EMPOWERING YOUR TOMORROW

YOUR GUIDE TO MERALCO'S SOLAR PV NET METERING PILOT PROJECT

MERALCO
Ang liwanag ng bukas

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PUBLISHED BY MERALCO UTILITY ECONOMICS AND CORPORATE COMMUNICATIONS
IN COOPERATION WITH THE INTERNATIONAL COPPER ASSOCIATION SOUTHEAST ASIA.

Foreword

A more environmentally secure future, rapid advances in technology and innovation, and continuing depletion of traditional energy sources are driving the increasing adoption of renewable energy in various parts of the globe. Consumer affordability and grid competitiveness are challenges towards the much wider participation of renewable energy in the total energy mix, and continuing technology and economic advances are helping accelerate this process.

Here in our country, spurred by the Renewable Energy Act of 2008, we are seeing increasing interest in the application of the commercial and "own-use" renewable energy, specifically Wind, Solar, Run of River and Biomass power. We expect a more visible build up in generating capacity from these sources over the years.

This is certain a welcome development. Meralco fully supports the Government's drive towards a more secure and sustainable energy future in partnership with other key players. We see renewable energy as an integral part of the energy value chain, with clear advantages and benefits for all stakeholders.

> Responsible generation. Renewable energy generation taps into a vast and virtually inexhaustible energy supply which can complement existing fuels and technologies in driving progress.
>
> Reliable distribution. Feed-in-tariffs and net metering policies are spurring advancements in distributed generation and in the creation of micro-grids. In the near future, distributors will have access to embedded supply, enabling more consistent and reliable network uptime.

This industry shift will be demanding on our distribution and transmission infrastructure. To continue enabling these developments, we will need to put the right framework and policies in place, and invest in the necessary system infrastructure, hardware and software.

We in Meralco launched our Meralco Net Metering Pilot Project to model and simulate the effects of interfacing with Solar PV systems on the distribution network. Through the efforts of our engineers and analysts, the project now serves as our proof-of-concept for Net Metering and paves the way for the creation of Meralco's Net Metering Program.

The movement towards mainstreaming renewable energy requires a different way of thinking about energy, and a transformation in how we produce, deliver, and use it. As a next step, we are releasing this Net Metering Pilot Project Handbook to guide the commercial roll-out of our Net Metering Program. This handbook collects the knowledge and best practices we have accumulated throughout the pilot study, outlining tangible guidelines towards a successful Net Metering implementation.

I congratulate and thank the project team for pioneering this important effort, and I anticipate that it will serve as an added catalyst for the adoption of renewable energy sources at a more meaningful scale.

OSCAR S. REYES
President and CEO, Meralco

Message from the Energy Regulatory Commission (ERC)

On behalf of the Energy Regulatory Commission (ERC), I congratulate the Manila Electric Company (MERALCO) on the publication of the Meralco Net Metering Pilot Project Handbook.

At present, the Philippines' demand for power grows alongside its growing economy and populace. Aside from the need to put up additional power plants, increased maintenance of existing power plants is necessary to prevent future power outages and to address the issue of tightening electricity supply. The use of renewable energy (RE) technologies such as run-of-river hydro, solar, wind, and biomass is highly urged.

In support of the Renewable Energy Law (R.A. 9513), the ERC promulgated Resolution No. 9, series of 2013, otherwise known as the Rules Enabling the Net-Metering Program for Renewable Energy, including the Net-Metering Interconnection Standards (Net-Metering Rules).

The Net-Metering Rules allow qualified electricity end-users to engage in distributed generation as they can generate electricity from RE sources and supply the electricity that they generate in excess of their consumption directly to their respective distribution utility (DU). Electricity users may now become generators and not just mere recipients of electricity. The can now supply not only their electricity requirements but also that of the others through their distribution utilities' system. This will result in more savings and in earning a reasonable price for the generation of electricity which would have not been consumed anymore, if not for the net-metering system.

The Philippines is blessed with vast RE resources which need to be developed and maximized. Efficient and proper utilization of such resources will not just meet the energy demands of the country but also contribute to economic progress.

This Handbook will help jumpstart a progressive change which will positively affect and direct us toward achieving a stable, safe, and quality supply of electricity for every Filipino.

ZENAIDA G. CRUZ-DUCUT
Chairperson and CEO,
Energy Regulatory Commission (ERC)

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PROJECT CONCEPT

MERALCO NET METERING PILOT
Project Concept

RENEWABLE ENERGY (RE) ACT MANDATE

The Renewable Energy Act of 2008 (RE Act) declared it the policy of the State to accelerate the development and utilization of the country's renewable energy resources by providing fiscal and non-fiscal incentives. Chapter III of the RE Act provides four (4) non-fiscal incentive programs for on-grid RE systems, namely: (i) Renewable Portfolio Standard, (ii) Feed-in Tariff System, (iii) Green Energy Option, and (iv) Net Metering.

With the Energy Regulatory Commission's (ERC's) promulgation of Resolution No. 09, Series of 2013, Net Metering became the first non-fiscal incentive program to be implemented. According to the Resolution, Net-Metering is defined as a system, appropriate for distributed generation, in which a distribution grid user has a two-way connection to the grid and is only charged or credited, as the case may be, the difference between its import energy and export energy . Accordingly, distribution utilities (DUs) are required to provide mechanisms for the physical connection and commercial arrangements necessary for net metering.

RESPONSIBILITY OF THE DISTRIBUTION UTILITY

With the Net Metering Program acting as a catalyst in ushering in low voltage renewables in the distribution network, the DUs have the responsibility to manage these connections and monitor the impact to the system to ensure personnel and equipment safety and system reliability. Monitoring from the stage of interconnection to the operation phase is essential to protect and maintain distribution system stability and integrity.

Under the ERC's Net Metering Interconnection Standards, net metering installations are single- or three-phase generating facilities with maximum capacity of 100 kW connected to and operating in parallel with the DU. Thus, DUs will have to learn to work with facilities that will synchronize with, and possibly export power to, the DUs' secondary voltage lines. In the case of Meralco, this is a new scenerio, given that of its more than five million connections, there are only a handful of generators, all in the MW scale and synchronized with its distribution network at primary voltages.

Interconnecting an RE generation facility at low voltage and requiring a DC to AC conversion is a novel connection arrangement in the Philippine context.

In order to address these challenges, Meralco commissioned its Net-Metering Pilot Project on 05 June 2013 using a grid-tied 6.16 kWp solar PV system.

PROJECT OBJECTIVES

The main objectives of the Pilot are (i) to provide Meralco engineers and process caretakers a controlled venue for learning and evaluating an actual connection and synchronization of low voltage renewables with the Meralco system, and (ii) to establish a standard process of safely and efficiently connecting and synchronizing low voltage renewables, applicable not only to Meralco but to all RE stakeholders such as distribution utilities, LGUs, system designers and installers, and all customers in general.

More importantly, the installation will also serve as proof of concept for Net Metering. The metering set-up installed should be able to capture the two-way flow of electricity and measure kWh registrations at both directions.

After the completion of the year-long study, Meralco now shares its observations, learnings, and recommendations on low voltage renewable interconnection.

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[1] *Republic Act No. 9513 "An Act Promoting the Development, Utilization and Commercialization of Renewable Energy Resources and for Other Purposes"*
[2] *Section 6, RE Act*
[3] *Section 7, RE Act*
[4] *Section 9, RE Act*
[5] *Section 10, RE Act*
[6] *ERC Resolution No. 09, Series of 2013, entitled "A Resolution Adopting the Rules Enabling the Net Metering Program for Renewable Energy" (Net Metering Rules)*
[7] *Section 4 (n), Article I, Net Metering Rules*
[8] *Section 10, RE Act; Section 7, Article III, Net Metering Rules*
[9] *Section 2, Annex A-1 Interconnection Standards, Net Metering Rules*

THE GROUNDWORK

Installation of Low Voltage
Renewable Energy Generating Facility

The first step in installing an RE generating facility is identifying the ideal location to ensure optimal power generation. Evaluation of possible locations for the installation must also take into account structural support and accessibility for maintenance and emergency purposes.

With the installation site identified, the next step is to select an RE integrator for the project. This involves assembling the general requirements and technical specifications of the RE system components safeguarding that they conform to applicable industry and regulatory standards.

Finally, the installed components and wiring layout of the RE system would have to be documented to facilitate post-installation maintenance activities.

Detailed discussion on the steps undertaken for the Meralco Pilot can be found in the sections below.

I. Site Selection

To identify the most viable location for the solar PV panels, several requirements were considered. These initial considerations were:

1. Building construction. The structure on which the panels will be mounted must be able to withstand the additional load with a comfortable margin of safety.

2. Accessibility. The location must be readily accessible for maintenance and emergency purposes.

3. Shading. The location of the panels must get a reasonable amount of sunlight given the location of other buildings in the area.

Initial Assessment

Based on the initial parameters set for selecting the ideal site, two locations/buildings were shortlisted, the Operations Building and the Covered Tennis Court.

FIGURE 1.1 Aerial view of Operations Building

OPERATIONS BUILDING

The location of the Operations Building is parallel to a major road often used by both employees and visitors going to the Fitness Center. The building's rooftop is made of flat concrete slabs, which makes it attractive in terms of stability and ease of installation. Actual shading analysis was done on the rooftop of the Operations Building. Initial survey results showed that shadows from the surrounding buildings may affect the panels during different times of the day. The effects of the shadowing were seen to be minimal and a significant portion of the day's sunlight can still be harvested. However, investigations on the structural integrity of the building discouraged installation on the rooftop because of the building's age and current condition.

FIGURE 1.2 Covered Tennis Court

COVERED TENNIS COURT

The Covered Tennis Court was the second site considered. In terms of visibility and accessibility, it is a good location. It can be easily seen because of the building's height and slanted roof construction. The building's structural supports are made of steel on concrete blocks. The structural integrity of the building was found to be sufficient to carry the additional weight of the panels. Also, the area is very accessible for maintenance purposes since two of its sides are right along wide roadways. Another plus for this location is the roof angle and orientation which favors panel installation technical requirements – panels should have a tilt of at least 10 degrees to promote natural cleansing of dust whether artificially or by rainwater. Also, the roof is tilted facing south – the ideal orientation of PV installations in the Philippines. However, a quick survey of the area showed that sunlight harvest may be affected by buildings located south-east of the building. This merits a more intensive investigation on its shadowing effects.

Shading Analysis

An in-depth shading analysis of the specific location can be provided and ideally should be mandatory for a solar PV panel supplier/installer for their computation of the annual energy yield.

The survey has shown that the Medical City building and the Rockwell Business Center Towers (RBC) may cast shadows on the Covered Tennis Court. The Medical City is taller but farther and situated at about 70° southeast with an approximate height of 60 meters. The Rockwell Tower 2, on the other hand, is situated at about 55° southeast and approximately 50 meters tall.

For simplification purposes the sun was considered as a point source at a very large distance from earth (thus shadow cast shall be parallel and will not widen significantly when the sun is low on the horizon). Also, the shadowing effect from RBC Tower 2 was disregarded as it will cast cover only at a limited period of time. It was assumed that since the top of the Medical City has about 18 degrees elevation from the location of the Covered Tennis Court, there will be no shading when the sun has reached an altitude of 18 degrees.

A Sunpath Diagram was plotted using the geographic coordinates of Manila, located at approximately 15 degrees latitude. The diagram was used to determine the monthly positional changes in the movement of the sun and to project the shading effect of the Medical City building on the roof of the Covered Tennis Court based on their relative location.

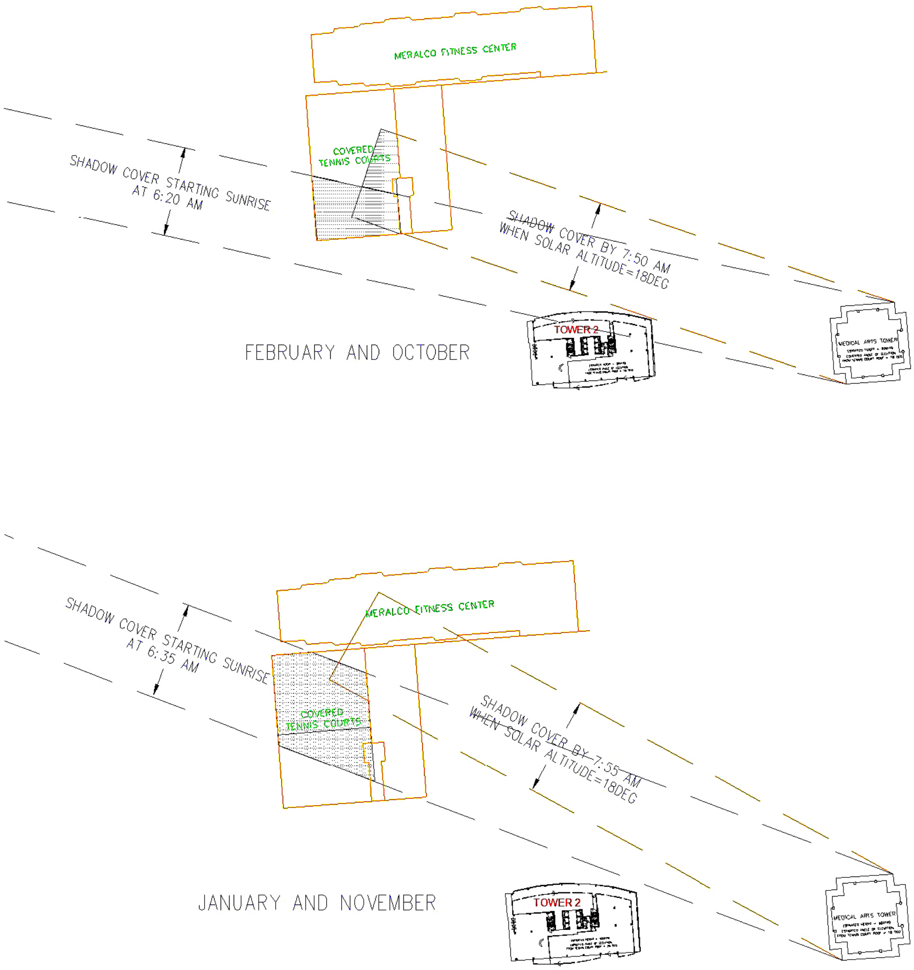


FIGURE 1.3 Shadow Analysis

It was determined that the months of January, February, October and November will have a shading effect on the roof, as shown in Figure 1.3.

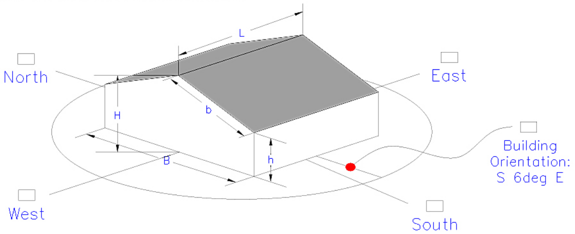
As can be deduced from the diagrams in Figure 1.3, about 1.5 hours of sunlight during the months of February and October and 1 hour 20 minutes during January and November will be lost. It is also important to note that these values were estimated using interpolated data on a sunpath diagram suited for Manila (15 degrees latitude). Also, the difference between Solar Time and Local Mean Time (ranging from 5 to 15 mins) was not considered. These assumptions may contribute to some differences in the actual and the abovecited hours of sunlight.

Basic Conditions			
Location of the Installation:	Meralco Center - Ortigas Avenue, Pasig City		
Elevation above sea level:	29 meters	Wind Load:	195kg per sqm
Terrain Category:	City Center, paved concrete surroundings		

Facility Data:	
Module type:	N/A (c/o supplier)
Module dimensions:	N/A (c/o supplier)
Facility capacity:	3kW
Module Alignment	N/A (c/o supplier)

Roof Parameters:	
Roof Type:	Ridge
Roof Material:	G.I. Sheets

Roof Orientation and Dimesions:



Length L:	38m
Width B:	35m
Width b:	18.5m
Hight H:	13m
Hight h:	7m
Roof Pitch:	19 deg

FIGURE 1.4 Technical Data Sheet - Meralco Covered Tennis Court

FINAL RECOMMENDATION: Based on the considerations detailed above, the Covered Tennis Court is the more viable and optimal location for the solar PV panel installation.

II. Technical Evaluation of Supplier Bids

In March 2013, Meralco released an invitation to bid for a 6 kWp solar PV facility to be installed at the Meralco Covered Tennis Court, and proposals from six (6) bidders were received. All were given the opportunity to conduct site survey and take relevant measurements. Below is a summary of technical specifications of the project:

Detailed System Design

SYSTEM CAPACITY

- DC Power Plant Capacity (kWp) refers to the summation of capacities in kilowatt-peak (kWp) of all the solar modules in the proposed system. This data gives the maximum DC input capacity to the inverter. For the Meralco Pilot Project, the DC Plant Capacity is at 6.16 kWp.

- Net AC Output (kW) refers to the estimated equivalent AC net real power output of the inverter. This data gives the estimated AC power generation of the entire solar PV system. Based on simulations, the net AC output of the 6.16kWp installation is 4.44kW. This capacity was initially assumed to handle a significant portion of the demand requirement of the project load and even export power to the grid under favorable conditions.

SHADOW ANALYSIS

To determine the average irradiance per day, which is critical to optimizing the PV system design, shadow analysis needs to be conducted. It determines solar obstructions with reference to the position of the sun on different seasons throughout the year.

In conducting shadow analysis, different tools can be used like the Solar Pathfinder, SunEye, and PVSYST Software. These equipment also provide far-shading analysis which gives the azimuth and altitude of the sun on different seasons throughout the year. Far-shading is caused by physical obstructions like mountains, trees, and buildings. The far-shading data is an input to the software for graphical presentation.

DESIGN SIMULATION

To ensure that the system design maximizes the plant output, simulations on system components were required. Examples of software used for design simulation are PVSYST, Homer, and Sunny Design. Input parameters to these software include solar module and inverter specifications. The winning bidder used PVSYST Software to determine the projected power generation, average monthly projected energy yield, average monthly projected performance ratio, and the plant's AC net real power output of the PV System.

PROJECTED POWER GENERATION

The energy production in kWh of the solar PV system was estimated for the first year. Based on the result of simulation, the initial year energy production of the pilot project is 6,858kWh.

- Average Monthly Projected Energy Yield (kWh/kWp). Energy yield is the ratio of total energy output to the DC power output expressed in kWh/kWp. This parameter provides a convenient way to compare the energy produced regardless of the solar PV system size. Using the assumed initial year module degradation of 3% used by the supplier, the specific production is 1,116kWh/kWp/year. This parameter is divided by the number of months in a year to get the average monthly projected energy yield of 93kWh/kWp or dividing the projected power generation by the number of months in a year and DC power plant capacity.

- Average Monthly Projected Performance Ratio (%). The Performance Ratio is the ratio between actual (i.e. annual production of electricity delivered at AC side) and the theoretical energy output of the solar PV system. The performance ratio, often called "Quality Factor", is independent from the irradiation and therefore useful to compare systems. The performance ratio informs you as to how energy efficient and reliable your solar PV system is. Based on the result of the simulation, the average monthly projected performance ratio is 70.9%.

SYSTEM DIAGRAM

The system diagram illustrates the physical connection of different parts of the solar PV system such as the solar modules, inverters, check meter, protective devices, and switches.

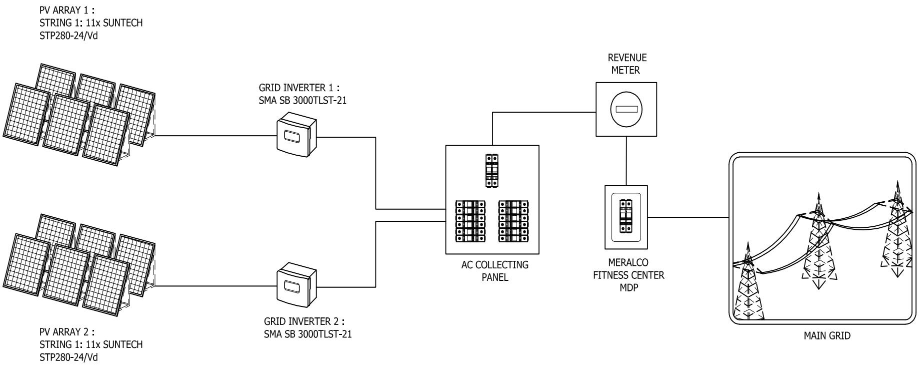


FIGURE 1.5 Proposed System Diagram

PV Panels

MODULE TYPE

There are two common types of PV modules, the polycrystalline and monocrystalline module. Taking into account the weather conditions in the Philippines, long-run efficiency, and component cost, polycrystalline modules were used in the system design.

PV CONFIGURATION

The supplier, model number, and count of PV modules to be installed in the system are major considerations in the design simulation. Also, the number of PV units will determine the area required for the installation. For the project, twenty-two (22) units of 280Wp Suntech STP 280-24/Vd solar modules were used to arrive at the 6.16kWp designed DC plant capacity.

WIND PRESSURE WITHSTAND

This criteria determines the quality of the PV module. The higher the wind pressure capability, the higher the quality of the PV module. Based on the PV supplier's submitted specifications for the solar PV module, the entire module is certified to withstand high wind loads of 2.4 up to 5.4 kilo Pascal (kPa).

Module Support Structure (Framing)

LOAD ANALYSIS

Load analysis is needed to determine if the wind pressure withstand capability of the module support structure can handle the maximum wind velocity at the installation site. The participating bidders were requested to conduct wind pressure analysis based on the roof area, mean roof, exposure, occupancy category, basic wind speed, topographic factor, wind directional factor, and importance factor.

MOUNTING DETAILS

The module support structure model is dependent on the roof type. The model used by the winning bidder is Schletter Single Fix HU Model made with anodized aluminum with high grade steel screws. Based on the wind pressure analysis, the module support structure can withstand the wind pressure of 1.332 kPa or an equivalent wind velocity of 167kph.

INVERTER

The brand and model of PV units serve as inputs to the design simulation for the inverter. In general, the more inverter units in the PV system, the higher the reliability of the solar power system. However, this would also mean higher costs. The PV supplier used 2 units of SMA Sunny Boy SB3000TLST-21 model with a maximum efficiency of 97%.

III. Design Parameters for 6.16 kWp Meralco Solar PV Solar Power Plant

The winning bidder conducted a site survey on March 9, 2013, to determine the potential solar energy harvest based on the sunpeak hours and shading in the area. Other factors considered include the rooftop wind load capacity, safety during installation, cleaning and maintenance during the plant's operation.

Shading Analysis

One basic consideration to any Solar Rooftop design is the shading analysis of the project site. Shading analysis will provide the solar resource that can be harvested in the given project site. Solar resource is rated in terms of watt per meter square (W/m^2), which is also called Solar Irradiance.

Sunpeak Hours is defined as the equivalent number of hours per day when solar irradiance averages 1,000 W/m^2. For example, six (6) sunpeak hours means that the energy received during total daylight hours equals to the energy that would have been received had the irradiance for six hours been 1,000 W/m^2. (www.ecowho.com).

Meralco Covered Tennis Court

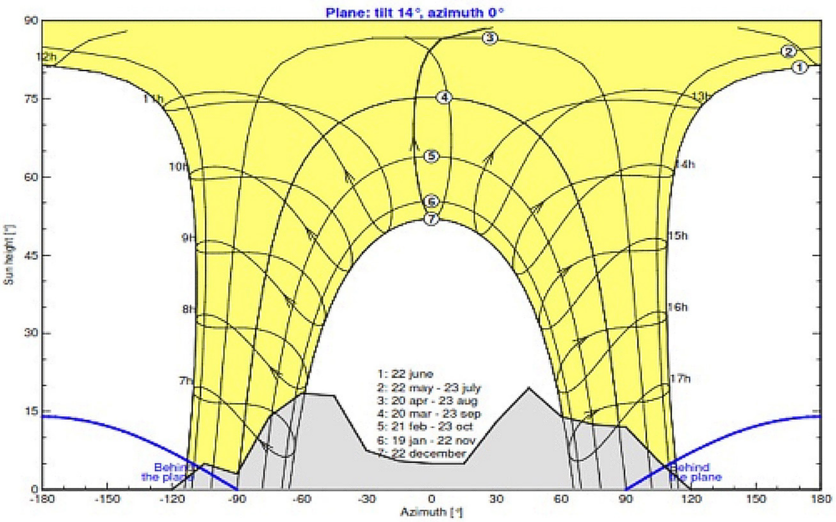


FIGURE 1.6 Far-Shading Graph for the MERALCO Pilot Project

THE GRAY AREA FROM THE FAR-SHADING GRAPH REPRESENTS THE SHADINGS IN DIFFERENT SEASONS THROUGHOUT THE YEAR WHILE THE YELLOW FIGURE REPRESENTS THE SOLAR WINDOW AND THE BLACK LINES REPRESENT THE SUN PATH. For instance, Line 4 represents the sun path from March 20 to September 23. This means that sunlight will strike the solar modules as early as 6:15 AM at the suns' height of 4.0° and azimuth of -90° until 5:13 PM at the sun's height of 13° and azimuth of 90°. Azimuth refers to the sun's position with reference to the earth's North-South Axis.

Two types of shadings influence the performance of the Solar Rooftop performance. These are: (1) the linear shading which is the direct casting of shadows into the solar PV modules and (2) the far-shading which pertains to the obstructions within the 15 km radius of the solar PV modules.

Shading can be determined using several equipment like solmetrics, parabolic glass, etc. The results from this equipment are interpreted using the shading analysis software, PVSYST.

The coordinates of the PV installation site is essential to the shading analysis as this ascertains the sun path with respect to the location. In this particular project, the coordinates of the Covered Tennis Court rooftop are 14.6° North, 120.1° East at 42 meters above sea level.

Roof Bearing Capacity

Determining the roof bearing capacity of the project site is very important in designing a Solar PV Rooftop power plant. This is inherent to the design consideration since the Philippines is visited by at least 20 typhoons per year. Roof bearing capacity is the capability of a structure to withstand vertical loads to include live loads, dead loads and wind pressure caused by weather disturbance.

Investigation showed that the roof bearing capacity of the Covered Tennis Court is 600 Pascal (Pa) or about 60 kgs/m^2.

Comparing this capacity with the projected solar facility load of about 15 kgs./m^2 load, the Covered Tennis Court would be able to bear this load easily since it is only 25% of the roof bearing capacity of the site.

Meteorological Data

Meteorological data is important in designing a Solar PV Rooftop. This will give the average temperature, wind velocity, global and diffused irradiance. Meteorological data will dictate the performance of the Solar PV Rooftop.

Data from the PAGASA (Philippine Atmospheric Geophysical and Astronomical Services Administration) Manila Science Garden weather station was integrated with the shading analysis using a designer's software. The result of which is shown below:

Geographical Site	
MERALCO Fitness Center	
Latitude	14.6 N
Longitude	120.1 E
Altitude	42 m

Month	Hor. Global	Hor. Diffuse	Extraterrestrial	Clearness Index	Amb. Temper.	Wind Velocity
	kWh/m²/day	*kWh/m²/day*	*kWh/m²/day*		*°C*	*m/s*
January	3.66	2.12	8.29	0.441	26.3	2.7
February	4.38	2.54	9.19	0.476	26.8	3.0
March	5.29	3.07	10.03	0.528	27.9	3.2
April	5.41	3.14	10.57	0.512	29.2	3.2
May	5.11	2.96	10.69	0.478	29.4	3.0
June	4.38	2.54	10.63	0.412	28.2	2.7
July	4.18	2.42	10.62	0.394	27.9	2.9
August	4.27	2.48	10.56	0.404	27.6	2.9
September	3.88	2.25	10.20	0.380	27.1	2.7
October	3.80	2.20	9.46	0.402	27.7	2.1
November	3.65	2.12	8.52	0.428	27.0	2.2
December	3.19	1.85	7.99	0.399	26.4	2.3
Year	***4.27***	***2.47***	***9.73***	***0.438***	***27.6***	***2.7***

Source: GH Solar Pathfinder

TABLE 1.1 Monthly Meteorological Values.
From this table, the project site Sunpeak hours are 4.27 kWhr/m²/day.

Energy Projection

The Solar PV integrator provides warranty on the performance of the Solar PV power plant for a period of 25 years.

Table 1.2 below is the projected initial year performance of the plant.

Values	Global Horizontal Irradiance	Diffused Horiz. Irradiance	Array Monthly Energy Production	Projected Monthly Energy Production	Monthly Performance Ratio	Projected Efficiency
Month	$kWh/m^2/Day$	$kWh/m^2/Day$	kWh/month	kWh/month	%	%
January	3.66	2.12	559.8	535.0	72.92	95.57
February	4.38	2.54	593.7	568.7	65.24	95.79
March	5.29	3.07	768.1	736.6	71.92	95.90
April	5.41	3.14	723.6	693.9	69.90	95.90
May	5.11	2.96	682.2	652.8	71.92	95.69
June	4.38	2.54	567.7	542.2	69.90	95.51
July	4.18	2.42	562.6	536.6	72.23	95.38
August	4.27	2.48	590.4	563.4	71.92	95.43
September	3.88	2.25	538.0	512.6	69.60	95.28
October	3.80	2.20	560.6	535.5	71.92	95.52
November	3.65	2.12	533.7	509.4	69.90	95.45
December	3.19	1.85	493.8	471.2	72.92	95.42
Yearly Ave.	***4.27***	***2.38***	***7,174.2***	***6,857.9***	***70.69***	***95.57***

TABLE 1.2 Projected Energy Generation for Initial Year

Initial year performance of a solar PV rooftop power plant is important since this will be used as an input for computing the guaranteed AC Net of the plant on the initial year without imputing the degradation factor.

The Meralco pilot project is designed to produce energy for the next 25 years or more. The projected energy generation during these years takes into account the degradation factor and the projected irradiance on site for 25 years.

Table 1.3 on the next page will show the projected annual energy generation of the 6.16 kWp Solar PV Power Plant for a period of 25 years.

Year	Total Derating Factor	Performance Ratio (%)	Total Energy Generation (kWh)
Initial	0.72	70.7	6,857.80
1	0.65	69.29	6,269.72
2	0.66	69.47	6,286.19
3	0.66	69.47	6,286.19
4	0.66	69.47	6,286.19
5	0.66	69.47	6,286.19
6	0.65	69.35	6,275.77
7	0.65	69.35	6,275.77
8	0.65	69.35	6,275.77
9	0.65	69.35	6,275.77
10	0.65	69.35	6,275.77
11	0.65	69.35	6,275.77
12	0.65	69.35	6,275.77
13	0.65	69.27	6,268.25
14	0.65	69.27	6,268.25
15	0.65	69.27	6,268.25
16	0.65	69.27	6,268.25
17	0.65	69.27	6,268.25
18	0.65	69.27	6,268.25
19	0.65	69.35	6,275.77
20	0.65	69.35	6,275.77
21	0.65	69.35	6,275.77
22	0.65	69.35	6,275.77
23	0.65	69.35	6,275.77
24	0.65	69.35	6,275.77
25	0.65	69.35	6,275.77

TOTAL	**156,884.76**

TABLE 1.3 Projected Energy Generation in 25 Years

Equipment Selection

For the Meralco 6.16 kWp Solar PV Solar power plant, reliable and efficient equipment were selected. Twenty two (22) units of Suntech STP 280-24/Vd 280 watt-peak solar modules were installed connected to two (2) SMA Sunny Boy SB 3000TLST-21 inverter via XLPE cables.

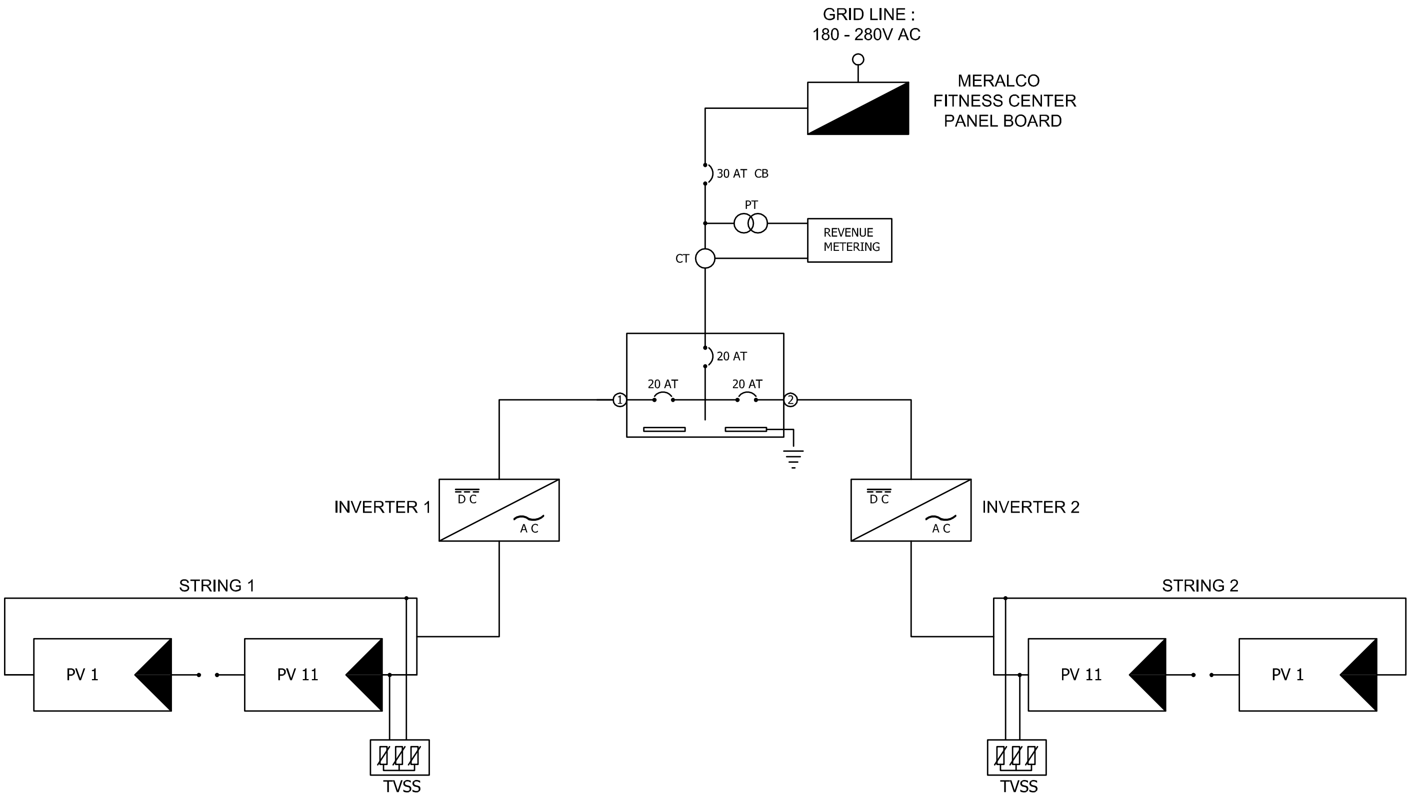


FIGURE 1.7 Single line diagram of the 6.16 kWp Solar PV Power Plant

In order to ensure compliance to the distribution network system parameters, the inverter supplier requested Meralco to provide the threshold values for voltage, frequency, islanding detection and reconnection time. Attached in Figure 1.8 is the accomplished inverter form, which was provided prior to the release of the Net Metering Interconnection Standards.

Thresholds questionnaire

Please enclose the filled-in questionnaire with your order or return it to SMA per fax: +49 561 9522-4700

General information	
Name of customer:*	MERALCO
Address:*	Ortigas Ave., Pasig City, Philippines
Phone / fax number:*	+63-2-1622 6265 / +63-2-6328751
Contact person:*	Ronoel Dellota
Information on the plant	
Project name:*	Low Voltage Solar PV Interconnection Pilot Project
Installation location (country/zip/city):*	Philippines / Pasig City
Information concerning the utility	
Name of the utility:*	MERALCO
Contact person:*	RONOEL DELLOTA
Phone / Email:*	+63-2-1622 6265 / rmdellota@meralco.com.ph
Type of plant*	X Grid-connected ☐ Off-grid
Nominal voltage (U_{nom})*	230 V
Nominal frequency (f_{nom})*	60 Hz

The boxes marked with an asterisk (*) are mandatory

Fill in the following table in case the inverter shall feed into the public grid (grid-connected):

	Recommended value		Customer request	
Voltage and frequency monitoring	threshold	time until disconnection	threshold	time until disconnection
Lower limit AC voltage	U_{nom} -15 %	0.2 s	207 / 115 V	2s / 0.16 s
Upper limit AC voltage	U_{nom} +15 %	0.2 s	253 / 276 V	1s / 0.16 s
Lower limit AC frequency	f_{nom} -2.5 Hz	0.2 s	59.7 / 57.6	5s / 0.16 s
Upper limit AC frequency	f_{nom} +0.5 Hz	0.2 s	60.3 / 62.4	5s / 0.16 s
Islanding detection	active	time until disconnection	active	time until disconnection
Active recognition of stand-alone operation	☐ yes X no	5 s	X yes ☐ no	2 s
Reconnection time	active	grid monitoring time	active	grid monitoring time
Time until reconnection after grid fault	☐ yes X no	30 s	X yes ☐ no	60 s
Grid quality	active	threshold	active	threshold
DC injection - max. permitted value for offset of AC current	☐ yes X no	1 A	X yes ☐ no	0.5 % of full load
Voltage rise protection- Monitoring of 10 min. mean value, e.g. as per EN 50160	☐ yes X no	253 V	☐ yes X no	
Should the settings be saved for all future orders for the specified country? (except for undo)	X yes	☐ no	☐ yes	X no

Name* RONOEL DELLOTA Date* 4/17/13 Signature* [signature]

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FRAGENETZ-ZEN091311 2/3

FIGURE 1.8 Accomplished inverter form

THE METERING BLUEPRINT

Net Metering Setup

Net Metering

In a net metering arrangement, the end-user maintains a two-way connection to the distribution system. The customer is only charged or credited, as the case may be, for the difference between the electricity supplied by the DU (import energy) and the electricity it supplies to the DU during times when it has excess RE generation (export energy), both of which are metered using either 2 uni-directional meters, one for import and one for export, or a single bi-directional meter[1].

The Net Metering Rules also include the Interconnection standards, which shall be complied with and observed by the net metering customer to address engineering, electric system reliability, and safety concerns for net metering interconnections, such as those concerning voltage level, frequency, and power quality, and those relating to system protection.

NET METERING IS DIFFERENT IN OTHER COUNTRIES

SINCE THE PHILIPPINES APPLIES A DIFFERENT PRICING METHODOLOGY FOR BOTH IMPORT AND EXPORT, IT CANNOT APPLY THE "NET" FOR THE ENERGY READING BUT RATHER THE "NET" FOR THE PRICE OF BOTH IMPORT AND EXPORT READINGS.

In a Net Metering setup, the generation facility is connected to the utility grid via the customer's main service panel and energy meter. When the energy generated by the facility is greater than the customer's consumption, the excess energy will be exported to the grid through the power meter, reversing the meter from its usual direction. As a result of the energy meter working in both directions – one way to measure power purchased (when on-site demand is greater than on-site power production), the other way to measure power returned to the grid – the customer pays the "net" of both transactions. In a deeper context, since the Philippines applies a different pricing methodology for both import and export it cannot apply the "net" for the energy readings but rather the "net" for the price of both import and export readings.

[1] *Resolution No. 9, Series of 2013, Section 4 (n) Definitions*

Metering Scheme

FIGURE 2.1
Two uni-directional meters scheme

For the pilot project, Meralco installed a working metering set-up that demonstrates both single bi-directional meter and two uni-directional meter schemes.

The two unidirectional meters use simple meters with detent function to register import kWh on 1st meter and export on the 2nd meter.

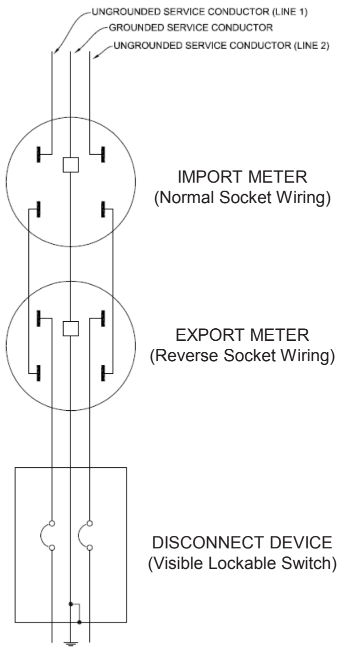


FIGURE 2.2 Wiring diagram for two uni-directional metering scheme

AN ENERGY METER IS A DEVICE THAT MEASURES THE FLOW OF ELECTRICITY TO OR FROM A RESIDENCE, BUSINESS, OR AN ELECTRICALLY POWERED DEVICE.

Electricity meter has three types of configuration:

(1) Net Metering
- registers forward energy and subtracts the reverse energy.

(2) Detent Metering
- registers forward energy and ignores the reverse energy

(3) Non-Reversing Metering
- registers forward energy and also adds the reverse energy.

With two simple and identical meters having detent feature, the connection is made in such a way that the second meter is wired in reverse fashion with respect to the energy flow in the first meter. When the two meters are connected in series or tandem as described, both meters will see the same current flow. But due to the detent feature of the meters, only one meter will register a consumption at any given instant.

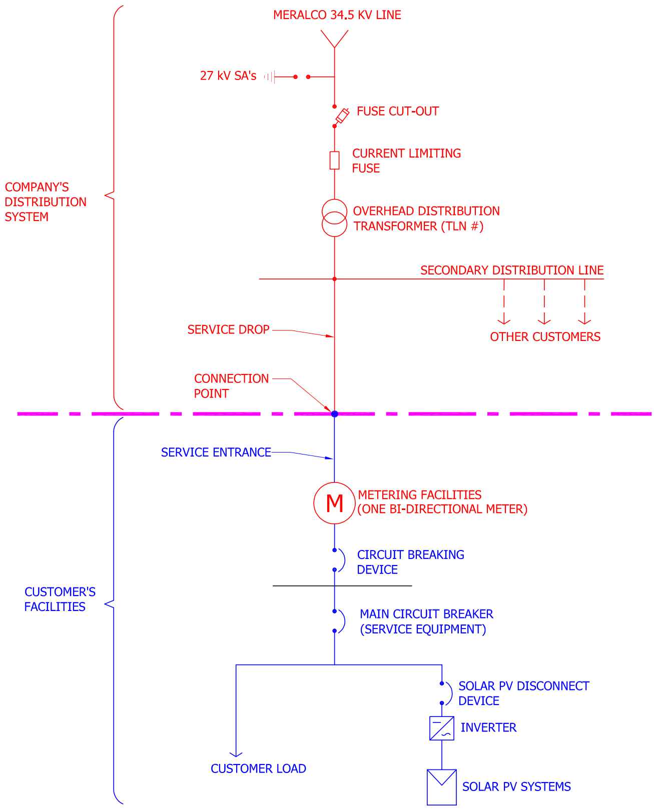


FIGURE 2.3 Typical one bi-directional metering scheme

If the net energy flow is towards the customer, the import meter will register the consumption but the export meter will just ignore it. On the other hand, if the net energy flow is towards the utility, the export meter will register the export kWh while the import meter will just ignore it. It should be noted however that the correct designation of the meters should be done during the wiring or installation part to properly identify which is the export and import meters.

One bi-directional meter is a net meter that records both the import and export kWh registrations. The readings are displayed alternately on the LCD of the meter.

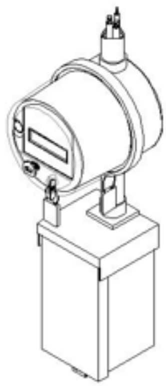


FIGURE 2.4 One bi-directional meter scheme

PEEKING INTO PQ

Assessment of Power Quality Parameters

Power Quality Monitoring Report

Under Article III of the Net Metering Rules, the RE System to be installed must be compliant with the standards set by Philippine Electrical Code (PEC), Philippine Distribution Code (PDC), Distribution Service Open Access Rules (DSOAR) and the Net Metering Interconnection Standards.

To check for any disturbance being introduced by the RE facilities to the distribution system, power quality monitoring was conducted at different periods.

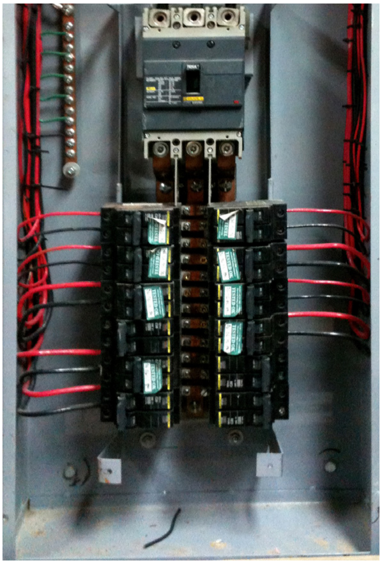
Methodology

A. EQUIPMENT USED

A power quality analyser was used to capture the behaviour of the voltage, current, demand in kw and other power quality parameters.

Power Quality Analyzers - Fully Class-A compliant: Conduct tests according to the stringent international IEC 61000-4-30 Class-A standard

FIGURE 3.1
Power Quality Analyzer



CONNECTED LOAD

1. Lighting	7. Spare
2. Hand dryer	8. ACU-3
3. Lighting	9. ACU-4
4. ACU-1	10. SPARE
5. ACU-2	11. ACU-5
6. E. Light	12. SPARE

FIGURE 3.2 Main Circuit Breaker - Meralco Fitness Center Canteen

To verify if the RE source is creating unwanted disturbance to the distribution system, the analyser was installed at the main circuit breaker of the MFC canteen.

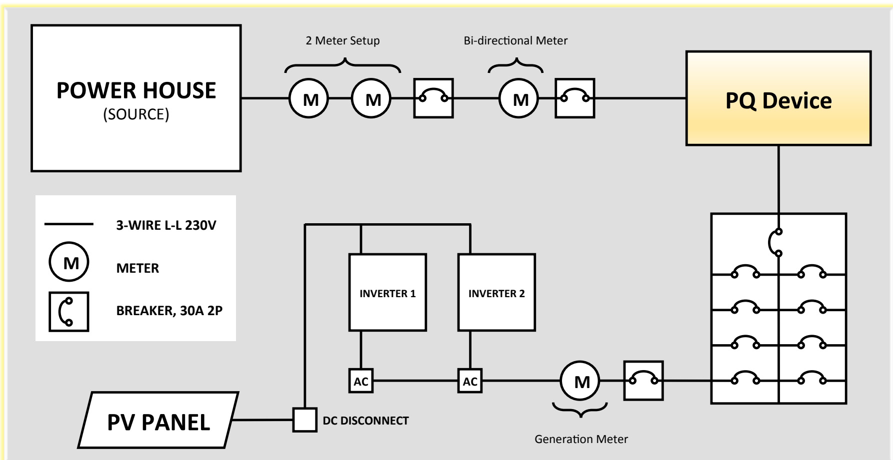


FIGURE 3.3 Monitoring Setup

B. MONITORING DURATION

To verify any unwarranted effect of the RE facility to the distribution system, three measurements were made: 1st was for the establishment of a baseline data; 2nd and 3rd were conducted to check the system after the installation of the RE source during the wet and dry season respectively.

	Baseline Data (Prior to installation of solar PV system)	**Wet Season**	**Dry Season**
Start of Measurement	January 16, 2013	July 30, 2013	April 30, 2014
End of Measurement	January 23, 2013	August 6, 2013	May 7, 2014

TABLE 3.1 Power Quality Parameter Monitoring Period

Parameters Measured

A. VOLTAGE VARIATION

Voltage variation is the deviation of the root-mean-square (RMS) value of the voltage from its nominal value, expressed in percent. The voltage variation at the utilization level should be within ±10% of the nominal value limit[1]. Maintaining the voltage level within the standard range is imperative to avoid the following common power quality problems:

• SHORT DURATION VOLTAGE VARIATION. Occurs for a time greater than ½ cycle but not exceeding one minute.

Voltage Sag: RMS value of the voltage decreases to between 10% and 90% of the nominal value. This is manifested by electronic equipment malfunction, unnecessary operation of protective relays, nuisance tripping of adjustable speed drives, and/or facility shutdown.

Voltage Swell: RMS value of the voltage increases to between 110% and 180% of the nominal value. This is manifested by unnecessary tripping of overvoltage relay, nuisance tripping of adjustable speed drives, and/or facility shutdown.

[1] *Philippine Distribution Code (PDC) Section 3.2.3.1*

• LONG DURATION VOLTAGE VARIATION. Occurs for a time greater than one minute.

Under Voltage: RMS value of the voltage is less than or equal to 90%of the nominal voltage. This is manifested by the actuation of under voltage relay, dropping out of motor controllers, increased heating losses, and/or facility shutdown.
Over Voltage: RMS value of the voltage is greater than or equal to 110% of the nominal voltage. This is manifested by the actuation of over voltage relay, immediate malfunction of electronic devices, accelerated aging of equipment insulation, and/or facility

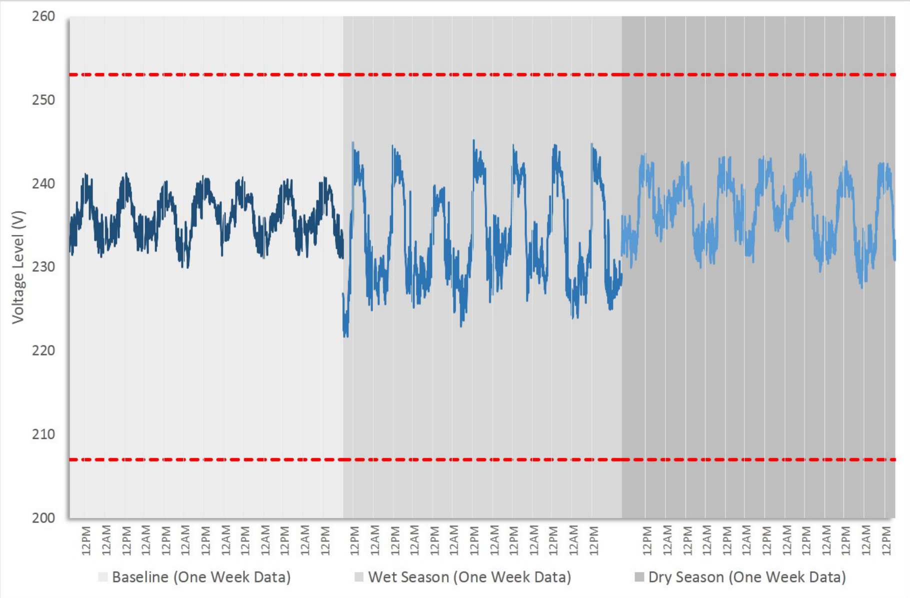


FIGURE 3.4 Comparison of Voltage Variation Across PQ Monitoring Periods

Baseline Voltage. The line-to-line voltages varied from a minimum of 227.31 V (between lines 2 and 3) and to a maximum of 242.90 V (between lines 3 and 1). These values translate to a variation of 1.17% below and 5.61% above the nominal value of 230V.

The post-installation voltage variation readings (Wet Season and Dry Season) in Figure 3.4 show a wider variation range compared to the Baseline readings.

B. TOTAL HARMONIC DISTORTION

Harmonics are the sinusoidal voltages and currents having Frequencies that are integral multiples of the fundamental Frequency. The following are effects of harmonics on equipment:

- Transformers: abnormal heating, iron and copper losses, stray flux
- Capacitors: resonance, dielectric failure
- Metering: inaccurate measurement

The total harmonic distortion (THD) is the industry standard used to measure the level of harmonic distortion for voltage. Voltage THD is defined as the ratio of the Root-Mean-Square (RMS) of the harmonic content to the RMS value of the fundamental quantity, expressed in percent[2]. The PDC requires that voltage THD should not exceed 5% during normal operating conditions[3].

The THD readings for the Baseline, Wet, and Dry Season are within the standard threshold as shown in Figure 3.5.

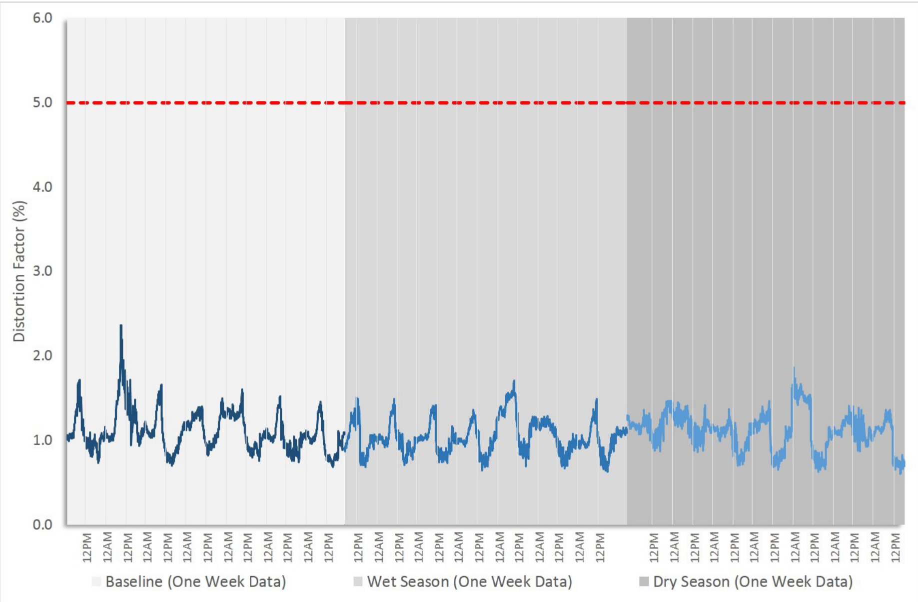


FIGURE 3.5 Comparison of Total Harmonic Distortion Across PQ Monitoring Periods

[2] *PDC Section 3.2.4.2*
[3] *PDC Section 3.2.4.4*

C. FLICKER SEVERITY

Flicker shall be defined as the impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time. Manifestation of flicker include video monitor distortion, nuisance tripping of electrical equipment, and light flicker. Typical causes of flicker are operation of arc furnaces, and constant switching on and off of electrical equipment.

The Flicker Severity at the Connection Point of any User shall not exceed 1.0 unit for short term (Pst) and 0.8 units for long term (Plt)[4]. Readings for Pst (see Figure 3.6) and for Plt (see Figure 3.7) are within their respective standard thresholds.

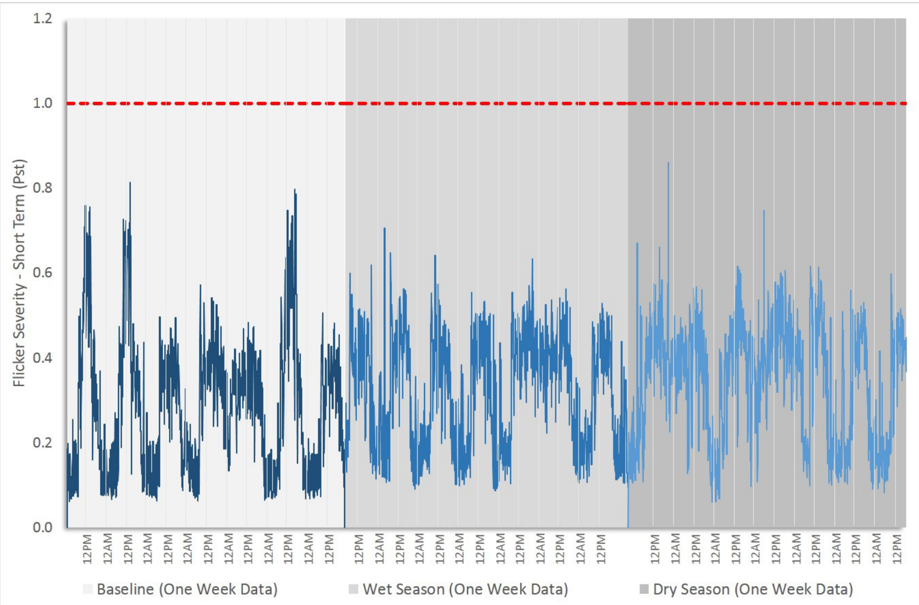


FIGURE 3.6 Comparison of Short-Term Flicker Severity Across PQ Monitoring Periods

[4] *6.3.2 Net Metering Interconnection Standards, Annex A-1, ERC Resolution No 9, Series of 2013*

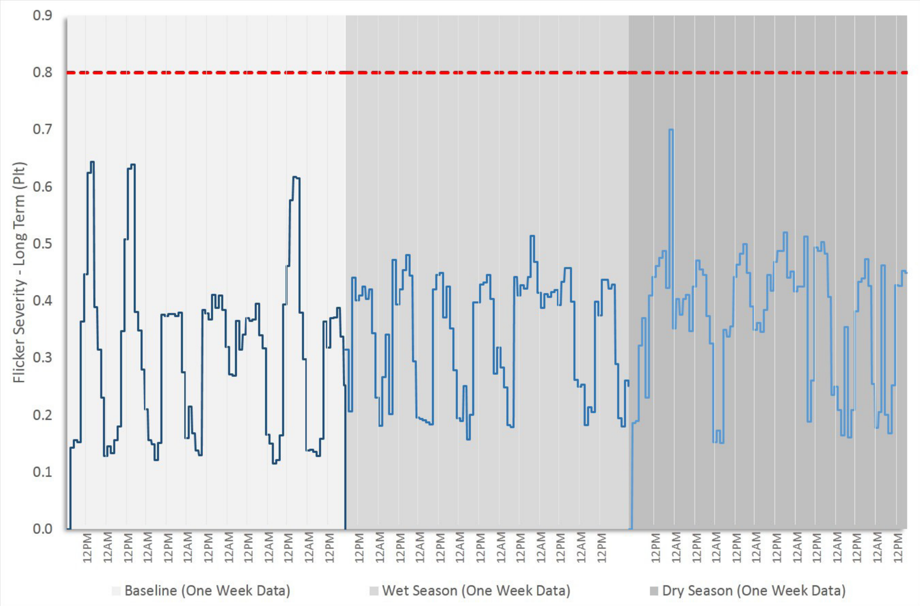


FIGURE 3.7 Comparison of Long-Term Flicker Severity Across PQ Monitoring Periods

D. FREQUENCY VARIATIONS

According to PDC 3.2.2.1, the nominal fundamental Frequency shall be 60Hz. It should be maintained within the limits of 59.7 and 60.3 Hz during normal conditions. Figure 3.8 shows the summary of the recorded Frequency. The Frequency readings remained within the threshold set in the Net Metering Interconnection Standards[5].

Over frequency and under frequency may cause high core loss and overheating of the machines and possible failure, lower equipment efficiency, increase or reduction in speed of rotating machines, and increase in fault levels due to the reduction of reactance.

[5] *6.2 Net Metering Interconnection Standards, Annex A-1, ERC Resolution No 9, Series of 2013*

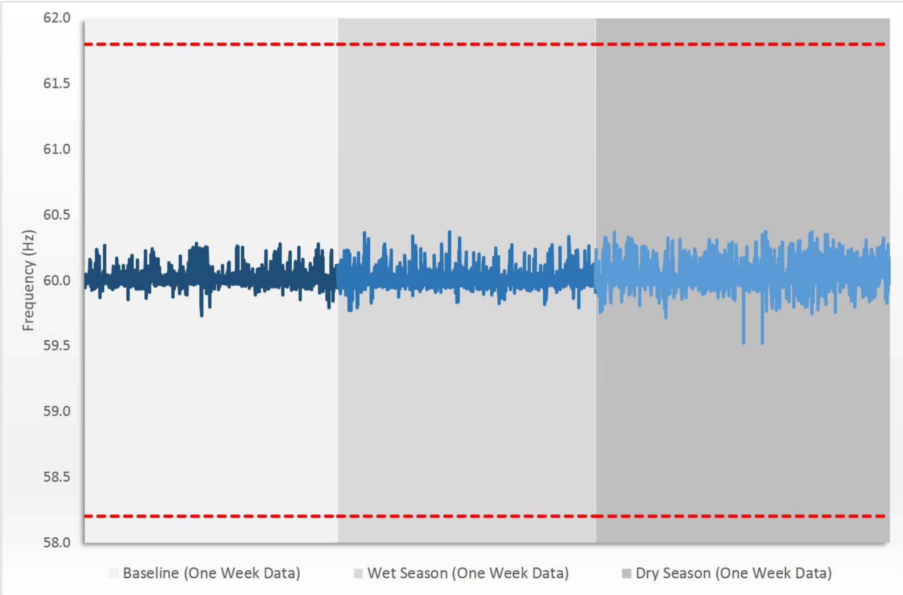


FIGURE 3.8 Comparison of Frequency Variation Across PQ Monitoring Periods

OVER-ALL, THE RESULTS OF THE POWER QUALITY MONITORING REVEALED THE ABSENCE OF ANY UNWARRANTED DISTURBANCE INTRODUCED BY THE RE FACILITIES TO THE DISTRIBUTION SYSTEM. THROUGH THE PROPER DESIGN, SOLUTION AND OPERATION OF THE RE SYSTEM, THE VOLTAGE VARIATION, VOLTAGE TOTAL HARMONIC DISTORTION, LONG AND SHORT TERM FLICKER AND FREQUENCY FELL WITHIN THE PRESCRIBED LIMITS AFTER THE INSTALLATION OF THE RE SOURCE.

E. TEST FOR ANTI-ISLANDING AND SYNCHRONIZATION

Under Section 7.5 of the Interconnection Standards[6], the RE facility should immediately disconnect when the distribution system is down. The RE facility should wait for two (2) minutes until the recloser has normalized before synchronizing back to the system. To test the compliance of the installed RE system, a live test detailed in Table 3.7 was conducted.

	Action on the Main Panel	Checklist on the Inverter
1	De-energize load side by opening the main breaker	Check if inverter ceases to energize; Record time when inverter re-synchronizes
2	Hold for 2 seconds	
3	Re-close main breaker	
4	Re-open main breaker	
5	Hold for 15 seconds	
6	Re-close main breaker	

TABLE 3.2 Test Procedure for Anti-Islanding and Synchronization

Anti-Islanding Test

As shown in Figure 3.9, turning off the AC source from the distribution network by opening the main breaker instantaneously disconnected the inverter from grid. A quick "ON and OFF" (i.e. items 2 and 3 of Table 3.7) of the AC source showed that the inverter remained disconnected from the grid. This demonstrates the cease-to-energize functionality of the inverter.

[6] *7.5 Net Metering Interconnection Standards, Annex A-1, ERC Resolution No 9, Series of 2013*

FIGURE 3.9 Comparison of Voltage Levels at the Inverter Side and at the Main Panel During the Anti-Islanding Test

Synchronization Test

After turning "ON" the AC source from the grid (i.e. item 6 of Table 3.2), the inverter was fully synchronized within 72 seconds which is shorter than the minimum period of two (2) minutes set in the Interconnection Standards.

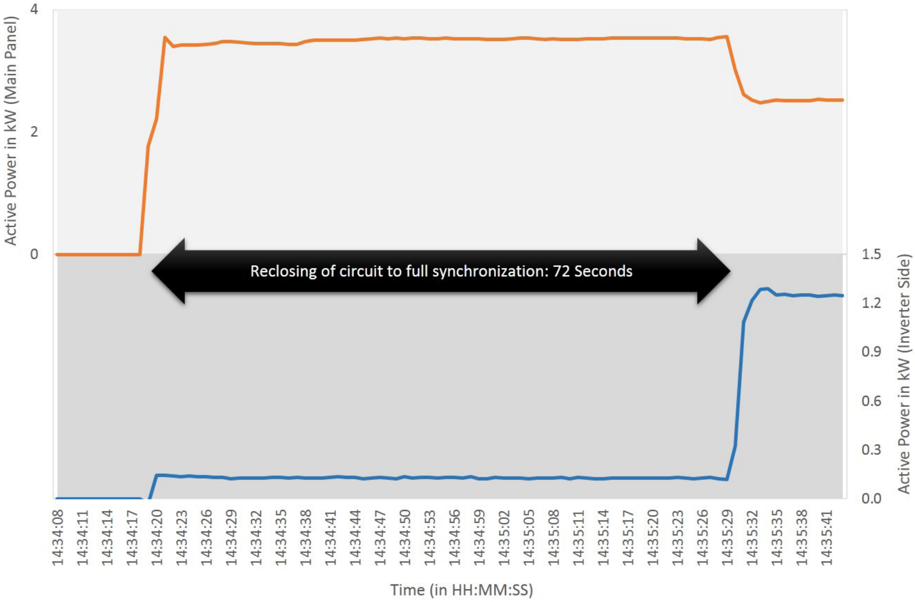


FIGURE 3.10 Comparison of Active Power (in kW) at the Inverter Side and at the Main Panel During the Synchronization Test

To address this issue and ensure compliance to the Interconnection Standards, the inverter re-synchronization setting was adjusted by the supplier.

F. ENERGY GENERATION

The energy generated by the pilot installation from July 2013 to June 2014 was 7 MWh, matching the Projected Annual Generation for the initial year guaranteed by the RE integrator. This translates to a capacity factor of 18.8%. Figure 3.11 shows that the actual peak generation months of March, April, and May correspond to the projected peaks.

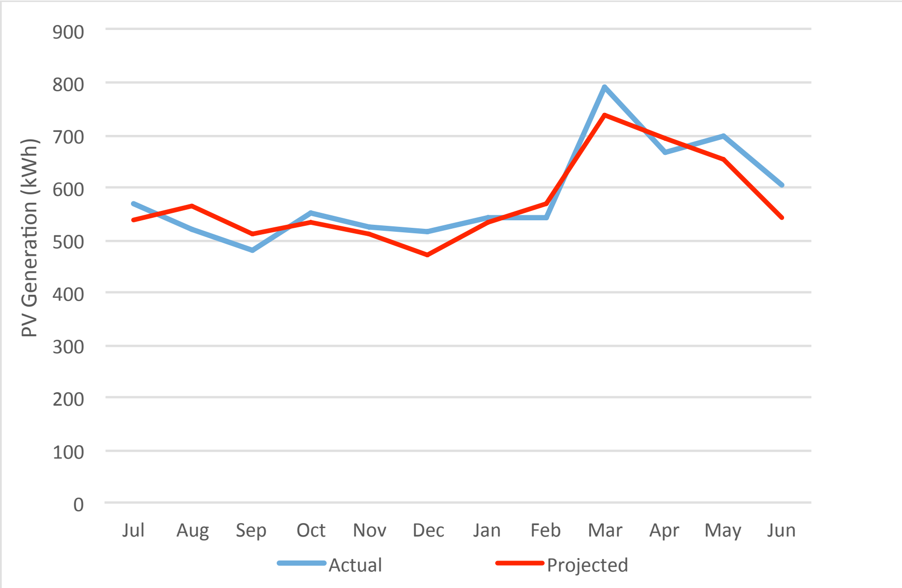


FIGURE 3.11 Comparison of Monthly Projected and Actual Energy Generation

WAY FORWARD

Learnings and Future Considerations

Learnings and Future Considerations

With the completion of the first year of Meralco's Net Metering pilot study, the team presents the following selected learnings and recommendations based on its experience and observations in interconnecting a 6.16 kWp solar PV system to the distribution system:

• ON THE RELIABILITY OF THE GRID. With solar PV systems, it is essential that the grid to which it will be interconnected is reliable for smooth and successful synchronization. The provision of accurate grid form configuration of the DU is crucial as the inverter would be configured based on the information supplied. It is also important to note that a grid-tied solar PV system would not work properly without a good AC feed from the distribution grid and that the efficient performance of a solar PV system is highly dependent on its seamless interconnection to the distribution system. This may point to increasingly stringent reliability requirements in the near future from customers, as interconnected inverter-based RE-systems become more prevalent.

• ON THE COMPATIBILITY OF THE SOLAR PV COMPONENTS WITH THE DU SYSTEM. With the absence of Philippine product standards or an official certification that the components of a solar PV system conform to local standards, end-users and DUs need to adopt processes to ensure the quality and reliability of each component of the solar PV system. During the development of Meralco's pilot system, we were pleased to note that even before the installation of the solar PV system, SMA, the supplier for the inverter, requested for Meralco's DU system parameters, including the grounding scheme - a practice that we strongly encourage other inverter suppliers to adopt. For end-users, it will be a challenge to ensure that the solar facility they will acquire is of a quality that will perform through the years according to their expectations under local conditions. Thus, it is recommended that the industry establish a certification process for the solar PV system components, as well as the accreditation of system installers and integrators, to assure the safety and quality of the Net Metering installations.

• ON COMPLIANCE WITH STANDARD TECHNICAL PARAMETERS. During the pilot system's initial synchronization, it was determined that the inverter had to be reconfigured to conform with the then-contemplated Interconnection Standards. This observation re-affirmed the need to conduct a testing and commissioning step for interconnection applications of customers. After the inverter was reconfigured, the team conducted a series of tests, with the use of power quality analyzers, and the installation was found to be compliant with the technical parameters as mandated in the final Net Metering Interconnection Standards.

The Net Metering Pilot Project provided Meralco's technical personnel a venue for learning and evaluating an actual connection and synchronization of low voltage renewables, which is something that has not been widely done before in the Philippines. With the pilot project, the engineers were familiarized with the intricacies of low voltage interconnection, and learnings were applied in the actual handling of Net Metering customers of Meralco. Procedures such as load assessment and profiling, provision of a disconnect switch to ensure system protection, and the conduct of testing and commissioning were adopted as integral steps in Meralco's application process, following observations made from the company's pilot system.

Since the pilot project scope was limited to a single installation, the study may be expanded to cover several solar PV systems connected to a single distribution transformer, so that the aggregate impact of multiple systems on the operation of the distribution network may be assessed. The distribution network needs to prepare for the increased adoption of end-use generation and integration of these variable renewable energy while maintaining the integrity and stability of the system.

With the pilot project and other initiatives to prepare for Net Metering, Meralco is working towards continuously improving the Net Metering Program's implementation, especially, in terms of the assurance that the whole process of installation and interconnection is done in a safe and efficient manner – from the acquisition of quality products and components that conform to industry and technical standards, contracting of accredited installers/integrators, up to the actual interconnection and operation of the facility. All these will redound to the protection of consumers, the distribution system's reliability, and the sustainability of the Net Metering Program.

Appendix

READING A NET METER

Reading a net meter is typically the same as with another electronic meter. The only difference is the inclusion of sequence number 11 for the bi-directional meter that indicates that it is the export kWh registration. Sequence number is normally on the upper left corner of the LCD display.

Notice also that the emulator bar (the arrow) is pointing to the left, this indicates that the energy flows back to the grid.

Sequence Number for Net Meters

Net meter display sequence number as shown in the example below for a net meter connected to a CT rated service.

However, for our two meter scheme only the sequence number 01 will be visible for both import and export.

Sequence Number	Function
01	kWh (+) – Import
02	kW Demand
03	kVarh
04	Cumulative Demand
11	kWh (-) - Export

TABLE 1. Description

ELECTRONIC METER DISPLAY

The display of an electronic meter is typically composed of 5 parts which are as follows:

1. Sequence Number. Sequence number is the indicator on which value is being displayed in the Reading Display.

2. Reading Display. Reading display simply shows the reading, which can be in kWh, kVar, kW demand, etc.

3. Display ID. This aids the sequence number on what value is being shown.

4. Emulator Bar. Emulator bar is an indicator of the energy flow. This blinks to the right if an energy is being drawn from the grid (import). A blink to the left indicates energy returning to the grid (export).

5. Phase Indicator. Shows which phase is active.

CHECKLIST FOR INSPECTION AND TESTING OF SOLAR PHOTOVOLTAIC (PV) GENERATION SYSTEM FOR NET METERING APPLICATIONS

Project/Customer Name: ______________________________

Location: ______________________________

PV Capacity (kWp): ______________________________

Date Installed: ______________________________

PV Service Provider: ______________________________

START-UP SYSTEM

Refer to system manual for the inverter and follow start-up procedure. This generally involves turning on the PV DC main switch followed by the PV AC main switch but the procedures as recommended by the inverter manufacturer must be followed.

TEST	YES	NO
1. System connects to grid after 2 minutes when the AC grid or normal supply is turned ON and the inverter start-up procedure was followed (Cease to Energize)		
2. Input power of the inverter (if available)	________ W	
3. Output power of the inverter (if available)	________ W	
4. Output power as expected? (If Item # 3 has value)		
5. System disconnects from grid within 2 seconds when AC grid or normal supply was turned OFF? (For Unintentional Islanding)		
6. Initial reading of Generation Check Meter	Date: Time: Reading: ______ kWh	
Criteria: Items 1, 4, and 5 should be "YES"		

DECLARATION

I hereby certify that the work done on the installation of this Solar PV generation system meets the requirements of Meralco.

____

PV Service Provider

Date / Signature over printed name

Report Prepared By:	Approved By:	Witnessed By:
Name:	Name:	Name:
Signature:	Signature:	Signature:
Company:	Company:	Company:
Date:	Date:	Date:

CHECKLIST FOR INSPECTION AND TESTING OF SOLAR PHOTOVOLTAIC (PV) GENERATION SYSTEM FOR NET METERING APPLICATIONS

I. PHYSICAL INSPECTION

Project/Customer Name: ________________________________

Location: ________________________________

PV Capacity (kWp): ________________________________

Date Installed: ________________________________

PV Service Provider: ________________________________

	Accepted	Not Accepted	Reason(s) for Non Acceptance
Construction			
Solar Array			
Inverter			
DC Cabling Termination			
DC Junction Box			
AC Cabling Termination			
AC Control Box			
Mounting Structure			
Others (please specify):			
Wiring			
Solar Array			
Inverter			
DC Cabling Size & Type			
DC Junction Box			
AC Cabling Size & Type			
AC Control Box			
Others (please specify):			
Equipment Grounding			
Solar Array			
DC Junction Box			
AC Control Box			
Mounting Structure			
Others (please specify):			
System Grounding			
DC Grounding			
AC Grounding			
Total Ground Resistance			
Others (please specify):			

Protection System			
Lightning Air Terminal			
DC TVSS			
DC Disconnect			
AC Disconnect			
Signage/Labelling			
Solar Array			
DC Junction Box			
AC Control Box			
Others (please specify):			
Documentation			
Manuals			
Technical Specifications			
Others (please specify):			

II. FUNCTIONAL / INSPECTION TEST

A. PV Array (DC Side). Disconnect the array string fuses and/or circuit breakers. With the PV DC main switch OFF:

TEST		YES	NO
1. CHECK continuity between PV DC main switch and inverter. Is there a continuity?	Array (+ve)		
	Array (–ve)		
2. Is the polarity between PV DC main switch and inverter CORRECT?			
3. RECORD open circuit voltage (Voc) at input side of the array DC main switch.		________ V	
WARNING: If polarity is reversed at the inverter, damage may occur which is generally not covered under warranty			
Criteria: Item A should be "No" and Item B should be "Yes"			

B. Inverter (AC Side). Ensure that the AC grid or normal supply is isolated and the PV AC main switch is OFF:

TEST		YES	NO
1. CHECK continuity between inverter and PV AC main switch. Is there a continuity?	Line		
	Neutral		
2. CHECK continuity between PV AC main switch and Generation Check Meter. Is there a continuity?	Line		
	Neutral		
3. Is the polarity at the inverter and the PV AC main switch CORRECT?			
4. Is the polarity at the output of PV AC main switch from the Generation Check Meter CORRECT?			
Criteria: Items A and B should be "NO" and Items C and D should be "YES"			

C. Inverter Response Time. Refer to system manual for the inverter and follow start-up procedure. This generally involves turning on the PV DC main switch followed by the PV AC main switch but the procedures as recommended by the inverter manufacturer must be followed.

TEST	YES	NO
1. System connects to grid after 2 minutes when the AC grid or normal supply is turned ON and the inverter start-up procedure was followed (Cease to Energize)		
2. System disconnects from grid within 2 seconds when AC grid or normal supply was turned OFF? (For Unintentional Islanding)		
Criteria: Items 1 and 2 should be "YES"		

DECLARATION

I hereby certify that the work done on the installation of this Solar PV generation system meets the requirements of Meralco.

PV Service Provider

Date / Signature over printed name

Report Prepared By:	Approved By:	Witnessed By:
Name: Signature: Company: Date:	Name: Signature: Company: Date:	Name: Signature: Company: Date:

LIVE TEST SIMULATION

1. Voltage Level. The PV system shall operate their facility to maintain the same voltage level as Distribution System at the Connection Point.
- The voltage level is within the limits (refer to load logger data results)

2. Frequency. The PV system shall operate at a frequency of 60 Hz.
- The frequency is within the limits (refer to load logger data results)

3. Power Quality

3.1. Limitation of DC Injection. The RE Facility and its interconnecting system shall not inject DC current greater than 0.5% of the full load rated output current at the Connection Point.
- Based on the inverter specifications, it complied.

3.2. Flicker Severity. The flicker severity at the Connection Point shall not exceed 1.0 unit for short term and 0.8 units for long term as specified in Section 3.2.6 of the PDC.
- The impact of PV inverters on flicker is generally low because a PV inverter does not represent a considerable flicker source, as long as the controller of the PV inverter is properly tuned. The inverter has this characteristic.

3.3. Harmonics. The harmonic content of the voltage and current waveforms in the Distribution System shall be restricted to levels which will not cause interference or equipment-operating problems. The harmonics shall be within the limits defined in Section 3.2.4 of the PDC.
- The harmonic level is within the limits (refer to load logger data results)

4. Cease-to-Energize Functionality Test. System connects to grid after 2 minutes when the AC grid or normal supply is turned ON and the inverter start-up procedure was followed.
- The system synchronized by about 50 seconds on average. The supplier adjusted the setting to comply for the 2-minute synchronization.

5. Anti-Islanding Functionality Test. System disconnects from grid within 2 seconds when AC grid or normal supply was turned OFF.
- The system disconnects instantaneously.

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