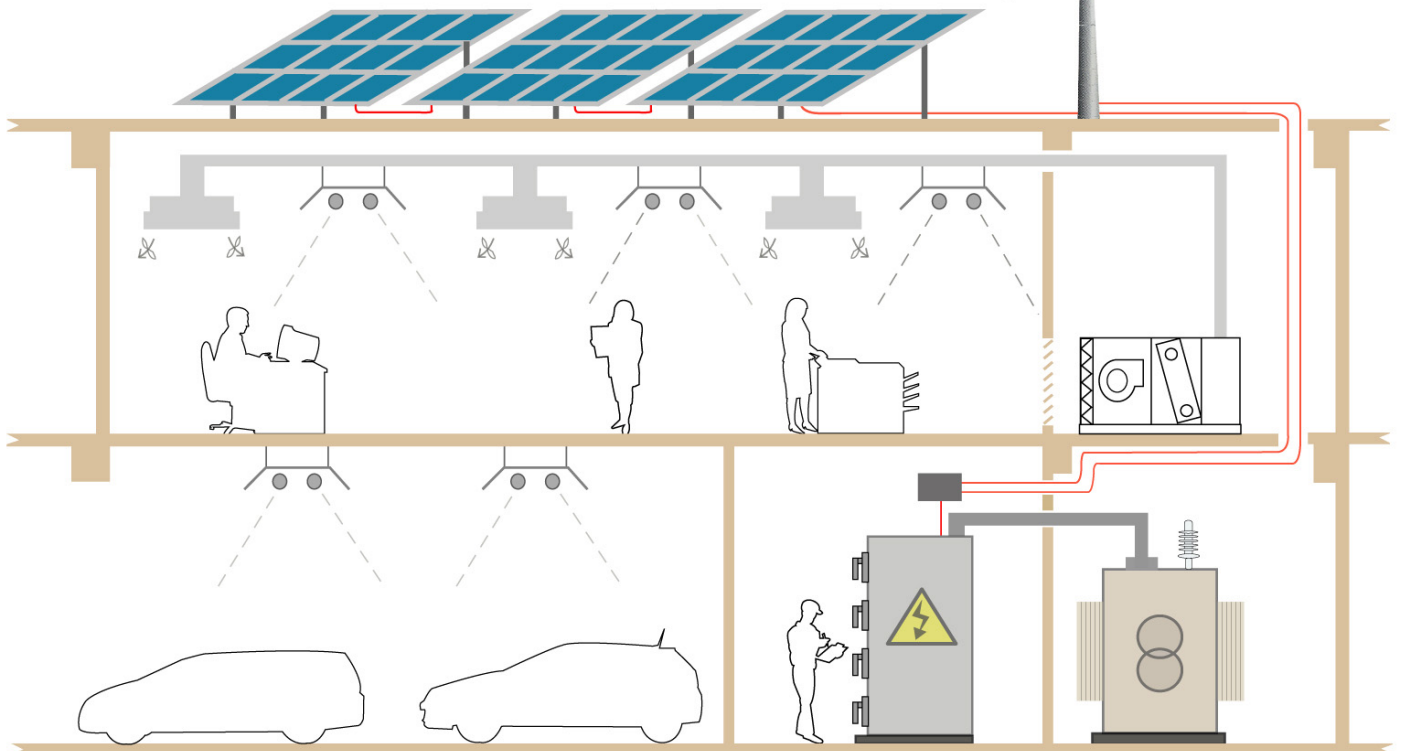
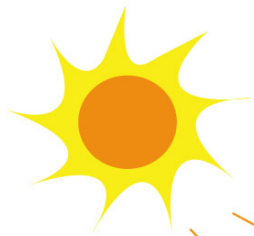


Technical Guidelines on

Grid Connection of Small-scale Renewable Energy Power Systems

2005 EDITION

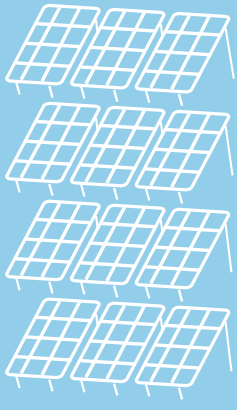


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Foreword

This set of 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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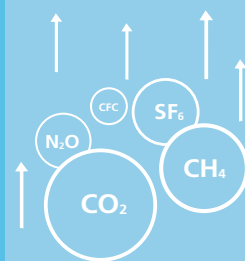


1.0 Glossary of Terms and Abbreviations

- 1.1 Aggregated Power Rating - The arithmetic sum of the power rating of each power generating equipment of all the Small-scale Renewable Energy Power Systems (SREPSs) 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 SREPS.
- 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 Small-scale Renewable Energy Power System (SREPS) – 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 SREPS 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 the CLP Power Hong Kong Limited and the Hongkong Electric Company Limited.

2.0

Introduction



2.1 Like all other developed economies, Hong Kong requires reliable and secure supplies of energy to support its social and economic development, 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 commissioned 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 Small-scale Renewable Energy Power System (SREPS) such as building integrated wind power systems and other non-building-integrated SREPSs which can be used for meeting part of the load demand on the same site.

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

2.8 This document 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 SREPS proposals. It also provides the list of information in general to be submitted to the Utility to support applications for connecting SREPSs to the Grid.

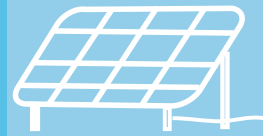
2.9 The Owner should ensure that the SREPS complies with all prevailing statutory requirements and best practices on safety, reliability and power quality of electrical installations, such as the Electricity

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 SREPS 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 SREPS is a sophisticated electrical installation and 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 SREPS to the Grid



3.1 RE sources are mostly intermittent in nature. To ensure a reliable electricity supply to the designated loads of a SREPS, it is necessary to provide either a battery system to store electricity generated from the SREPS or a backup power to the SREPS 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 SREPS to the Grid is very common in some overseas countries. The Grid serves to complement and backup the electrical load demand supplied by a SREPS. The common practice is to connect the SREPS to the Grid at a certain point of the Distribution System at the location where the SREPS was installed.

3.3 After connected to the Grid, the SREPS 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 SREPS can operate in a safe and reliable manner.



4.0 Scope

4.1 This set of guidelines is applicable to grid-connected SREPSs of Aggregated Power Rating up to 200 kW. This rating limit is determined based on local SREPS installations which were designed in accordance with established international / national standards and also in compliance with the Utility's technical requirements on fault level, power quality and capacity of distribution transformers. These grid-connected SREPS installations have been operating satisfactorily and this set of guidelines draws experience from these installations to provide technical reference for future similar installations.

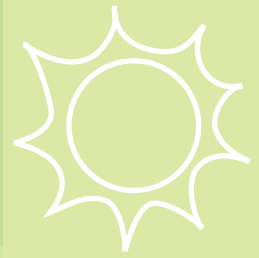
4.2 This set of guidelines covers only the technical requirements for connection of SREPS to the Grid. However, the addition of a grid-

connected SREPS 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 SREPS at any moment even when the SREPS is out of service. The Owner may therefore be required to bear extra costs in addition to the installation cost of the SREPS. 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 SREPS to the Grid.

4.3 For grid-connected RE installation proposals with power rating exceeding the limit of 200 kW, enquiry on the technical requirements can be addressed to the EEO of EMSD.

5.0

Safety Considerations



5.1 If a SREPS is connected to the Grid through the Distribution System, it is possible that the SREPS 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:

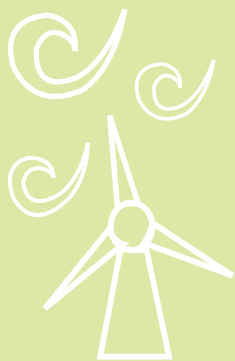
(a) Incorporate an "anti-islanding" function in the design of the SREPSs. This function can automatically disconnect any grid-connected SREPS from the Distribution System in the event that the Grid is de-energized for whatever reasons. The purpose of an "anti-islanding" function is to ensure that SREPS 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.

(b) Install a lockable switch at a readily accessible position to allow authorized electrical workers to manually isolate the SREPS 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 SREPS 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 Provide protection to equipment is important as damage to equipment may lead to other safety issues. This section describes the provisions recommended for the protection of the SREPS, 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 SREPS 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 SREPS 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 SREPS 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 SREPS, unsynchronized connection which would damage equipment of both parties, may occur.

- (d) Incorporate facilities to isolate the SREPS from the Distribution System automatically when fault occurs in the SREPS.
- (e) Use 4-pole type circuit breakers or isolators on all isolation points of the SREPS to allow complete isolation from the Distribution System when the SREPS is not in service. This arrangement is to ensure that the Distribution System would remain intact and not be affected by the SREPS.
- (f) Incorporate appropriate protection facilities in the design of the SREPS to avoid damages to the SREPS 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 SREPS can handle the normal voltage and frequency fluctuations in the Distribution System.
- (h) Incorporate facilities in the SREPS which can automatically disconnect the SREPS 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 SREPS which can automatically re-connect the SREPS 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 repeatedly 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 SREPS. Any fault developed in the SREPS 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 SREPS:

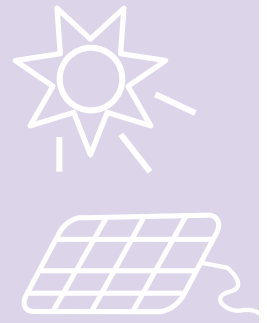
- (a) Select an inverter, with high reliability, such as having a high "mean-time-to-failure" index. This is essential since the inverter is the principle component in the SREPS that directly connects the SREPS to the Distribution System.
- (b) Set the operating levels of all the protective devices in 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 SREPS to match the

voltage and frequency of the Distribution System. This would reduce electrical stress on the SREPS and help to minimize failures.

- (d) Provide an automatic disconnection function in the SREPS 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 SREPS 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 SREPS:

- (a) Install an inverter with power conditioning function to control the harmonic currents and the output power factor of the SREPS within an acceptable range such that the SREPS 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 SREPS 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 SREPS 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 SREPS 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 SREPS.

(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 SREPS is energized, it is important that the Owner has carried out a thorough inspection and functional / safety tests to ensure that the SREPS has been properly designed and commissioned in accordance with the technical requirements of this set of guidelines and other case-specific technical requirements. The Utility may specify and witness certain tests of the grid-connected SREPS, 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 SREPS including power factor, direct current level and total harmonic distortion.



11.0

Post-installation Obligations of the Owners

11.1 After the SREPS is put into normal operation, the Owner should provide the Utility with information on the electrical energy output of the SREPS 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 SREPS.

11.2 Periodic inspection of the SREPS 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 SREPS. 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 SREPS 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 SREPS. In addition, the Utility will also need to be informed when the SREPS 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 SREPS is finalized. Supporting information, such as relevant literature describing the SREPS, 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 SREPS. 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 SREPS and the tests to be witnessed by the Utility.



13.0

Local and Overseas Standards and Best Practices

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 SREPS.

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. Hongkong Electric Company Limited

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



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

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

A. Initial information to be submitted should include:

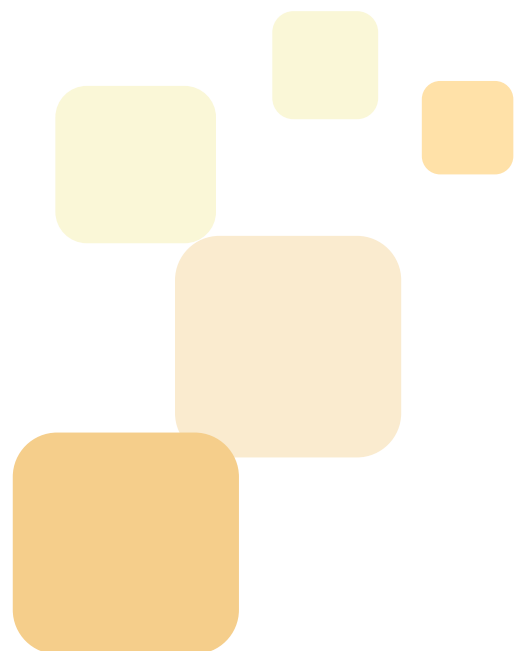
- 1 Information of Applicant
 - (a) Name
 - (b) Postal address
 - (c) Utility account number / meter number (for existing customer)
 - (d) Contact telephone number
 - (e) Facsimile number
 - (f) Email address
- 2 Information of the Proposed SREPS Installation
 - (a) Address of installation
 - (b) Expected installation commencement date
 - (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
- 3 Brief Description of the Mode of Operations and Control of the SREPS.
 - (h) Technical specifications of power generation equipment
 - i) total rating
 - ii) single-phase or three-phase electricity output
 - iii) frequency of electricity output
 - (i) Expected annual generation (kWh)
 - (j) Any other known SREPS installation on site

B. Additional information to be provided may include:

1. Detailed System Description

- (a) Scheme for electrical and mechanical interlocks between the SREPS 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 SREPS to Grid
 - ii) means of detection and conditions for disconnection from Grid
 - iii) time delay for re-connection of SREPS to Grid
 - iv) details of checking synchronization
 - v) arrangement for local/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 SREPS 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 electro-magnetic compatibility of the SREPS
- 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

Standard	Title
	Code of Practice for Electricity (Wiring) Regulations, EMSD.
	Supply Rules of the Hongkong Electric Co., Ltd.
	Supply Rules of the CLP Power Hong Kong Ltd.
IEC 61727 – 1995	Photovoltaic System - Characteristics of the Utility Interface
IEC 61724 – 1998	Photovoltaic System Performance Monitoring – Guidelines for Measurement, Data Exchange and Analysis
IEC 61173 – 1992	Overvoltage Protection for Photovoltaic Power Generation Systems – Guide
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 61400-2 – 1996	Wind Turbine Generator Systems - Part 2: Safety of Small Wind Turbines
IEC 61400-21 – 2001	Wind Turbine Generator Systems - Part 21: Measurement and Assessment of Power Quality Characteristics of Grid Connected Wind Turbines
IEEE Std 519 – 1992	Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
IEEE Std 928	Recommended Criteria for Terrestrial PV Power Systems
IEEE Std 1374 – 1998	Guide for Terrestrial Photovoltaic Power System Safety
IEEE Std P1547 – 2003	Distributed Resources Interconnected with Electric Power Systems

Standard	Title
IEEE P1547.1	Draft Standard For Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
IEEE P1547.2	Draft Application Guide for IEEE Std 1547-2003, IEEE 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
UL Std 1741	Static Inverters and Charge Controllers for use in PV Power Systems
UL Std 1703	Flat-Plate Photovoltaic Modules and Panels
NFPA 70 Article 690 (NEC)	Solar Photovoltaic Systems
NFPA 70 Article 692	Fuel Cell Systems
NFPA 70 Article 705 (NEC)	Interconnected Electric Power Production Sources
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 G74 – 1992	Procedure to Meet the Requirements on IEC 909 for the Calculation of Short-circuit Currents in Three-phase AC Power 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
IEC 61000-3-4 (1998). Part 3: Limits – Section 4	Limitation of Emission of Harmonic Currents in Low Voltage Power Supply Systems for Equipment with Rated Current Greater than 16 A
IEC 1000-3-5 (1994). Technical Report. Electromagnetic compatibility – Part 3: Limits- Section 5	Limitation of Voltage Fluctuations and Flicker in Low-voltage Power Supply Systems for Equipment with Rated Current Greater than 16 A
IEC1000-4-7 (1991). Electromagnetic compatibility – Part 4: Testing and measuring techniques – Section 7	General Guide on Harmonics and Interharmonics Measurements and Instrumentation, for Power Supply Systems and Equipment Connected thereto