Assessment of Net-Metering Based Solar Systems Installed at IESCO & LESCO

January 2022

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DEUTSCHE ZUSAMMENARBEIT

Implemented by giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Institute of Policy Studies Islamabad

AEDB

Ministry of Energy
Power Division
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This study has been conducted by Institute of Policy Studies, Islamabad and commissioned by GIZ under Renewable Energy and Energy Efficiency II Project, jointly pursued by Power Division, Ministry of Energy (Government of Pakistan) & Federal Ministry of Economic Development and Cooperation (Federation of Germany).

IPS-Institute of Policy Studies (est. 1979) is an independent think-tank based in Islamabad, Pakistan, dedicated to promoting policy-oriented research, dialogue, and human development. With the particular focus on Energy, Water & Climate Change, Sustainable Development is one of the thematic areas at IPS.

January, 2022

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Foreword

Institute of Policy Studies, founded in 1979, is an independent, not-for-profit, civil society organization dedicated to promoting policy-oriented research. ‘Energy, Water and Climate Change’ is one of its comprehensive research programs, where the principal and dedicated focus is on the facilitation of renewable energy uptake in Pakistan.

Under the comprehensive domain of renewable energy transition in the country, IPS energy program is focused to provide workable insights into the pressing issues of power sector for integration of renewable energy sources. For successful energy transition, IPS provides support by investigating and developing pragmatic framework to the regulatory and facilitating bodies for increasing the share of renewable energy sources in generation mix. Some of the earlier IPS studies on the subject have focused on identifying the barriers and drivers in uptake of renewable energy based distributed generation as well as techno- economic assessment of grid-tied solar PV systems, market orientation of renewable energy integration and discovering the transition towards competitive trading of energy tilted towards the bilateral contract markets in the power sector.

IPS focus is primarily on Pakistan. Nevertheless, it maintains a conducive collaboration with the global community to highlight and discuss climate change mitigations in the context of global warming and increasing carbon emissions. The report in hand concludes the research undertaken to assess procedural, technical and quality related barriers and issues with the practices adopted in installation of solar PV systems in Pakistan. The study has gone through different stages and designed within a 4-month long activity plan under the Renewable Energy and Energy Efficiency (REEE II) project. The project is being jointly pursued by Ministry of Energy (Power Division), Pakistan and German Federal Ministry of Economic Cooperation and Development (BMZ) under the umbrella of GIZ (German Agency for International Cooperation). The objective is to move for a flawless and technically-sound deployment of solar photovoltaic systems at the grass-root level of the society. The suggestions, given in the study are based on quality check-up and technical inspection of installed systems which also include a roadmap keeping in view the vision of Alternative Energy Development Board (AEDB).

While presenting the report I would like to immensely thank Dr. Hassan Abdullah Khalid, Head of Electrical Power Engineering Department, Center for Advanced Studies in Energy, National University of Sciences and Technology (NUST), who lent his competent technical expertise, and provided expert input for this study. I am also grateful to the distinguished members of IPS Energy Steering Committee, especially Mirza Hamid Hassan, Ashfaq Mehmood, Ameena Sohail, and Syed Akhtar Ali for their valuable inputs and feedback during the course of the study. We also owe our thanks to members of GIZ Pakistan, AEDB, NEPRA, IESCO and LESCO for their much-needed participation for the assessment and finalization of the study. The recognition is to be given to IPS team led by Naufil Shahrukh, Shafaq Sarfaraz and Wali Farooqi for leading the operation and above all, Muhammad Hamza Naeem and Lubna Riaz from IPS ‘Energy, Water and Climate Change’ program deserve our appreciation for producing this valuable document.

Khalid Rahman
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The research team acknowledges and proffers tribute to the stakeholders and participants of the study who helped in providing operational, technical and administrative support regarding the necessities pertaining to the project. The team is highly thankful to the lead management of REEE project, GIZ including Mr. Ali Zain Banatwala (Team Leader, REEE), Mr. Asif Farid (Distributed PV Expert, REEE), and Mr. Muhammad Saeed (PGREF Lead, REEE) for their remarkable contributions.

We would like to also thank Mr. Shahjahan Mirza (Chief Executive Officer), Mr. Sheeraz Anwar (Director, Solar Thermal/ Wind), Mr. Syed Aqeel Hussain Jafri (Director, Policy), Mr Naeem Memon (Director, Solar-PV) and Mr. Muhammad Yaseen (Assistant Director, Solar Thermal) from Alternative Energy Development Board (AEDB), Ministry of Energy (Power Division) for their noteworthy coordination and keen involvement in the activity. The insights provided by Dr. Irfan Yousaf (Advisor-Renewable Energy) from National Electric Power Regulatory Authority (NEPRA) is appreciated for refining the study.

The support and assistance provided by the officials and staff of Institute of Policy Studies is highly appreciated. The team is immensely thankful to Mr. Naufil Shahrukh (General Manager-Operations), Mr. Muhammad Wali Farooqi (Research Officer-Pak Affairs) and Ms. Shafaq Sarfraz (Manager Outreach) for their operational and administrative support.

The study could not have been conducted without the consent and contribution of solar PV prosumers in Islamabad and Lahore, who agreed for the physical inspection of PV systems. All the noteworthy participants from the distribution companies, Islamabad Electric Supply Company (IESCO) and Lahore Electric Supply Company (LESCO) are appreciated for their insights and consultative sessions, which helped us understanding the problem and its various dimensions.

We also owe our thanks to executives and officials of Renewable Energy Association of Pakistan (REAP), Solar Quality Foundation (SQF), Solar Sigma (Pvt) Ltd., Renergy (Pvt) Ltd., Beacon Energy (Pvt) Ltd., Hadron Solar (Pvt) Ltd., and Green Nighbou Energy (Pvt) Ltd., for their volunteer and unconditional participation which assisted in the completion of the research work. The assistance provided by International Network of Energy Transition Think-Tanks (INETTT), a global network of think-tanks pioneering the policy directives for renewable energy uptake, is also appreciated for providing the global trends and experiences for the stated cause.

Principal Investigator

Executive Summary

With the approval of Distributed Generation and Net-Metering Regulations, 2015 by National Electric Power Regulatory Authority (NEPRA), the adoption of grid-tied solar photovoltaic systems by the consumers of the utility grid is on rise. The main driver behind the adoption is cost-effectiveness and green electrification. Net-metering is therefore gathering the pace as it attracts financial levers for the consumers. Total capacity of 268 MW[1] has been added to the distribution companies till October 2021, which is mostly concentrated in the urban areas of Pakistan.

NEPRA has specified the procedural requirements for the interconnection of the solar PV system, while AEDB has provided the descriptive guidelines to maintain the adequacy and compliance of the installations according to the international grid interconnection procedures. Nevertheless, there are indications of the barriers as well. They are mainly pertaining to the technical inspection and assessment of solar PV systems during the installations. There is no mechanism of technical inspection and quality check-up based on the necessary parameterization.

The study is based on the assessment and analysis of 40 prosumers. Physical inspection of the installations of these prosumers was conducted to inspect the major aspects of non-compliances being made. More than one in every five (***22.5%)*** of the solar PV systems were found non- compliant, where the PV module quality issues, lack of craftsmanship, non-compliance of standard electrical interconnection procedures and issues in mounting structure are identified. The common issueof quality compromise was thus evident in these systems. The existence of snail trail contamination, hotspots and delamination demonstrates the quality compromise of the PV modules. Furthermore, non-compliance was observed in the installed modules with the international standards defined for conformity.

One of the major findings demonstrates the non-compliance of electrical standard interconnection procedures, where the cabling and wiring, earthing, grounding and the technicalities associated with these aspects are not followed as per the regulations and standard procedures. Likewise, there are issues in the mounting structure of the PV modules in many cases, where the mounting structure is incompatible for balancing the mass of modules, which can lead to system damages in the longer run. The instances of malpractices being made by solar vendors in documentation of the prosumers are also highlighted and observed. The highlighted reasons behind the findings are assessed as:

1. There is a tendency to import non-compliant PV modules with the IEC standards. These modules, while cost less, have lesser efficiency due to some manufacturing defect/s and can reduce the technical productivity of the PV system.
2. Some of the uncertified solar vendors with AEDB are involved in quality and procedural noncompliance.
3. A technically strong checklist for the inspection and assessment is lacking. The resources in the distribution companies are insufficient to assess the noncompliance of the quality and procedures.
4. Lack of capacity of the stakeholders who are involved in PV system installation. This includes professionals from distribution companies and solar vendors.

It was assessed that the PV systems with quality compromise yield less energy than anticipated. This is mainly due to manufacturing defects, which damages the cells or the strings. Then non-compliances of the electrical interconnection standards can lead to serious incidents as well.

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[1] The data of the solar prosumers has been recorded from NEPRA's Generation Licenses for Net-Metering Solar PV systems.

Interactive sessions and meetings with the officials of distribution companies and solar associations were conducted to assess the insights on the key non-compliances. The meetings with the officials of distribution companies revealed that due to increasing concentration of adoption of grid-tied PV systems, the quality and technical inspections are not carried out regularly or sometimes at all. The staff and resources are insufficient to assess the technical configuration. The necessity of online portal is in order to streamline and speed up the application processes. The findings have also been shared with the officials of solar associations and vendors, who have assisted in projecting the issues in the installation of PV systems based on the current practices. The improvement in craftsmanship was identified as a key significant factor for the way forward. Training requirements and digitalization of the application process are yet other key factors highlighted by the REAP, SQF and several vendors.

It was observed that AEDB has regulated the guidelines and procedures for the import of qualified products associated with the solar PV systems in order to assess the import procedures and to detect the grey areas. While, the guidelines require proper documentation and compliance with the international standards, some solar vendors highlighted the practices where the non-compliant products are also being imported.

Based on these findings, following suggestions are presented in the report:

1. Third-party inspection by independent technical team can help in determining the shortcomings in the technical configuration of the PV system. The technical inspection based on certification and quality assurance, site inspection, locality, inverter and modules testing according to the prescribed checklist shall help in improving the installation practices of PV systems.
2. Digitalization of the process is required which is highlighted by major stakeholders.
3. For enhancement in the capacity-building and craftsmanship as well as streamlining the practices comprehensive and need-based trainings are required.
4. Creating awareness will create opportunities for the advancement in grid integration of distributed generation facilities.

Chapter 1

Introduction

Pakistan is situated in a region where atmospheric conditions are ideal for solar power generation. As the signatory of Paris Agreement and Kyoto Protocol, Pakistan is inclined to increase renewable energy integration into the energy mix with the ambitious target of 25% by 2025 and further enhancing to 30% by 2030 through Alternate and Renewable Energy Policy (ARE-2019). In this context, Government of Pakistan is emphasizing to implement enablers and drivers that can thrust up the renewable energy intake in the country. Amid the high cost of energy and load-shedding (in the past), the facility to integrate renewable energy based distributed generation was allowed in the context of net-metering. Distributed generation and Net-Metering Regulations 2015 allowed the consumers of the distribution utility to be shaped as "prosumers" where they are allowed to export the excess energy units to the grid and at the end of billing cycle, the units are offset. Net-metering based on solar photovoltaic systems is gathering pace globally as it attracts the financial instruments from the grid users. Pakistan has also experienced a rise in net-metering applications, but the growth has been significantly slow as compared to regional-peer analysis as well as the set target by Alternative Energy Development Board (AEDB).

Net-metering based solar PV distributed generation facilities have integrated the total capacity of 268 MW with the distribution grid[2]. The study previously conducted on the net-metering facilities and associated barriers indicated "lack of technical oversight and quality assurance" as a major aspect which can rust integration of distributed generation at the utility scale. Pertaining to the lack of technical regulatory oversight, one of the significant overlooked section lies with the distribution companies in complying with the technical regulations of integrated net-metered systems. Alternative Energy Development Board (AEDB) is streamlining quality assurance through certification of solar vendors and service providing companies to ensure the optimum operation of grid-tied PV systems, but technical constraints are being overlooked at the time of grid integration. The technical resources in the distribution companies are insufficient to prelude the compromise of defined standards necessary for sustainable performance of grid-tied PV systems[3]. In parallel, there is no appropriate "regulatory and accountability mechanism" where solar vendors could be penalized in case of providing subpar technology, or misleading/false claims on the products. AEDB has specified the technical regulatory codes which implies on solar PV panels, inverters, technical configuration, and Grid Interconnection Standards, which includes voltage operation ranges, frequency distortion, compliance of power factor, islanding and malfunction protection, harmonic distortions and power stability-transient analysis. But the technical oversight on quality assurance is a much weaker area which needs to be assessed.

1.1- Objectives of the Research Project

The study on technical oversight of the solar PV based net-metered system have the following objectives and scope of activities:

a. Preparation of checklist based on procedural requirements for setting up of a net-metering-based system through NEPRA's approved regulations.

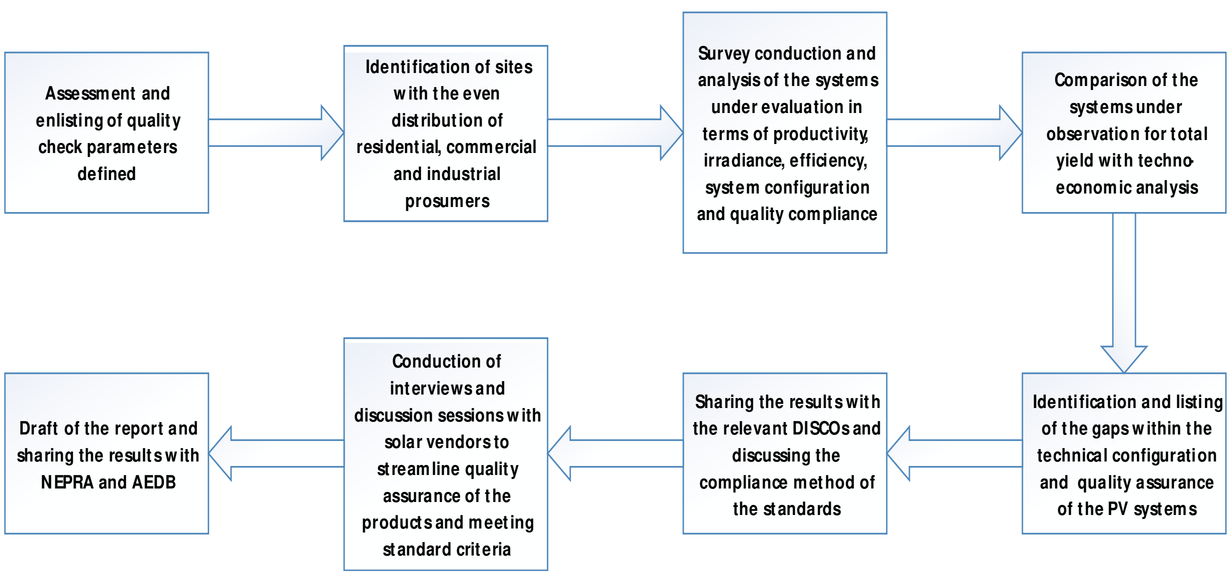
[2] Recorded till the month of October 2021

[3] The research study conducted by Institute of Policy Studies titled, "*Barriers and Drivers of Solar Prosumage –Case Study for Pakistan",* indicated that a strong inertia exists in compliance of quality standards by solar vendors and distribution companies.

b. Preparation of the checklist to ascertain quality from AEDB regulations guidelines and AEDB Certification Regulations, 2018.
c. Conduction of surveys of the selected sites for carrying out physical inspection of the installed systems as per checklist.
d. Verification of actual production of energy units produced by net-metering facility against the ones committed by the solar vendors/installers.
e. Conduction of consultative sessions with owners of solar systems to identify the problems/ issues faced during installation and operations.
f. Identification of the gaps in net-metering installations with respect to fulfilling procedural requirements of NEPRA's regulations and standards/specifications given under AEDB Certification Regulations, 2018.
g. Conduction of interviews and meetings with solar associations, vendors and installers to identify the issues faced by them in processing and installation of net-metering based systems.
h. Conduction of interviews and meetings with officials of IESCO and LESCO to identify the procedural requirements and practices adopted by them for quality installation of the systems.
i. Conduction of meetings with AEDB and NEPRA officials on the issues faced by the sector.
j. Evaluation of Billing of Quantities (BOQs) and quality assessment check-up for 50 kW solar PV system for Ministry of Foreign Affairs, supported by German Government.

1.2- Methodology

The research methodology for the activity comprises of the following steps:



1.3- Stakeholders' Engagement

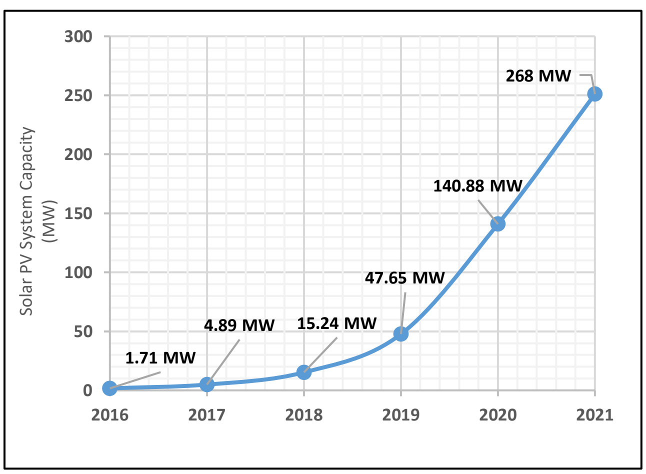
The progression of the activity involved a good set of stakeholders belonging to different aspects of the solar industry. The research study has the participation from regulatory and facilitating bodies, distribution companies, solar associations and vendors and prosumers. On the whole, a sample of 40 PV installations in Islamabad and Lahore have been included for the assessment of the procedural and quality check-up. **Table 1.1** shows the number counts for the stakeholders' engagement for this project.

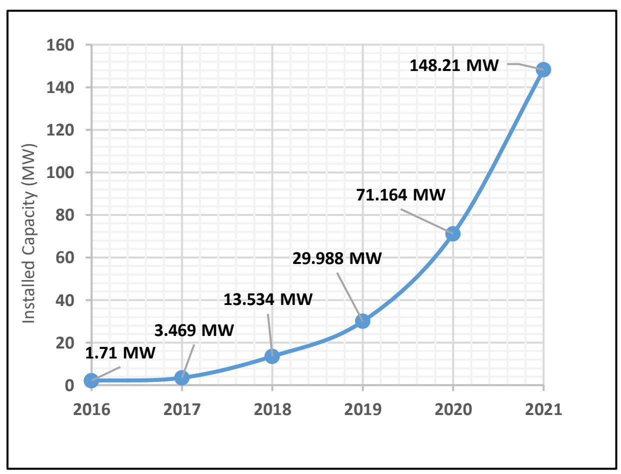
Meetings & Interactive Sessions with officials of REEE-GIZ, AEDB and NEPRA	7
Surveys Conduction of PV installations and Interviews of the Prosumers	44
Interviews and Meetings with Distribution Companies	2
Interviews and Meetings with Solar Associations	2
Interviews and Meetings with Solar Vendors	5
Pilot Project(s) for Third Party Validation Process and Mechanism	1

Table 1.1: Stakeholders engagement for persuasion of the research project.

1.4- Status and Appraisal of Progress in Adoption of Net-Metering Based Solar PV Systems in Pakistan

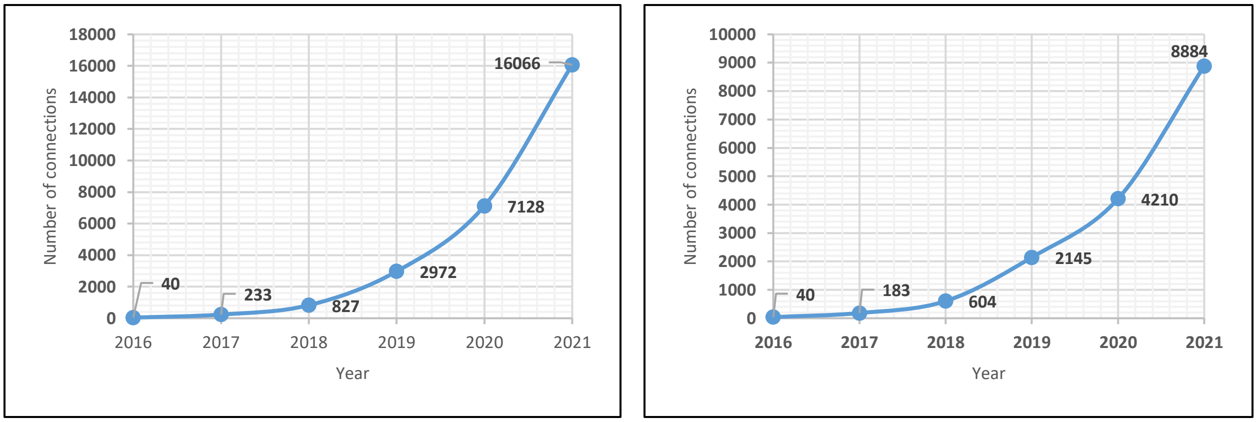
The growth in the adoption of solar PV based net-metering by the consumers of distribution utility has recently seen an exponential rise. The important driver behind the adoption is significantly related to the high electricity tariffs. About 88% of the installed systems are residential prosumers, while a large number of industrial, commercial and institutional consumers are also gathering pace of adoption. Cumulatively, 268 MW capacity with a total of 16,066 net-metered connections has been added to the distribution grid as of October 2021.





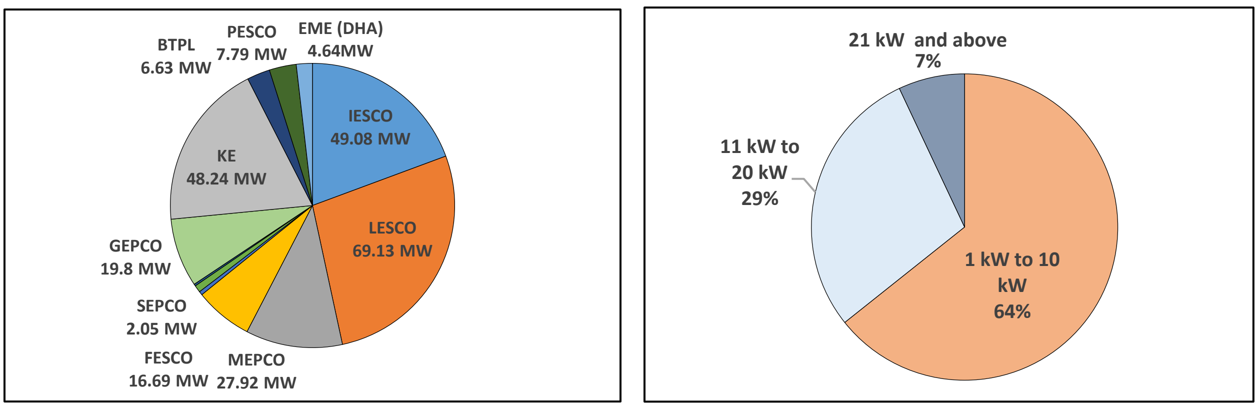
(a) *(b)*

Figure 1.1: (a) Expansion of cumulative installed capacity from solar PV net -metered systems.(MW)
(b) Yearly installed capacity (MW)



(a) *(b)*

Figure 1.2: (a) Total commissioned systems (Nos).
(b) Yearly commissioned systems (Nos)



(a) *(b)*

Figure 1.3: Capacity-wise distribution of net-metered PV systems in DISCOs of Pakistan. (MW)
(b) Distribution of net-metered solar PV system (Size)

Chapter 2

Regulations on Grid Integration of Solar PV-based Distributed Generation

This chapter assesses the technical and procedural regulations being implemented for the installation and grid integration of PV systems.

2.1- Regulation Framework by National Electric Power Regulatory Authority

National Electric Power Regulatory Authority (NEPRA) through its exercise of power related to the regulations of generation facilities, has established a framework of regulations for distribution generation namely Alternative & Renewable Energy Distribution Generation and Net-Metering Regulations, 2015. Through the SRO 892/2015, NEPRA has introduced the process of net-metering with the definition, application & interconnection processes, terms of agreement, facility design and operating requirements, and billing mechanisms, paving a roadmap for the distributed generators and distribution companies to facilitate a transition towards the integration of distributed generation on the utility side of the grid. The framework of regulations from NEPRA are defined as:

i. Eligibility of Distributed Generator

An electricity consumer of the distribution grid can avail the facility of distributed generator who falls into the category of **residential, commercial and industrial** consumer and should have **three-phase 400V or 11 kV** connections from the distribution company licensed by NEPRA. The distributed generation facility can be set up using **solar** and **wind** energy resources for power generation up to **1 MW**. Moreover, NEPRA has waged a fee of Rs. 1000 per kilowatt of the installation to acquire generation license.

ii. Licensing of the Generation Facility

The license is granted to the distributed generator (or prosumer) upon the completion of the application process for the customers meeting the eligibility criteria, opting for the distributed generation facility ***less than 25 kW***[4]. The eligibility of the applicants is based upon the type of consumer as specified in section 1, while the application requirements are being fulfilled with the respective distribution company. The proposed generation facility is assessed by its technical feasibility by the distribution company through the submission of Schedule-II which is meant to be **Standard Distributed Generation Application Form for Distribution Company.** The Schedule-II of the application describes the information of the consumer as well as the installer, with the following technical requirements of the distribution generation facility:

a. Geographical coordinates of the site (this requirement is optional).
b. Anticipated energy generation, consumption and export.
c. Schematic and single line diagram.
d. Technical configuration of the generation facility, which includes solar panel manufacturers, inverters specifications, nameplate ratings, and contractor's information.

[4] Through SRO 1448 (I)/2021, NEPRA has notified to exempt the requirement of generation licenses for the renewable energy distributed generation less than 25 kW.

After the fulfillment of the technical requirements from the consumer, the distribution company and the respective applicant enters into an agreement. In NEPRA Licensing Regulations, 1999, the interconnection studies and Schedule-II is made part of the licensing documents which is processed by the distribution company.

iii. General Obligations of Distribution Companies

For the eligible consumers to pursue net-metering, the metering requirements are to be met by the consumer itself. This comprises all the interconnection arrangements, including bi-directional meters, cables, system setup, etc. After the fulfillment of all the requirements, the distribution company and the distributed generator enters into an agreement of seven years.

iv. Technical Regulations Defined by NEPRA

a. Protection Requirement: The protection and control diagrams of the PV system site should be in accordance with the Grid and Distribution Codes. The Grid and Distribution Codes define the voltage and frequency should be in the specified limits. In accordance to it, a variation of 5% is allowed for the voltage range fluctuations while 1% is allowed for frequency.

b. Technical Codes for Inverters: The international standard for inverter integration with the grid is followed, named as UL 1741. While the grid integration follows IEEE 1547:2003, and the PV modules should be standardized with IEC 61215.

c. Interconnection Disconnect Switch: For the isolation of the system from the utility grid, NEPRA has mandated for the installation of interconnection disconnect switch.

d. Anti-islanding and Single-line Diagram: The inverters are specified to be compliant with the anti-islanding functions and single-line diagram of the distributed generation facility is required to make the part of documents.

2.2- Interconnection Requirement Defined by Alternative Energy Development Board (AEDB)

Alternative Energy Development Board (AEDB) through the Net-Metering Reference Guide for Installers, Consumers and Distribution Companies has described the roll-out standards for grid interconnection. According to it, the distribution companies have to ensure compliance of the initial requirements as well as technical configuration of the distributed generation prior to the agreement.

I. Grid Interconnection Standards - Electrical Parameters

The protection range has been standardized with the disconnection of the distributed generation facility from the grid if voltage, frequency, power factor and harmonics deviate from the specified range of operation.

- **Voltage Range**

The voltage level for the distributed generation facility has been defined in accordance to **IEC 61727** and defined as follows:

Voltage Range	Maximum Tripping Time (Seconds)
V < 50%	0.1
50% ≤ V ≤ 85%	2.0
85% ≤ V ≤ 110%	Normal Operation Range
110% ≤ V ≤ 135%	2.0
135% ≤ V	0.05

- **Frequency Range**

As per IEC 61727, the frequency range is defined as follows:

Frequency Range	Maximum Tripping Time (Seconds)
***f* < 47.5 Hz**	0.1
47.5 Hz < *f* < 51.5 Hz	Normal Operation Range
51.5 Hz < *f*	0.1

- **Power Quality Regulations**

As specified in IEC 61727 for the regulation of power quality associated with power factor incurred by the distribution generation facility, it should be 0.9 and greater (lagging) when the output is greater than the 50% of the system ratings. To manage the power factor in the prescribed range for the industrial consumers, the setup for power factor correction would be required in case the regulations are not met.

- **DC Current Injection**

In accordance to the IEC 61727, the DC injection of current from the PV system should not be greater than 1% of the rated inverter output current into the utility interface.

- **Islanding Protection**

Islanding protection for the PV system is defined as per IEC 61727 which specifies disconnection with the distribution grid in the case of grid de-energization.

- **PV Module and Inverter Standards**

The grid interconnection with the grid is specified to be standardized by **IEEE 1547:2003** according to the technical regulations defined by the distribution grid code.

- **Safety Recommendations:** Safety recommendations including protection of inverters, solar panels, DC wiring and mounting frame are defined as follows:
  - **Earthing Protection:** A minimum of two separate dedicated interconnection earth electrodes must be used for earthing of the solar system. The total resistance shall not exceed than 5 ohms. The equipment and system earthing shall be done separately with the dedicated conductors.
  - **Lightening and Surge Protection:** Lightening or surge arrestors are designed to absorb voltage spikes caused by electrical storms. The arrestors bypass the electric charge by providing the zero potential.
  - **Circuit Breakers:** Fuses and circuit breakers are to be used for the safety and electrical protection of the PV system due to short-circuiting.

Chapter 3

Quality and Procedural Non-compliances in Installation of PV Systems

In line with the activity, the assessment was carried out on number of PV system installations based in two distribution companies, Islamabad Electric Supply Company (IESCO) and Lahore Electric Supply Company (LESCO). From each of the distribution companies, a sample of 40 systems—evenly distributed, were considered where the selection criteria of the samples consisted of proper allocation of prosumers in the respective category of residential, commercial/institutional and industrial consumers. The assessment needs of the technical inspection and compliance of the procedural regulations in installation of solar PV system was considered on the base idea to detect the quality non-compliance of the solar system accessories, follow-up of the technical procedures regulated by AEDB and NEPRA for grid integration, and the narrative of the prosumer on after-sale services and efficiency of solar PV based net-metering in availing the leverages of net-zero billing and reliability of the operations.

3.1- Status of Net-metering Installation in IESCO and LESCO

IESCO and LESCO have a large number of solar PV system installations amid the existence of resourceful society, industrial sector and commercial activities. IESCO and LESCO are considered the pioneer distribution companies to allow solar PV based net-metering. In the **Figure 3.1** and **Table 3.1**, the progress and installed capacity erected due to net-metering has been shown in both distribution companies.

DISCO	Total Connections	Year-wise Issued Net-Metering Licenses						Total
		2016	2017	2018	2019	2020	2021[5]	
IESCO	2,837,238	18	86	189	682	1,261	2,585	4,821
LESCO	4,598,784	2	95	204	704	1,487	2,745	5,237

Table 3.1: Issuance of generation licenses for solar PV systems in IESCO and LESCO

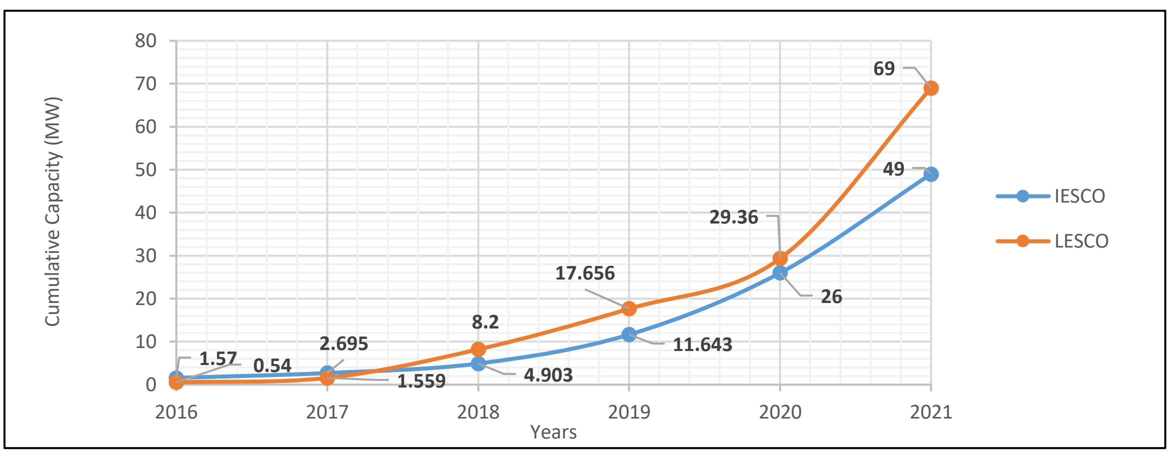


Figure 3.1: Cumulative capacity of solar PV net -metered systems installed in IESCO and LESCO (MW)

[5] The data of the generation licenses have been recorded till October 31, 2021.

3.2- Survey Criteria and Systems Under Observation

The selection criteria for the survey conduction was based on the following key aspects:

i. The installed PV system should be more than one year or older.
ii. The distribution based on the category of the prosumer is based upon the concentration ratio of residential, commercial/institutional and industrial consumers in net-metering connections.
iii. Any shortcoming in the selection of the sites should be covered with selection of other categorical prosumers with the availability of consent.

Based on these aspects, the details of the sites and prosumers have been provided in **Table 3.2** The **Figure 3.2** summarizes the solar PV systems inspected and surveyed to assess the non-compliances, based in both distribution companies.

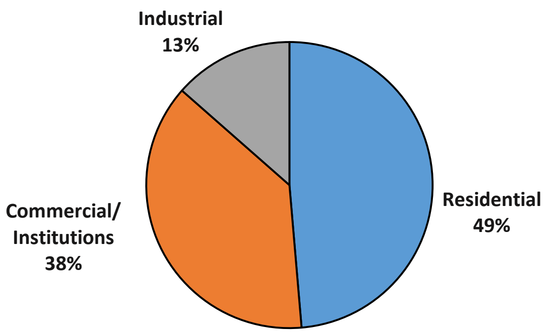


Figure a: Category of Prosumers under assessment in IESCO & LESCO

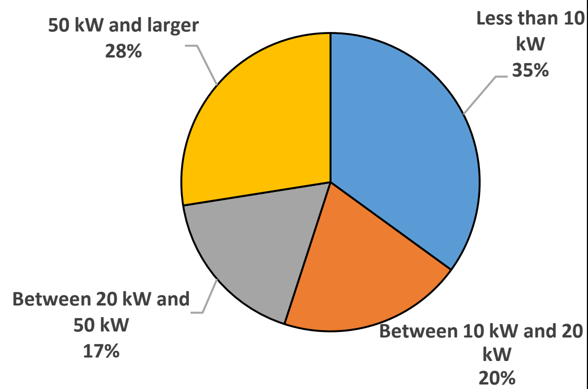


Figure b: PV System Size under assessment in IESCO & LESCO

Figure 3.2: Solar PV systems for assessment in IESCO & LESCO

Of the 40 solar PV systems assessed, the non-compliant systems with the procedural and technical regulations were found to be 9 in number, which constitutes less than one-fourth (22.5%) of the overall sample number of PV installations. The PV installations which are found non-compliant with the procedures do have the common issues of quality compromise on the modules being used in all the systems. Inadequacy in wiring and interconnection procedures, improper mounting structure and lack of technical craftsmanship are yet other practices being used in installation of PV systems. Some of the issues pertaining to these are listed as:

a. The solar PV modules have physical abnormality on the cells, glass and laminated sheets. These abnormalities can be seen with the naked eye at a distance of 7 feet or less.
b. The proper interconnection procedures between the modules, strings, and inverters were found inadequate.
c. There are the problems with the mounting structure. Some of the structures are found improper, where the modules are disoriented or in a shape demonstrating immense stress, as the structure is not adequate to carry the weight of the modules.
d. Some of the prosumers were observed to be dissatisfied with the services being provided by the solar vendors. The provision of services, related to after-sale and warranty and guarantees are not properly made by some solar vendors.

e. Some of the instances are experienced with the malpractices in the documentation of the prosumers. The information of the prosumers which is provided to NEPRA for issuance of generation licenses is found improper or misleading.

IESCO			
Sr. No.	Category	System Size (kW)	Name of the Consumer
1	Residential	5.1	Mr. Muhammad Rizwan
2	Residential	5.22	Gp. Captain Naseer Ud Din
3	Residential	5.28	Mr. Pervez Iftikhar
4	Residential	6	Syed Aziz Ui Hassan Rizvi
5	Residential	6.49	Mr. Muhammad Arshad
6	Residential	9	Mr. Yasir Rehman
7	Residential	10.24	Mr.Ghulam Jilani
8	Residential	10.24	Mr. Zafar Ahmad
9	Residential	10.45	Mr. Raja Muhammad Nadeem
10	Residential	16.905	Mr. Aized Hassan Mir
11	Industrial	21	Mr. Rao Atiq ur Rehman
12	Commercial/ Institutional	21.2	Mr. Haroon Ur Rasheed Farooqi
13	Industrial	29.9	Mr. Muhammad Naeem Awan
14	Commercial/ Institutional	35.1	Beacon house School Systems
15	Industrial	39.6	Mr. Shabir Ahmed Khan
16	Commercial/ Institutional	50	GM (ADMN) Foundation University
17	Commercial/ Institutional	59.73	Sec Rawalpindi Ch. Of Commerce & Industries
18	Commercial/ Institutional	90	Mr. Aamir Hussain
19	Industrial	100.36	Mr. Abid Ali
20	Commercial/ Institutional	137.6	Mr. Ghulam Mohiuddin

LESCO			
Sr. No.	Category	System Size (kW)	Name of the Consumer
1	Residential	3	Mr. M. Pervaiz Chaudhary
2	Residential	4.68	Mr Abdullah Husnain
3	Residential	7.26	Mr. Khalid Naeem
4	Residential	7.29	Muhammad Iqbal Tahir
5	Residential	7.5	Mrs. Anjum Nafees Khan Chaudhry
6	Residential	8.8	Mr. Muhammad Hanif
7	Residential	10.45	Mian Abdul Quddous
8	Residential	12.6	Mr. Agha Adnan Khan
9	Residential	12.96	Mr Shaharyar Hamid
10	Commercial/ Institutional	14.85	Mr. Arshad
11	Commercial/ Institutional	18.5	Mr. Zahid Sultan Jadoon
12	Commercial/ Institutional	26	Akbari Public School (Muhammad Ahmad Raza)
13	Commercial/ Institutional	44	Mian Muhammad Ali
14	Industrial	137.6	Rana Ghulam Shabbir
15	Commercial/ Institutional	117.48	Mr. Sohail Afzal
16	Industrial	118.8	Mr. M Haroon
17	Commercial/ Institutional	131.04	Mr. Sohail Afzal
18	Commercial/ Institutional	139.42	University of Engineering & Technology, KSK
19	Industrial	236.54	Mian Ghulam Murtaza (Fast Cables)
20	Industrial	479.88	Mr. Muhammad Hanif

Table 3.2: List of solar PV installations under assessment

3.3- Ratio of Non-compliances

In the nine solar PV installations, the categorical sectoring of the non-compliances detected are given as below.

Quality compromise on PV module	9
Non-compliance of standard electrical connection scheme (Includes DC, AC, grounding and earthing)	6
Malpractice in documentation and application	7
Issues in structure mounting and improper cleaning	4
Customer's dissatisfaction with after-sale services and vendor's response after installation	3

Table 3.3: Number of instances of non-compliances detected in survey.

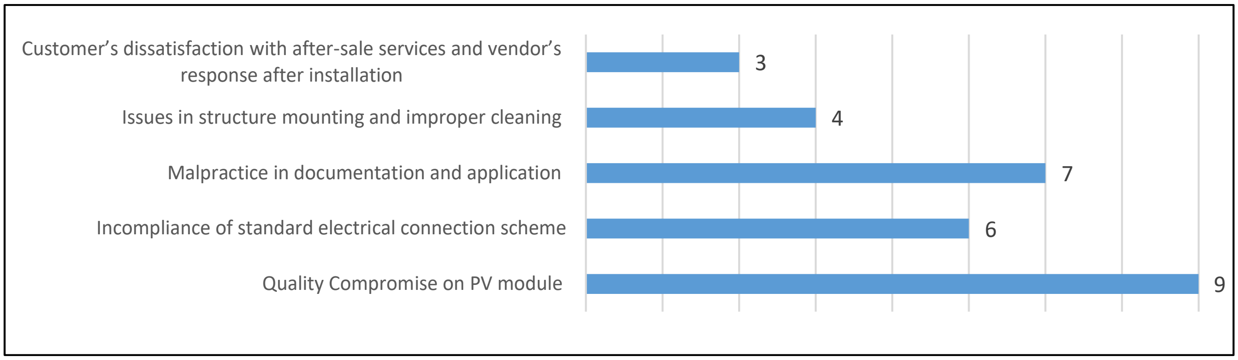


Figure 3.3: Instances of non-compliance found in sample PV systems in IESCO & LESCO

3.4- Quality Compromise on PV Modules

The quality compromise in installation of the PV modules is the most dominant issue where non-standardized modules with manufacturing defects are found installed. These modules are assumed to be flawless in the visual inspection at the time of installation – yet over the course of time and connectivity, as well as exposure to sunlight leads to arising of spots, fading of the color of internal sheet, delamination and yellow-buds, which demonstrates the quality compromise when the module was manufactured. All the PV modules are apparently clean and spotless when these arrives from the manufacturing assembly, but over time the issues, as mentioned above, start showing upon the module's surface. The quality compromise on PV modules has been further investigated with the following categories of defects.

i. Snail Trail Contamination

Snail trails or snail tracks are the discolored lines that occur in the front side metallization of PV cells. It usually appears after 3-5 months of outdoor exposure. Snail trails are discoloration of the modules, majorly caused by moisture entering through the back-sheet and diffuses to the cell surfaces. It has been established through the literature that a degradation of 2.36% annually was observed with 58.5% of PV modules impacted by snail trails. Moreover, snail trail and micro-cracks are found correlated with each other on the PV modules, increasing the normal degradation factor to 0.12% annually. The snail trail observed during the surveys is visible with the naked eye, with varying level of concentration found on the PV modules.

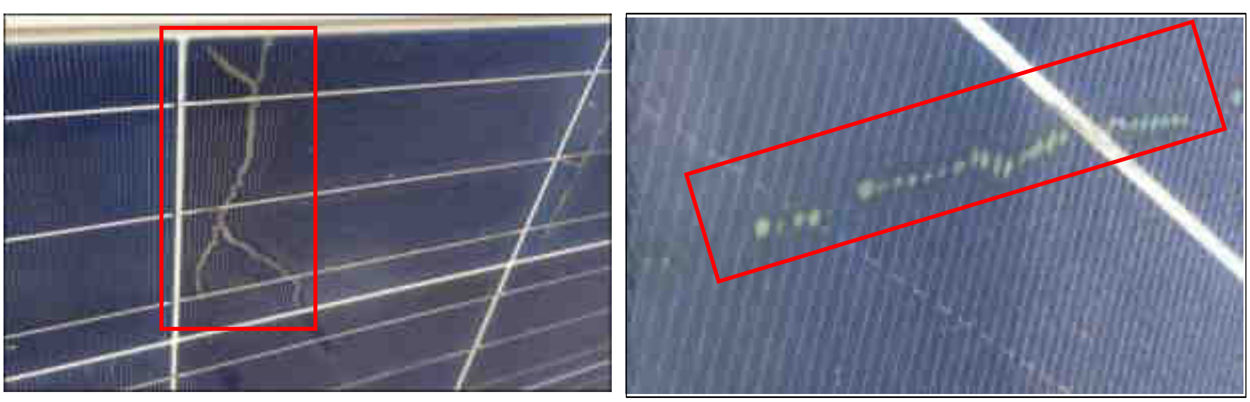


Figure 3.4: Snail trail can be seen contaminating on the surface of PV modules.

ii. Hotspots

Hotspots are the defects on PV modules where the high temperature concentration affects the cells or other component. Some of the reason of penetration of hotspots on the PV module are mismatching of the cells, or corrosion due to moisture in back-sheet or the defects in the interconnection between the cells in the module. Moreover, badly soldered connection points also contribute to this defect. In summary, the internal module failure, such as cell material defects (e.g. inappropriate shunt and high series resistance), cell cracks, poor soldered joints and local delamination are some of the causes for the emergence of hotspots on the PV module.

Hotspots impact on the performance of the PV module when observed, the hotspot reduces the performance with an annual degradation of 2.16%. As much as 15.47% of the energy generation is reduced due to hotspots compared with the actual anticipated power.

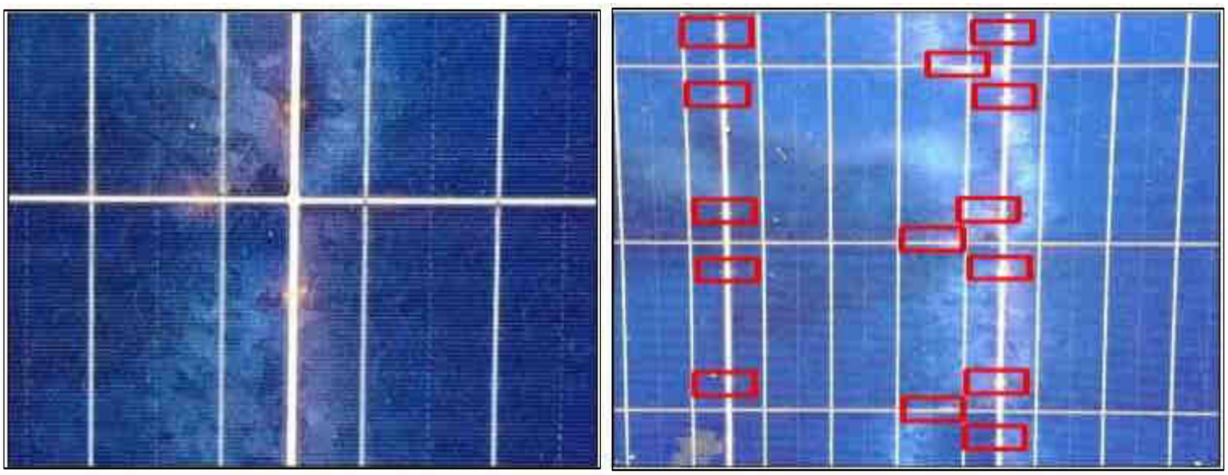


Figure 3.5: Hotspots on the PV modules. The defects can be seen highly concentrated on the module and having formed a symmetry.

iii. Delamination

Delamination is one of the failures of the PV module due to usage of cheap material and wrong processing techniques in manufacturing. This type of defect causes the penetration of moisture inside the glass plate of the module where it corrodes the inner protective components. The main reason of delamination happens to be the manufacturing defect which causes the inappropriate fixture of the outer components. Bad cross-linking and polluted cell surface are two of the prominent reasons of delamination of the PV module surface. During inspection for the activity, it was observed that the delamination itself arises with the other PV module defects, such as hotspots and snail trail contamination. Mutually, delamination occurs with the subsequent variable defects.

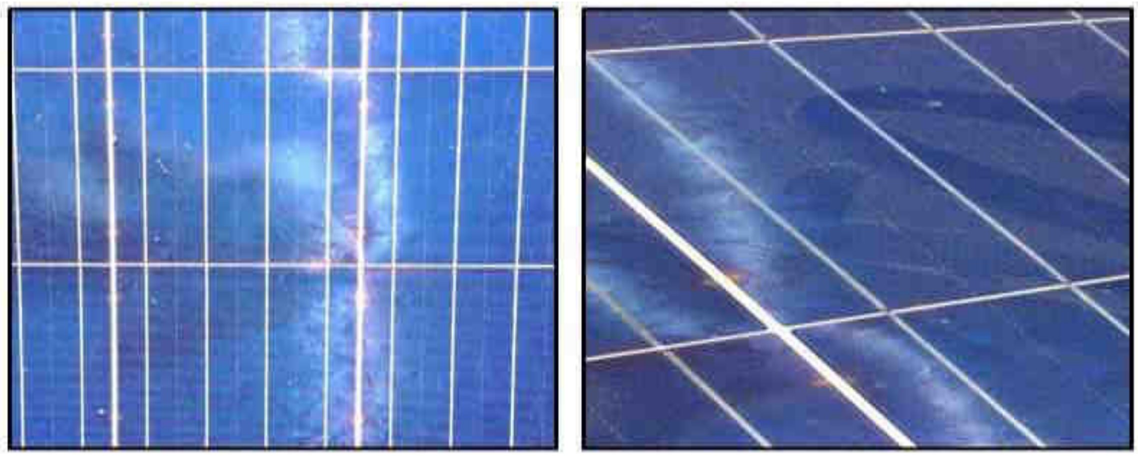


Figure 3.6: Delamination on the PV modules

iv. Installation of Unverified and Uncertified PV Modules

The PV modules are required to be verified and certified under the International Electro-Technical Commission provided standards which ensure the performance testing at the time of manufacturing. According to the IEC standardizations, the PV modules are required to be tested as per defined sequence, which includes module performance testing, module safety tests, partial discharge test, conduct bending test, and terminal knock-out testing. The summation of all these tests is governed by the schematic tests of IEC 61215, IEC 61646 and IEC 61730[6]. Further, performance testing for each type of PV module is being done according to the specified standards, i.e. IEC 61215, that leads to the standard compliance necessary for crystalline PV modules, while IEC 61646 specifies thin-film PV modules.

During the surveys, there were some PV installations where these standards were not mentioned on the "nameplate sticker" of the module. At finalization of the product on the assembly line, IEC makes it mandatory to mention the safety and performance testing to be displayed on the electrical products. Against this context, missing of the standards from the specification plate demonstrates two hypotheses;

a) The PV modules have not qualified these standards and are in the low-graded category with respect to quality.
b) Or the nameplate specifications have been manipulated or changed by local practitioners of PV installation.

The specification stickers without the standards define their non-compliance of the necessary standards, or assumed to be manipulated or changed. The **Figure3.8** shows a sticker which lacks the necessary tests that had to be conducted.

[6] PV Modules Safety and Performance Qualification Standards according to IEC 61730:2004. The details of these standards can be accessed at: http://www.solar-academy.com/menuis/IEC_61730022701.pdf

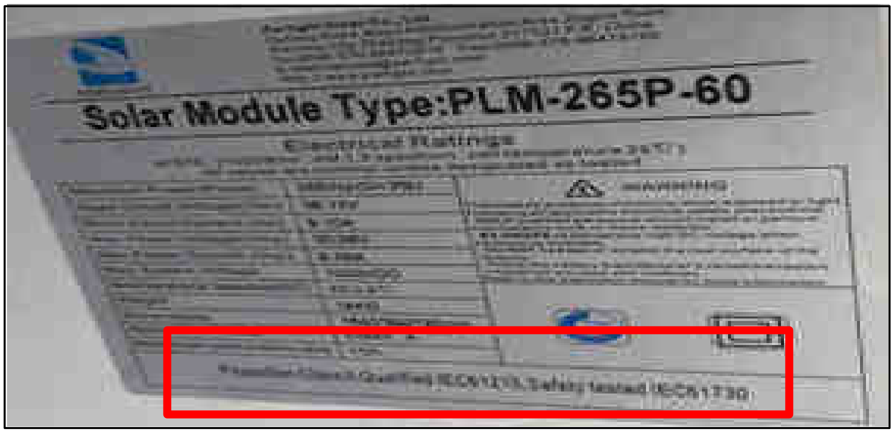


Figure 3.7: The performance and safety qualification tests are mentioned on the sticker of the PV modules by the manufacturers.

Figure 3.8: The nameplate sticker does not show the IEC Standards compliance.

3.5- Non-Compliance of Standard Electrical Interconnection Procedures

The lack of technical craftsmanship among the technicians and installers of solar PV systems has caused the non-compliance of standards electrical interconnection schemes, defined and mandated in IEEE 1547[7]. IEEE 1547 specifies the electrical interconnection schemes which integrate the distributed generation facility with the utility grid. The non-compliance with the standard electrical interconnection schemes is associated with the followings;

a. The wiring and cabling of the PV modules are not appropriately done. Some of the inspection results show unclipped power cables and can result in some hazardous incidents.
b. The appropriate grounding and earthing procedures are not followed according to the set compliance.

[7] Interconnection of Distributed Generation with the power system, IEEE 1547.

c. The electrical interconnection work is being done with issues emerging from proper cabling schemes, lack of craftsmanship and ignorance of fatal incidents which may result from inadequate cable installation.

The details are more specified regarding the non-compliance of electrical interconnection with respect to three main issues.

i. Inadequate Wiring and Cabling

One of the most pressing issues found in the non-compliant systems is associated with the cabling and wiring practices being followed by PV system installers. The cables connected with the PV strings and inverter which has to pass through the external atmosphere on a roof-top or building are found very inappropriately lying on the ground, or unclipped with the mounting structure. The inadequacy in wiring and cabling may increase the probability of severe and serious hazards such as fires, short-circuiting, and electricity shock.

Figure 3.9: The DC power cables are lying on the roof/ground exposed to external interventions.

Figure 3.10: Power cables lying unclipped can result in serious incidents and fire hazards.

Figure 3.11: The inadequacy in wiring and cabling when PV module is connected in strings.

ii. Non-Compliance of Earthing and Grounding Procedures

The technical interconnection guidelines instructed to be adopted by solar installation companies refers to IEEE 1547 and the same has been emphasized by AEDB in its technical guidelines. IEEE 1547 stresses the importance of connectivity of earth wire, or zero ground, with all the metallic exposed components of PV system. It is generally done to meet the safety parameters and to avoid accumulation of static charge. Moreover, the instances of lightening destruction of the PV modules are also minimized. While during installation, there are some instances where the requirement of a proper interconnection of the ground and earth mechanisms are not followed. This non-compliance is majorly associated with the lack of technical craftsmanship of the solar PV installers.

The modules are needed to be electrically connected with each other to avoid the curtailment of static charge. Moreover, during the lightening surges, this protection arrangement provides a robust zero-potential. The common practice being adopted is to connect the ground wire of the module with the mounting structure. The mounting structures are generally made of stainless steel, which provides higher metallic resistance. The stainless steel, or iron garter, are strong metals appropriately used for mounting structure for PV systems, but lack in electrical characteristics of conductivity. Connecting the ground wires with the mounting structure only, while not providing a separate ground or neutral wire to the PV modules structure, is taken not as appropriate practice.

The best practices indicate the connection of panel-to-panel for appropriate earthing. It also reduces the instances of damages caused by lightning storms, giving an extra ground potential in parallel to the lightening arrestors. The appropriate practice to be adopted for grounding is demonstrated in **Figure 3.13**.

Figure 3.12: The proper grounding procedures for earth connectivity needs the PV panels to be connected electrically.

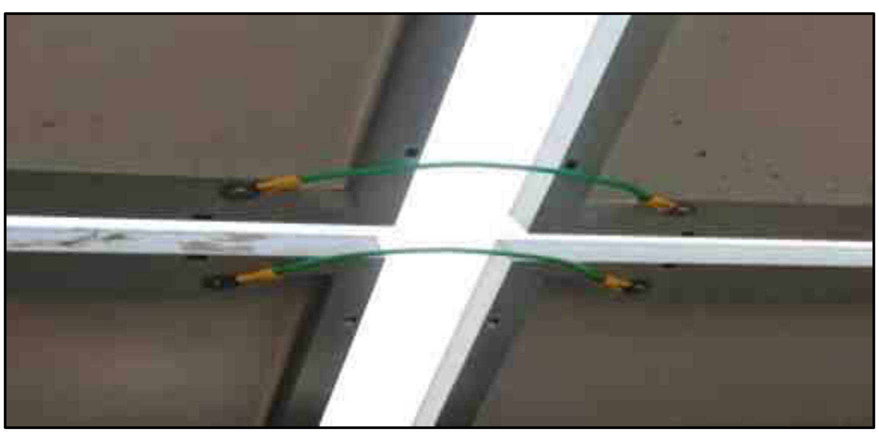


Figure 3.13: The panel-to-panel electrical connection of the module's frame is recommended for compliance of the standards.

iii. Lack of Craftsmanship

Improvement in craftsmanship is one of significant elements which is needed to be implemented. The issues in the electrical standards interconnection procedures are very much likely to arise due to lacking in craftsmanship and technical training of the technicians and installers. Moreover, due to this lacking, issues have arisen pertaining to negligence in proper connectivity which on one hand can be the reason of fatal incidents, but on the other hand can reduce the performance of PV system in the longer run causing interruptions and system blackouts.

3.6- Issues in Mounting Structure of PV Systems

On some instances, the mounting structure is found inappropriate in handling the design and mass of the PV modules. This causes the probability of damage of PV modules. Also, during the inspection under the activity, the consequences were demonstrated where the PV modules in a string became "convex" due to inappropriate mounting structure. In the longer run, this makes the PV system likely to be vulnerable to the breakage of upper glass plate, tilting of the metallic structure of module, and collapse of structure during the severe climatic interventions.

Figure 3.14: The string highlighted in the picture is convexed due to inappropriate mounting structure

3.7- Malpractices in Documentation and Application of the Prosumers for Issuance of Generation Licenses

For the installation of PV system based distributed generation facility, NEPRA has made it compulsory to acquire generation licenses, which has been recently exempted for the systems lesser than 25 kW. The issuance process of the generation licenses needs the prosumer to apply in the respective distribution companies, from which the application is forwarded to NEPRA. During the inspection, one of the issue with the administrative domain has been highlighted concerning the proper documentation of the prosumer.

The practice is commonly conducted by the solar vendors to hide or manipulate the identity of the prosumers. The contact details and address of the installed site is incorrectly provided, where the instances of feedback and site inspection from the authority or distribution company are minimized. Moreover, this administrative malpractice is identified to be conducted to avoid the communication linkage between the regulatory authority and the prosumer. Seven systems were found with these malpractices.

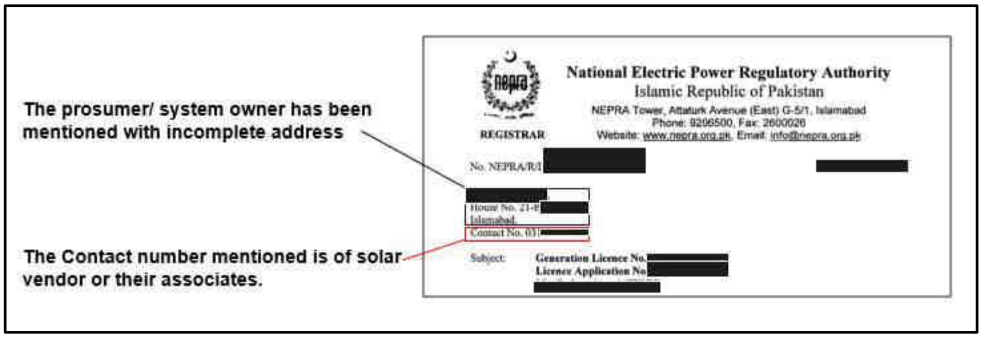


Figure 3.15: Malpractices in the documentation of the prosumers

3.8- Summary of the Assessment

Overall, the nine systems and the problems specified are shown in the **Table 3.3**.

Distribution Company	System Size (kW)	Quality Compromise on PV Module			Non-Compliance of Electrical Interconnection Procedures	Issues in Mounting Structure
		Snail Trail Contamination	Hotspots	Delamination		
IESCO	10.24	✓			✓	✓
	16.905	✓			✓	
	21.2		✓	✓	✓	✓
	90		✓	✓		
	100.36	✓			✓	
	137.6		✓			
LESCO	7.5		✓	✓	✓	✓
	18.5	✓	✓		✓	✓
	26	✓				

Table 3.4: Summary of issues in PV systems

From the technical inspection and assessment, it was evident that the deliberate usage of quality compromised and low-grade PV panels is being practiced. The inspection and research for the possible causes of PV system installation can be summarized as following:

i. Import of Quality-compromised PV Panels

In Pakistan, the availability and purchase of PV modules is dependent on the foreign market. The PV modules, inverters and the other associated accessories, like data logger, energy export limiters, etc. are being imported. The specific issue with the import of non-compliant and uncertified PV modules is an important one where the retailers or the solar vendors import low-grade PV panels. This practice not only reduces the energy productivity of PV systems, but also causes inadequacy in the market dynamics.

ii. Role of Uncertified Solar Vendors

To maintain the quality assurance and adequacy of the whole operation, AEDB has regulated the certification of solar vendors. The solar vendors are specified in three categorical sequences based on their expertise and experience in erection of PV projects. The non-certified vendors with AEDB are also performing PV installations. It is assumed that, these solar installers are mainly accountable for the non-compliances. As the inspection procedures do not exist, the non-compliances are difficult to prelude in routine installation. There are the certified solar vendors who are in the practice of receiving money to process the applications from non-certified vendors and this specific problem is quite the prominent.

iii. Lack of Technical Inspection and Parametrization Checklist

The technical inspection of the PV system, when in the stage of commissioning, is mandated to be done by the distribution companies. But, technical inspection by the staff of DISCOs is not done after installation. Furthermore, the necessary parameters are not documented pertaining to the installed system. This leaves a grey area, where the malpractices and procedural non-compliances are adopted by the solar vendors.

iv. Necessity for Capacity Building and Enhancement of Technical Resources

The technical resources and training of the installers and solar vendors are insufficient. The technical resource-building and standardized practices are needed to be regulated.

v. Lack of Quality Check-list for Adoption for PV System Installation

The demand of solar PV equipment is met through the foreign markets and the set of procedures which specifies the quality assurance are specified. There is the complete absence of a checklist which assures the quality and category of solar PV panels.

3.9- Technical Productivity and Yield Analysis of PV Systems

The inspection and assessment of the issues and problems is further investigated with the yield analysis and technical productivity of these PV systems. The sample of four systems, installed at four different locations, is assessed on the basis of their billing, anticipated energy generation and actual energy generation. Two of these four PV systems are non-compliant with the quality and interconnection procedures. This highlight the impacts of quality compromise on the PV systems, while the operational time span of these systems is not more than four years.

i. PV Systems Under Assessment Providing Operational Efficiency

Two systems which comply with the procedural and technical interconnectivity are assessed to check for the yield analysis from each distribution company. The technical yield analysis provides a brief presentation of energy exchange. For both of these systems, the energy generation is adequate for fulfilment of household requirements, as well as to maintain a net-zero of energy import-export. The comparison of the anticipated and actual energy generation significantly shows that the systems are well-performing while the system capacity is good enough to meet the demand of the prosumer and energy export to the grid.

DISCO	System Size (kW)	For the month of October 2021						Comparison of System Yield and Percentage Productivity
		Total Anticipated Energy Generation from PV System (kWh)	**Total Energy Generation** (kWh)	**Self-Consumption from PV System** (kWh)	**Energy Consumption from Grid** (kWh)	**Energy Export to Grid** (kWh)	**Net-Metered Energy**[8] (kWh)	
LESCO	**6**	810	789	128	224	661	**+ 437**	97.4%
IESCO	**19.2**	2592	2404	829	706	1575	**+ 896**	92.7 %

Table 3.5: Yield analysis for 2 systems compliant with procedural requirements

ii. Yield Analysis for PV Systems with Quality Compromise on PV modules

The sample of two PV system installations has been assessed to check the impacts of quality compliance on the productivity and yield. The PV installation with the capacity of 10.24 kW is contaminated with snail trail, while the system with capacity of 21.2 kW is affected by hotspots. The detail table for the technical yield assessment of the systems non-compliant with the quality of the PV modules are shown in **Annexure VII**.

DISCO	System Size (kW)	For the month of October, 21						Comparison of System Yield and Percentage Productivity
		Total Anticipated Energy Generation from PV system (kWh)	**Total Energy Generation** (kWh)	**Self-Consumption from PV system** (kWh)	**Energy Consumption from Grid** (kWh)	**Energy Export to Grid** (kWh)	**Net-Metered Energy**[9] (kWh)	
	10.24	1382	1104	585	1338	519	**1186**	79.8%
IESCO	**21.2**[10]	2943	2365	2080	5196	285	**4911**	80.3 %

Table 3.6: Yield analysis for the systems with quality compromise on PV modules.

The system with the capacity of 10.24 kW, as demonstrated above, could optimally meet the energy consumption if the system yield could be maximized. However, due to the snail trail contamination, the reduction of 21.2% of energy generation is eminent. Similarly, for the system with the capacity of 21.2 kW which is affected by the hotspots, the reduction in energy generation can be assessed at 19.7%. The degradation of energy based on the percentages and daily prosumerism highlights that energy generation capacity is sufficiently reduced by the defects, while the installation of these two systems is not older than three years.

iii. Empirical Presentation of Technical Yield and Grid Export of Netmetered Systems

To demonstrate the empirical presentation of the net-metered systems, two systems are considered for a detailed analysis. The analysis has been demonstrated for the month of October, 2021 for 10.24 kW and 19.2 kW PV system, installed at the residential prosumers. Figures and the tables demonstrate the grid-

[8] The positive (+ve) sign demonstrates the units are credited against the export of units to the grid.
[9] The energy is net-metered while the energy import from grid is higher than the export to the grid.
[10] The system with the capacity 21.8 kW is undersized according to the energy usage of the prosumer.

parity and consumption of energy from PV system. The PV system with 10.24 kW is undersized according to the energy consumption of the user. Moreover, it can be assessed that with the consumption of 1,754 kWh of the units for a month, the net-metered PV system facilitate the reduction in the bill with the percentage of 64%. While, for the other system under assessment, which yields enough production to credit the net-metered units, the demonstration is given. The system is found optimally adequate for Net-Zero, as it yields 2,404 kWh of energy against the total consumption of 2,431 kWh for the month, with the net-metered units are 896 kWh.

Total Consumption of Energy	1,754 kWh
Energy Produced from PV system	1,127 kWh
Self-Consumption of Energy from PV system	491 kWh
Energy Export to Grid	636 kWh
Energy Import from Grid (Off-Peak)	974 kWh
Energy Import from Grid (On-Peak)	289 kWh
Net-Metered Energy Units	**338 kWh (Payable to DISCO)**
Payable Bill	**627 kWh**

Table 3.7: Technical yield analysis and grid-parity for 10.24 kW PV system

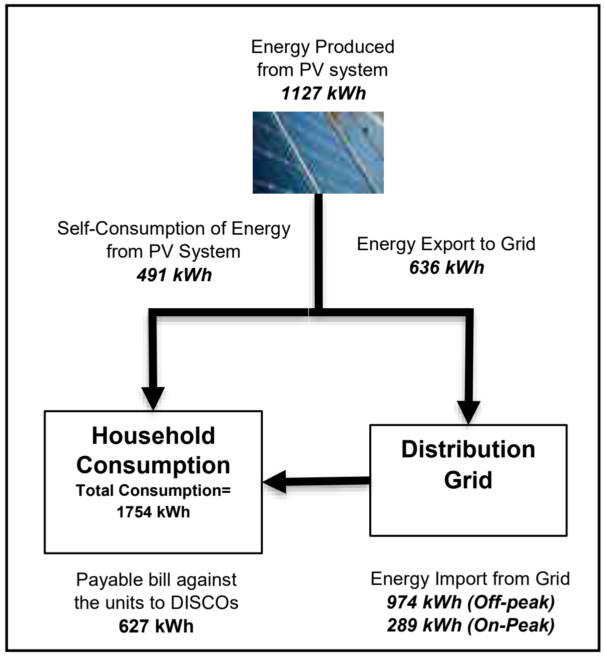


Figure 3.16: Graphical demonstration of grid-parity and self-consumption from 10.24 kW PV system

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Total Consumption of Energy	2,431 kWh
Energy Produced from PV system	2,404 kWh
Self-Consumption of Energy from PV system	829 kWh
Energy Export to Grid	1,575 kWh
Energy Import from Grid (Off-Peak)	706 kWh
Energy Import from Grid (On-Peak)	677 kWh
Net-Metered Energy Units	**896 kWh (Creditable)**
Payable Bill	**Nil**

Table 3.8: Technical yield analysis and grid-parity for 19.2 kW PV system

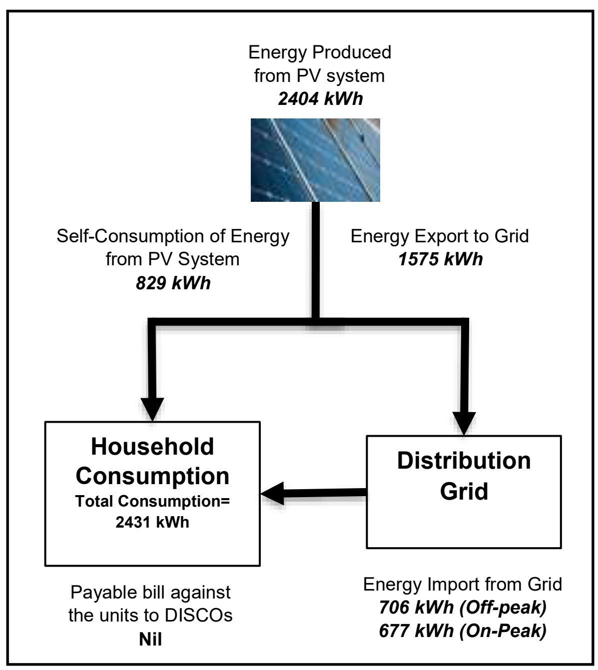

Figure 3.17: Graphical demonstration of grid-parity and self-consumption from 19.2 kW PV system

In a similar manner, the yield analysis has been demonstrated for the different range of systems with the capacity of *10.8 kW, 35 kW, 39.6 kW* and *137 kW* to anticipate the grid parity and the actual billing mechanism of the PV prosumer.

10 kW:

Total Consumption of Energy	949 kWh
Energy Produced from PV system	1,689 kWh
Self-Consumption of Energy from PV system	760 kWh
Energy Export to Grid	929 kWh
Energy Import from Grid (Off-Peak)	113 kWh
Energy Import from Grid (On-Peak)	76 kWh
Net-Metered Energy Units	**816 kWh (Creditable)**
Payable Bill	**Nil**

Table 3.9: Technical yield analysis and grid-parity for 10 kW PV system

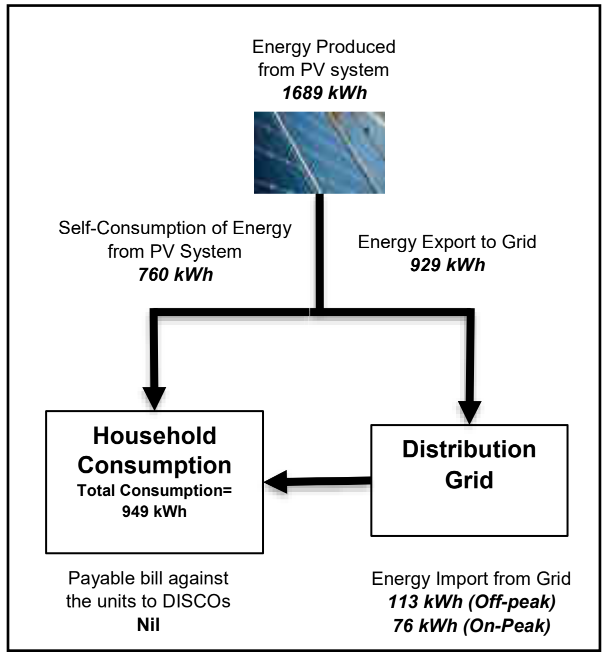

Figure 3.18: Graphical demonstration of grid-parity and self-consumption from 10 kW PV system

35 kW:

Total Consumption of Energy	6,650 kWh
Energy Produced from PV system	5,770 kWh
Self-Consumption of Energy from PV system	4,650 kWh
Energy Export to Grid	1,120 kWh
Energy Import from Grid (Off-Peak)	1,840 kWh
Energy Import from Grid (On-Peak)	160 kWh
Net-Metered Energy Units	**720 kWh (Payable to DISCO)**
Payable Bill	**880 kWh**

Table 3.10: Technical yield analysis and grid-parity for 35 kW PV system

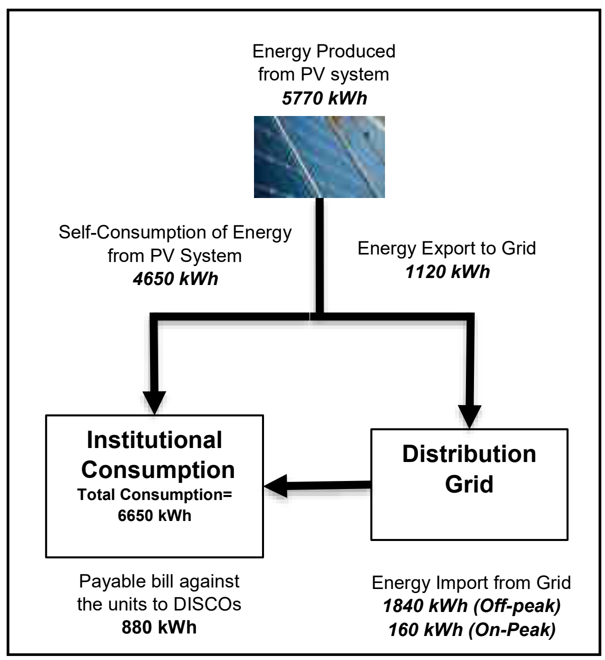

Figure 3.19: Graphical demonstration of grid-parity and self-consumption from 35 kW PV system

39.6 kW:

Total Consumption of Energy	7,228 kWh
Energy Produced from PV system	6,468 kWh
Self-Consumption of Energy from PV system	4,908 kWh
Energy Export to Grid	1,560 kWh
Energy Import from Grid (Off-Peak)	1,480 kWh
Energy Import from Grid (On-Peak)	840 kWh
Net-Metered Energy Units	**80 kWh (Payable to DISCO)**
Payable Bill	**760 kWh**

Table 3.11: Technical yield analysis and grid-parity for 39.6 kW PV system

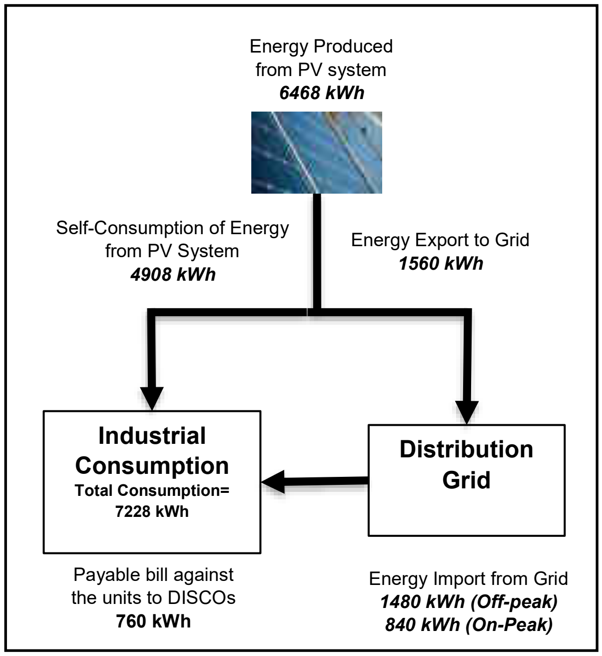

Figure 3.20: Graphical demonstration of grid-parity and self-consumption from 39.6 kW PV system

137 kW:

Total Consumption of Energy	18,285 kWh
Energy Produced from PV system	22,605 kWh
Self-Consumption of Energy from PV system	15,405 kWh
Energy Export to Grid	7,200 kWh
Energy Import from Grid (Off-Peak)	1,920 kWh
Energy Import from Grid (On-Peak)	960 kWh
Net-Metered Energy Units	**4,320 kWh (Creditable)**
Payable Bill	**Nil**

Table 3.12: Technical yield analysis and grid-parity for 137 kW PV system

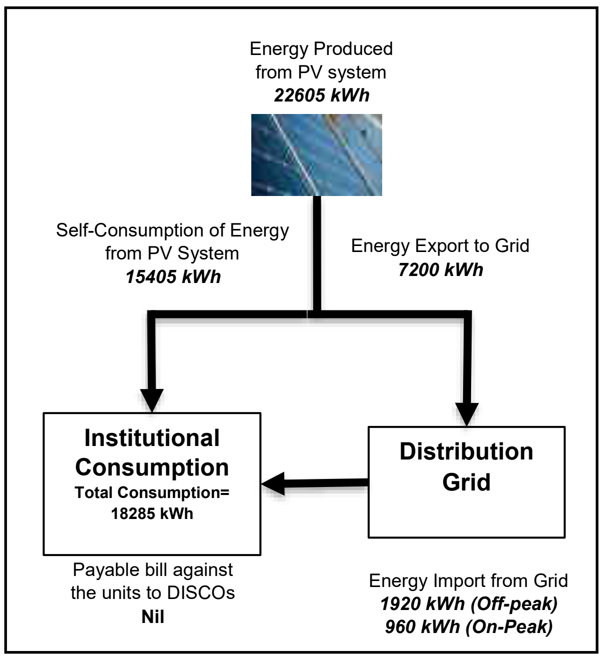

Figure 3.21: Graphical demonstration of grid-parity and self-consumption from 137 kW PV system

Chapter 4

Interactive Sessions and Meetings with Distribution Companies and Solar Associations

In the second phase of the activity, the highlights and assessment results were presented and discussed with the officials of distribution companies and solar associations. The objective of the meetings was to project the highlights and to further investigate the procedural and regulatory framework in which the PV systems are installed. Through these meetings, the narrative from the relevant stakeholders regarding the quality noncompliance, malpractices, technical inspection, technical resources and craftsmanship was assessed. This portion of the report demonstrates the highlights of the interactions and meetings with officials of DISCOs, solar installation practitioners and business holders.

The interactions were conducted with the officials of IESCO and LESCO. For taking the relevant stakeholders from the solar industry on-board, meetings were conducted with Renewable Energy Association of Pakistan (REAP) and Solar Quality Foundation (SQF). IESCO and LESCO are the distribution companies with the jurisdiction of electrification of regions of Islamabad-Rawalpindi, Lahore, Okara, Jhelum, and Chakwal, and both of these distribution companies have a large concentration of solar PV systems with net-metering installed. REAP and SQF are two associations consisting of solar vendors and renewable energy based business holders.

4.1- Interactive Sessions with Distribution Companies

The interactive sessions with IESCO and LESCO were mandated to highlight the technical grey areas during the inspection. Accordingly, the feedback and narrative of the officials were recorded. The salient features and the practices adopted by distribution companies in installation of grid-tied PV systems are provided.

i. No Framework of Technical Inspection

In accordance to the regulations provided by NEPRA, the application process requires the technical inspection of the installed PV system before the commissioning and installation of green meter. From the interactive sessions conducted, it was revealed that inspection before the commissioning is not conducted, pertaining to the unavailability and incompetency of sub-divisional staff of the distribution companies. The applications are processed without the review on technical design, and further the connection for net-metered system is provided without technical inspection. Due to rising concentration of net-metered PV systems, the technical staff based at the sub-divisions are reluctant to inspect due to high occupancy in the routine jobs and lack of necessary resources.

ii. Lack of Technical Resources Available with Distribution Companies

Lack of technical resources in the distribution companies is another major barrier to prelude and assess the technical configuration of PV installations. The staff in the distribution companies are not well technically trained for grid integration of distributed generation. So, the technical configuration and installation procedures remain at the disposal of solar vendors. Moreover, the technical tools and proper training are evidently required for the different levels of professionals of the distribution companies. The distribution companies lack in assessment of power stability constraints due to variability of the distributed generation and in case of fault detection.

iii. Necessity of Online Portal

The necessity of online portal was demonstrated equally by both distribution companies. With the support of AEDB, the online portal for the processing of applications was launched, which was regarded as a much useful tool. Due to some technicalities, the portal has been shut down. The processing of applications through the manual procedures is leading to many malpractices among the staff of distribution companies, where the complete procedures are also not being followed. The necessity of the online portal to maintain the transparency of the process is demonstrated by all the stakeholders.

iv. Procedures for Frequent Inspection of PV Systems

To improve the technical configuration and quality compliance, the distribution companies highlighted the possibility of frequent visits to the prosumer's premises for technical check-up and yield analysis. The procedures for frequent inspection do not exit. The frequent or sample-based technical inspection would assist in the adoption of appropriate practices where the grey areas in the PV systems would be highlighted before the prosumers and the relevant system installer.

v. Documentation of Flash Test Report for PV Modules

To control the quality non-compliance and maintain it, it was suggested to make flash test report of PV modules a part of application documentations. Flash test report is provided to the importers/retailers of PV modules on import of the panels. The inclusion of flash test report would validate the quality of the modules to be used in installation.

vi. Mismatching of Distribution Utility Codes and Distributed Generation Integration Codes

The applicability of grid integration of distributed generation with the utility is also being affected by the mismatch of distribution utility codes and standards for grid integration of PV systems. The distribution utility codes are obsolete and have been applicable since the unbundling of these distribution companies. These codes have not been revised through the pace of distributed generation is rising exponentially. The mismatch between the two technical codes is yet a barrier pertaining to the grid integration mechanism and assessment of power quality constraints.

vii. Necessity of Prosumer's Awareness Program

Through the assessment, a significant factor was highlighted regarding the prosumer's awareness about the technical configuration of PV systems. The prosumers are not aware of the key non-compliances being made in their PV systems. Further, the tendency of installation of "*cheap*" systems also leads to key non-compliances. To curb the quality non-compliances and malpractices, prosumers can play an important role, which can be promoted by initiating an awareness program. It is recommendable to provide guidelines for the prosumers which would help them to indicate the issues in the PV system.

4.2- Meetings with Solar Associations and Solar Vendors

As important stakeholders, the meetings were conducted with the solar associations and vendors to grasp and document a better understanding of the issues as highlighted. REAP and SQF were taken onboard while some meetings with prominent and recognized solar vendors also helped in assessment of the root cause reason for the non-compliances and malpractices. The salient points discussed in these meetings are:

i. Outsourcing of PV System Installations by Certified Solar Vendors

The interactive sessions with the solar associations and vendors helped in understanding the key practices. It is observed that the installation procedures of PV system are based on three types; one is, where the solar vendors, who have achieved the contract commission the project; second being, where the erection or civil work is outsourced partially; and last one, where the complete project commissioning is outsourced. The third practice is assumed to be the key factor behind the non-compliances. Some of the certified vendors from AEDB are in the practice of selling their certification, or let uncertified solar vendors to do erection of grid-tied PV systems by availing the credentials of certified solar vendors. Under the procedural regulations, this practice is considered malpractice. This practice involves the monetary advantage for the certified solar vendors as they earn money.

This aspect of malpractices is the reason of affecting the business dynamics of the majority of certified solar vendors who highlighted the emergence of "*price outliers*" in the market. The tendency of awarding of the contract for project installation is tilted towards the cheap systems, which are falsely manipulated as cost effective and the margin of high profitability is developed based on malpractices and quality compromise.

ii. Requirements of Improvement in Craftsmanship

Yet, another significant barrier is lack of technical craftsmanship of the technicians and technical staff of solar vendors. The dire requirement to intervene in this aspect is eminent and a general consent is emerging with all solar vendors. The trainings specifically mandated for the staff and technicians—are required. Some of the vendors have their in-house training facilities, while others agree to avail the training programs to improve the technical craftsmanship.

iii. Need Assessment-based and Advanced Trainings

Customized and need-assessed trainings are required to be included in the general schedules of the solar vendors. In this aspect, the dedicated advanced trainings would improve the overall practical dynamics of solar PV installation. Trainings are also needed to be made part of learning for the students and attendants of engineering universities and technical vocational institutes, which would improve the market-based practices.

iv. Requirement of Digitalization Process of Applications

The requirement of the digitalization of the application process is the most prominent barrier being faced by the solar vendors in application process. The lack of online portal has compromised the transparency of the application process, where its existence would improve the processing time and shall maintain the monitoring of the application procedure for each system installed.

v. Expectation of Improvement in Compliance of Installation

It was mentioned by Solar Quality Foundation that the quality of the PV modules and other components is expected to be improved which are imported in the year 2020 and onwards. AEDB has emphasized strongly on the import of the components, maintained by the process flow chart which defines all the standard obligations and compliances against the specific product. The process flow chart and the import procedures have been mentioned and demonstrated in the next chapter of this report in detail.

4.3- Summary of the Interactive Sessions

The meetings and interactive sessions with the officials of distribution companies and solar vendors can be summarized in the following points:

1. The requirement of an online portal is paramount. The online portal shall not only maintain the transparency of the process, also it shall make the procedures concise.
2. The practices related to complete outsourcing of the PV system installations cannot be controlled completely. Rather, a strong inspection procedure is needed to be intervene which shall look over the non-compliances at the time of installation of PV system.
3. The technical resources and capacity of the distribution companies and solar vendors are needed to be enhanced. In this regard, the expertise can be expedited, already available with the technical teaching institutions.
4. Advancement in the grid integration techniques is required which needs to include all the stakeholders of the solar industry, distribution companies, policy and regulatory authorities and educational and training institutions.
5. A mechanism for technical inspection of the PV systems is needed to be developed, which shall include all the necessary parameters for assessment.

Chapter 5

Assessment of Import Procedures of Solar PV Accessories in Pakistan

The Ministry of Commerce and Textile has regulated the rules for the import of solar equipment as part of its efforts to provide a level-playing field for import of standardized products for renewable energy systems. The ministry has notified that solar equipment including solar or photovoltaic (PV) panels, inverters, PV generators and other accessories are importable subject to compliance with the quality and safety standards approved by Pakistan Standards and Quality Control Authority (PSQCA). The additional guidelines in the Import Policy Order (IPO) vide SRO 604(I)/2019 demonstrate the test reports and certificate of conformance to be issued by accredited laboratory/agency in the country of origin or exporting country which should be verified by the Customs in Pakistan. Moreover, Pre-Shipment Inspection (PSI) report should be issued by accredited inspection body in the country of origin or the exporting country for the type of inspections in accordance with the requirements of ISO/IEC 17020. Pakistan has already waived off taxes and duties on the import of renewable energy products. The country imports more than 95 percent of the solar panels and other renewable energy systems largely from China[11].

Imports of solar panels rose from as little as $1 million in 2004 to a peak of $772 million in the fiscal year ending June 30, 2017. While they have since dropped down to $409 million in fiscal 2019, the country's imports of solar panels appear to be in a strong upward trajectory, growing at an average rate of 15.9% per year in US dollar terms (22.6% per year in Pakistani rupee terms) in the five years between 2014 and 2019. While a substantial portion of those imports are for grid-scale projects, a significant proportion is for domestic, commercial, and industrial users who are not necessarily connected to the grid.[12]

5.1- Regulations on Import of Solar Accessories in Pakistan

The Federal Government of Pakistan vide SRO 604 604(1)/2019, dated May 28, 2019 (SRO 604) issued amendments in the Import Policy Order, 2016 ("IPO"). The purpose of issuance of the SRO 604 was to adopt international standards for import of solar PV equipment irrespective of the country/source of origin and uniform applicability of the standards all over the country. Subsequent to issuance of this SRO 604 the importer requested Ministry of Commerce to issue a process flow that would define steps that are needed to be followed while importing solar PV equipment for uniformity and better understanding.

The importers are required to ensure that the manufacturers are conforming to the standards as approved and adopted by PSQCA for solar PV equipment and given in the SRO 604/IPO.[13] The detailed list of required regulations and standards are provided in Annexure.

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[11] Numbers are taken from article in The News https://www.thenews.com.pk/print/486563-solar-power-setup-import-rules-tightened-to-leverage-local-industry

[12] It has been noted that since last couple of years adoption of solar technology has increased in Pakistan and import of solar panels has also risen https://profit.pakistantoday.com.pk/2020/05/04/solar-is-the-future-so-might-as-well-hurry/

[13] Ministry of Commerce through SRO 604 has defined and regulated the international codes applicable for import. SRO 604 has also annexured a checklist which specifically makes compliance of standards necessary for import. https://www.commerce.gov.pk/wp-content/uploads/2019/06/SRO-604.pdf

5.2- Compliance of International Standards for Import

Through the SRO 604, the international standards compliance is made mandatory for import applications, which are given below.

PV Modules	IEC Standard
Solar PV Module	IEC: 61730-1
Solar PV Module - Crystalline Type	IEC: 61730-2
	IEC: 61215-1
Solar PV Module - Thin Film (CdTe based)	IEC: 61215
Solar PV Module - Thin Film (amorphous silicon based)	IEC: 61730-1
	IEC: 61730-2
Solar PV Module - Thin Film (In, GA based)	IEC: 61730-1
	IEC:1730-2
PV Test Equipment for System Performance Testing	PS:IEC: 61724
	PS:IEC: 62782
	PS:5289
	PS:5290
Photovoltaic Concentrator (CPV)	PS:IEC:62670
Solar PV standalone systems (including AC or DC Off-grid Systems)	IEC/TS: 62257

Table 5.1: PV modules and IEC standards regulations for import

Similarly, inverters, breaker boxes, charge controllers, balance of system components, power converters, junction boxes and electronic components have their designated IEC Standards which are required to be met before clearance for the shipment.

PV Component	IEC Standards
Inverter for Use with Solar PV system.	IEC: 62109-1
Inverters for Use with Solar PV On-Grid System only	IEC 62116
	IEC 61727
Inverter Testing Equipment	UL:1741
	IEEE:1547
Charge Controllers for Use with Solar PV System	IEC: 62509
Balance-of-System Components for Photovoltaic Systems	IEC: 62093
Power Converters for Use in Photovoltaic Power Systems	IEC:62109-1 &- 2
Electronic equipment and Parts Suitable for Use in Solar PV Power Installations	IEC 62013
Junction Box with Covers for Solar Panels	IEC 61439
	IEC 60947-3
Electric cables for Photovoltaic Systems	IEC:62930

Table 5.2: Compliance of PV accessories with IEC regulated for import

5.3- Procedural Requirements for Import

Alternative Energy Development Board (AEDB) has provided the process flow chart for import of solar PV equipment after detailed consultations with the stakeholders. This process chart explains the steps which are needed to be followed while importing solar PV equipment for uniformity of procedures and better understanding. As the solar PV market is strongly reliant on the foreign countries to fulfill the demand, the import procedures are provided to streamline the import of quality products. The defined procedures comprise testing of the product, issuance of shipment formalities, arrival of consignment & inspection, documentations review and clearance by Pakistan Customs. All these steps have been appropriately mentioned through the flow-chart of operation.

i. Pre-shipment Procedures

Before the shipment, the vendors or the importers are required to comply with the set of procedural documents needed to be loaded with the shipment. These documents include:

a. Invoice of the shipment
b. Packing List
c. Bills of Lading
d. Copy of bank statement
e. Manifest Machine or Equipment Details
f. Test Type Certificate (*The test certificate from the manufacturers of the equipment*)
g. Certificate of Conformity
h. Pre-Shipment Inspection Certificate

The guidelines have mandated the provision of Certificate of Conformity and Pre-Shipment Inspection Certificate other than the conventional documents. ***Certificate of Conformity*** is directed to be issued from the accredited agency registered in the country of origin, and the agency is needed to be complied by IEC/ISO 17065. The certificate of conformity is required to ensure the compliance of the products to be shipped to Pakistan with the international standardized codes of manufacturing, and meeting the set of regulatory, technical and safety requirements. Besides, the requirement of ***Pre-Shipment Inspection Certificate*** is standardized to be issued by the accredited agency in accordance with the requirement of ISO/IEC 17020. The PSI certificate is meant to physically inspect the goods or equipment for shipment.

ii. Post-arrival Procedures

At the port of arrival, the importer is required to submit the pre-shipment documents to the Customs officials for the clearance of the goods/equipment. The documents review and product inspection is done at the Custom's end, for the clearance of the goods. The additional requirement mandated by SRO 604 makes the provision of checklist necessary for clearance. The checklist has been attached in Annexure of the report. The checklist for the port clearance contains the IEC standards respective to each of the solar accessory. Moreover, the checklist is also needed to assess the Certificate of Conformity and Pre-Shipment Inspection Certificate. Through the SRO 604, these requirements have been exclusively provided for the shipment and import of solar PV modules, inverters, and associated equipment.

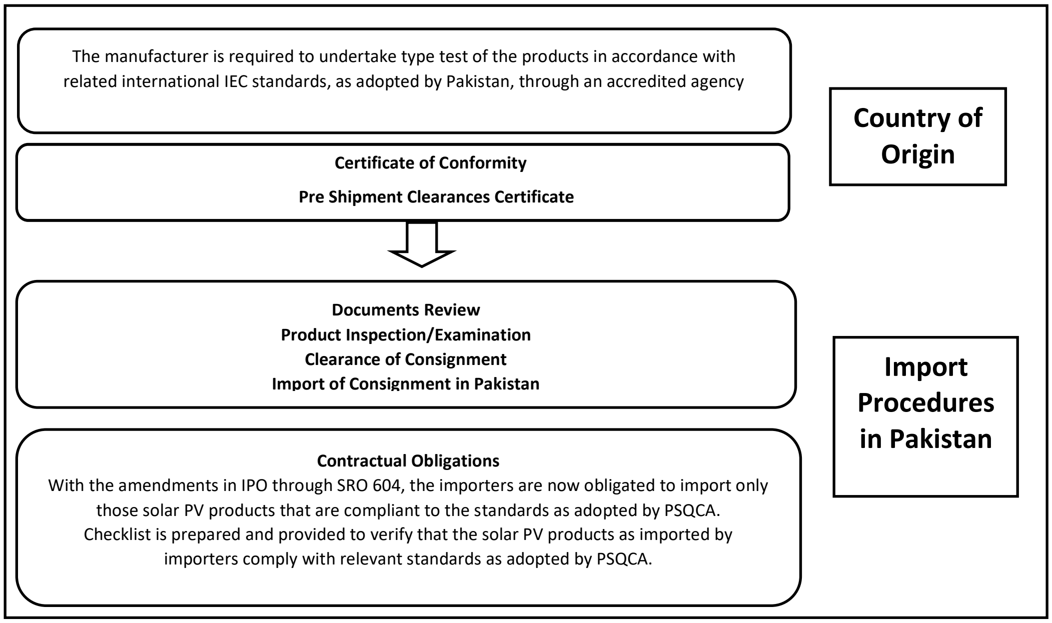


Figure 5.1: Procedural map for import of solar accessories

5.4- Quality Compromise of PV System & Role of Import Procedures

Solar industry is growing in Pakistan and ensuring the quality of solar PV products has become crucial. As it has been noted that, in spite of having all the required PV import procedures in place, IEC standards and quality check parameters, still some malfunctioning does exist which leads to quality noncompliance of PV system. In order to ensure quality there is need to foist standards at import, design and installation of solar system which eventually will lead to long-term success of solar industry. The import of non-compliant PV modules and panels is evidently found during the inspection. The PV panels constituted in the category of low-graded, inappropriately manufactured, or rejected by the assembly lines are imported with the compliance of all the requirements. Yet, the window for the import of quality-compromised products is also available. The hiccups and technical limitations are assessed pertaining to the process, which can be summarized in the following salient points:

a) The mandatory inspection of the PV equipment from the third party agency for acquiring of Certificate of Conformity and Pre-Shipment Inspection Certificate incurs a large tranche of amount amid the foreign remittances. This also provides the opportunity for the malpractices on import of PV equipment and products.
b) The low-graded and quality compromised PV modules can be imported by declaration of their specifications in Certificate of Conformity and Pre-Inspection Certificate. Yet, it has to be researched and assess thoroughly, if the quality compromised modules meet the international standards required for the import.
c) There is a crucial need of digitalization of the process, where the vendors can provide the details and documents through online portal. The manual processing methods also add more time in import of the equipment.

Chapter 6

Recommendations and Suggestions

In the previous sections of the report, description about the technical and procedural issues was provided. In this section, the recommendations and suggestions have been devised regarding a swift deployment of solar PV systems based distributed generation. Before delving into the suggestions, a quick review of the issues pertaining to the current practices of PV installations are:

1- The quality of the PV systems is being compromised. The snail trail contamination, delamination and hotspots indicate the problem with the quality of the PV modules, which are not being assessed at the time of installation. These quality compromises reduce the technical productivity.
2- The malpractices and inadequacies in interconnection schemes for connection of PV systems have been indicated. This aspect is specifically related to the constraints regarding the practices of solar vendors and installers.
3- The technical inspection for certification of the interconnection schemes and mechanism is not being followed by the technical committees of the distribution companies.

In view of these issues, the recommendations and suggestions are based on maintaining adequacy of the practices and to detect the malpractices/shortcomings in installation of PV systems.

6.1- Inclusion of Third Party Inspection and Validation Mechanism

One of the highlighted reason behind the procedural and quality non-compliance is observed to be a lack of technical inspection. The solar PV associated business in Pakistan is on the rise, but broken quality chain has negative consequences for the solar industry, and the severity can increase in the future –if left unchecked. Alternative Energy Development Board (AEDB) have standardized the PV system installation, which comprises of detailed technical and procedural guidelines. Instead, the practices are adopted by some solar installation companies to cut the costs of PV system installations the issues have been highlighted related to quality compromise and lack of craftsmanship. To determine the flaws, and to promote qualified-best practices, a third party interventional inspection framework and validation/certification process can prove to be an accelerator for a conducive businesses and practices.

Quality inspection services by a third party for PV plants shall ensure that the installation of photovoltaic power plant is carried out to the exact specifications and meets all existing standards and regulations. In the conventional procedures, a detailed and specified system checklist is not being adopted by the distribution companies, and post-installation inspection has no existence. The concept and principle objective of the third party validation and inspection procedures have been described in detail.

1) Principal Stance of Third Party Inspection

With regard to the gaps mentioned, the third party validation mechanism is aimed to inspect the PV system installation to ensure the compliance of all the specified system integration standards and quality constraints. The three domains which can cover the PV installation procedures are; procedural, quality and system inspection. **Figure 6.1** explains the working objectives for implementation for third-party inspection.

Procedural Inspection	Verification of PV plant according to the precise specifications
	Compliance with international standards
	Assurance of operation of PV system with safety regulations and according to the relevant local guidelines
Quality inspection	Visual inspection of the generator field, including support structure, modules, mounting, cabling and shadowing
	Visual inspection of cabling to the inverter
	Visual inspection of the inverter and connecting boxes, including location and mounting
	Visual inspection of the safety system and labeling, including lightning and overvoltage protection
System Inspection	Inspection of the PV system based on; Product type, Quantity, Dimensions, Completeness, Obvious Defects. Material and Documents

Figure 6.1: Working objectives for third party inspection mechanism.

2) Technical Inspection of Grid-tied PV Systems

In compliance with the international grid integration procedures, the inspection procedures shall comprise the following elements:

a. Certifications and Quality Assurance

The aspect shall cover the assessment of PV system technical configuration according to IEEE 1547 specified standards. Furthermore, it is suggested that the flash report/details from the vendors about the import of the accessories can be made the element for certifications and quality assurance.

b. Site Inspection and Assessment of Locality

This aspect is necessary to assess the condition of the site with the verification and validation of necessary earthing and grounding procedures. Moreover, installation of lightening arrestors and cabling practices can be improved.

c. Inverter Testing and Inspection.

According to the AEDB guidelines for grid integration, in accordance with the UL 1741, the inverter is required to be tested for the protection systems. This includes; *anti-islanding test, short-circuit and overload, peak-generation*, etc. at the time of installation.

d. Modules Inspection

In accordance with the specified international standards and the designer's specifications, the PV modules can be validated for the installation. The orientation of the PV modules, physical condition, configuration, STC testing and strength of the mounting structure are the other important factors to be the element of modules inspection.

The adoption of a detailed checklist is required for the inspection. In the inspection conducted for the activity, the checklist has specified the compliance with all the required standards. Also, it would maintain the uniformity of the PV system installation techniques and practices, which shall also improve the level of craftsmanship and quality of the PV system installation. **Figure 6.2** presents technical inspection, key constraints and determinants required for third party inspection.

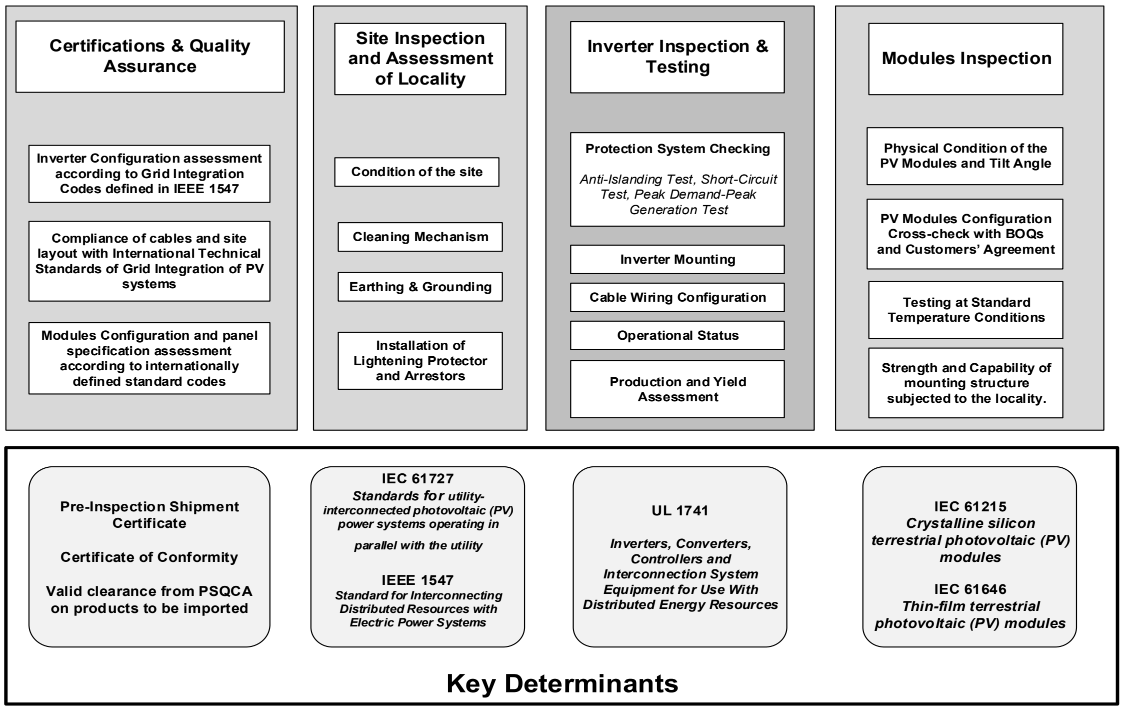


Figure 6.2: Technical inspection through third party mechanism, key determinants and constraints

3) Proposed Mechanism for Third Party Inspection

The third party validation can be implemented parallel with the application process of the net-metering installation. While the conventional application process is required to proceed with the documentations as per the detailed specifications, bills of quantities, customer agreement, consent from distribution companies and an affidavit to legalize the interconnection, the proposed mechanism is suggested to be merged into the current application process with the followings features:

1. When the application is received for the installation of net-metering, the certification and quality assurance can be carried out based on the documentation from the solar vendors. In this step, the validation of the PV modules, inverter and technical configuration is required.
2. In the second step of the application where the screening and verification of the components are required, the third party inspection can assist the distribution companies in proper screening and validation based on the provided technical design and bills of quantities. The verification at this step can include the specifications detail, flash report, certificate of conformity and pre-shipment certificates to ensure the origin and quality of the PV modules and inverters.
3. After the issuance of generation license from NEPRA, or in the case of systems under 25 kW, the on-site inspection after the installation of the system is proposed to verify the practical compliance of all the procedural regulations. This step includes physical inspection of site, assessment of locality, modules and inverter inspection and testing, and validating the interconnection procedures.

An integrated model of third party inspection with the conventional application process is demonstrated in **Figure 6.3**.

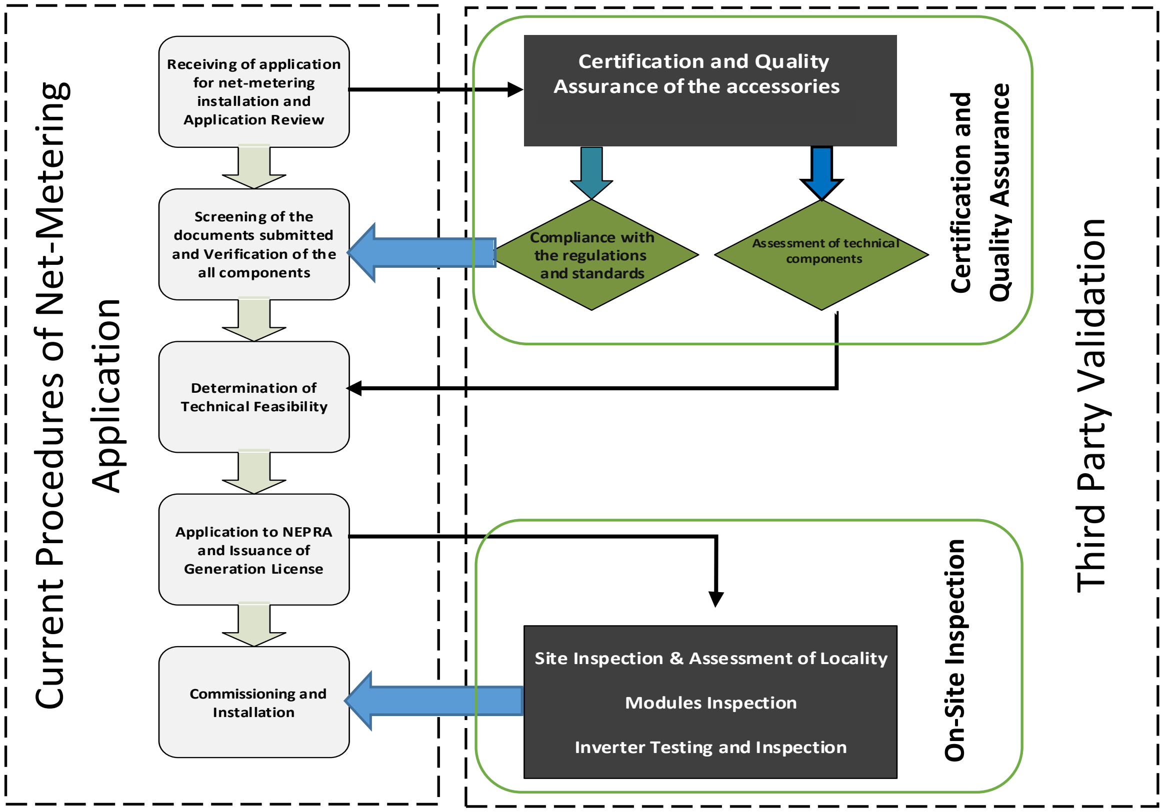


Figure 6.3: Proposed model for third party validation and inspection process

6.2- Revival of Solar Quality Passport

Solar Quality Passport is an initiative taken by GIZ (German Agency for International Cooperation) with the support of Solar Quality Foundation, and coordinated by Alternative Energy Development Board (AEDB), which includes the software based certification and documentation for the PV systems. SQP is also instrumental for assessing the training needs and measures for registered installers, which endorse best knowledge and skills for solar PV installations.

Solar Quality Passport records and digitalize the specifications of each solar installation. The SQP features information about built-in components, system design, safety measures, applicable standards and guidelines, which is issued by authorized and trained PV installers. With the collaborative support of AEDB, the solar vendors and the companies can be regulated to register and acquire the passport, upon which, the standard compliance and the necessary interconnection information can be recorded. In the longer run, the solar quality passport can be merged into the third party validation mechanism, where the inspection would be required to validate the provided specifications in the documents. An independent working organization would be beneficial for the realization and sustainability of Solar Quality Passport initiative. SQP would be supported by the modern information technology infrastructure which would assist the overall administration of the processes.

The revival of the Solar Quality Passport was also emphasized by the executives of Solar Quality Foundation (SQF), who agreed to cooperate in this regard and highlighted that the proper documentation of all the specifications would improve the overall practices. Also, it is worth mentioning that the Solar Quality Passport would provide an adequate short-term solution to curb the quality and procedural non-compliances, where the digitalization of the specifications would create an overall monitoring of the installations.

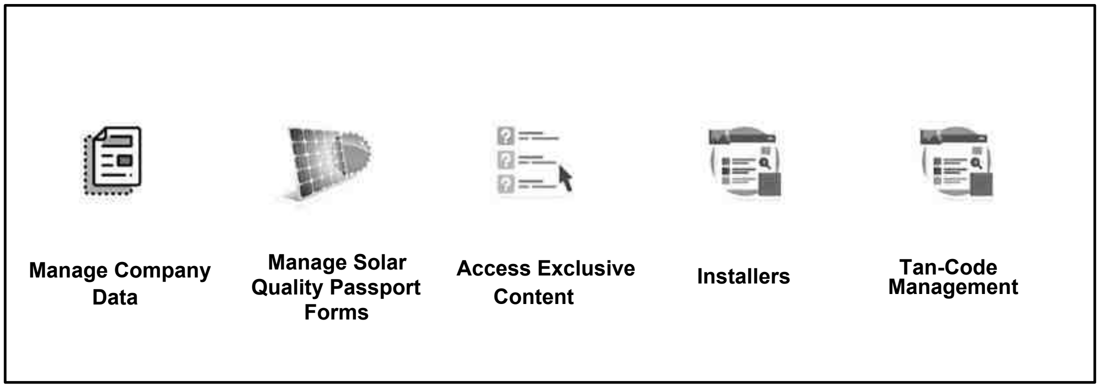


Figure 6.4: Segments for registered installers in Solar Quality Passport

6.3- Existence of Online Portal for Processing of Application

The requirement for the online portal and digitalization of the application process is highly demonstrated by all the stakeholders. Through the online portal, it is believed that the malpractices, which emerge due to lack of transparent procedures –can be snubbed or controlled. The solar vendors highlight the existence of online portal as a requirement to exclude extra costs – which is incurred in manual processing of applications and bribe received by the staff of distribution companies. Whereas, the digitalization of the application process leads to include the details of the PV system specifications, which can be utilized efficiently to restructure the conventional process with third party inspection and validation processes. The existence of online portal can significantly improve the overall application process and also, can reduce the malpractices related to the uncertified solar vendors, where the status of each PV installation can be transparently checked and examined.

6.4- Enhancing Capacity Building Through Training Programs

It was evidently observed that due to lack of advanced techniques and methods of grid integration, the practices are not being followed complied with the standard procedures for distributed generation. In this regard, apart from the third party inspection, need-based trainings and campaign for capacity building of the technical resource of distribution companies and solar vendors are needed to be enhanced.

One of the significant observations is related to lack of craftsmanship that has led to inadequacy in proper installation techniques. With respect to the trainings needs, the solar vendors highlighted the barriers which consist of lack of time availability, lack of job securities and lack of resources. The solar vendors do not intend to provide the trainings to the technicians and the staff because of the tendency where the trained staff is more likely to switch jobs in pursuit of a better financial package. Similarly, the vendors also lack the resources required for trainings. In this aspect, the dedicated need-based trainings for the PV system technicalities can be provided by the respective technical institutions. The engineering universities can be suggested to include the advanced-level curriculum on solar technologies where the graduating students can avail the opportunity of hands-on trainings on the technology. Likewise, the vocational and trainings institutions can be benefit from conducting specific need-based short-term training programs. The solar vendors are required to make a framework to avail the services provided by public and private technical institutions, which can be regulated also with the existence of certification for technicians and technical staff necessary for grid integration.

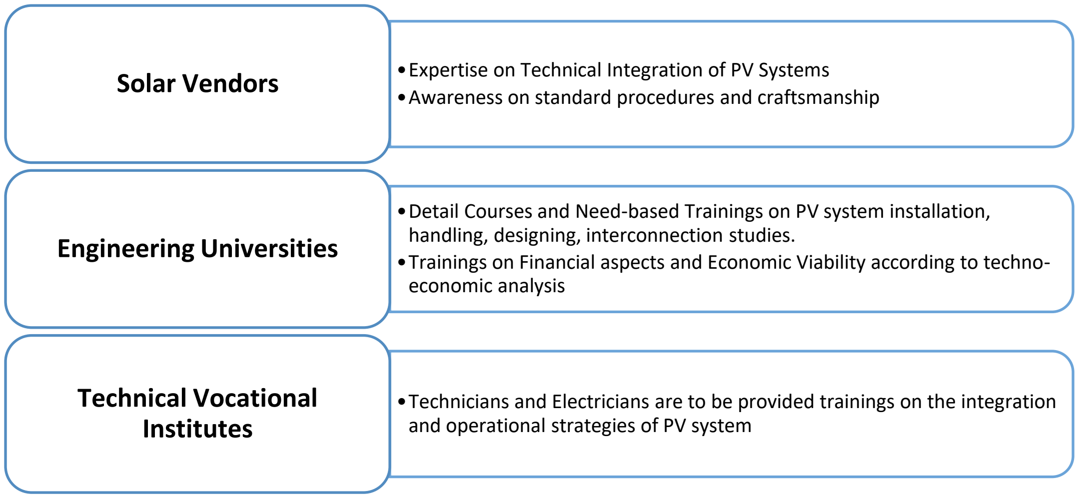


Figure 6.5: Suggested need based training framework

6.5- Transition Towards the Modern Technological Trends in Distributed Generation Integration

The maturity of solar technologies globally has attracted various numbers of modern and smart-infrastructure based technologies to be embedded. The inclusion of smart metering infrastructure, internet of things based communication technologies, central monitoring services, system supervisory and data recording and human to machine interface are some of the applicable modern technologies which are in utilization worldwide. The gradual transition towards the smart infrastructure can be realized by regulations which shall ensure the improvements in overall solar sector of Pakistan. Moreover, this shall also lead to the various business opportunities for the investors.

6.6- Initialization of Awareness Program for Solar PV Prosumers

One of the highlighted reason behind the procedural and regulation non-compliance is related to the awareness of the prosumers about the technical configuration and standard operation of the roof-top solar PV systems. It was revealed by officials of solar vendors and distribution companies that the lack of awareness of prosumers leads to the malpractices incurred by solar installers. The awareness of standard procedures, regulations, and practices shall enlighten the technical configuration and the capabilities for the best optimal operation can be streamlined. The awareness campaign can be carried by pamphlets, guideline booklets and through electronic media.

Annexure I

Detailed Checklist and Technical Report of 50 kW Solar PV System Installation at Foreign Service Academy, Ministry of Foreign Affairs, Supported by the Federation of Germany

Checklist - Distributed Generation-based Solar PV Systems							
Solar System Capacity	**50 kWp**			**Site Location**	**Foreign Service Academy, Diplomatic Enclave, Islamabad**		
Evaluation Team	**Dr. Hassan Abdullah Khalid** (Technical Lead & PV Expert) & **Muhammad Hamza Naeem** (Principal Investigator)			**DISCO**	Islamabad Electric Supply Company (IESCO)		
Name of the Installer	DS Global Renewable Energy			**Date of check**	Tuesday, October 12, 2021		
Vendor's Category	V1	**Assessment Result**	Verified and Validated	**Energy Produced since commissioning**	62 kWh	**Peak Power recorded during assessment**	29 kWp

Checklist							
No	**Section**	**Component**	**Checkpoint**	**Test procedure**	**Check Result**	**Comments**	**P: Pass; F: Fail; N: Not Tested**
1	1	**General Check**	**Time of site visit**		**1240-1400 hrs.**		
2			**Weather conditions**		**Bright Sunny Day**		
3			**Condition of site**	No unnecessary material is lying around the installed location and it gives a clean impression	The surroundings around the PV modules are clear no unnecessary/objectable condition found		Pass
4			**Shading**	No immediate shading from trees and buildings around the PV Panels	No shading or disturbance found.		Pass
5			**System status**	Whether the system is operational or not	The system was operational and active in energy generation		Pass
6	2	**Modules**	**Model No. and IEC certificate**	Model numbers on site match with plans. Valid IEC certificate available for the used model (documentation from vendor)	The details about PV modules, number of strings, IEC Certifications (IEC61215 & IEC61730) match with the specifications in BOQs provided by the solar vendor		Pass
7			**Modules Check**	Modules are in good conditions e.g. no broken glass or cells, frames are not damaged.	The modules are found in suitable operation conditions.		Pass
8			**Verification of modules and IEC Standardization**	To check and validate the modules with the manufacturers invoice and Pre-Port Inspection	The Third Party Validation would be completed upon the provision of requested documents regarding the import and certification of the modules		

9			**Modules properly fixed**	Panels properly clamped at structure: Torque is correct; contact sufficient for earthing connection (no corrosion, contact visually OK)	Panels are found properly mounted and potentially zero grounded	Pass
10			**Cabling between modules**	Cables properly tightened to the structure (not hanging in the air); cable ties UV-resistant. Cables protected against damage at sharp edges. Not too much tension in cables	The cables are clamped properly and meet the standard criteria	Pass
11	3	**Structure**	**Corrosion**	Any rust / corrosion detected?	The structure was found corrosion-free and adequate in condition	Pass
12			**Earthing**	Structure and modules are properly grounded with dedicated grounding conductor. Grounding rod properly mounted in earth. Grounding cables of sufficient diameter	The structure and modules are electrically grounded	Pass
13			**Cleaning Process**	To check if the cleaning process of modules against the soiling or any other disturbance is carried and the structure design is compatible for regular cleaning	As the site has been recently installed, the cleaning mechanisms were advised to be followed	
14			**Mounting Structure**	The PV system has been mounted on the structure which would restrict the climatic interventions and would carry the system as per the system lifecycle	The mounting structure were found enough suitable to withstand the climatic interventions based upon the height and location	Pass
15	4	**Inverter**	**Inverter safety**	Inverter properly grounded? Properly housed (or otherwise protected from water (especially if outdoor!), dust, human interference)? Cable connections at inverter all properly done, no blank wires? High voltage connections, if accessible, properly protected?	The inverter was found adequately mounted, grounded, electrically connected, and suitably installed. The cables were connected according to the standardized practices and no inadequacy detected in/near the installation	Pass
16			**IEC certificate**	Model numbers on site match with plans. Valid IEC certificate available for the used model (documentation from vendor)	The inverter specifications comply with the relevant grid integration standards. Moreover, the warranty Performa of the inverter has been verified online	Pass
17			**Inverter Validation from Manufacturers Portal**	Model number and Serial Number to be verified from the Manufacturers website	The inverter's warranty card and specifications have been verified	Pass
18	5	**Cabling**	**Cable wiring**	1. The electrical wiring works performed by the SSC are clean and were carried out properly and labelled. 2. Cable ducts, where used, are securely fastened and ends are properly closed to make it water proof	The cables were found clipped properly and connected with the modules & units meeting all the standard criteria's	Pass
19			**Grounding on DC+AC side?**		DC and AC units and equipment were found properly grounded	Pass
20			**Lighting protection**	If lightning arrestor (at least for 40ft and above buildings) with separate grounding installed? Grounding measurement: Below 5 Ohm (or according to local requirements)? If no lightning arrestor: Surge protection installed, at least on DC side before entering the house?	Proper protection against the lightening exists. The lightening arrestors are installed	Pass
21	6	**Breakers**	**Breaker box protection**	Breaker box is secure inside the room / closed place and protected from any rain, spray water or dirt	All the DC and AC breakers were installed appropriately	Pass

Annexure II

Questionnaire for Interactive Sessions with Distribution Companies

1. What is the procedural system of signing the customer agreement?
2. How does the technical inspector inspect the site for signing the customer agreement?
3. What quality checklist does your staff follow for commissioning of the site?
4. Is your staff aware of international standards of distributed generation facilities with the power grid?
5. Has your staff received training for advancing net-metering?
6. Which most pressing issues do you include in the installation phase of the systems?
7. About what the net-metering prosumers complain after commissioning?
8. Describe the billing procedures of net-metering facilities and how does the distribution company does include financial perception related to rising concentration of net-metering.
9. What are the complaints and issues that arise with the billing procedures? How frequent they are?
10. How much technical resource exist dedicated for the net-metering procedures?
11. What are the most technical issues at the grid side which are needed to be addressed to accommodate net-metering?
12. How you are managing the capacity cap of the net-metering at transformer level?
13. Please state the nature of power system disturbances and stability issues that arises due to DG integration.

Annexure III

Questionnaire for Interactive Sessions with Solar Associations and Vendors

1. Who carries out the solar installations? Do vendors directly engage their teams in the system installation, or they outsource it to other sub-contractor after confirmation of order?
2. What is the technicians' background qualification? How many of the staff has pursued diploma, any short courses, or technical training?
3. What is the average experience of the staff which is engaged on solar PV system installation?
4. Are vendors are willing to enhance their technicians' capacities, who are on ground and providing service? How long they can spare their staff to participate in trainings?
5. How many technicians does the company have specially for solar PV and particularly for net metering installation? Do they assign different teams for net metering installations?
6. On average, how many projects are being carried out at a time by your company?
7. What are the after-sale services being offered by the companies? Do you think the after-sale services should be regulated to ensure transparent competition?
8. How frequently customers complain about the problems in installed PV system and what they mostly complain about?
9. From where your company buys solar PV system accessories? From the open market, through retailers, or through import from the manufacturer?
10. What major barriers are faced in import of the solar accessories?
11. Do you have a dedicated monitoring cell? How often you monitor the system installed? And what is the methodology? Do you get the feedback from customers through phone calls, physical inspection, or online monitoring?
12. Please extend your views about the net-metering online portal which was applicable for processing of the applications. Please share your hand-on experience about the portal and suggestions you want to give.

Annexure IV

Checklist for Import of Solar PV Accessories Regulated by PSQCA

A. General Import Documents

	Mark With✓
a. Invoice of shipment	
b. Packing list	
c. Bill of lading	
d. Copy of letter of credit or import contract bank contract	
e. Additional information have to be stated in the paper	
✓ The manifest machine number and group number (set by customs department)	
f. Status AEDB certificate (if applicable):	
✓ Approved (please provide certificate)	
✓ Pending (please provide Date of Submission):	
✓ Not applied if not applicable (Kindly contact AEDB for certification process, if applicable)	

B. Import of PV Modules Required Documentation

	Mark with✓
Type test certificate as issued by an accredited laboratory in the country of origin or exporting country operating in accordance with the requirements of ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories for compliance.	
✓ IEC 61730-1, Solar PV Modules	
✓ IEC 61730-2, Solar PV Modules - Crystalline Type	
✓ IEC 61215- I, Solar PV Modules - Crystalline Type	
✓ IEC 61215, Solar PV Modules - Thin Film (CdTe based)	
✓ IEC 61730-1, Solar PV Modules - Thin Film (amorphous silicon based)	
✓ IEC 61730-2, Solar PV Modules - Thin Film (amorphous silicon based)	
✓ IEC 61215-1, Solar PV Modules - Thin Film (amorphous silicon based)	
✓ IEC 61730-1, Solar PV Modules - Thin Film (In, GA based)	
✓ IEC 61730-2, Solar PV Modules - Thin Film (In, GA based)	
✓ PS: IEC 62670: Photovoltaic Concentrator (CPV)	
Certificate of conformity issued by an accredited product certification body in the country of origin or exporting country operating in accordance with the requirements of ISO/IEC 17065, Conformity assessment Requirements for bodies certifying products and services.	

Certificate of Pre-shipment inspection as issued by an accredited inspection body in the country of origin or exporting country operating in accordance with the requirements of ISO/IEC 17020, General criteria for the operation of bodies performing inspection.	
a. Data Sheet including information about:	
✓ Performance Parameter STC Under Standard Test Conditions (STC) of irradiance of 1OOOW /m-, spectrum AM 1.5 and cell temperature of 25°C	
✓ Nominal Maximum Power (P_{max})	
✓ Optimum Operating Voltage (V_{max})	
✓ Optimum Operating Current (I_{mp})	
✓ Open Circuit Voltage (V_{oc})	
✓ Mechanical data specification of a module	
✓ Temperature coefficients/characteristics	
✓ Conformity label (after introduction in Pakistan)	
Warranty documentation:	
✓ Limited product warranty of 10 years or longer	
✓ Performance warranty of 90% at the end of 10 years and 80% at the end of 25 years for crystalline and thin film technology or more	

Annexure V

GIS Mappings of the Systems Under Assessment in IESCO & LESCO

Mapping of solar PV systems assessed in IESCO

Mapping of solar PV systems assessed in LESCO

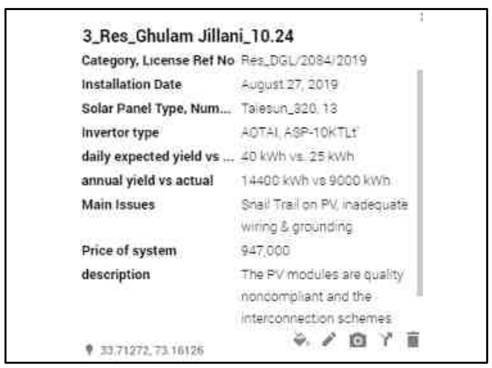
Color coding applied in the map:

The PV Installations with all the procedural and quality Compliances

The PV Installations with quality compromise on PV modules only

The PV Installations with quality compromise and inadequate wiring and interconnection schemes

Name & System Size	License No	Installation Date	Solar Panel Type and Numbers	Inverter Type	Daily Expected vs Actual Yield	Annual Expected vs Actual Yield	Main Issues	Price of the System	Description
REDO_21kW	DGL/370/2018	5/9/2018	JinkoSolar_440W	Aotai_25KTL	105 kWh vs 84.7 kWh	37,800 kWh vs 299,800 kWh	Broken Panels, Hotspots and Inadequate Wiring	PKR 23,00,000	The system has quality and procedural non-compliances based on existence of hotspots and non-compliant interconnection schemes.



Data compilation for mapped sites under assessment

Link for the GIS Map:

https://www.google.com/maps/d/viewer?mid=1VGbit473bDnwS27axsMRmim7bD2BEWtr&ll=32.58703855804572%2C73.68163504999998&z=7

Annexure VI

Technical Productivity and Energy Yield Analysis for Quality Non-compliant PV Systems under Assessment

DISCO	System Size	Peak Power Observed During Assessment	Main Issues	Daily Yield		Annual Yield (Estimated[14])	
				Anticipated	Actual	Anticipated	Actual
IESCO	**10.24 kW**	6.7 kW	Snail Trail and Inadequate wiring	38 kWh	24 kWh	12540 kWh	7940 kWh
	16.9 kW	8.9 kW	Snail Trail	83 kWh	79 kWh	29880 kWh	28440 kWh
	21.2 kW	7.6 kW	Hotspots on PV panel	105 kWh	84 kWh	37800 kWh	29931 kWh
	90 kW	57.3 kW	Hotspots and Delamination	455 kWh	433 kWh	172 MWh	162 MWh
	100.36 kW	61 kW	Snail Trail	470 kWh	437 kWh	180 MWh	167 MWh
	137.6 kW	90 kW	Hotspots	685 kWh	655 kWh	246.6 MWh	246 MWh
LESCO	**7.5 kW**	4.3 kW	Hotspots and Delamination	33.75 kWh	31 kWh	12150 kWh	11222 kWh
	18.5 kW	9.8 kWh	Snail Trail and Hotspot	81 kWh	69 kWh	29160 kWh	24840 kWh
	26 kW	13.4 kWh	Snail Trail	142 kWh	126 kWh	47190 kWh	41580 kWh

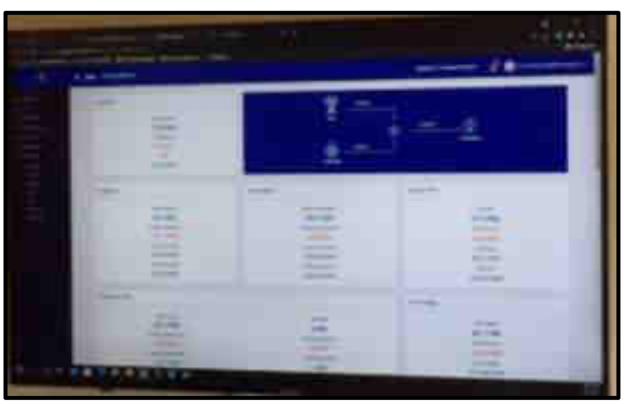
[14] The estimated values have been recorded for each PV installation based on the PVSYST simulations.

Annexure VII

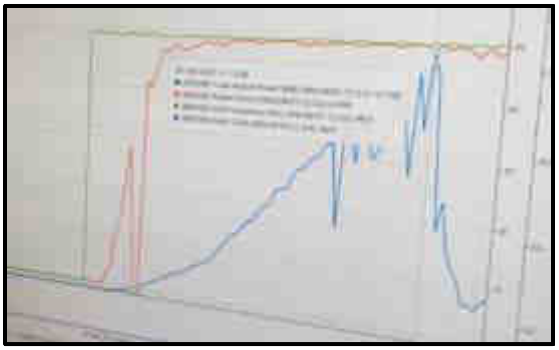
Modern Technological Advancements Adopted in Installation of Grid-Tied PV Systems

Advanced SCADA-based HMI (Human to Machine Interference) for data recording, monitoring and control.

Customer's monitoring and control center facility located at head-office of the solar vendor used to monitor production.



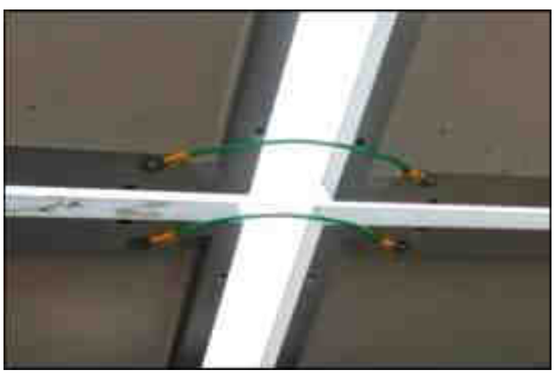
Centralized monitoring of PV systems installed at various sites through online services.



Centralized monitoring of PV systems installed at various sites through online services.

This includes; active and reactive power, grid frequency, nature of fault and output power.

All the exposed metallic components/ equipment are properly being grounded to avoid the risk of lightening surges and static.



The panel to panel electrical connection for the proper earthing and grounding is followed in the PV system installations. As per AEDB specifies, the lightening arrestor, modules frame and the mounting structure should be grounded with the separate earth electrodes.

In the picture, an example is given which is not mostly followed in practice and assessed during the inspection.

Automated Cleaning system at the facility.

Installed by prosumer itself.

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