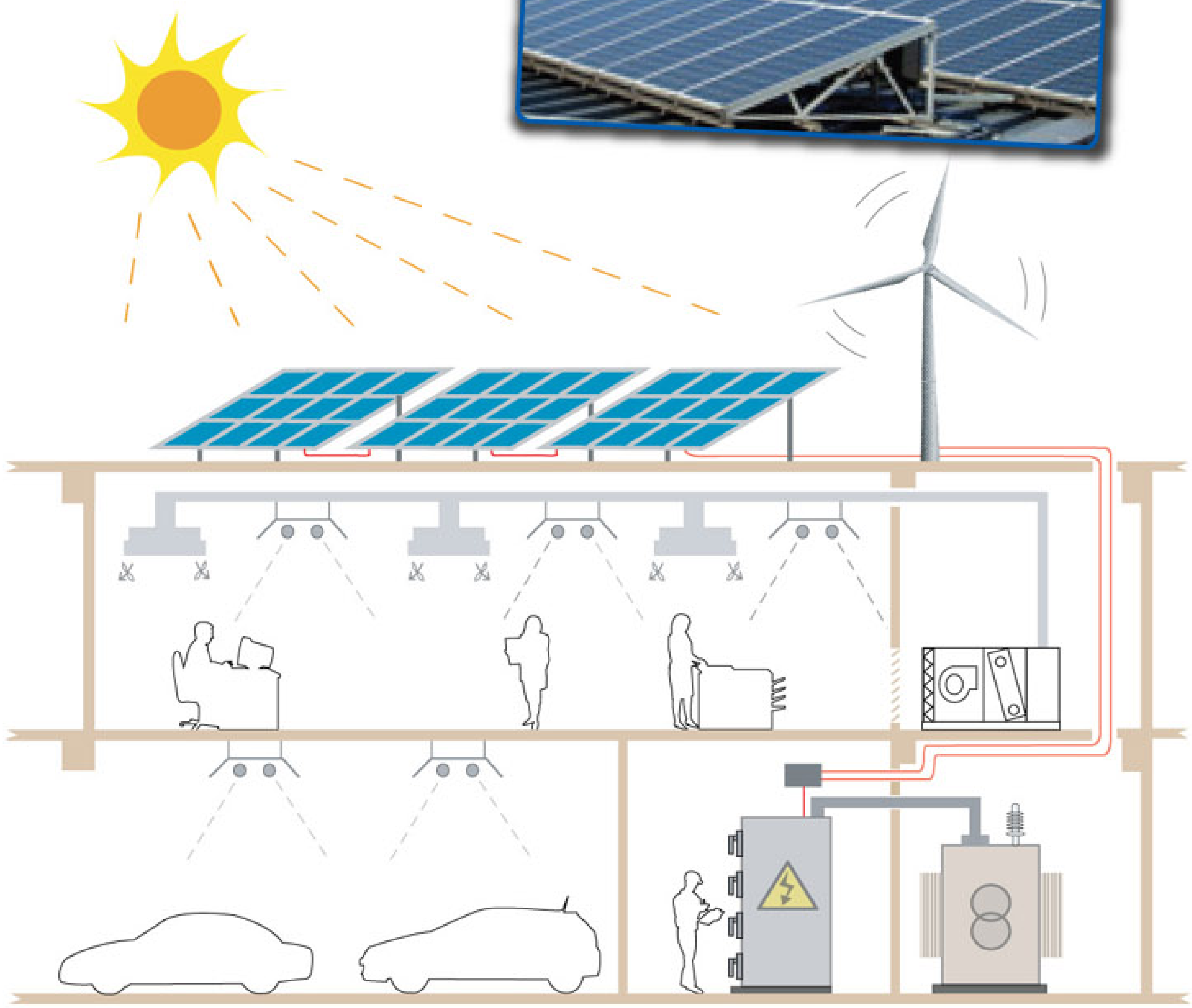
Technical Guidelines on

Grid Connection of Renewable Energy Power Systems

2007 EDITION



EMSD

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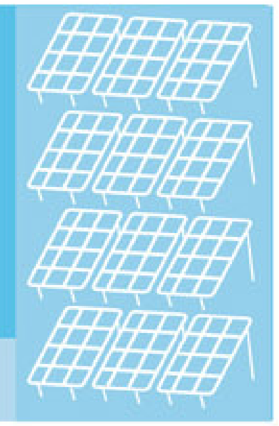

This Technical Guidelines was developed by the Working Group on Grid Connection of Small-scale Renewable Energy Power Systems which was established by the Energy Efficiency Office (EEO) of the Electrical and Mechanical Services Department (EMSD).

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1.0 Glossary of Terms and Abbreviations

1.1 Aggregated Power Rating - The arithmetic sum of the power rating of each power generating equipment of all the Renewable Energy Power Systems (REPSs) installed in each location or in each building, irrespective of whether they are installed by the landlord or tenants.

1.2 Building Integrated Photovoltaic (BIPV) system - An electricity generation system consisting of photovoltaic panels mounted on or fully integrated into the roofs, facades and walls of buildings.

1.3 COP - The current edition of the "Code of Practice for the Electricity (Wiring) Regulations" issued by the Electrical and Mechanical Services Department.

1.4 Distribution System - The on-site 220/380V low-voltage electricity supply network operated by the site owner or the site management team.

1.5 EEO - Energy Efficiency Office.

1.6 Electricity Ordinance - Chapter 406 of the Laws of Hong Kong, which is enforced by Electrical and Mechanical Services Department (EMSD) regulating the safe supply of electricity and the safety of household electrical products.

1.7 EMSD - Electrical and Mechanical Services Department.

1.8 Grid - The 220/380V low-voltage electricity supply network operated by the Utility.

1.9 Kilowatt-hour (kWh) – A measure of electrical energy required to provide power at one kilowatt for one hour.

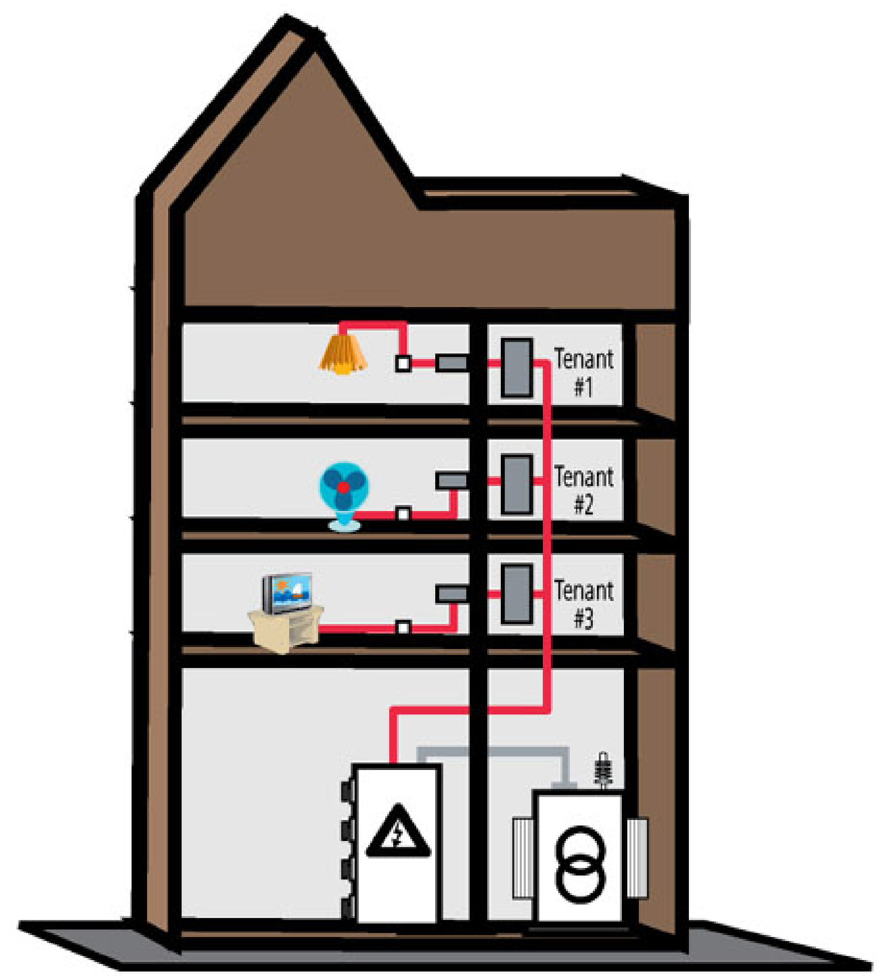
1.10 Owner - The owner of the grid - connected REPS.

1.11 Renewable Energy (RE) - Energy generated from sources that are secure and inexhaustible, in the sense that there is no problem of reserves being depleted. Examples of RE sources are solar, wind, etc.

1.12 Renewable Energy Power System (REPS) – Electricity generation facilities owned by a customer of the Utility, with RE sources as the primary feedstock to meet part of the on-site electrical energy demand from the customer's other electrical installations. In addition, the REPS is not expected to export electrical energy to other parties.

1.13 Supply Rules - The general and technical terms and conditions under which the Utility supplies to its customers.

1.14 Utility – A power company that supplies electricity to its customers. Currently the two power companies in Hong Kong are CLP Power Hong Kong Limited and The Hongkong Electric Company Limited.

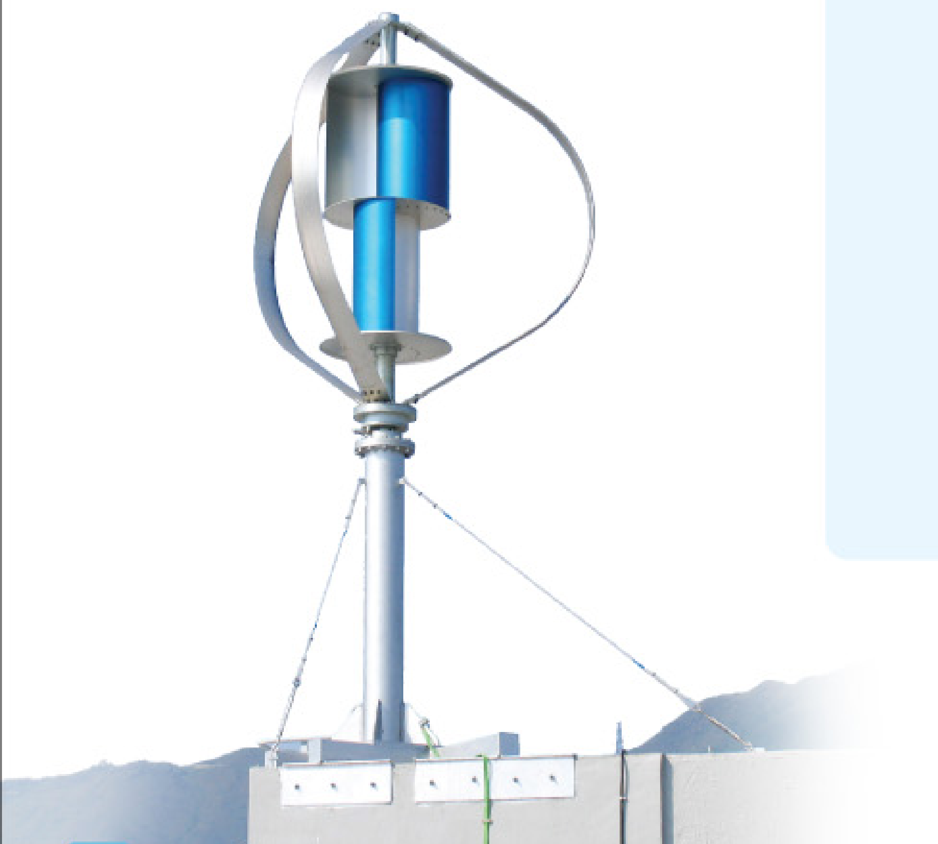


Distribution System

2.0 Introduction

General

2.1 Like all other developed economies, Hong Kong requires reliable and secure supplies of energy to support its social and economic develop - ment, and electricity is the most common form of energy in our daily lives. Electricity is conventionally generated by burning fossil fuels such as coal, oil and natural gas. The burning of these fuels releases greenhouse gases and air pollutants into atmosphere causing global warming as well as air pollution.



2.2 Another problem associated with the use of fossil fuels for electricity generation is that fossil fuel reserves are diminishing in a rate that it is very likely fossil fuels would become more scarce and expensive in future.

2.3 Renewable Energy (RE) produced from sustainable natural sources such as wind and solar can make a contribution in mitigating the problems associated with the use of fossil fuels.

2.4 The promotion of the use of RE is one of the initiatives on energy efficiency and conservation implemented by the Energy Efficiency Office (EEO) of the Electrical and Mechanical Services Department (EMSD). A two-stage consultancy study was commis-sioned by the EEO in late 2000 to evaluate the potential of various RE technologies appropriate for local use. Stage 1 Study has identified solar power and wind power as promising RE technologies for wide - scale application in Hong Kong.

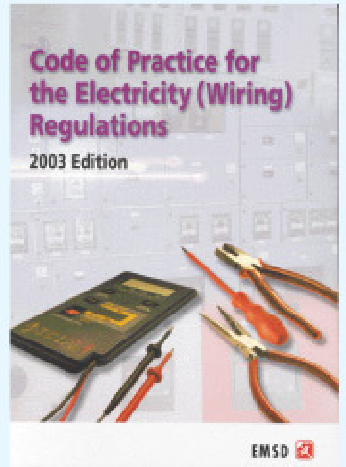
2.5 Stage 2 of the EEO's RE consultancy study was to monitor the performance of a grid-connected Building Integrated Photovoltaic (BIPV) system installed in Wanchai Tower. The BIPV system has been in operation since 2003 and has demonstrated to the general public the successful application of photovoltaic technologies in buildings.

2.6 Besides BIPV systems, there are some other typical examples of Renewable Energy Power System (REPS) such as building integrated wind power systems and other non-building-integrated REPSs which can be used for meeting part of the load demand on the same site.

Objective of Technical Guidelines

2.7 The objective of this Technical Guidelines is to give an outline on various technical issues relating to the connection of the REPS to the Grid through the Distribution System of the building concerned.

2.8 This Technical Guidelines does not purport to be a design manual. However, it serves as a quick reference to establish the technical requirements for developing any prospective grid - connected REPS proposals. It also provides the list of information in general to be submitted to the Utility to support applications for connecting REPSs to the Grid.



2.9 The Owner should ensure that the REPS complies with all prevailing statutory requirements and best practices on safety, reliability and power quality of electrical installations, such as the Electricity Ordinance and its subsidiary regulations, the Supply Rules, details of case-specific technical requirements of the Utility, etc. The requirements in the "Code of Practice for the Electricity (Wiring) Regulations" (COP) should be complied with when relevant. Installation details of REPS not covered in any of the local regulations or best practices may make reference to relevant international standards or overseas national standards as given in Appendix (III). The final design details should be agreed by both the Owner and the Utility.

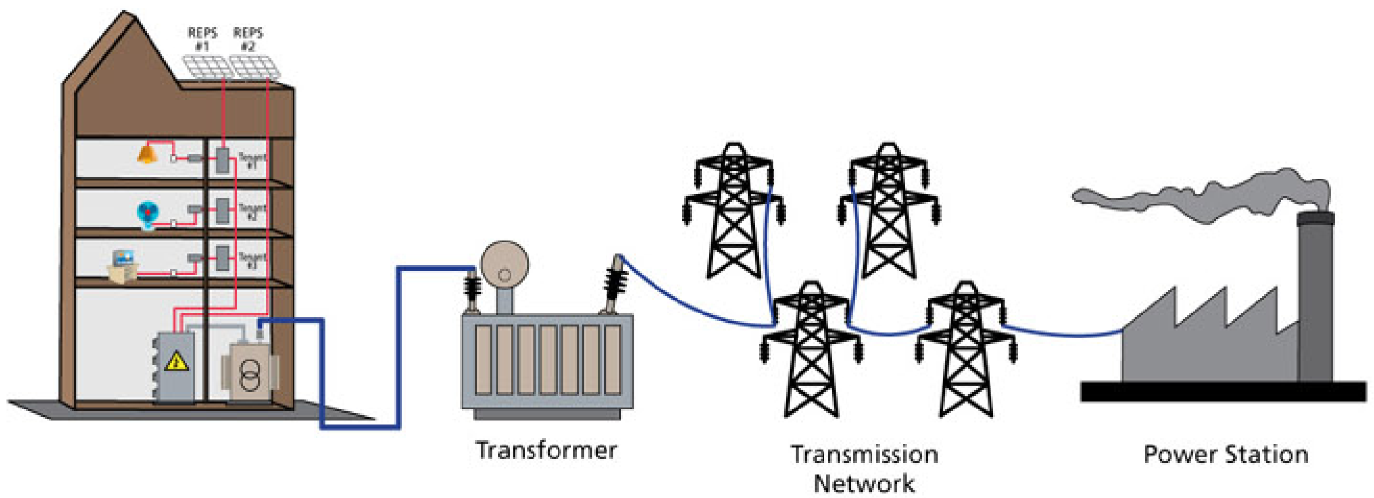
2.10 To ensure the proper operation of the REPS, Owners should note the importance of using high quality equipment in addition to employing skilled workers to work on the installation.

3.0 Connection of the REPS to the Grid

3.1 RE sources are mostly intermittent in nature. To ensure a reliable electricity supply to the designated loads of a REPS, it is necessary to provide either a battery system to store electricity generated from the REPS or a backup power to the REPS from another power source. However, the use of battery system is not normally considered as a viable option since the disposal of batteries may also cause other environmental problems.

3.2 Connection of a REPS to the Grid is very common in some overseas countries. The Grid serves to complement and backup the electrical load demand supplied by a REPS. The common practice is to connect the REPS to the Grid at a certain point of the Distribution System at the location where the REPS was installed.

3.3 After connected to the Grid, the REPS becomes part of the Distribution System and it is to the common interest of the Owner, the Utility and the government to ensure that the REPS can operate in a safe and reliable manner.



Grid Connection of Renewable Energy Power Systems

4.0 Scope

4.1 This Technical Guidelines is generally applicable to grid-connected REPSs of Aggregated Power Rating up to 1,000 kW, and the following chapters address the technical requirements for grid connection of REPSs. For REPSs of Aggregated Power Rating greater than 200 kW and up to 1,000 kW, additional requirements as described in 4.3 below will apply.

4.2 This Technical Guidelines covers only the technical requirements for connection of REPS to the Grid. However, the addition of a grid - connected REPS may require the Utility to pay special efforts and provide additional electrical equipment and/or services for ensuring a safe, adequate and reliable power supply to the designated loads of the REPS at any moment even when the REPS is out of service. The Owner may therefore be required to bear extra costs in addition to the installation cost of the REPS. It is therefore important that both parties should also discuss and agree on other related non-technical issues which are not covered in this document for connecting REPS to the Grid.

4.3 RE installations with Aggregated Power Ratings greater than 200 kW should be referred to the Utility on a case-by-case basis as more technical considerations on the Utility's side such as fault current ratings of switchgear, etc. may possibly be required. As a general rule, for a location or building supplied from more than one 1,500 kVA distribution transformers, a loading limit of 200 kW of installed RE power per distribution transformer can be applied. Furthermore, under certain circumstances it may be permissible to exceed the per-transformer RE power loading limit when there is fault-current limiting function on the RE equipment, and this shall be handled on a case-by-case basis.

5.0 Safety Considerations

5.1 If a REPS is connected to the Grid through the Distribution System, it is possible that the REPS may also supply electricity to the Grid under abnormal conditions. The Owner should ensure such a connection would not create any safety problem to electrical workers carrying out works on related electrical installations under normal and emergency situations. Appropriate safety precaution should also be taken by the Utility to prevent danger to its electrical workers due to back energization.

5.2 The following provisions are recommended:

(a) Incorporate an "anti-islanding" function in the design of the REPSs. This function can automatically disconnect any grid-connected REPS from the Distribution System in the event that the Grid is de-energized for whatever reasons. The purpose of an "anti-islanding" function is to ensure that REPS would not continue to supply power to the Distribution System so as to allow electrical workers to work safely on the Grid or the Distribution System during the power interruption, and to cater for circuit breaker auto-reclosing operation on the Grid.

(b) Install a lockable switch at a readily accessible position to allow authorized electrical workers to manually isolate the REPS from the Grid whenever necessary.

(c) Display warning labels at all electrical equipment with dual power supply sources so as to alert the maintenance personnel.

(d) Update circuit diagrams regularly and display them at appropriate locations to facilitate maintenance personnel to properly shut down the grid connection arrangement under normal and emergency operations.

(e) Establishing a direct communication channel between the Owner and the Utility is essential to ensure the safe operation of the REPS and the Grid. Designate a suitably qualified person to communicate directly with the Utility under normal and emergency operations.

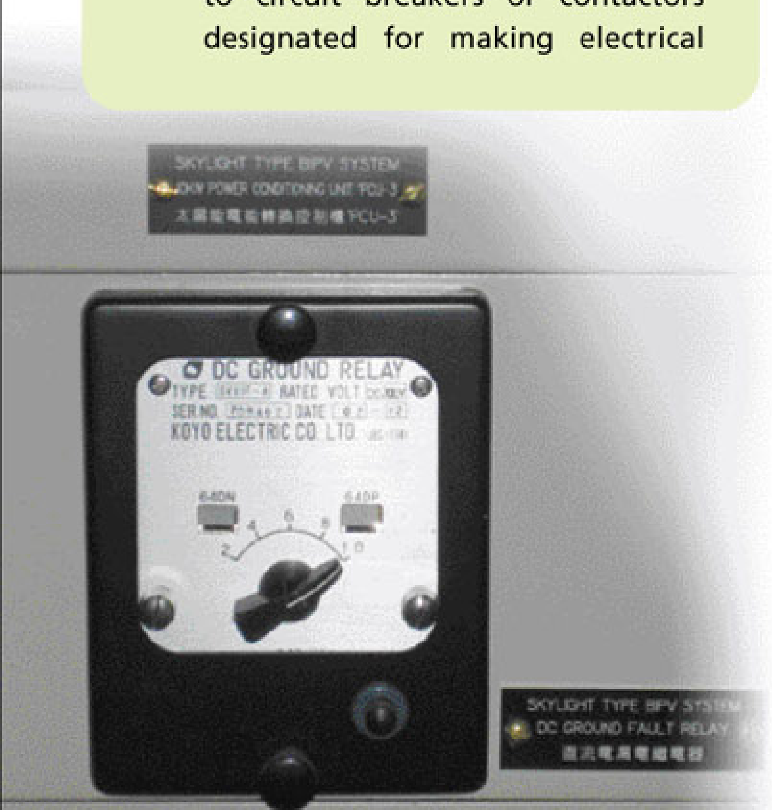
6.0 Equipment Protection

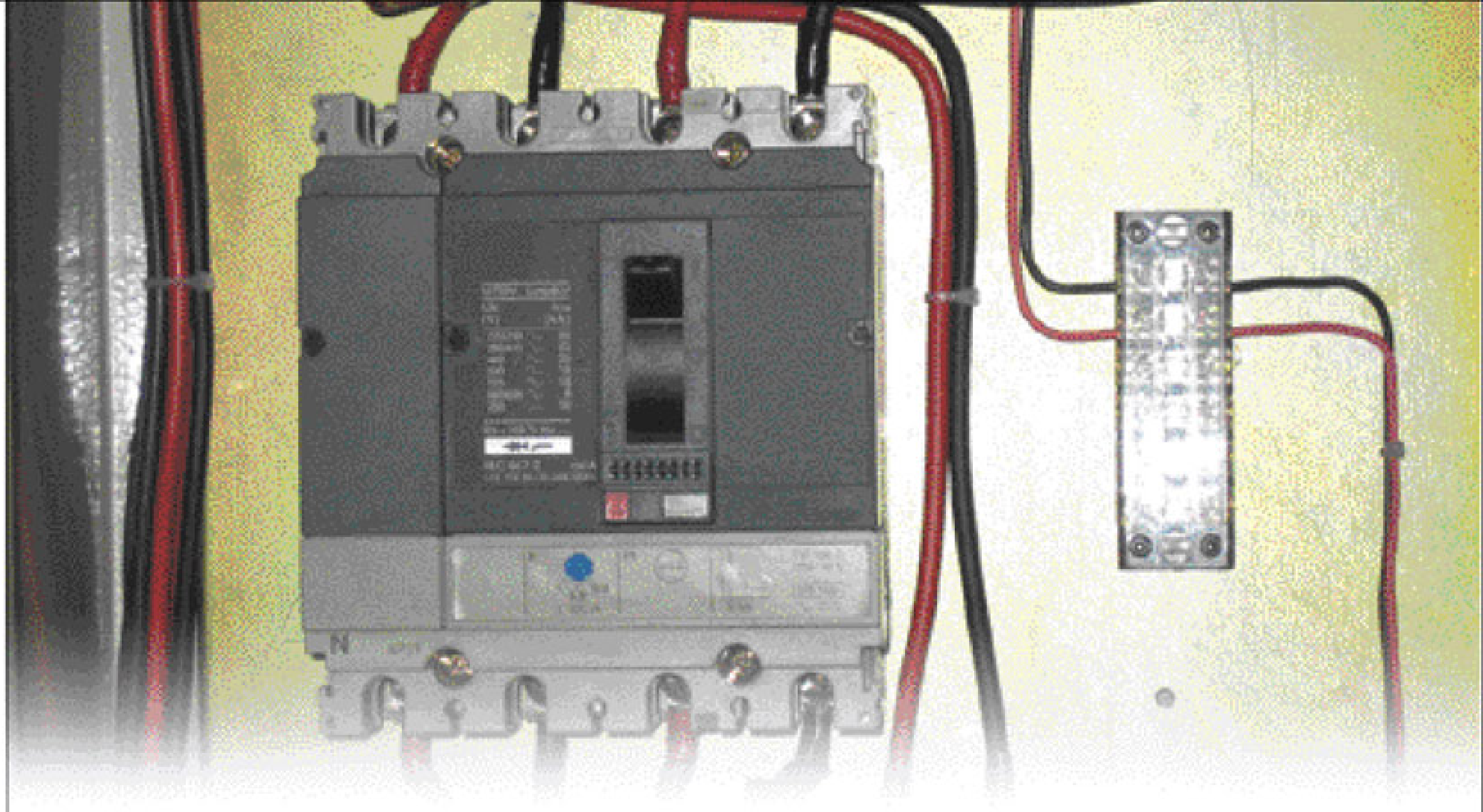
6.1 Providing protection facilities for eqipment is important as damage to equipment may lead to other safety issues. This section describes the provisions recommended for the protection of the REPS, the Distribution System and the Grid when they are connected together.

(a) Carry out assessment on the new fault level due to the connection of the REPS to the Grid such that all equipment in the Distribution System and the Grid can operate safely under the new fault level.

(b) Install facilities with synchronization check function, whenever necessary, to circuit breakers or contactors designated for making electrical connection to the Distribution System. The connection of the REPS to the Distribution System would only take place when they are operating in synchronization, i.e. the differences in voltage magnitude, phase angle, and frequency of these two power sources are controlled within acceptable limits.

(c) Incorporate protection function in the design of the REPS to avoid unsynchronized connection. To enable fast restoration of supply after power failure, the Utility has equipped with auto-switching and auto-reclosing facilities that would operate soon after power failures. If the Distribution System is still energized by the REPS, un-synchronized connection which would damage equipment of both parties, may occur.





(d) Incorporate facilities to isolate the REPS from the Distribution System automatically when fault occurs in the REPS.

(e) Use 4-pole type circuit breakers or isolators on all isolation points of the REPS to allow complete isolation from the Distribution System when the REPS is not in service. This arrangement is to ensure that the Distribution System would remain intact and not be affected by the REPS.

(f) Incorporate appropriate protection facilities in the design of the REPS to avoid damages to the REPS caused by transient abnormalities that would occur in the Distribution System and the Grid, such as supply interruption, voltage and frequency fluctuation, voltage dip, etc.

(g) Incorporate a stable and fast responding voltage and frequency regulator to ensure that the REPS can handle the normal voltage and frequency fluctuations in the Distribution System.

(h) Incorporate facilities in the REPS which can automatically disconnect the REPS from the Distribution System when sustained voltage and frequency fluctuations are detected in the Distribution System. The time delay setting before automatic disconnection can take place may make reference to the recommendations of international standards as given in Appendix (III) and agreed by both the Owner and the Utility.

(i) Incorporate facilities in the REPS which can automatically re-connect the REPS back to the Distribution System after fluctuations in voltage and frequency in the Distribution System have been cleared. The time delay setting before re-connection can take place may make reference to the recommendations of international standards as given in Appendix (III) and agreed by both the Owner and the Utility. The time delay is to avoid repeated operation of the circuit breakers due to premature electrical connection.

7.0 Reliability

7.1 It is important that the electricity supply to existing electrical equipment connected to the Distribution System would not be affected by the introduction of a grid-connected REPS. Any fault developed in the REPS that cause power interruption of the Distribution System and the Grid can be avoided if the following recommended provisions are considered in the design of the grid-connected REPS:

(a) Select an inverter, with high reliability, such as having a high "mean - time - between-failure" index. This is essential since the inverter is the principle component in the REPS that directly connects the REPS to the Distribution System.

(b) Set the operating levels of all the protective devices in the Distribution System to suit the new fault level. This arrangement is to avoid improper operation of protective devices during fault conditions.

(c) Incorporate a fast responding voltage and frequency regulator that can adjust the output of the REPS to match the voltage and frequency of the Distribution System. This would reduce electrical stress on the REPS and help to minimize failures.

(d) Provide an automatic disconnection function in the REPS that can operate when the voltage and frequency of the Distribution System deviate outside the allowable limits persistently for a pre-determined period recommended by international standards as given in Appendix (III) and agreed by both the Owner and the Utility.

8.0 Power Quality

8.1 In general, good power quality in the electricity supply is essential for the normal and efficient operation of all electronic and electrical equipment. A Distribution System with good power quality would therefore benefit both the Owner and other consumers receiving power supply from the same Distribution System. The power quality issue should be well considered in the design stage to avoid post-installation mitigation action.

8.2 An inverter is normally included as part of a REPS and it may impair the power quality of the Distribution System. The following provisions are recommended to minimize the effect on the power quality of the Distribution System caused by the grid-connected REPS:

(a) Install an inverter with power conditioning function to control the harmonic currents and the output power factor of the REPS within an acceptable range such that the REPS can operate efficiently and other parties would not be affected.

(b) Install an isolation transformer on the output side of the power inverter to eliminate the possibility of injection of direct current from the REPS into the Distribution System. Excess direct current injected into the Distribution System would distort its voltage and cause problems to other connected equipment.

(c) Install a fast responding voltage and frequency regulator to minimize voltage flickering in the Distribution System which is undesirable to other connected electrical equipment.

(d) Evaluate the electromagnetic compatibility requirements specified in international standards as given in Appendix (III) at the design inception stage. Conducted or radiated electromagnetic emissions from the REPS would then be properly controlled so as not to interfere with the normal operation of other electrical equipment in the Distribution System.

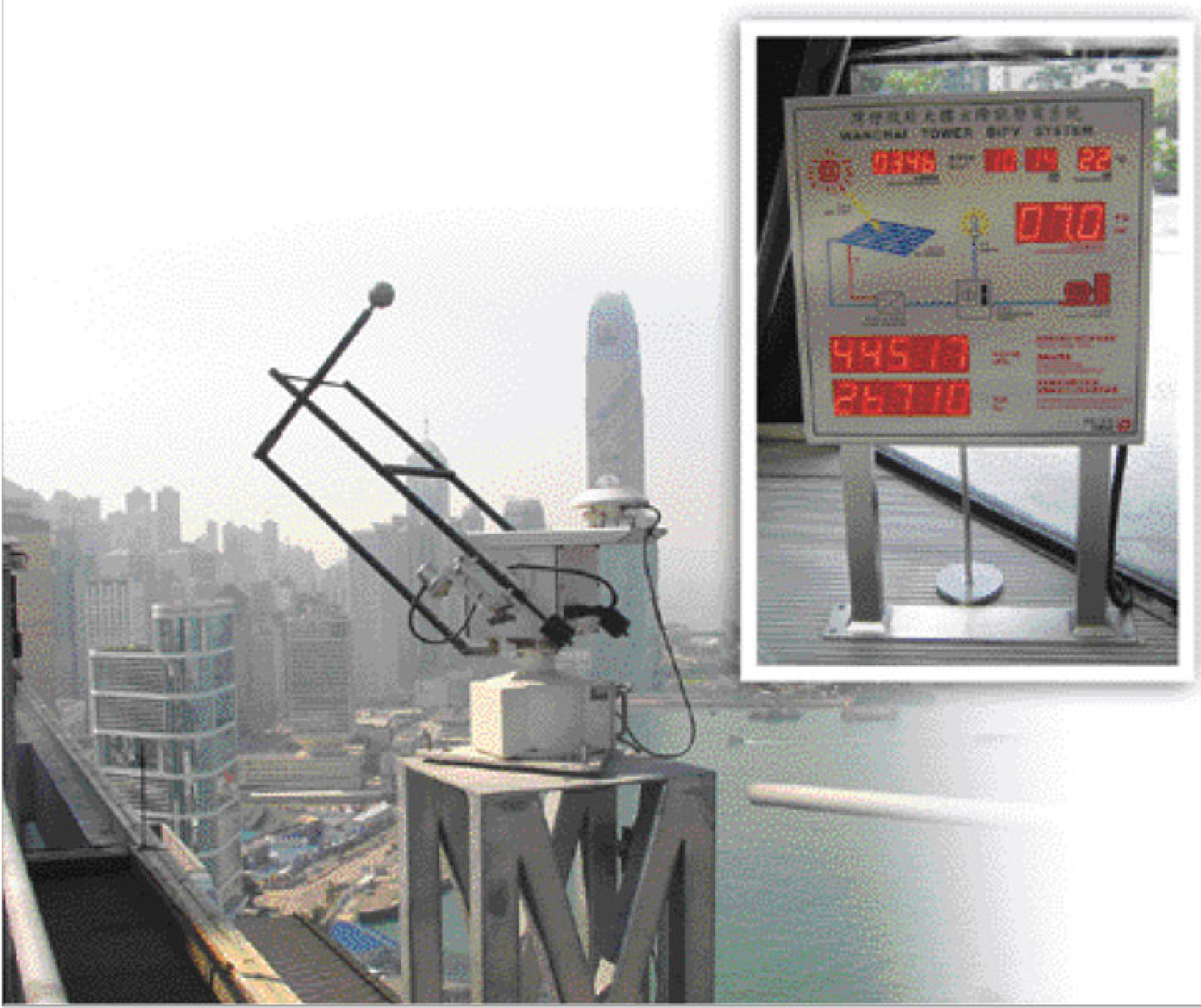
(e) Design a REPS with three-phase inverter or three identical single-phase inverters to supply current which is balanced over the three phases to the Grid. This would minimize voltage and current unbalance in the three-phase supply system and would ensure that the capacity of the Distribution System can be fully utilized. However, this provision is not applicable if the site is being supplied or will be supplied with single-phase power from the Utility.

9.0 Performance and Monitoring

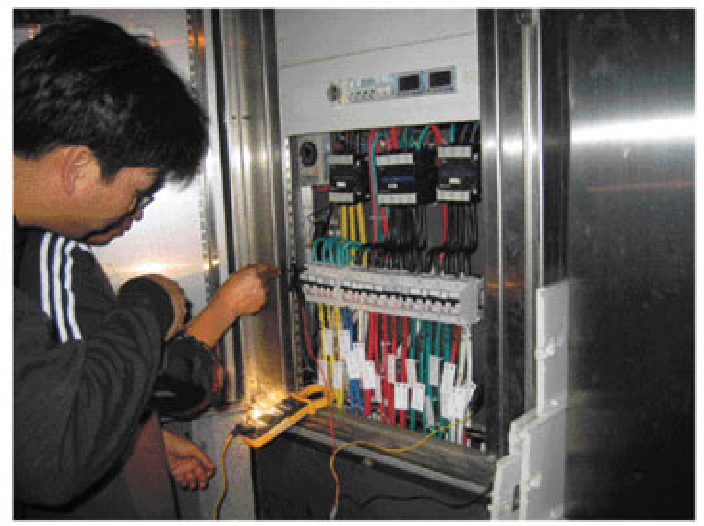
9.1 The following provisions can be considered by the Owner for his own research or record purpose:

(a) Additional control and monitoring facilities to measure and monitor the performance of the REPS.

(b) A data collection and reporting system to provide real time data, data summaries and failure reports.



10.0 Testing and Commissioning



10.1 Before the REPS is energized, it is important that the Owner has carried out a thorough inspection and functional / safety tests to ensure that the REPS has been properly designed and commissioned in accordance with the technical requirements of this Technical Guidelines and other case-specific technical requirements. The Utility may specify and witness certain tests of the grid-connected REPS, or at least to be informed of the test results. The grid connection arrangement will only be energized after the test procedures and test results are both accepted by the Owner and the Utility. The following testing and commissioning procedures are recommended:-

(a) To test all the protection level and time delay settings.

(b) To check the operation of the anti-islanding function.

(c) To check the operation at all isolation points.

(d) To check that all the warning labels, equipment labels and circuit diagrams are displayed in appropriate locations.

(e) To check and record the voltage and current output of the REPS including power factor, direct current level and total harmonic distortion.

11.0
Post-installation Obligations of the Owners

11.1 After the REPS is put into normal operation, the Owner should provide the Utility with information on the electrical energy output of the REPS on a regular basis, e.g. bi-monthly, if requested by the Utility. The Utility may also install check meters to monitor the electrical energy (kWh) output of the REPS.

11.2 Periodic inspection of the REPS by registered electrical worker is recommended. The Owner can consider adopting an inspection arrangement similar to the requirements as stipulated in the Electricity (Wiring) Regulations of the Electricity Ordinance for fixed electrical installations. It is not necessary for the Owner to submit the relevant inspection certificate and checklist to the Utility.

11.3 The Utility may conduct on-site inspections and request the Owner to perform verification tests on the operation of the REPS. In this regard, the Utility may request the Owner to provide access and the test results.

11.4 It is important for the Owner to compile an operation and maintenance manual to record all procedures needed to operate and maintain the REPS including all protection settings and test results. Regarding grid connection operational procedures which form part of this manual, the details should be agreed by the Owner and the Utility. This manual should be reviewed regularly and modified where necessary.

11.5 The Owner should inform the Utility on any change in power rating or modification of the REPS. In addition, the Utility will also need to be informed when the REPS is decommissioned.

12.0
Outline of Application Procedures

12.1 The contact information of the Utility for grid connection applications is given in Appendix (I).

12.2 It would be advantageous for the prospective Owner to make contact with the Utility from inception. This ensures that the Utility can provide advice on the grid connection aspect before the design of the REPS is finalized. Supporting information, such as relevant literature describing the REPS, layout drawings, schematic drawings etc. listed in Appendix (II), can be submitted in stages to the Utility.

12.3 The Owner and the Utility should come to an agreement on the most suitable connection arrangement for the proposed REPS. Both parties should also discuss and reach an agreement on the terms and conditions of grid connection.

12.4 The Owner and the Utility should also agree on a commissioning date for the REPS and the tests to be witnessed by the Utility.

13.0 Local and Overseas Standards and Schematic Diagrams of Example Installations

13.1 A list of local and overseas standards, codes and best practices relating to grid-connected RE installations is given in Appendix (III). These documents can be used as reference materials in the design of grid-connected REPS.

13.2 Schematic diagrams for three example installations are given in Appendix (IV). These schematic diagrams show the configurations of those installations at the time of compiling this Technical Guidelines, for the purpose of illustrating the grid connection arrangements adopted by various designers. There are no standand grid connection arrangements and each installation should be designed on a case-by-case basis.

Appendix (I) - Contact Information of Utility for Grid Connection Application

1. CLP Power Hong Kong Limited

Contact Division / Department:	Power Systems Business Group / Asset Management Department
Postal Address:	215 Fuk Wa Street, Kowloon, Hong Kong.
Post of Responsible Person:	Network Planning Manager
Telephone Number:	2678 7131
Facsimile Number:	2678 6863
Email Address:	csd@clp.com.hk
Website:	www.clpgroup.com

2. The Hongkong Electric Co., Ltd.

Contact Division / Department:	Distribution Planning Department of Transmission and Distribution Division
Postal Address:	G.P.O. Box 915, Hong Kong.
Post of Responsible Person:	Chief Distribution Planning Engineer
Telephone Number:	2814 3459
Facsimile Number:	2843 3163
Email Address:	mail@hec.com.hk
Website:	www.heh.com

Appendix (II) - Information to be Submitted with Grid Connection Application

Submitted technical drawings would better be in duplicate and in original size.

A. Information to be submitted initially should include:

1 Information of Applicant
- (a) Name
- (b) Postal address
- (c) Utility account number / meter number (for existing customer)
- (d) Contact telephone number
- (e) Facsimile number
- (f) Email address

2 Information of the Proposed REPS Installation
- (a) Address of installation
- (b) Expected commencement date of installation
- (c) Expected commissioning date
- (d) Type of RE technology (e.g. photovoltaic, wind, hybrid etc.)
- (e) Manufacturer / Brand and type (inverter, synchronous machine, asynchronous machine, etc.) of power generation equipment
- (f) Country of origin
- (g) Standard of compliance
- (h) Technical specifications of power generation equipment
  - i) total rating
  - ii) single-phase or three-phase electricity output
  - iii) power output frequency
- (i) Expected annual generation (kWh)
- (j) Any other known REPS installation on site

3 Brief Description of the Mode of Operations and Control of the REPS.
- (a) Technical drawings illustrating the physical locations of the REPS and other major electrical equipment installed or to be installed
- (b) Single-line electrical diagrams of the Distribution System showing details of the proposed grid connection and the associated metering points/ supply points

B. Additional information to be provided may include:

1. Detailed System Description
   - (a) Scheme for electrical and mechanical interlocks between the REPS and Utility's supply point, in particular during outage of the Grid
   - (b) Protection schemes with settings and operating time
     - i) overload
     - ii) short-circuit
     - iii) earth fault
     - iv) over- and under-voltage
     - v) over- and under-frequency
     - vi) anti-islanding
   - (c) Control and monitoring scheme
     - i) means of detection and conditions for connection of REPS to Grid
     - ii) means of detection and conditions for disconnection from Grid
     - iii) time delay for re-connection of REPS to Grid
     - iv) details of synchronization check function
     - v) arrangement for local and remote isolation from Grid by Utility during emergency
     - vi) metering arrangement, if any
2. An analysis and estimation on the demand and load sharing between the Grid and the REPS over a typical week
3. An analysis on the following effects on Grid
   - (a) Current balancing among the 3 phases
   - (b) Effect on fault level
   - (c) Power quality including
     - i) harmonic distortion and power factor
     - ii) voltage flickering
4. An analysis on electromagnetic compatibility of the REPS
5. Procedures for testing and commissioning
   - (a) Performed by the applicant
   - (b) Jointly performed by the applicant and the Utility
   - (c) Details of indicative and warning labels on site
6. Operational procedures for grid - connection

Appendix (III)
Local and Overseas Standards and Best Practices

Local codes and rules

Title
Code of Practice for Electricity (Wiring) Regulations, EMSD
Supply Rules of The Hongkong Electric Co., Ltd.
Supply Rules of CLP Power Hong Kong Limited

General technical standards/guides/recommendations on grid connection

Standard/Guide/ Reconmmendation	Title
IEEE Std P1547 – 2003	IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
IEEE Std P1547.1 – 2005	IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
IEEE P1547.2	Draft Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems
IEEE P1547.3	Draft Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems
Electricity Association, UK Engineering Recommendation G59/1 – 1991	Recommendations for the Connections of Embedded Generating Plant to the Public Electricity Suppliers' Distribution Systems
Electricity Association, UK Engineering Recommendation G83 – 2003	Recommendations for the Connection of Small-scale Embedded Generators (up to 16 A per phase) in Parallel with Public Low-voltage Distribution Networks
Electricity Association, UK Engineering Technical Report TR113 – 1995	Notes of Guidance for the Protection of Embedded Generating Plant up to 5 MW for Operation in Parallel with Public Electricity Suppliers' Distribution Systems

Technical standards/guides/recommendations on grid connection of PV systems

Standard/Guide/ Reconmmendation	Title
IEC 60364-7-712 – 2002	Electrical Installations of Buildings - Part 7-712: Requirements for Special Installations or Locations - Solar Photovoltaic (PV) Power Supply Systems
IEC 61173 – 1992	Overvoltage Protection for Photovoltaic (PV) Power Generating Systems - Guide
IEC 61727 – 2004	Photovoltaic (PV) Systems - Characteristics of the Utility Interface
IEC 61724 – 1998	Photovoltaic System Performance Monitoring - Guidelines for Measurement, Data Exchange and Analysis
IEEE Std 929 – 2000	Recommended Practice for Utility Interface of Photovoltaic Systems

Technical standards/guides/recommendations on power quality

Standard/Guide/ Reconmmendation	Title
IEC/TS 61000-3-4 (1998). Electromagnetic Compatibility – Part 3-4	Limitation of Emission of Harmonic Currents in Low Voltage Power Supply Systems for Equipment with Rated Current Greater than 16 A
IEC/TS 61000-3-5 (1994). Electromagnetic Compatibility – Part 3-5	Limitation of Voltage Fluctuations and Flicker in Low-voltage Power Supply Systems for Equipment with Rated Current Greater than 16 A
IEC 61000-3-12 (2004). Electromagnetic Compatibility - Part 3-12	Limits for Harmonic Currents Produced by Equipment Connected to Public Low-voltage Systems with Input Current >16 A and <=75 A Per Phase
IEC61000-4-7 (2002). Electromagnetic Compatibility – Part 4-7	Testing and Measurement Techniques – General Guide on Harmonics and Interharmonics Measurements and Instrumentation, for Power Supply Systems and Equipment Connected Thereto
IEEE Std 519 – 1992	Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

Note:

(1) The IEC publications can be purchased from the IEC Webstore: http://webstore.iec.ch/

(2) The IEEE publications can be purchased from the IEEE Standards Online website: http://standards.ieee.org/

(3) The UK Electricity Association publications can be purchased from the Energy Networks Association website: http://www.energynetworks.org/

Appendix (IV)
Schematic Diagrams of Example Installations

Explanatory notes for the schematic diagrams

1. These schematic diagrams are given here for the purpose of illustrating the grid connection arrangements adopted by various designers, and should not be taken as standard arrangements for grid-connected systems.
2. The graphical symbols generally conform to IEC 60617 - Graphical Symbols for Diagrams.
3. The functions of some of the principal components shown in the schematics are briefly described below.

PV array
The PV array is made up of PV modules (and/or BIPV laminates) connected in series to form strings, then with these strings further connected in parallel.

Array combiner box / sub-array combiner box / DC junction box
The PV strings are connected in parallel in these boxes, for connection to the inverters. The necessary blocking diodes, surge arrestors, and DC fuses are incorporated into these boxes.

Inverter
The inverter converts the DC output of the PV array into AC. Power conditioning function is incorporated into the inverter to control harmonics and output power factor. An isolation transformer is included either within the inverter unit, or external to the inverter to prevent injection of direct current into the Distribution System.

The following functions are also incorporated into the inverter:

(a) maximum power point tracking (MPPT) function, to continuously adjust the DC voltage to ensure that maximum power will be generated by the PV array under the varying solar irradiance conditions;

(b) anti-islanding function, with tripping time as required by the Utility, to disconnect the inverter automatically from the Distribution System in the event that the Grid is de-energized for whatever reasons;

(c) under/over-frequency/voltage protection function, to disconnect the inverter from the Distribution System when the frequency and/or voltage of the Grid falls out of normal range;

(d) auto-reconnection function, to reconnect the inverter back to the Distribution System when the frequency and/or voltage of the Grid resumes to normal operational range for a pre-defined period of time (with such time period to be agreed with the Utility);

(e) synchronization check function, to ensure that connection of the inverter to the Distribution System will only take place when the inverter output and the Distribution System are operating in synchronism.

In the case of Example 3, the anti-islanding function is arranged in a separate anti-islanding panel.

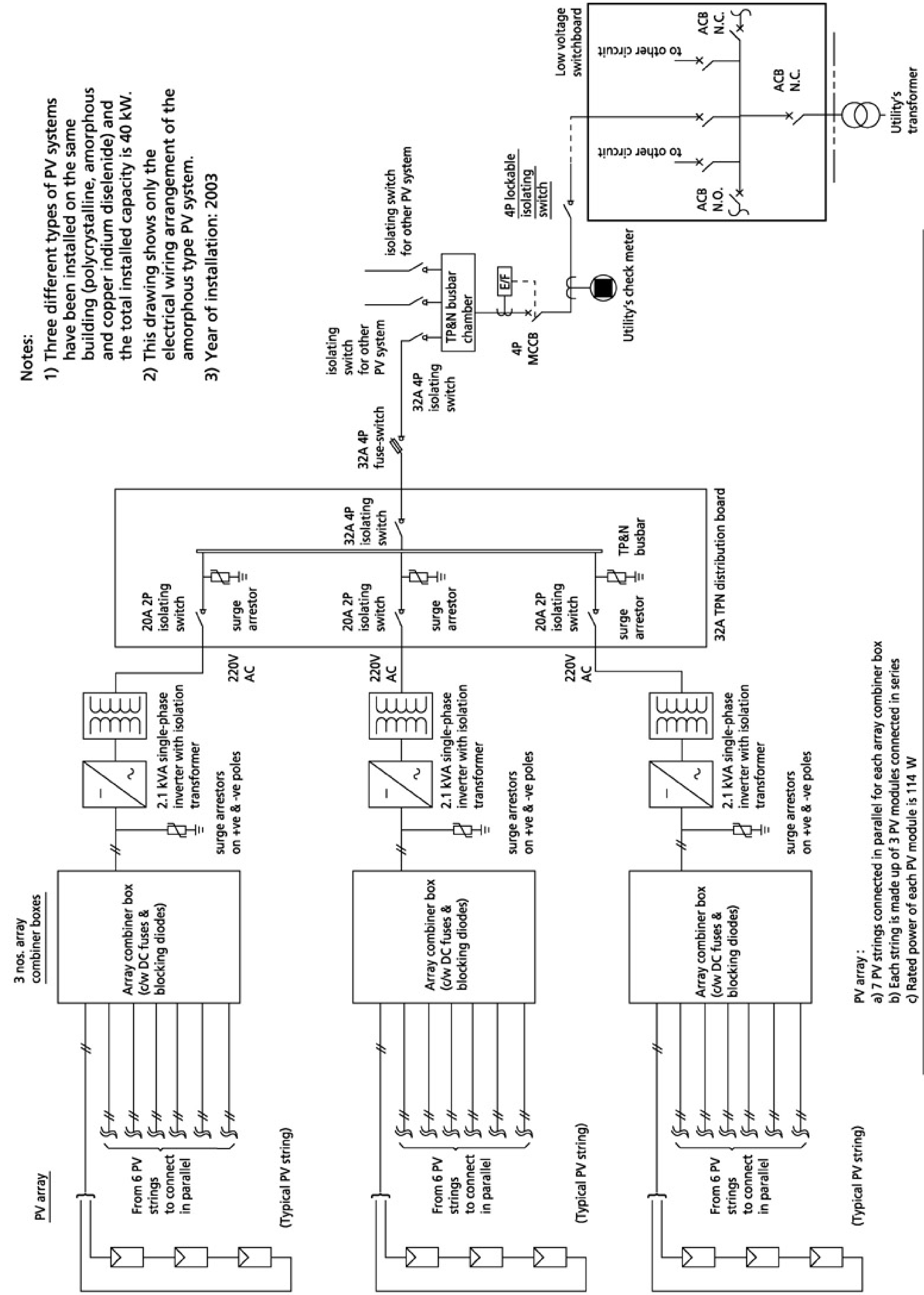
In the case of multiple inverters with their outputs connected in parallel, the protection settings of the inverters will differ slightly to allow for sequential tripping under abnormal conditions, and sequential auto-reconnection afterwards.

AC distribution board
If installed for a multi-inverter system, the AC outputs of the inverters (after isolation transformers) are connected together in the AC distribution board, for further connection to the Distribution Systm through the main isolating switch.

Utility's check meter
This may or may not be required by the Utility. Its function is to record the electrical energy generated and sent out by the PV system.

Main isolating switch (four-pole, lockable)
This is a manually operated lockable isolating switch (or circuit breaker) to allow authorized electrical workers to manually isolate the PV system from the Distribution System whenever necessary.

Notes:
1) Three different types of PV systems have been installed on the same building (polycrystalline, amorphous and copper indium diselenide) and the total installed capacity is 40 kW.
2) This drawing shows only the electrical wiring arrangement of the amorphous type PV system.
3) Year of installation: 2003



PV array :
a) 7 PV strings connected in parallel for each array combiner box
b) Each string is made up of 3 PV modules connected in series
c) Rated power of each PV module is 114 W

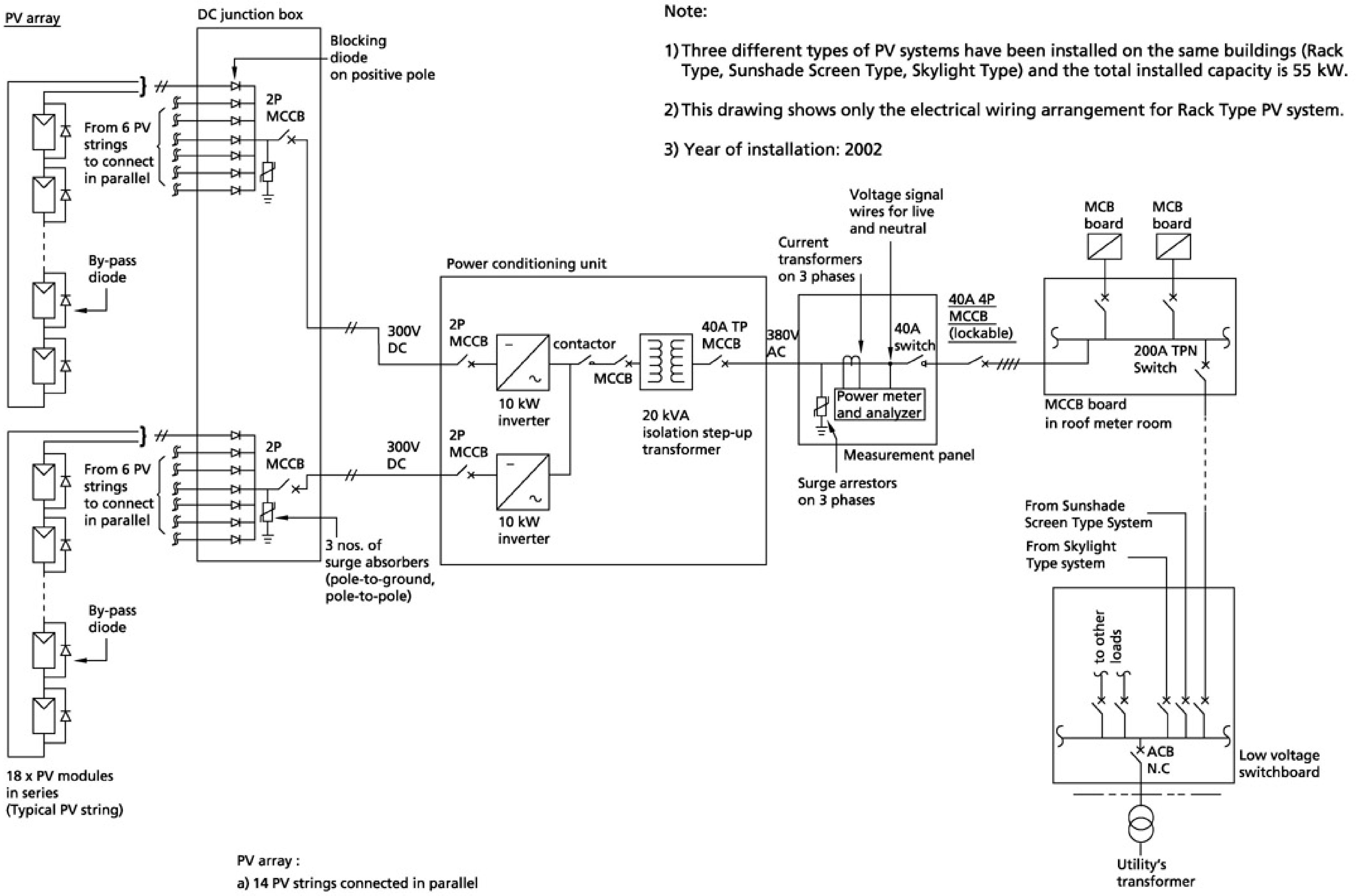
Example 1 - Schematic diagram of a 7.2 kW photovoltaic system (single grid-connection point)

Note:

1) Three different types of PV systems have been installed on the same buildings (Rack Type, Sunshade Screen Type, Skylight Type) and the total installed capacity is 55 kW.

2) This drawing shows only the electrical wiring arrangement for Rack Type PV system.

3) Year of installation: 2002



PV array :

a) 14 PV strings connected in parallel

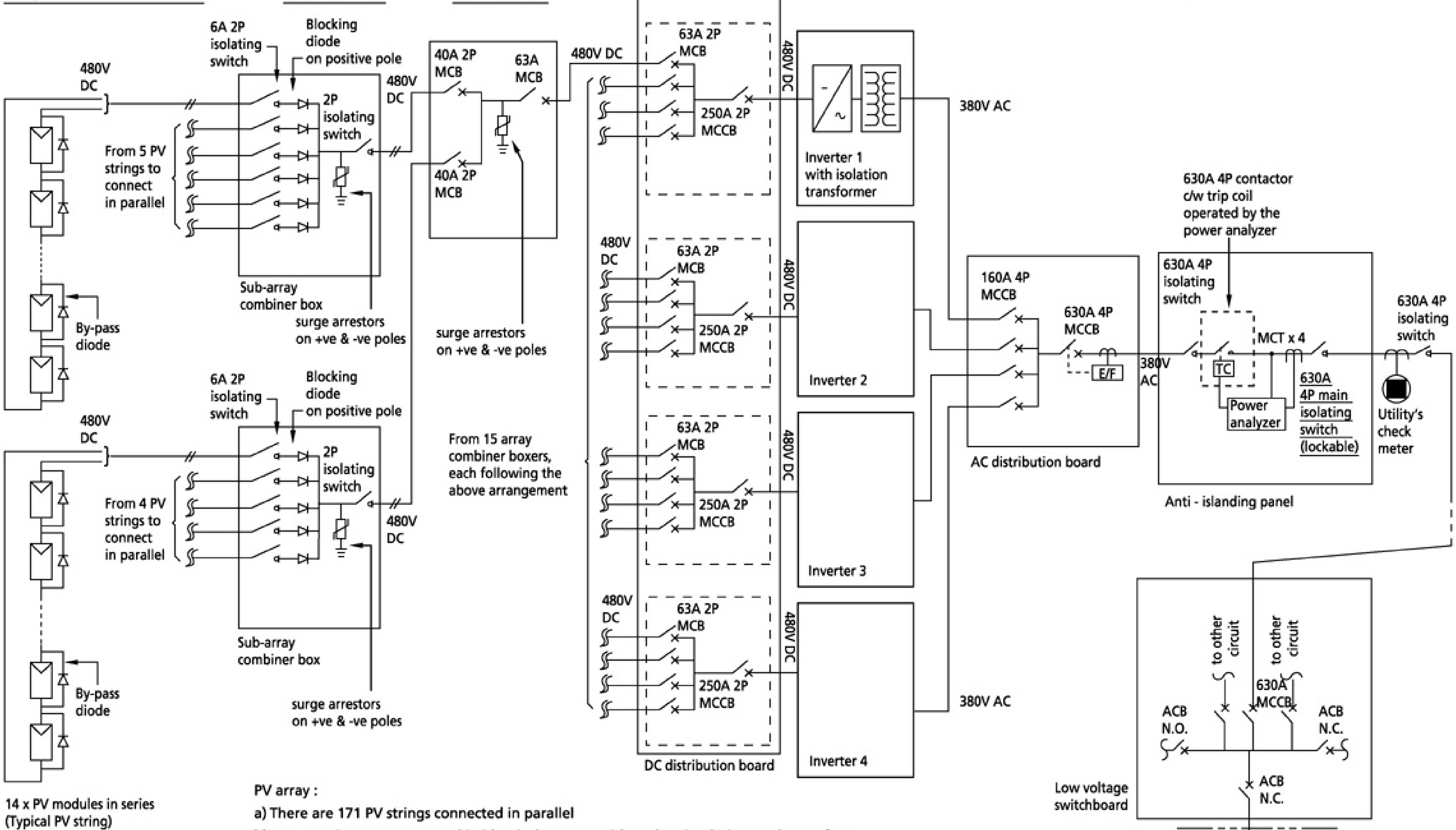
b) Each string is made up of 18 PV modules connected in series

c) Rated power of each PV module is 80 W

Example 2 - Schematic diagram of a 20 kW photovoltaic system (multiple grid-connection points)

Notes:

1) Year of installation: 2005



PV array :

a) There are 171 PV strings connected in parallel

b) 168 PV strings are connected in identical manner with each string being made up of 14 PV modules connected in series.

c) There are 2357 pieces of PV modules & 20 pieces of BIPV laminates

d) Power ratings of each PV module and BIPV laminate are 150 W and 270 W respectively

Example 3 - Schematic diagram of a 350 kW photovoltaic system (single grid-connection point, > 200 kW)