
# MANUAL FOR INTERCONNECTION

Report for supporting the interconnection of rooftop-PV systems in the Philippines

www.exportinitiative.bmwi.de

M.P.E.
MOELLER & POELLER ENGINEERING

Supported by:
Federal Ministry of Economics and Technology

on the basis of a decision by the German Bundestag

# Imprint

**Author**

Moeller & Poeller Engineering
(M.P.E.) GmbH
Europaplatz 5
72072 Tübingen, Germany

Email.: info@moellerpoeller.de

Web: www.moellerpoeller.de

**Version: 12 August 2013**

**Publisher**
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
On behalf of the
German Federal Ministry of Economics and Technology (BMWi)

**Contact**
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Köthener Str. 2, 10963 Berlin, Germany
Fax: +49 (0)30 408 190 22 253
Email: pep-southeastasia@giz.de
Web: www.giz.de/projektentwicklungsprogramm
Web: www.renewables-made-in-germany.com

This report is part of the Project Development Programme (PDP) South-East Asia. PDP South-East Asia is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry of Economics and Technology (BMWi) under the "renewables – Made in Germany" initiative. More information about PDP and about renewable energy markets in South-East Asia can be found on the website www.giz.de/projektentwicklungsprogramm.

# Table of Contents

# List of Tables



# List of Figures



# Currency

1 USD = 43.73 PHP (August 2013)
1 EUR = 58.13 PHP (August 2013)

# Measurement

| | | | | | |
|---|---|---|---|---|---|
| W | Watt | Wp | Watt peak | Wh | Watt hour |
| kW | Kilowatt | kWp | Kilowatt peak | kWh | Kilowatt hour |
| MW | Megawatt | MWp | Megawatt peak | MWh | Megawatt hour |
| GW | Gigawatt | GWp | Gigawatt peak | GWh | Gigawatt hour |

# 1 Introduction

High end-user tariffs and the support of a net-metering concept will soon initiate a relevant market for rooftop-PV systems in the Philippines.

The purpose of this *Manual for Interconnection* is to provide relevant information about distribution grids in the Philippines for enabling or simplifying the interconnection of rooftop PV-systems in the Philippines.

Following a brief survey about distribution grids and distribution network operators, this manual will provide an overview about typical medium-voltage (MV) and low-voltage (LV) network technologies of the Philippines including aspects relating to system grounding.

Other sections of this manual give an introduction to the Net Metering Rules [1] and the corresponding Interconnection Standards [2] followed by a brief section relating to the impact that the Net Metering Concept may have on the optimum sizing of rooftop PV-systems.

# 2 Distribution Companies in the Philippines

**Table 1: Distribution Companies in the Philippines**

| Company Name | Franchise area (Cities/Municipalities) | Residential customers | Industrial customers | Area in $km^2$ |
|---|---|---|---|---|
| **Angeles Electric Corp (AEC)** | Angeles City | 81,601 | 678 | 62.17 |
| **Clark Electric Distribution Co. (CEDC)** | Clark Special Economic Zone | 596 | 108 | 320 |
| **Subic Enerzone** | Subic Bay Freeport Zone | 1,697 | 93 | 674.52 |
| **Davao Light & Power Co. (DLPC)** | Davao City, Panabo City/Carmen, Sto. Tomas & Dujali | | | |
| **Iligan Light & Power Inc (ILPI)** | Iligan City | 42,117 | 25 | 775 |
| **Dagupan Electric Corp (DECORP)** | Dagupan City/Calasiao, Sta. Barbara, San Fabian, San Jacinto & Manaoag | 70,000 | | 349.79 |
| **San Fernando Electric Light & Power Co. (SFELAPCO)** | City of San Fernando/Floridablanca | 85,000 | 11,500 | 203 |
| **Cabanatuan Electric Corp (CELCOR)** | Cabanatuan City | 53,399 | 42 | 192.78 |
| **Cagayan Power & Light Co. (CEPALCO)** | Cagayan de Oro City/Tagoloan, Jassan & Villanueva | 100,740 | 245 | 720 |
| **MERALCO** | Metro Manila, the provicens of Rizal, Cavite and Bulacan, and parts of the provinces of Pampanga, Batangas, Laguna and Quezon | 4,662,429 | 9,662 | 9,337 |
| **Cotobato Light & Power Co. (CLPC)** | Cotobato City | | | |
| **Mactan Electric Co. (MECO)** | Mactan City | 68,000 | 500 | 84 |
| **Tarlac Electric Inc (TEI)** | Tarlac City | 60,571 | 21,799 | 395 |
| **Visayan Electric Co (VECO)** | Cebu, Mandaue & Talisay/Consolacion, Lilioan, Mnglanilla, Naga & San Fernando | 293,323 | 1,393 | 672 |

There are various distribution network companies in the Philippines operating distribution grids of various sizes and various areas.

Meralco is by far the largest distribution network operator in the Philippines having more the 4.5 million clients and operating the distribution grid of Metro Manila and of some provinces.

The distribution companies listed in

Table 1 all operate distribution grids that are connected to the main transmission grid of the Philippines. Besides this, there are various grid operators, so-called Electric Cooperatives, operating island networks (networks not connected to the main transmission grid) of various size ranging from a few kW to several MW.

The overview according to

Table 1 and Annex A is a result of a survey amongst most distribution network operators that has been carried out during a workshop in Manila in November 2012.

The results of this survey can be summarized as follows:

- Electricity prices to residential customers range between 5.6 PHP/kWh and 9.5 PHP/kW, which is equivalent to around 0.1 Euro/kWh and 0.18 Euro/kWh (average 2011).
- Electricity prices to industrial customers range between 6.2 PHP/kWh and 10.5 PHP/kWh (0.12 Euro/kWh and 0.2 Euro/kWh, June 2012).

- Average generation costs range between 2.6 PHP/kWh and 6.5 PHP/kWh (0.05 Euro/kWh and 0.12 Euro/kWh), whereas the average generation cost in 2011 (average over all utilities) was at 4.8PHP/kWh (0.09 Euro/kWh).
- Only the representatives of Dagupan Electric Corp., Cepalco, Cotubato Light and Power and Veco stated that they had some experience with renewable generation.
- According to the survey, there is only embedded generation in the grid of Cepalco (1 MW).
- Only two distribution network operators indicated that they had an interconnection policy in place: Cepalco, adopting the Philippine distribution code and Meralco ("Technical Guidelines of the Interconnection of distributed generation to the Meralco system") applying to generators >100kW connected to Meralco's subtransmission grids (115 kV and 69 kV) and distribution networks (34.5 kV and 13.8 kV).

The result of this survey shows that, despite of the high end-user tariffs, embedded generation in MV and LV networks in the Philippines is still very much at the beginning of its development and that there is still a lot of work to do for implementing codes and procedures for supporting the development of embedded renewable generation in the Philippines.

# 3 Low-voltage and Medium-voltage Networks in the Philippines

Low-voltage (LV) and medium-voltage (MV) network technologies in the Philippines are widely in line with US-American standards. This includes the network frequency, which is 60 Hz and voltage levels at MV and LV levels.

All aspects with regard to electrical installations, safety and design are described in the Philippine Electrical Code (PEC) [11], which has to be considered for all electrical installations.

## 3.1 MV-Networks

**Table 2: Typical MV levels in the Philippines**

| Voltage Level | Number of Phases | Number of Wires | Comment |
|---|---|---|---|
| 34,5kV | 3 | 4 | In Meralco and Cepalco areas |
| 34,5kV | 2 | 3 | In Meralco also named "3-phase" |
| 23kV | 3 | 4 | Veco, Beneco |
| 20kV | 1 | 2 | Cepalco area only (LN of 34,5kV LL) |
| 13,8kV | 3 | 4 | Most common MV level |
| 13,2kV | 3 | 4 | Standard in Electric Cooperatives |
| 7,96kV | 1 | 2 | Cepalco area only (LN of 13,8kV LL) |
| 7,62kV | 1 | 2 | Electric Cooperatives (LN of 13,2kV LL) |
| 4,16kV | 3 | 4 | Olongapo City only |

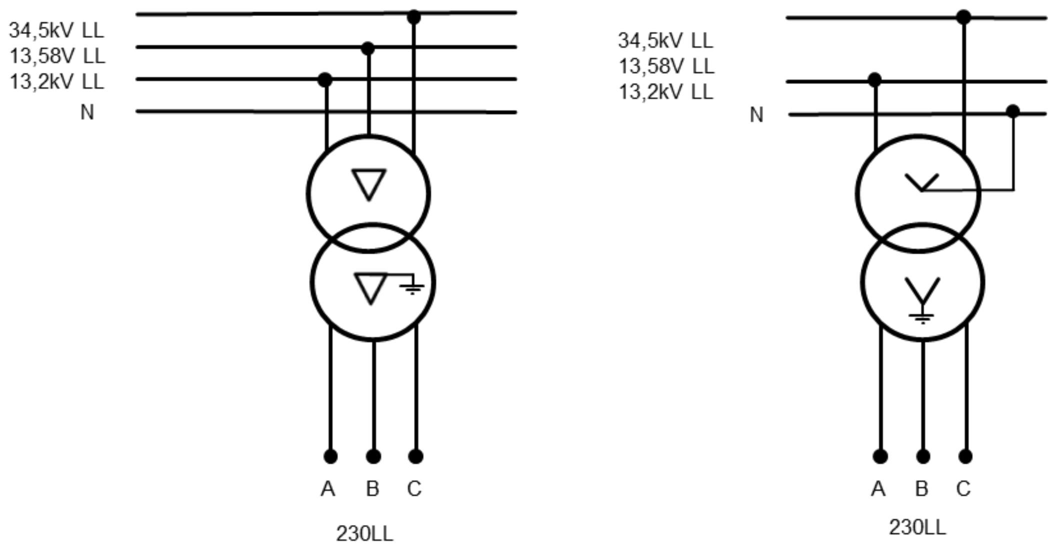



*Figure 1: 3-phase-4 wire and 2-phase-3-wire (“three-phase”) systems*

Public MV-feeders in the Philippines typically operate at 34.5 kV or 13.8 kV. MV-feeders are predominantly three-phase, four wire. The neutral conductor is connected to the star point of the transformer in the substation and solidly earthed.

In some areas, also two-phase – three wire systems can be found (see Figure 1), with distribution transformers being connected in an open delta connection to the HV-side and hence allowing a three-phase network at the LV-side. Therefore, these systems are also called “three-phase”-systems.

Electric Cooperatives use 13.2 kV 3-phase, 4-wire as standard distribution technology

Single phase, neutral return systems can be found at voltage levels of 20 kV (on LN-voltage of 34.5 V) and 7.96 kV (LN-voltage of 13.8 kV), especially in the area of Cepalco.

Most distribution networks in the Philippines are built by overhead lines. For clearing transient faults, automatic reclosing schemes apply, which can lead to short-term interruptions of the underlying LV networks.

## 3.2 LV-Networks

**Table 3: Typical LV levels in the Philippines**

| Voltage Level | Number of Phases | Application |
|---|---|---|
| 600 | 3 | industrial/commercial |
| 600Yn/347 | 3 | industrial/commercial |
| 460 | 3 | industrial/commercial |
| 460Yn/265 | 3 | industrial/commercial |
| 400Yn/230 | 3 | public (underground cables) |
| 347 | 1 | industrial/commercial |
| 230 | 1/2 | public |
| 115/230 | 1/2 | public |
| 115 | 1 | public |

The voltage levels listed in Table 3 represent standard voltage levels of the Philippines according to section 2.20.1.5 of the PEC [11].

### 3.2.1 Public LV-Networks

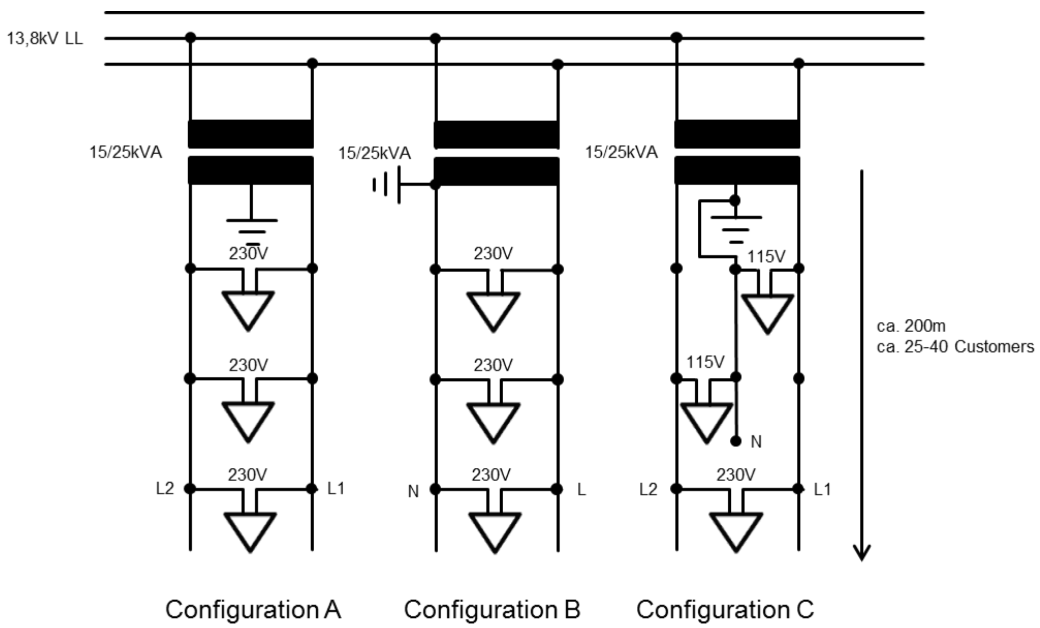



*Figure 2: Typical technologies and voltage levels for public LV-feeders in the Philippines*

Most LV networks of Meralco and PEPOA-DUs are according to Configuration A of Figure 2. This type of system corresponds to an American “split-phase” network, but with the exception that the neutral conductor does not extend to the load. Therefore, both conductors of a Configuration A – LV network represent a phase conductor, which is quite unique.

Electric Cooperatives predominantly use Configuration B. Here, one of the two conductors is earthed at the transformer side. As in case of Configuration A, the load voltage is equal to 230V but with one conductor being a phase conductor and the other conductor being a neutral conductor. This system corresponds to European standards.

Configuration C finally represents a classical 3-wire split phase connection, where both voltage levels, 230V and 115V, are available. As shown for Configuration C in Figure 2, it is possible that the neutral conductor of a LV feeder does not extend to the end of the feeder so that the end point may finally correspond to Configuration A.

According to the Distribution Utility Survey [8], the following observations can be made:

- The large majority of LV-feeders of Meralco and PEPOA are according to Configuration A of Figure 2.
- In Electric Cooperatives, Configuration B represents the standard configuration for LV-feeders.
- Typical sizes of MV-LV-transformers are 25 kVA or 15 kVA supplying between 25 and 40 customers.
- Typical length of public LV-feeders is around 200m.

### 3.2.2 Commercial and Industrial LV-networks/LV-loads

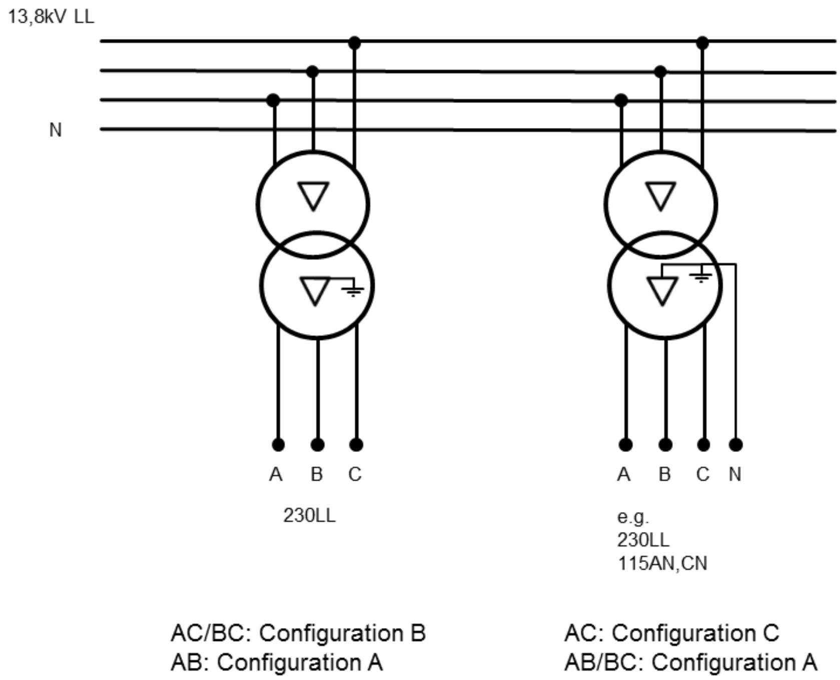



*Figure 3: Typical technologies and voltage levels for supplying commercial/industrial LV-loads in the Philippines*

For supplying commercial or industrial loads, the three phase transformers configurations according to Figure 3 are common.

Depending on the phase, the configuration at the LV-side is equivalent to Configuration A or Configuration B according to Figure 2.

It has to be highlighted, that usually only LL-voltages (230 V) shall be used, even if the right transformer in Figure 3 would also allow for a 115V LN-connection.

### 3.2.3 Grounding

*Rules*

Grounding rules that apply to electrical systems in the Philippines are described in Article 2.50 (Grounding and Bonding) of the PEC [11].

According to 2.50.1.4 a) of the PEC, every non-current carrying metal part of an LV-installation must be connected together and grounded in a manner that:

(1) limits the voltage to earth of such equipment

(2) establishes an effective ground-fault current path

Article 2.50.1.4 defines general safety rules for grounded systems allowing for various options with regard to the use of neutral and earth conductors.

*Common Practice*

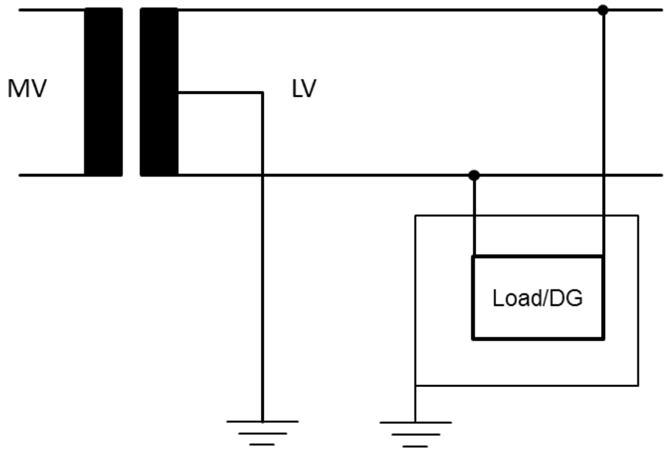



*Figure 4: Common grounding scheme of LV-feeders in the Philippines*

According to studies carried out by SMA Solar Technology AG the most common LV network technology is Configuration A of Figure 2. In these systems, appliances are with ground wire taken out usually near the 2-prong plug and then connected to ground, such as a water pipe or any means of grounding. Therefore the grounding system of Configuration A can be considered as TT but without neutral conductor (see Figure 4).

Due to the fact that water pipes lay underground but not as deep as a conventional grounding electrode, an isolation fault may not go to ground using the grounding wire as another way can have a lower resistance.

# 4 Net Metering Rules and Interconnection Standards

The general rules for enabling the interconnection of embedded renewable energy source (RE-sources) are described in the so-called Net Metering Rules (RULES ENABLING THE NET-METERING PROGRAM FOR RENEWABLE ENERGY [1]).

These rules cover:

- Purpose
- Applicability
- Qualification and Eligibility
- Inter-Connection Standards
- Commercial Arrangements

## 4.1 Purpose and Applicability (Article I)

The purpose of the net metering rules, as described in [1] is to

- Encourage end-users to participate in renewable energy generation.
- Enable data-gathering for the creation of a knowledge base and hence for improving and optimizing the net metering program.
- Allow local players to gain experience and the confidence in installing embedded RE-systems for net-metering applications under local conditions.

For the time being the net-metering rules only apply to grid connected RE technologies. The ERC can, in consultation with NREB and the electric power industry extend the applicability of these rules to off-grid installations.

## 4.2 Qualification and Eligibility (Article II)

Basically all end-users that intend to install a renewable, distributed energy source and connect it to the grid qualify for the net-metering program.

The net-metering program is explicitly limited to renewable energy sources that are installed within the premises of a qualified end-user. Hence, it does not apply to, e.g.:

- Non-renewable energy sources, such as mini-CHP etc.
- Renewable energy power plants like wind farms or PV-farms that are not installed within the premises of a qualified end-user.

## 4.3 Interconnection Standards (Article III)

This article of the net-metering rules makes provision to the technical rules and standards that need to be considered when installing a RE-generator that participates in the net-metering program.

### 4.3.1 Compliance Standards

Distributed RE-installations must comply with the following standards:

- Philippine Electrical Code (PEC) [1], which applies to all electrical installations in the Philippines and defines general installation and safety standards.
- Distribution Service Open Access Rules (DSOAR)

- Net-metering inter-connection standards, which are listed in Annex A of the net-metering rules (see [2]).

The Net-metering inter-connection standards [2] further refer to the Philippine Distribution Code (PDC, [12]), which requires particular consideration with regard to power quality aspects.

### 4.3.2 Summary of the Net-Metering Interconnection Standards

The Net-Metering Interconnection Standards [2] apply to all distributed generators

- that comply with the eligibility criteria of the Net Metering Rules (see section 4.2) and
- that are limited to 100 kW.

It is further stated in section 4.3 of the Net-Metering Interconnection Standards that only installations having an installed capacity of less than 100kW will get permission from the distribution utility (DU).

Hence, the limitation to 100kW effectively defines another eligibility criterion.

The Net-Metering Interconnection Standards [2] are subdivided into the following sections:

- Overview, Scope and Purposes, Definitions
- General Guidelines
- Application for Interconnection
- System Parameters
- System Protection
- Metering
- Testing and Commissioning
- Bibliography, Appendix

A brief summary of the Net-Metering Interconnection Standards together with some comments and reference to international practice is given in the following sections.

A detailed summary and comments related to each article of the Interconnection Standards can be found in section 5 of this document.

## 4.4 Commercial Arrangements (Article IV)

Article IV of the Net Metering Rules contains closes related to the pricing and cost recovery aspects. These clauses include:

- Aspects relating to the net metering agreement between DU and QE.
- Pricing methodology
- Cost recovery of net metering agreements
- Incremental supply and metering charge
- Billing Charges
- RE Certificate

Until another set of special rules for the remuneration of net exported electricity has been established, the net electrical energy (generation minus own consumption) is remunerated at the rate of the blended cost of power generation in each DU area. In the case of Meralco, this current rate is currently at about 6 PHP.

Cost of RE supply under net-metering agreements shall be included into the DU's total generation cost to be recovered from all DU customers.

# 5 Net Metering Interconnection Standards

## 5.1 General Guidelines (section 4 of [2])

The General Guidelines mainly define areas of responsibility of the Qualified End Unser (QE) and the Distribution Utility (DU). In brief, the main areas of responsibility are:

- The QE is responsible for design, installation, operation and maintenance of all installations on its property (unless otherwise agreed in the connection agreement) under consideration of the DU's standards. The QE's installation must conform to the PEC [11], PDC [12], DSOAR, other local codes and the Terms and Conditions of Service and Standard Rules and Regulation as approved by ERC.
- The DU shall conduct inspections, witness calibration and testing of the QE's lines, wires and switches and is entitled to remove the QE's generation from the system at any time for maintenance, test, repair, under emergency conditions or in case of safety concerns.

It is not explicitly stated but it can be concluded that the design, installation, operation and maintenance of all installations outside the property of the QE is within the responsibility of the DU.

Besides these areas of responsibility, the General Guidelines define that:

- The requirements of the Interconnection Rules have to be met at the connection point.
- The DU shall allow RE installations up to 100kW.

It is unclear at this stage what rules apply to RE installations with an installed capacity greater than 100 kW.

## 5.2 Application for Interconnection (section 5 of [2])

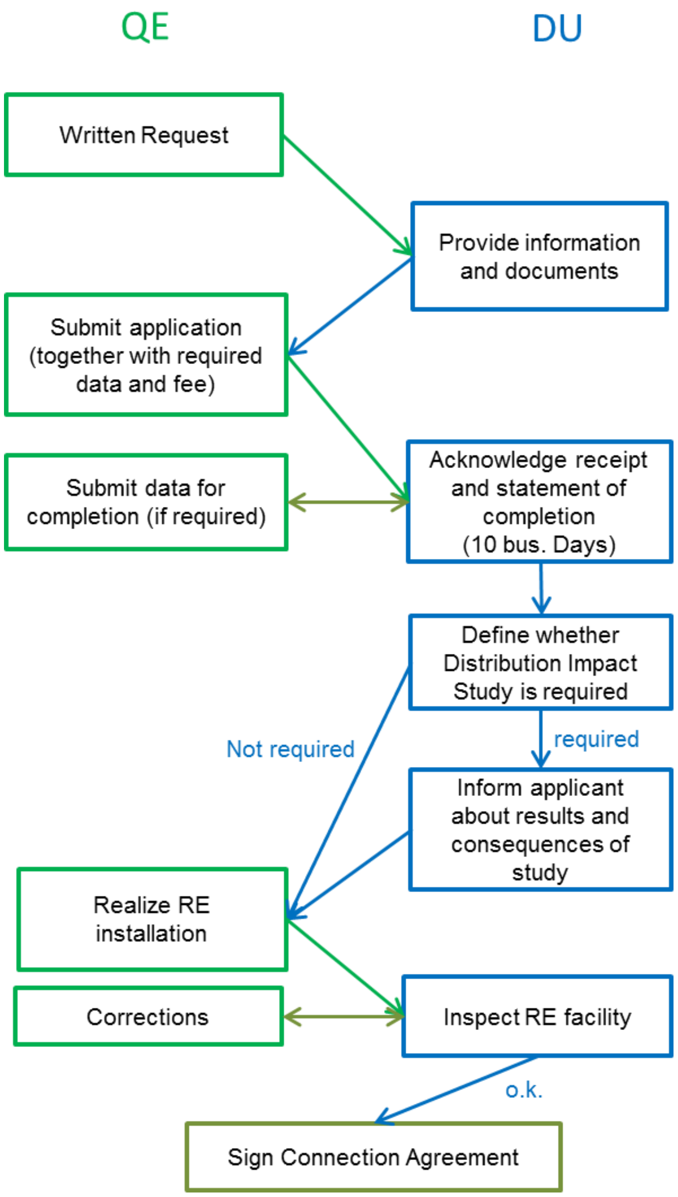



*Figure 5: Workflow of Application Process*

The application process for a RE-installation according to section 5 of the Net Metering Interconnection Standards [2] is illustrated in Figure 5.

The process clearly defines the relevant areas of responsibility and the sequence of actions. It further provides details about the documentation to be exchanged and makes reference to other relevant standards and codes, which are not further described in more detail here.

### 5.2.1 Comments

Generally the application process is clearly described but there are a few aspects that should be considered:

- **Response time for distribution impact study:**
  The process for a RE application defines a response time for the DU for verifying the completeness of an application. However, for the execution of a potentially required distribution impact study, guidelines about maximum acceptable response times are missing. In the case that these impact studies will be required on a regular basis for many applications, this step in the process will represent a serious bottleneck and has the potential to slow down the installation of distributed RE generation in the Philippines considerably.
  However, it is possible that the DUs of the Philippines will define more detailed processes for the interconnection of RE generation according to the Net Metering Rules and define corresponding response times as part of their internal processes.

- **Approval of compliance with interconnection rules:**
  The process doesn't foresee any formal approval of the conceptual design by the DU. Before the DU will carry out any compliance verification, the QE will have to build the RE-facility. Because no compliance statement is foreseen during the planning phase of a RE project, there is a high risk to the QE that changes/upgrades will be required after the installation has been completed, which can be very costly.
  In other countries (e.g. Germany), the application process foresees a compliance verification based on the conceptual design of a RE installation. Such compliance verification can either be within the responsibility of the DU or this responsibility can be "outsourced" to an independent, accredited certification body who, at the same time, takes full liability for this decision.
  In case of LV installations, it is common practice to submit certificates of conformity for the individual components of a RE facility to the DU for approval.
  Of course, an on-site inspection for verifying the conformity of the RE installation with the planning documents is always required prior to connection and energization. However, such an inspection cannot lead to a rejection as long as everything has been installed according to the relevant planning documents.
  For every QE who intends to realize a distributed RE facility in the Philippines, it is highly recommended to seek at least informal approval from the DU based on planning documents for avoiding costly modifications/upgrades of the RE facility after it has been installed or ask for manufacture declarations of conformance with the inter-connection rules of the Philippines (e.g. for PV inverter).

## 5.3 System Parameters (section 6 of [2])

Section 6 of the Inter-Connection Standards lists a number of main technical performance requirements, especially with regard to:

- Voltage range of operation
- Frequency range of operation
- Harmonics and Flicker
- Power factor

### 5.3.1 Voltage Range of Operation

**Table 4: Minimum Time Requirements for RE to Remain Connected at Different Voltage Ranges (Table 1 of [[2]])**

| Voltage in % of Base Voltage | Time in s |
|---|---|
| V<30 | 0,15 |
| V=30 | 0,60 |
| 30<=V<90 | Linear Interpolation between 0,6 and 3,0 seconds |
| 90<=V<=110 | Normal Operating Range |
| 110<V<120 | 1,00 |
| V>=120 | 0,16 |

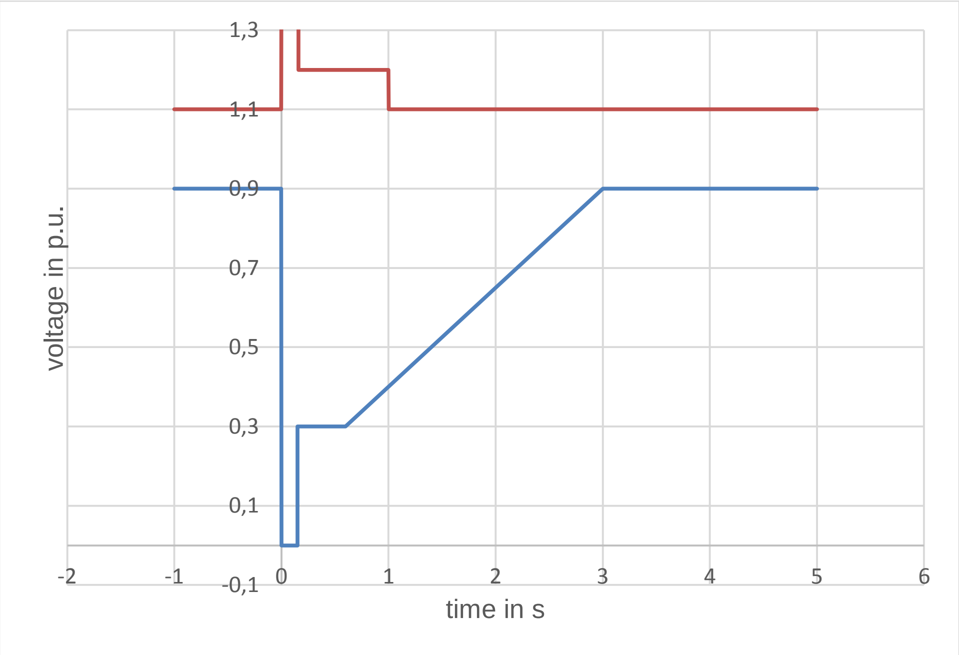



*Figure 6: LVRT and HVRT requirement*

The normal voltage range of operation is defined to be within 90% < V < 110% of nominal voltage. In the case that voltage gets out of the normal range, the RE facility must remain connected as long as voltage stays within the limits according to Table 4, which correspond to the LVRT and HVRT requirement according to Figure 6.

### 5.3.2 Frequency Range of Operation

**Table 5: Minimum Time Requirements for RE to Remain Connected at Different Frequency Ranges (Table 2 of [[2])**

| Frequency Range in Hz | Time |
|---|---|
| >62,4 | automatic disconnection allowed if so decided by VRE operator |
| 61,8<F<62,4 | 5 minutes |
| 58,2<F<61,8 | Continuous Operation |
| 57,6<F<58,2 | 60 minutes |
| F<57,6 | 5s |

The frequency range of continuous operation is within 58,2<F<61,83 Hz. For frequencies outside the normal frequency range of operation, the RE facility must automatically disconnect according to the frequency-time settings of Table 5.

### 5.3.3 Power Quality

With regard to power quality, the Interconnection Standards make reference to the Philippine Distribution Code [12].

The relevant power quality requirements are:

- Max. DC-current: 0,5% of rated full load current at the Connection Point
- Short-term flicker severity: Pst=1, Long-term flicker severity: Plt=0,8 (as specified in section 3.2.6 of the PDC [12].
- Harmonic current limits: Max. THD of 5% (as defined in section 3.2.4 of the PDC [12]).
- Harmonic voltage limits: Max. THD of 5% (as defined in section 3.2.4 of the PDC [12]).

As per the PDC, flicker limits at the Connection Point represent total Flicker Limits resulting from all varying loads and generators in the network, not only caused by the RE-installation to be connected.

The same applies to harmonic voltage limits.

### 5.3.4 Power Factor

It is required that the power factor stays above 0.85 lagging.

### 5.3.5 Comments

*Voltage and Frequency Range of Operation*

**Table 6: Response to abnormal voltage conditions – international standards (see also [7])**

| Country | Standard | Voltage monitoring – xx% of V nom | | |
|---|---|---|---|---|
| | | Lower limit | upper limit | trip time |
| international | IEC 61727 | 50% | 135% | 0.1 s / 0.05 s |
| | | 85% | 110% | 2 s |
| Europe | EN 50438 | 85% | 115% | 1.5 s / 0.5 s |
| Germany | VDE AR-N-4105 | 80% | 110% | 0.1 s |
| Spain | RD 1663 | 85% | 110% | 0.5 s |
| Italy | DK 5940 | 80% | 120% | 0.2 s / 0.1 s |
| Philippines | Net Metering | 0% | >120% | 0,16 s |
| | | LVRT | 120% | 2 s / 1 s |
| USA | IEEE 1547 | 50% | 120% | 0.16 s |
| | | 88% | 110% | 2 s / 1 s |
| South Korea | PV 501 | 50% | 120% | 0.16 s |
| | | 88% | 110% | 2 s |

**Table 7: Required response to abnormal frequency conditions - international standards (see also [7])**

| Country | standard | Frequency monitoring – deviation from fnom | | |
|---|---|---|---|---|
| | | Lower limit | upper limit | trip time |
| International | IEC 61727 | - 1 Hz | + 1 Hz | 0.2 s |
| Europe | EN 50438 | - 3 Hz | + 1 Hz | 0.5 s |
| Germany | VDE AR-N-4105 | - 2.5 Hz | +1,5 Hz | 0,1 s |
| Spain | RD 1663/661 | - 2 Hz | + 1 Hz | 3 s / 0.2 s |
| Italy | DK 5940 | - 0.3 Hz | + 0.3 Hz | 0.1 s |
| Philippines | Net Metering | - 2,4 Hz | +2,4 Hz | 5 s/0s |
| | | - 1,8 Hz | + 1,8 Hz | 60min/5min |
| USA | IEEE 1547 | - 0.7 Hz | + 0.5 Hz | 0.16 s |
| South Korea | PV 501 | - 0.3 Hz | + 0.3 Hz | 2 s |
| Australia | AS 4777 | - 5 Hz | + 5 Hz | 2 s |

The required response to abnormal voltage conditions is not in-line with standard international practice (see 6).

In previous (draft-) versions of the interconnection rules, the corresponding table defined maximum times to disconnect, hence maximum times for under-/overvoltage protection relays to operate. However, in the final version of the interconnection rules, the corresponding tables have been transformed into requirements defining minimum times for remaining connected in the case of a voltage event.

With these now rules, the Net-Metering interconnection rules in the Philippines effectively require LVRT/HVRT capability, which is not in-line with international practice for LV-connected PV systems.

It is therefore recommended, prior to the installation of solar roof top systems , to clarify with the distribution utility, if they indeed require LVRT/HVRT for LV connected PV systems and which requirements apply for undervoltage protection settings, ie the voltage settings and time to disconnect.

The required response to abnormal frequency conditions is in –line with corresponding practice in other parts of the world.

## 5.4 System Protection

Section 7 of [2] defines protection and other safety aspects of a RE-installation. This includes:

- Synchronization
- Islanding
- Grounding
- Disconnect Device
- Protective Relays
- Reclosing

### 5.4.1 Synchronization

The statements relating to synchronization don't relate to inverter connected RE-sources (see also Table 6 of [2].

### 5.4.2 Islanding

The RE installation must be equipped with protection against unintentional islanding that detects islanding conditions and automatically disconnects the RE-installation from the DU's system.

Automatic reconnection is allowed if the DU's network is re-energized for several minutes.

### 5.4.3 System Grounding

System grounding must be in-line with the PEC [11] (see also section 3.2.3 of this document).

### 5.4.4 Disconnect Device

For safety reasons, the RE-installation must be equipped with a disconnect device for use by the DU as a means of electrically isolate the RE-facility from the DU's network and to establish working clearances for maintenance, safety and system considerations.

The disconnect device shall be physically located:

- within 10 feet from the Connection Point
- or, if this is not practical, between the RE-facility and the Connection Point

The type of disconnect device must

- Allow for visual indication of the contact's position
- The handle must be lockable in the open position with a padlock
- Readily accessible at all times by DU personnel

### 5.4.5 Protective Relays

For inverter-based RE-facilities (PV), table 6 of [2] applies

**Table 8: Interconnection Protective Function Requirements for Inverters according to Table 6 of [2]**

| Device # | Protective Equipment | Inverter Size ≤ 100 kW |
|---|---|---|
| 27 | Under voltage Relay | x |
| 59 | Overvoltage Relay | x |
| 81/O, 81/U | Over/Under Frequency Relay | x |

The actual protection arrangement for an inverter, including the disconnect switch is depicted in **Fehler! Verweisquelle konnte nicht gefunden werden.**, which corresponds to Appendix D of [2].

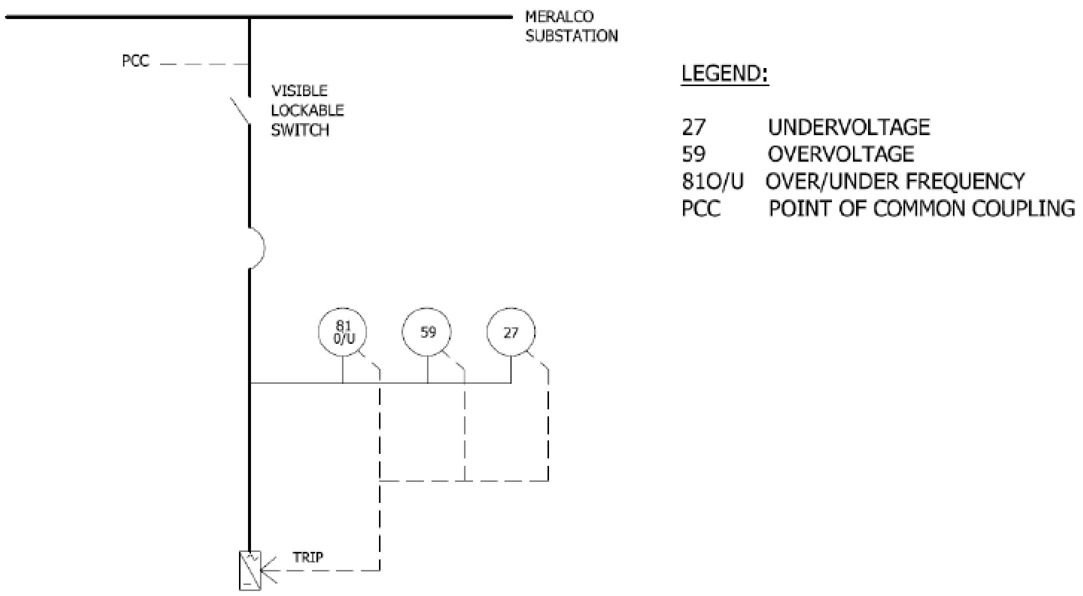



*Figure 7: Typical Single Line Diagram for the protection of Inverter (Appendix D of [2])*

### 5.4.6 Reclosing

This section of [2] defines that the response of a RE-facility to automatic reclosing actions in MV or LV-networks. The following is required:

- Immediate disconnection when the system is down
- Automatic resynchronization after the reclosing devices has reestablished the portion of the system to which the RE-facility is connected.

### 5.4.7 Comments

Protection and Disconnection requirements defined in in section 7 of [2] are in-line with international standards.

The requirement to disconnect “immediately” stated in the Reclosing-section for the case that the system is “down” is in slight contradiction with the required undervoltage protection settings according to **Fehler! Verweisquelle konnte nicht gefunden werden.**. With these settings, the system would disconnect with a delay of 0,16s. A requirement for an instantaneous trip because of undervoltage doesn’t exist in [2].

## 5.5 Operation and Maintenance

Section 8 contains some general rules about the QE’s obligations with regard to Operation and Maintenance of the RE-facility.

## 5.6 Metering

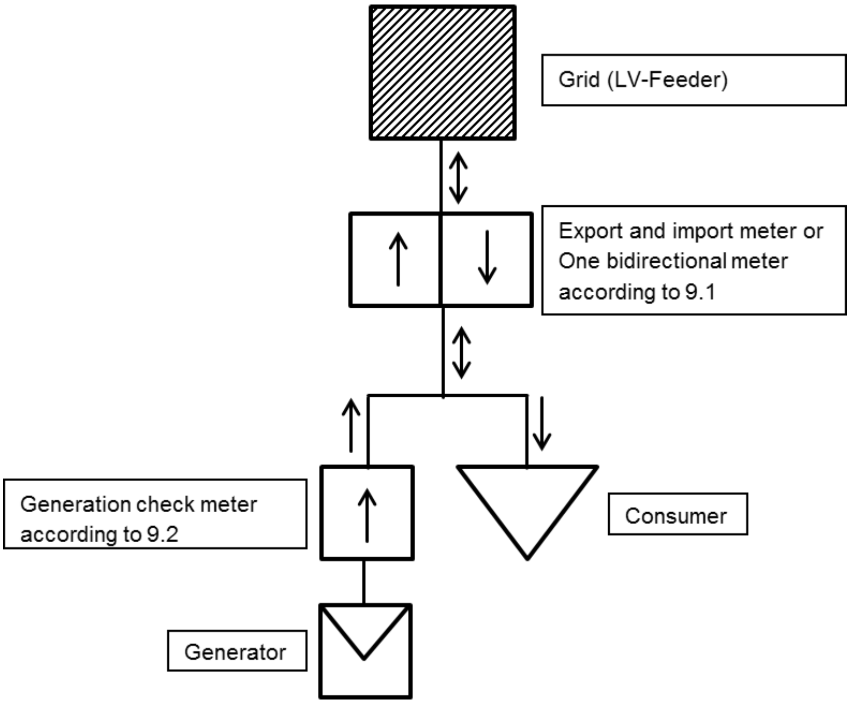



*Figure 8: Metering Arrangement*

The metering arrangements according to section 9 of [2] are depicted in **Fehler! Verweisquelle konnte nicht gefunden werden.**7. Essentially, it is required to install the following metering devices:

- Two uni-directional meters or one bi-directional meter at the connection point that can measure the hourly net-exchange with the system.
- A generation check meter may be installed for the purpose of recording the hourly RE production for purposes of issuance of RE Certificate, which the DU can use to comply with its RPS requirements.

The QE must provide the required space and associated civil works for the location of the metering devices. Meters are owned and operated by a Metering Service Provider (MSP).

## 5.7 Testing and Commissioning

After completion of installation and before energizing the system, the QE is responsible for carrying out the relevant commissioning tests. The DU has the right to witness these tests and to receive a copy of the test data. Commissioning tests of inverters include:

- Verification and inspections
- Production tests:
    - Response to abnormal voltage
    - Response to abnormal frequency
- Unintentional islanding test
- Cease-to-energize tests

The QE is responsible for installing the required test equipment at the RE facility.

Prior to final approval or at any time, the DU reserves the right to carry out protection tests.

# 6 Impact of Net Metering Rules on the Sizing of PV-Rooftop-Installations

## 6.1 Optimal Sizing of Solar Rooftop Installations

The optimal sizing of PV rooftop installations in the Philippines will have to consider the following constraints:

- Available rooftop space
- Daily and seasonal load variation

The value of electricity generated by a solar rooftop facility in the Philippines is equal to the end-consumer tariff (e.g. around 13P/kWh=0.25Euro/kWh in the case of Meralco), as long as the generated power is below the consumed power (net load >0).

During all times that generation exceeds load (net load <0, exporting, see dashed area in Figure 10), the value of electricity generated by a solar rooftop facility that exceeds the load drops to the blended generation costs (e.g. 6P=0.115Euro/kWh).

When evaluating the earnings resulting from a rooftop PV-installation, the electricity payment without PV installation has to be compared with the electricity payment with PV installation. Therefore, for each hour of the year, the energy consumption resulting from the load and from the residual load has to be calculated for each hour.

The resulting time series of kWh/h consumption has to be summed up for obtaining the total annual energy consumption. However, because export and import tariffs are different, two sums have to be calculated for the residual load:

- Sum of all hourly energies >0 (import)
- Sum of all hourly energies <0 (export)

The resulting imported and exported energies can finally be multiplied with the corresponding import and export tariffs.

By comparing the payment with and without PV installation, the return of investment of a rooftop PV-facility can be evaluated.

This has been done for one day based on the load and PV-generation profiles according to

Figure 9. The installed peak capacity of the PV installation has been increased in steps of 1kWp and the resulting earnings have been calculated (see Figure 11).

As Figure 12 shows, the return of investment for additionally installed PV-capacity decreases drastically when the installed capacity exceeds the limit of net export.

However, when carrying out this analysis for a complete year, under the consideration of cloudy days and seasonal variations, load variations between week-days and week-ends and seasonal load variations it is expected that the degradation of profitability would not as steep as in Figure 12.

For identifying the optimal size of a PV-installation, it is strongly recommended to carry out such a study for a complete year considering:

- Solar radiation over one or several years
- Load profile

However, in contrast to countries with a feed-in tariff that is higher than the end-consumer tariff, as it was the case in Germany until the beginning of 2012, it is expected that the size of PV-installations will be in proportion to the load.

Consequently, voltage problems resulting from excessive PV-infeed don't have to be expected.

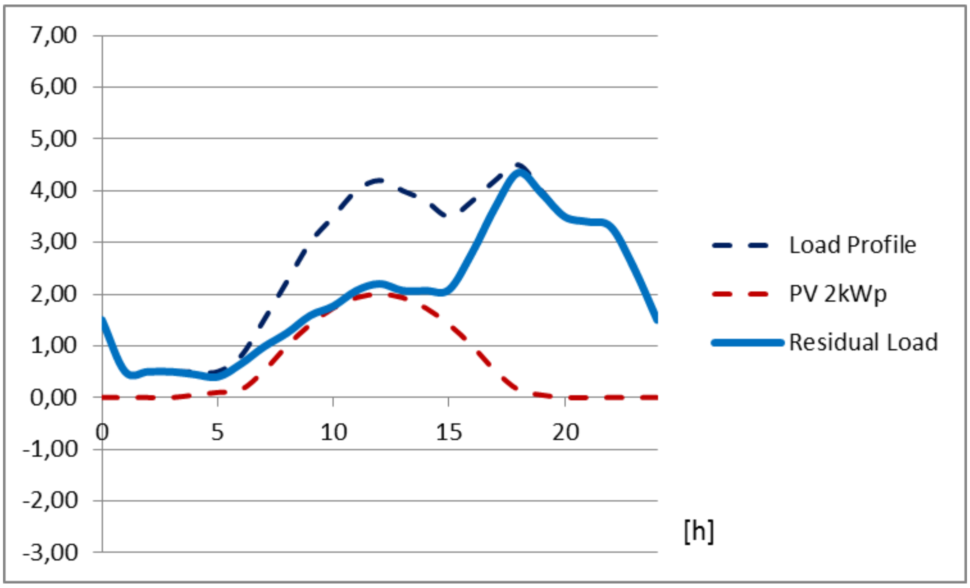



*Figure 9: Load, generation and residual load profile, Example 1: 2kWp*

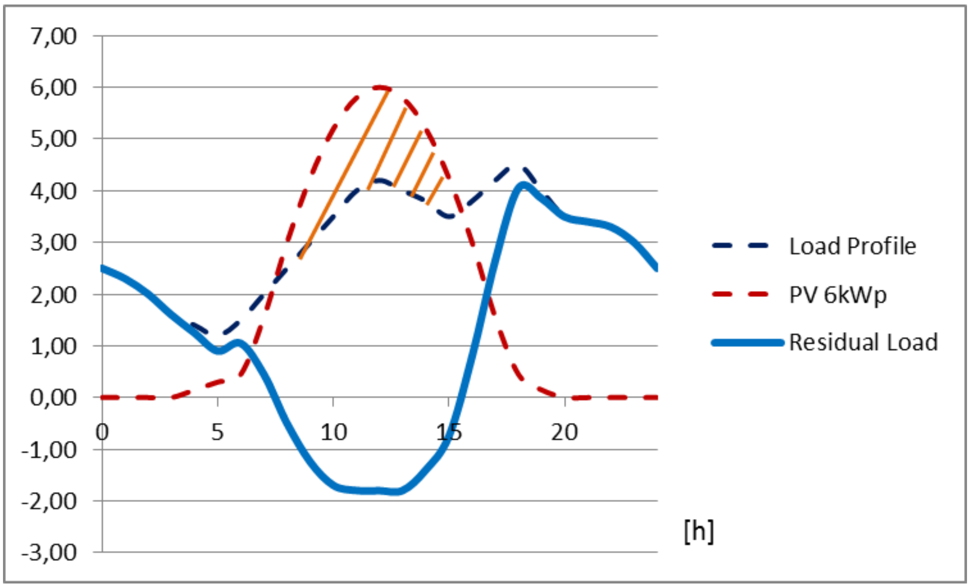



*Figure 10: Load, generation and residual load profile, Example 2: 6 kWp*

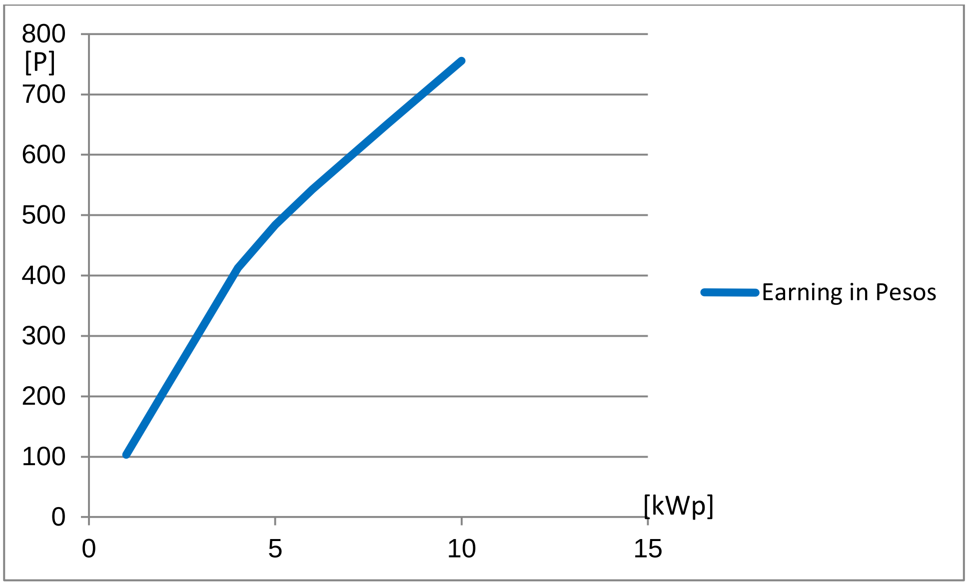



*Figure 11: Earning in Pesos for one day in function of installed peak capacity*

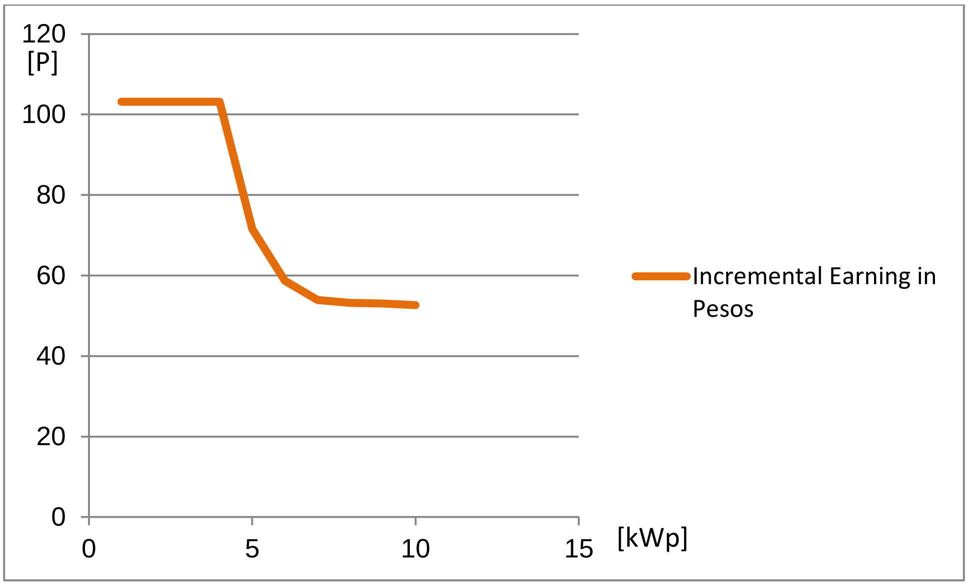



*Figure 12: Incremental Earning in Pesos for one day in function of additionally installed peak capacity*

## 6.2 The Use of Battery Storage

For avoiding high exports and low income during times of high PV production and low load, the use of additional battery storage could be a potential option. By storing the energy that is in excess to the load and feeding it into the grid during times of high load and low PV-generation (e.g. in the evening), the value of the generated electricity would increase from export tariff (e.g. 6PHP/kWh) to end-user tariff (e.g. 13PHP/kWh).

Assuming a battery with a net storage capacity of 3kWh and one load-de-load cycle per (sunny) day, the required cost of corresponding battery storage for making this an economical solution can be calculated: The assumptions are:

- Net storage capacity: 3kWh
- 1 load-de-load cycle during a sunny day (3kWh/day)
- 250 sunny days per year (250 load-de-load cycles per year)

Based on these assumptions, there will be around 750kWh of loaded and de-loaded energy per year. The resulting annual income from such battery storage system would be equal to:

$$I = 750kWh \times (13P - 6P) = 5250P \approx 100Euro$$

A commercially available battery storage system having a net capacity of 3kWh based on Lithium-Ion technology currently costs around 6000 Euro (including inverter). Hence the pay-back period would be in the order of magnitude of 60 years.

However, the actual lifetime of a Lithium-Ion battery is currently only in the order of around 15 to 20 years.

Consequently, assuming that electricity prices in the Philippines remain constant, costs of batteries would have to drop by at least a factor of three in order to pay its investment back over its lifetime.

# 7 Summary

This document contains guidelines for planning and installing solar rooftop systems in the Philippines under the Net-Metering Rules and Interconnection Standards, which have become effective in July 2013.

The guidelines presented in this document include:

- Overview about distribution companies in the Philippines, including a survey of end-consumer tariffs.
- Overview about MV and LV network technologies and grounding standards in the Philippines
- A commented summary of the Net Metering Rules and Interconnection Standards of the Philippines
- Some recommendations with regard to the sizing of solar rooftop systems.

# References


[1] Energy Regulatory Commission of the Philippines*: Rules Enabling the Net-Metering Program for Renewable Energy,* V.9, 2012

[2] Energy Regulatory Commission of the Philippines: Annex A - *Net Metering Interconnection Standards* – V4, 2012

[3] Energy Regulatory Commission of the Philippines: Annex B – *Sample Billing Formats and Simulations* – V2, 2012

[4] Energy Regulatory Commission of the Philippines: Annex C – *Net Metering Agreement* – V3, 2012

[5] Markus Pöller: *Connecting Solar Rooftops to the Grid – Lessons learned from the Workshop on 19.07.2012 and 20.12.2012 in Clark/Philippines,* 30.07.2012

[6] Ranulfo Ocampo: *Draft Net-Metering Rules, V.9*, Presentation from the PEPOA-Workshop on 19.07.2012 in Clark/Philippines

[7] SMA Solar Technology AG: *Technical Capabilities of Modern Solar Rooftop Solutions,* Presentation from the PEPOA-Worksho on 19.07.2012 in Clark/Philippines

[8] Workshop PEPOA-Connecting Solar Rooftops to the Grid: *Distribution Utility Survey*, 19.07.2012, Clark/Philippines

[9] PEPOA: *PV Roadmap Development Survey*, 25.07.2012

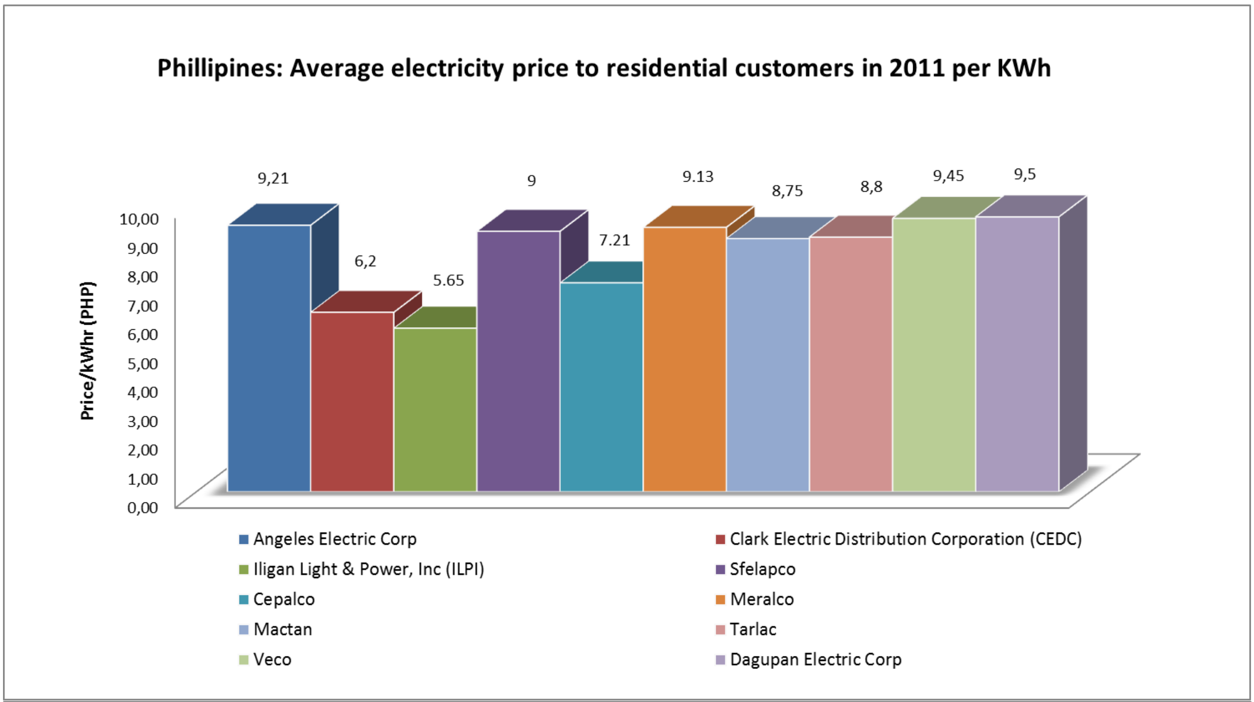
[10] Juan Pena de Juana/SMA: *Input for Manual of Interconnection*, Email from 27.08.2012

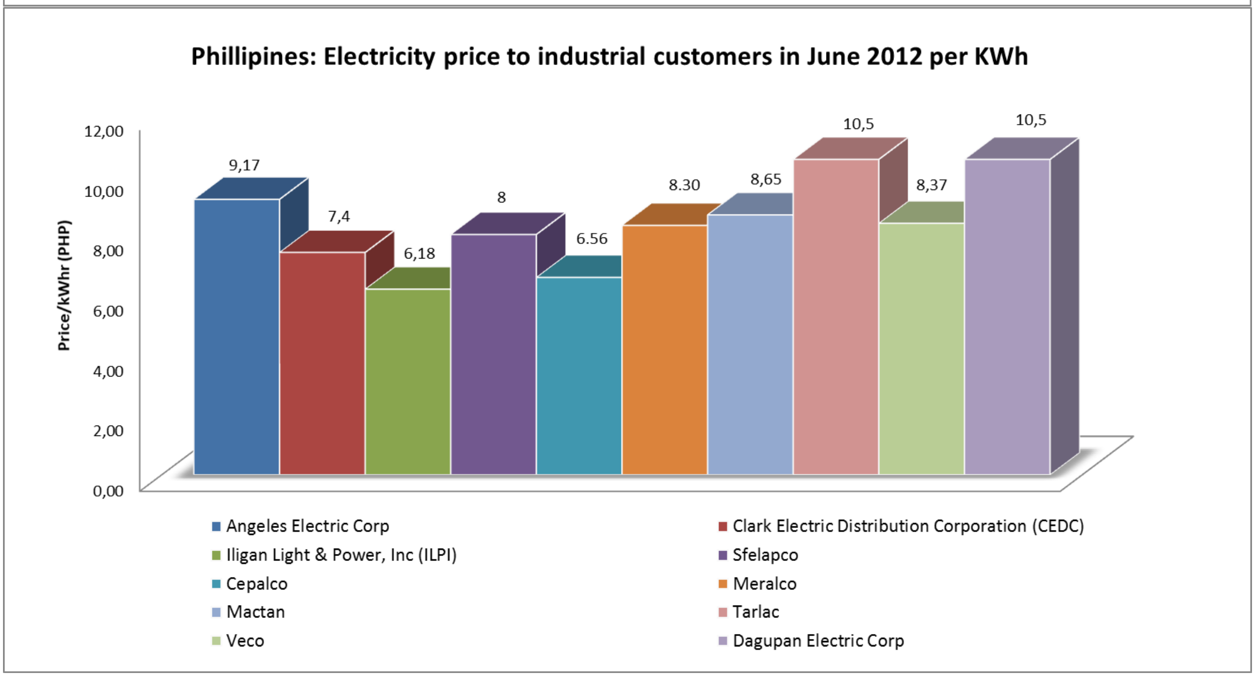
[11] Energy Regulation Commission (ERC): *Philippine Electrical Code* (PEC)

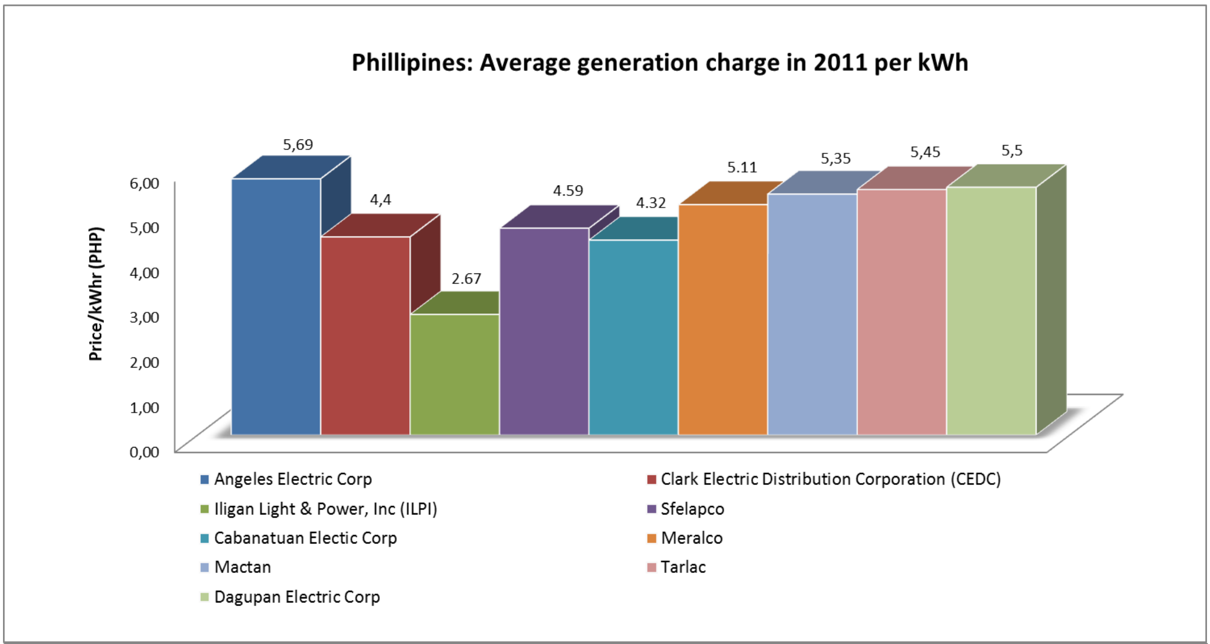
[12] Energy Regulation Commission (ERC); *Philippine Distribution Code* (PDC), December 2001

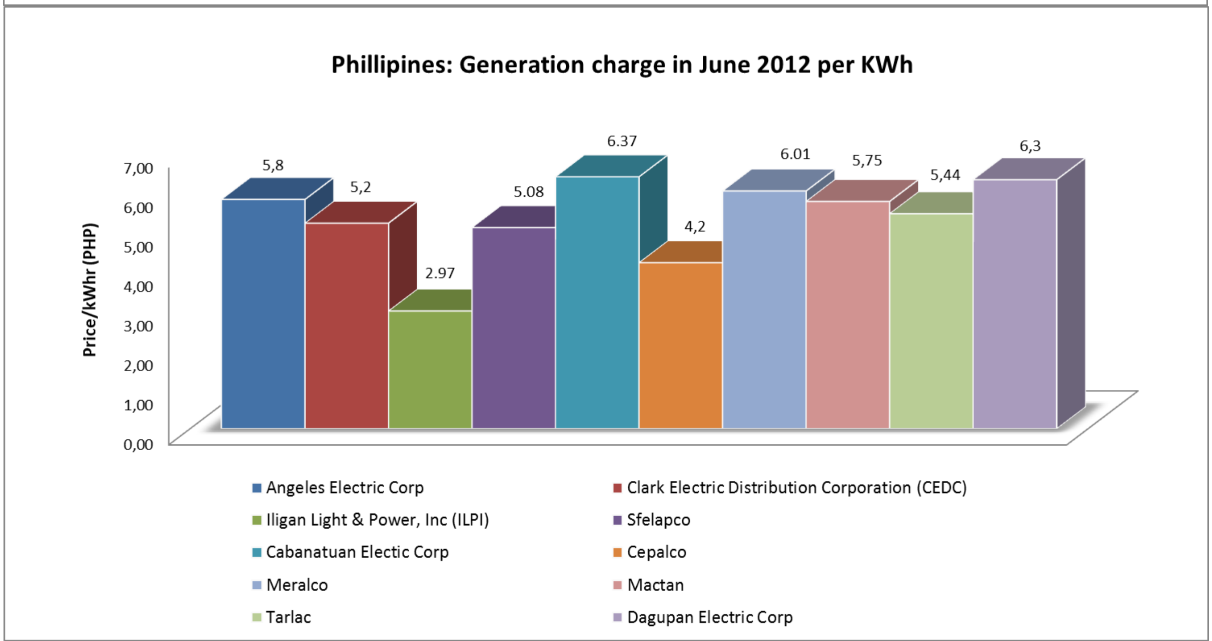
[13] Schneider Electric; *Planungskompendium Energieverteilung,* 2007

# Annex A: Survey of Distribution Companies of the Philippines




Phillipines: Average generation charge in 2011 per kWh
Price/kWhr (PHP)
0,00
1,00
2,00
3,00
4,00
5,00
6,00
5,69
4,4
2.67
4.59
4.32
5.11
5,35
5,45
5,5
Angeles Electric Corp
Clark Electric Distribution Corporation (CEDC)
Iligan Light & Power, Inc (ILPI)
Sfelapco
Cabanatuan Electic Corp
Meralco
Mactan
Tarlac
Dagupan Electric Corp


Phillipines: Generation charge in June 2012 per KWh
Price/kWhr (PHP)
0,00
1,00
2,00
3,00
4,00
5,00
6,00
7,00
5,8
5,2
2.97
5.08
6.37
4,2
6.01
5,75
5,44
6,3
Angeles Electric Corp
Clark Electric Distribution Corporation (CEDC)
Iligan Light & Power, Inc (ILPI)
Sfelapco
Cabanatuan Electic Corp
Cepalco
Meralco
Mactan
Tarlac
Dagupan Electric Corp