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Qualification Testing and Analysis of Photovoltaic Module Reliability: A 2-Year Study in Indonesia

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Abstract- A solar photovoltaic (PV) power plant plays a vital role in meeting the growing demand for sustainable electricity. The reliability of such systems depends heavily on the quality of PV modules. This study presents a two-year qualification test of PV modules conducted at the BRIN PV Laboratory in Indonesia. A total of 168 modules representing more than 14 designs from local and imported manufacturers were evaluated for installation in a 71 kWp solar power plant. Results showed that 43% of modules failed to meet the required standards, with local products contributing to 83.3% of failures. Major defects included wet leakage current (59%), cell metallization burn (12%), glass breakage (8%), back sheet delamination (8%), and other issues such as soldering defects and junction box malfunctions (8%). Some modules exhibited more than 5% degradation in maximum power output by the end of the study. These findings highlight the importance of strict quality control, proper raw material selection, and careful handling throughout manufacturing and deployment. The study recommends strengthening quality assurance protocols and improving material selection to reduce failure rates. Enhancing module reliability is essential for ensuring durable PV systems and supporting the global transition to clean and sustainable energy.

Keywords Photovoltaics, PV module, crystalline silicon, qualification testing, reliability, performance.

1. Introduction

In response to the escalating concern surrounding global warming and its direct correlation to carbon emissions, the imperative shift away from fossil fuels towards renewable energy sources has gained widespread acknowledgment [1-2]. Recognized as a key solution to the prevailing energy crisis and an alternative to fossil fuels, solar photovoltaic (PV) energy has become a global priority [3]. With its virtually boundless resource potential and environmentally friendly operational characteristics, PV technology stands as an invaluable asset in addressing imminent energy challenges [4].

Photovoltaic operate on the principle of the photoelectric effect. When sunlight strikes a semiconductor material, such as silicon, photons excite electrons, generating an electric current. This process, which converts light energy into electrical energy, has made photovoltaic technology a promising solution for renewable energy generation. [5-6]. Photovoltaic systems are currently employed in a wide range of applications, including battery charging, water heating, and satellite power systems [7].

The photovoltaic module industry, identified as pivotal for the evolution of national electricity systems, offers a sustainable alternative to fossil energy sources [8].

This study delves into Indonesia's journey with PV technology, particularly focusing on notable progress in rural electrification and large-scale solar projects [9]. Despite the presence of over 15 domestic solar module manufacturers, including 11 affiliated with the Indonesian Solar Module

Manufacturers Association (APAMSI), persistent challenges in reliability and performance remain focal points of concern [9]. The quality factor of PV modules emerges as a critical issue, bearing substantial significance in ensuring the performance and reliability of PV power systems [10]. Considering the interconnected nature of global energy challenges, the outcomes of research conducted in Indonesia have the potential to inform best practices and strategies applicable to diverse geographical and technological contexts. By briefly acknowledging Indonesia's role in the broader global picture of solar PV technology and its associated challenges, this research aims to contribute not only to Indonesia's sustainable energy goals but also to the collective global pursuit of a more sustainable and resilient energy future.

As reported by the National Renewable Energy Laboratory (NREL) in 2017, the predominant degradation modes observed in PV modules over the last decade encompass hot spots (33%), followed by ribbon discoloration (20%), glass breakage (12%), encapsulant discoloration (10%), cell breakage (9%), and potential-induced degradation (PID, 8%) [11]. A separate study by Oh. et al. [12] concluded that the quantitative power loss in PV systems was caused by yellowing (47.3%), hot spots (9.6%), bypass diode failures (2%), and degradation rates. There is a significant gap in understanding and addressing infant failures, which occur at the outset of a PV module's operational life due to construction defects, production faults, and non-conforming materials. Therefore, this study aims to fill this gap and contribute to a more comprehensive understanding of PV module performance and reliability.

The primary objectives of this study are to evaluate the performance and reliability of photovoltaic (PV) modules, specifically focusing on early-stage failures. Köntges et al. [13] categorizes typical PV module failures into three distinct groups: infant failures or early-stage failure, midlife failures, and wear-out failures. Infant failures occur at the outset of a PV module's operational life due to construction defects, production faults, and non-conforming materials. The existing research primarily concentrates on mid-life and wear-out failures.

To achieve these objectives, the study conducts design qualification testing, adhering to standards such as IEC 61215, which plays a pivotal role in ensuring high reliability [14]. The assessment scrutinizes the qualification procedures applied to PV modules and presents the outcomes of a two-year research endeavour conducted at the BRIN PV Laboratory. The primary focus is on terrestrial photovoltaic devices utilizing both mono- and polycrystalline silicon technologies in the context of Indonesia. This comprehensive investigation encompasses over 14 design variations of PV modules, sourced from both local and international manufacturers. By scrutinizing these procedures and design variations from local and international manufacturers, the study aims to provide insights that go beyond the current understanding of PV module reliability. The introduction's foreshadowing serves to engage readers in anticipating the potential implications of the study's findings, highlighting the significance of addressing infant failures for the broader advancement of solar photovoltaic technology.

2. Materials and Methods

2.1. Materials and Module Selection

The study focused on Si-based PV modules, specifically those with mono- and polycrystalline silicon (c-Si) cells. These types of PV modules were chosen due to their widespread prevalence in the market, holding over 94% of the market share and cumulative installations [15]. The dominance of Si-based PV modules in the industry makes them representative of mainstream technology, reflecting the current state of solar energy applications. The choice of Si-based PV modules is significant not only because of their market share but also due to their relevance to Indonesia's specific context. Considering the prevalence of these modules in the global market, their performance and reliability are crucial factors to investigate, especially in the Indonesian setting where the photovoltaic industry has shown notable progress in rural electrification and large-scale solar projects [9].

A solar cell, which is the core device inside a Si-based PV module, is made of semiconductor material, typically silicon, capable of converting light energy into electricity. This intrinsic property of silicon and its dominance in the PV industry justify the choice for Si-based PV modules in this investigation. The Si-based PV module is the assembly of several solar cells that are (i) electrically interconnected (typically in series, to increase the voltage output), and (ii) encapsulated between some materials that protect them from the environmental stress factors and provide electrical isolation of the electrical circuit. The study considered 14 design types of Si-based PV module with the total number of 168 pieces, as shown in Table 1.

Table 1. Technical specifications of the test sample

ID	Type	Voc [V]	Isc [A]	Vmp [V]	Imp [A]	Pmp [W]
01	M-Si	49.20 ±3%	10.1± 3%	40.3	9.68	390 ± 3%
02	M-Si	44.72 ±5%	9.57± 5%	37.26	8.86	330 ± 5%
03	M-Si	48.00 ±3%	7 ± 3%	40	6.7	270 ± 3%
04	M-Si	48.80 ±3%	9.92 ±3%	41.6	9.62	400 ± 3%
05	M-Si	46.49	9.32	37.8	8.99	340 ± 5%
06	M-Si	47.92 ±3%	9.94 ±3%	40.71	9.33	380 ±3%
07	M-Si	47.7	9.91	39.5	9.37	370 +3%
08	P-Si	45.28 ± 3%	9.10 ± 3%	38.68	8.53	330 ± 3%
09	M-Si	49,20 ± 3%	10,14 ± 3%	40,30	9,68	390 ± 3%
10	M-Si	49,62 ± 3%	13,03 ± 3%	40,90	12,47	510 ± 5%
11	M-Si	50.30 ± 3%	10.64 ± 3%	42.3	10.17	430 ± 3%
12	M-Si	45,7 ± 3%	16,08 ± 3%	38,4	15,07	575 ± 3%
13	M-Si	46 ± 3%	15,93 ± 3%	38,4	14,84	570 ± 3%
14	M-Si	42,54 ± 3%	14,23 ± 3%	35,21	13,49	475 ± 3%

2.2. Methods

The testing procedures employed in this study were meticulously designed to provide a thorough assessment of the performance and reliability of Si-based PV modules. The testing process aimed to evaluate the response of these modules to a range of environmental stress factors and assess their electrical performance under various conditions. These tests are done in different sequences in accordance with IEC 61215 standards [16], outlined in the standard as shown in Fig. 1. Before referring to the IEC 61215 standards, the study mainly used the IEC 60904-1 standard or national standards, to measure the current-voltage characteristics (I-V curves) of photovoltaic (PV) devices in natural or simulated sunlight. Figure 1 shows that after the initial tests (including visual inspection, initial stabilization, performance at STC, insulation test and wet leakage test), the modules are separated and subjected to one of the different sequence tests. The sequences are called A, B, C, D or E, and afterwards tested again for efficiency and safety. Each single sequence contains stress tests which specifically aim at clarifying one of the identified main degradations causes that are commonly faced in the field.

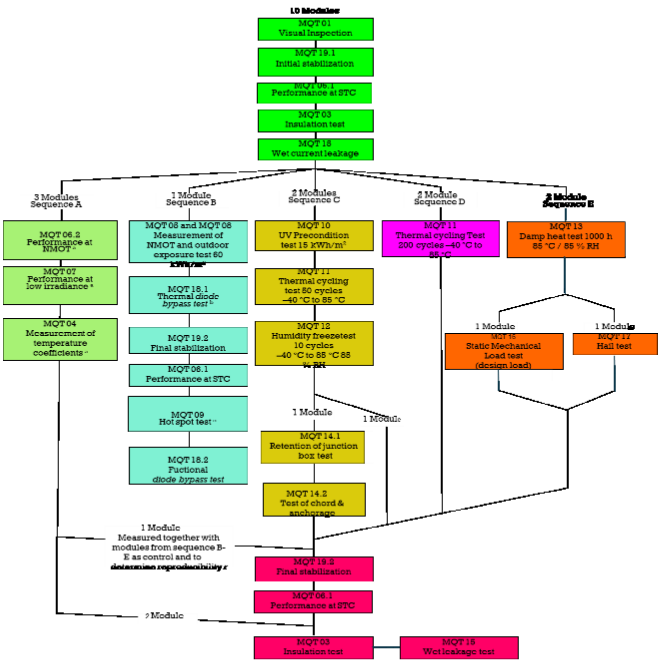

Fig. 1. Test flow diagram of the IEC 61215:2016 [14].

2.3. Pass-fail Criteria

Each of the modules must successfully pass the so-called test criteria [14]. If two or more modules fail to meet the following criteria, the design shall be deemed not to have met the qualification requirements.

2.3.1. Visual defects

There is no visual evidence of a major defect, as defined in Clause 8 of IEC 61215-1

2.3.2. Electrical Safety

a) The insulation test (MQT 03) requirements are met after the tests.

b) The wet leakage current test (MQT 15) requirements are met at the beginning and the end of each sequence.

c) Specific requirements of the individual tests are the measured insulation resistance of the modules shall not be less than 400 MΩ (for modules with an area of less than 0,1 m^2), and 40 $M\Omega m^{-2}$ (for modules with an area larger than 0.1 m^2)

2.3.3. Power Output and Electric Circuitry

Verification of rated label values (called Gate1) and maximum power degradation during type approval testing (called Gate2) requirements are met after the tests.

After stabilization, the measured maximum power, Pm(Lab) the modules shall be within the power rating of the name plate Pm(NP) including stated measurement uncertainty m1, called Gate1, as stated in Eq. (1).

$$P_m(Lab).\left[1+\frac{|m_1|(\%)}{100}\right] \geq P_m(NP).\left[1-\frac{|t_1|(\%)}{100}\right] \quad (1)$$

m_1 is the measurement uncertainty in % of laboratory for Pm (expanded combined uncertainty (k=2), ISO/IEC Guide 98-3), and t_1 is the manufacturer's rated lower production tolerance in % for Pm. For the arithmetic average of the measured maximum, Pm(Lab) shall be within the power rating of the name plate Pm(NP), as stated in the Eq.(2).

$$\bar{P}_m(Lab).\left[1+\frac{|m_1|(\%)}{100}\right] \geq P_m(NP) \quad (2)$$

The measured open-circuit voltage, Voc(Lab) of each module must meet criteria, as stated in Eq. (3).

$$V_{oc}(Lab)\left[1+\frac{|m_2|(\%)}{100}\right] \leq V_{oc}(NP)\left[1+\frac{|t_2|(\%)}{100}\right] \quad (3)$$

Voc(Lab) is a measured maximum Voc of each module under steady state, Voc(NP) is the maximum Voc stated on the nameplate of each module with no tolerance, m2 is the measurement uncertainty in % of laboratories for Voc, and t2 is the manufacturer's rated upper production tolerance in % for Voc.

Measured short-circuit current, Isc(Lab) of each module must meet the criteria, as stated in Eq. (4):

$$I_{sc}(Lab).\left[1+\frac{|m_3|(\%)}{100}\right] \leq I_{sc}(NP).\left[1+\frac{|t_3|(\%)}{100}\right] \quad (4)$$

Isc(Lab) is the maximum measured Isc of each module in stable conditions, Isc(NP) is the maximum Isc stated on the nameplate of each module with no tolerances; m3 is the measurement uncertainty in % of laboratories for Isc, and t3 is the manufacturer's rated upper production tolerance in % for Isc.

At the end of each test sequence or for sequence B after bypass diode test, the maximum power output drop of each module Pm(LabGate2) shall be less than 5%, referenced to the module's initial measured output power Pm(LabGate1). Each test sample shall meet the criterion, as stated in Eq. (5).

$$P_m(Lab_{Gate2}) \geq 0.95xP_m(Lab_{Gate1}).\left[1 - \frac{r(\%)}{100}\right] \quad (5)$$

The reproducibility r shall be less than stated in the technology specific parts of this standard. The reproducibility r is verified by comparing the control module(s) from sequence A after initial stabilization (beginning of the test) and after final stabilization (end of tests from sequence B to E).

2.4. The BRIN PV Laboratory

The study carried out at the PV laboratory at the National Research and Innovation Agency (BRIN), which was built in 2018, has been operating since 2019. The ISO 17025 accredited laboratory tests and certifies PV modules according to national and international standards, including IEC 61215. Figure 2 and Fig. 3. show the PV module test facilities at the BRIN PV Laboratory. The BRIN PV laboratory is equipped with the main equipment units, as shown in Table 2.

Fig. 2. PV laboratory (indoor) at the BRIN KST Serpong.

Fig. 3. PV laboratory (outdoor) at the BRIN KST Serpong.

This lab was chosen for research because it has complete facilities where equipment is integrated according to SNI IEC 61215:2016 standards. In addition, each test equipment has been calibrated and this laboratory has been accredited according to the SNI ISO/IEC 17025:2017 standard by the National Accreditation Committee since 2002. In addition, the BRIN PV Laboratory has been appointed as a testing laboratory by the Ministry of Energy and Mineral Resources. This appointment is based on Minister of Energy and Mineral Resources Regulation (PERMEN) Number 2 of 2021 which aims to implement quality standards for crystalline silicon photovoltaic modules.

Table 2. List of the PV testing laboratory

No	Test Equipment	Descriptions
1	Insulation tester	To evaluate the electrical insulation and wet leakage current test tester for MQT 03,15 in the module
2	Pulsed-state solar simulator	To determines the module max. power in STC conditions, low irradiance, and NMOT for MQT 02, 04, 06, 07
3	Steady-state solar simulator	To assesses module to withstand heat effects caused by hots pots for MQTs 09 & 19
4	Climate chamber (3 units)	To test the module to withstand thermal mismatch, fatigue, and other stresses; high-temperature and humidity effects (MQT-11, 12, 13)
5	UV precondition chamber	To identify materials and bonds vulnerable to UV-induced degradation for MQT-10
6	Visual inspection & EL testers	To detect visual defects in the module for MQT-01
7	Outdoor exposure test equipment	To measures module operating temperature for MQTs 01 and 08
8	Static mechanical load tester	To verify the module ability to withstand the minimum static load specified by the manufacturer for MQT-16
9	Hail impact tester	To verifies that the module can withstand hail impacts for MQT-17
10	Bypass diode testers	To evaluate the thermal design feasibility and long-term reliability of the bypass diode for MQT-18
11	Robustness of terminations tester	To determine module terminations and cable attachment to the module can withstand possible mechanical pressure during assembly, installation, or normal module handling for MQT-14

3. Results and Discussion

The study tested more than 14 module type design or in total of 168 pieces of C-Si PV modules from different local manufactures as well as imported products. Several PV module types failed to meet the pass criteria. Figure 4 displays the test results of 57% PV modules passed, and 43% failed. The 83% failed samples (5 out of 6) were from local manufacturer, highlighting performance and manufacturing concerns.

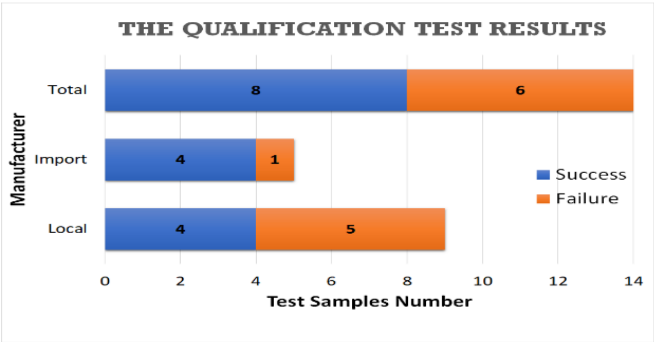

Fig. 4. Qualification test results of 14 PV module designs.

3.1. Types of Failure

Figure 5 shows the main issues with the PV modules were wet leakage current (59%), followed by cell metallization burn (12%), glass breakage, and frame looseness (8%). Additionally, back sheet delamination (8%) and other problems (8%). The observed visual defects of the modules observed are shown in Fig. 6.

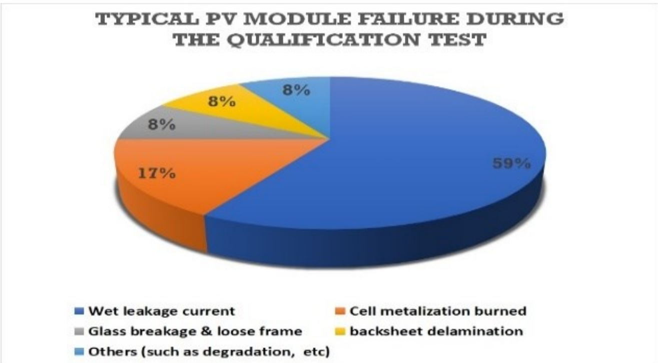

Fig. 5. Type of failure from the test results.

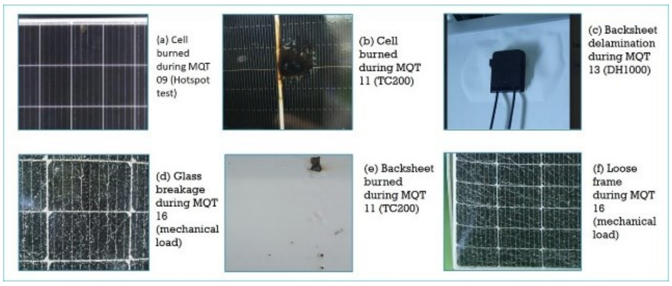

Fig. 6. Visual failure from the test results.

3.1.1. Visual failures

The burning or damage to solar cells during the qualification test of PV modules can occur due to several reasons, and it is an indication of potential issues in the module's design, manufacturing, or materials. The qualification test is intended to evaluate the performance, reliability, and safety of the PV module under extreme conditions. Figure 6(a) shows cell burning or damage, during hotspot (MQT09) and Figure 6(b) cell burning during thermal cycling (TC200, MQT-11) tests. Some possible reasons for solar cell burning during the qualification test, such as manufacturing defects, substandard materials, etc. To prevent solar cell burning during qualification testing, manufacturers must adhere to stringent quality control measures, use high-quality materials, and ensure proper module design and assembly. Failure to source proper bypass diodes may impose risk of hotspots and cell burning [19]. Thorough testing and continuous improvement based on test results are essential to enhance the reliability and safety of PV modules in the field.

Backsheet delamination is a common issue that occurs due to the combination of moisture and heat. Figure 6(c) and and 6(e) show backsheet delamination occurred during DH and TC200. The damp heat test is a reliability test used to assess the long-term durability and performance of PV modules under high humidity and elevated temperature conditions. During this test, the PV modules are subjected to high temperatures (typically around 85°C) and high humidity (typically around 85% relative humidity) for an extended period, often 1000 hours or more. Several factors contribute to backsheet delamination during the damp heat test, such as: moisture ingress, thermal cycling, backsheet material, manufacturing defects, etc. To prevent backsheet delamination during damp heat testing, manufacturers need to ensure high-quality backsheet materials, suitable adhesives, and robust lamination processes. Regular testing and improvements in backsheet design and materials can help enhance the reliability and longevity of PV modules in damp and hot environmental conditions.

Structural failure during the qualification test of PV modules can occur due to a variety of reasons related to design, manufacturing, and environmental factors. The qualification test is intended to evaluate the module's ability to withstand harsh conditions and ensure its long-term reliability. Figure 6(d) shows structural failure, i.e. glass breakage and loose frame. These failures occurred during the mechanical load test (MQT-16) in the sequence E of IEC 61215:20016. Some possible reasons for structural failure during the qualification test, such as: adhesive bond failure, manufacturing defects, material incompatibility, etc. To prevent structural failure during the qualification test, manufacturers need to ensure robust design and construction, proper material selection, and adherence to industry standards and testing protocols. Regular testing and quality control throughout the manufacturing process are essential to identify and address potential issues before modules are deployed in the field.

Understanding the implications of failures in PV modules is crucial for assessing their impact on reliability and safety in real-world applications. Failures in PV modules can reduce the overall reliability of a solar power system. The safety implications of these failures are substantial. Electrical malfunctions, fires, and physical damage not only jeopardize the longevity of the PV modules but also pose risks to personnel involved in system installation, maintenance, or operation.

3.1.2. Wet leakage failure

The wet leakage current, also known as moisture-induced leakage current, can occur during the qualification test of PV modules due to the presence of moisture or water ingress into the module's components. This phenomenon is a concern because it can lead to performance degradation and potential safety hazards. The wet leakage testing is carried out after the insulation test and repeated at the end of the quality tests after all other tests have been passed. The insulation resistance shall not be more than 40 MΩ per each square meter of the modules which have an area bigger than 0.1 m^2. The wet leakage current failure is the highest ranked failure during the PV modules test at the laboratory, as seen in the Fig. 7.

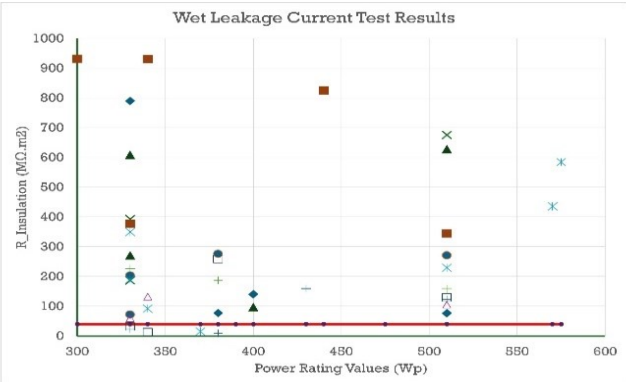

Fig. 7. Wet current leakage failure for different PV modules.

The wet leakage failure mainly occurred after the humidity freeze test or damp heat test for PV modules which may fail due to poor lamination or edge sealing defect during manufacturing, cracks or microcracks, delamination, etc. To prevent wet leakage current during the qualification test, it is essential for manufacturers to employ robust design and manufacturing processes. Proper encapsulation with high-quality materials, thorough sealing of all components, and rigorous quality control measures are crucial to ensure the module's resistance to moisture ingress. Regular testing and continuous improvement based on test results help enhance the reliability and performance of PV modules in damp environments.

3.2. Rated Values Verification

Maximum power verification according to IEC 61215 consists of verification of maximum power according to nameplate value (Gate1) and maximum degradation after final test (Gate2). In the Gate1 analysis, the results of the maximum power measurement of MQT 6.1 in the initial test are compared with the nominal value on the nameplate according to Eq. (1). Apart from that, the value of open-circuit voltage and short-circuit current is also compared with the nominal value of the nameplate, according to Eq. (2) and Eq. (3), respectively. While having no relation to safety in installation, deviation of voltage, current and therefore power value from those stated in nameplate will increase module mismatch losses in a string installation. Increased losses will subsequently lower PV plant output, revenue and economic calculation.

3.2.1. Maximum power values verification

Verification of the nameplate value for the maximum power (Pm) of the test sample is done in according to Eq. (1) and (2). Figure 8 and Fig. 9 show that the measured (Pm) values of maximum power and the average (Pm_avg) values of PV modules at the initial test are larger than the nameplate values. Two samples fail to meet the requirement due to their Pm values are larger than 0%, in the range of 0.87% to 6.59% than their nameplate.

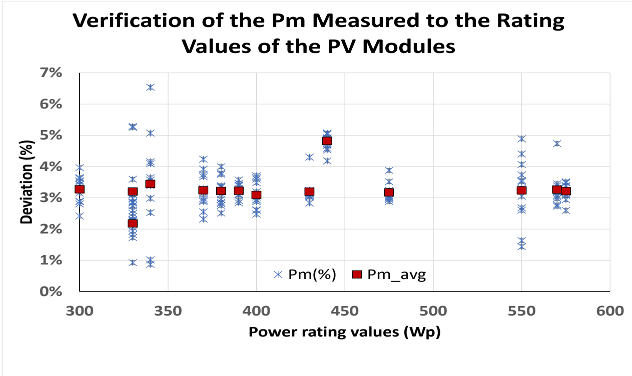

Fig. 8. Deviation of the measured Pm and Pm_avg to the rated values.

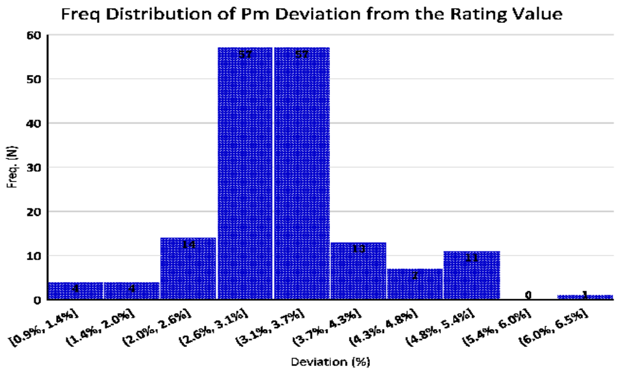

Fig. 9. Frequency distribution of the measured Pm to the rated values.

3.2.2. Open circuit voltage values verification

Verification of the nameplate value for the open circuit voltage (Voc) of the test sample is done in according to Eq. (3). The measured values for open circuit voltage (Voc) of the module are in general lower than the nameplate values. Figure 10 shows that deviation of the measured open circuit voltage (Voc) values of the PV modules in the range of -12.07% to 3.33%. Several modules fail to meet the passing criteria due to their Voc values are bigger than the rated values. The higher measured Voc might be danger for the design of PV system, especially for the input of MPPTs.

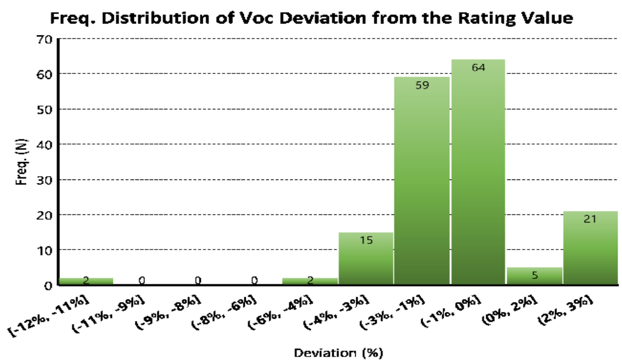

Fig. 10. Frequency distribution of the measured Pm to the rated values.

3.2.3. Short-circuit values verification

Verification of the nameplate value for the short-circuit current (Isc) of the test sample is done according to Eq. 4. Figure 11 shows that the measured short-circuit current Isc(Lab) values of the PV modules vary between -5% to 20% from the name plant values, Isc(NP). Around 30% of the test samples fails to meet the requirement due to the Isc(Lab) values are larger than the Isc(NP). The higher measured Isc might be danger for the design of PV system, especially for the grid-tie inverter.

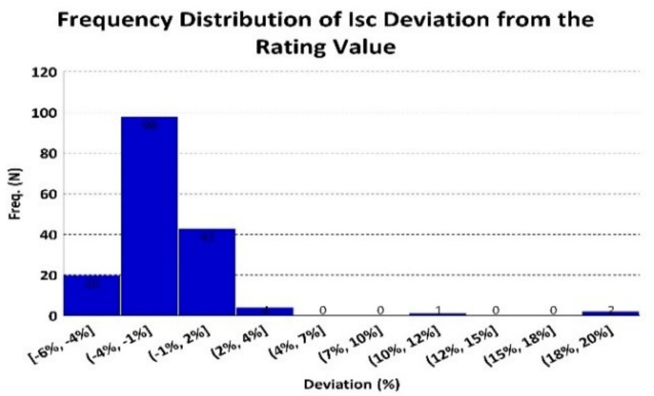

Fig. 11. Frequency distribution of the measured Isc to the rated values.

Verification of the rated values, including maximum power, open-circuit voltage, and short-circuit current, is integral to assessing PV module performance and safety. These verifications provide insights into the module's energy generation capabilities, compatibility with the overall system, and early detection of potential safety hazards, contributing to the long-term reliability and efficient operation of solar power systems.

3.3. Maximum Power Degradation (Gate-2)

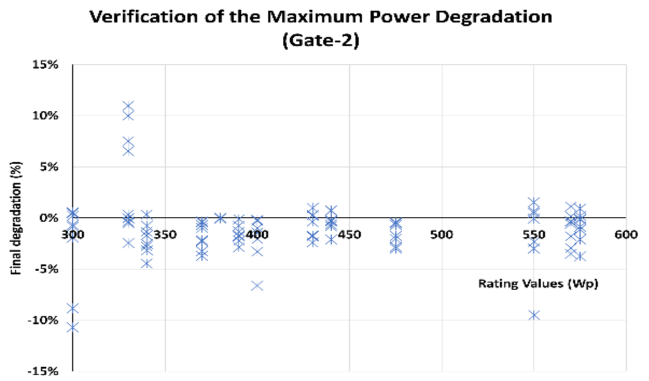

Fig. 12. Deviation of the maximum power degradation.

In general, the maximum power of silicon PV modules will experience degradation during operation at a rate of approximately -1% per year [18]. The maximum power degradation of a PV module during the qualification test can be verified according to the Eq. (5). To pass this test, the observed degradation should be less than -5%. Figure 12 and Figure 13 show that the maximum power degradation of the PV modules is mainly lower than -5%, with the average value of -0.9%. Only 4 out of 168 test samples (2.38%) fail to meet the requirement.

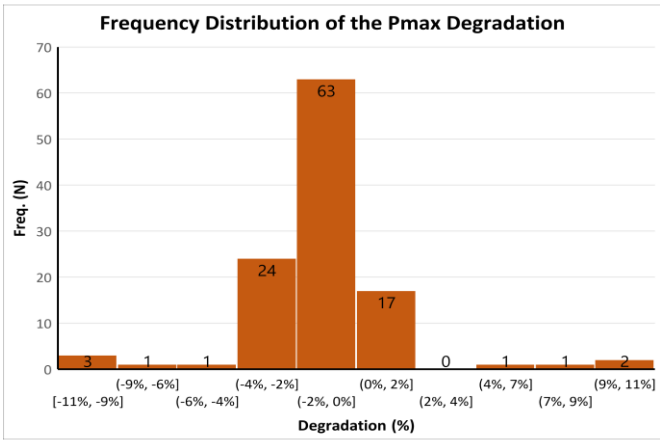

Fig. 13. Frequency distribution of the maximum power degradation.

Failure of any PV module to fulfil the requirements of 5% maximum degradation indicates that the module will degrade more than 1% per year as specified by most manufacturer as some tests in IEC 61215 standard are designed as accelerated aging test [19]. The parameter of maximum power degradation is a critical aspect in evaluating the long-term performance and reliability of PV modules. It refers to the maximum reduction in power output that a PV module can experience over its operational life. This parameter is crucial because it directly influences the economic viability and overall efficiency of a solar power system.

4. Conclusion

PV module performance and reliability issues is one of the challenges in solar PV development in Indonesia. This study has successfully identified, evaluated, and analyzed the performance and reliability of the PV products both from local manufacture and imported products in the country in accordance with IEC 61215:2016. In general, local manufacturers still need to improve the quality of their products, especially related to the selection of materials with high specifications, optimal manufacturing processes accompanied by quality control systems, safe handling and transportation of PV modules, as well as improving human resource expertise. In terms of policy, there is a need to protect consumers and local manufacturers to be able to compete with imported products. The Indonesian government through the Ministry of Energy and Mineral Resources stipulated PERMEN No. 2 of 2021 to ensure the quality and reliability of PV modules in Indonesia. This is in line with the National Energy Policy (KEN) which targets the utilization of New and Renewable Energy to reach at least 23% of the national primary energy mix by 2025 and reach at least 31% by 2050. As the use of renewable energy increases and the use of fossil fuels decreases, greenhouse gas (GHG) emissions will be further reduced in the coming decades. This will accelerate the achievement of net zero emissions globally. This research focuses on the overall performance and reliability issues of PV modules. For further research, it is necessary to conduct research related to the constituent materials of PV modules, such as solar cells, backsheet materials, by-pass diodes, even the optimum design and capacity of PV modules. Therefore, it is necessary to collaborate and share knowledge with local manufacturers, research institutions, international partners, and the government to maximize the energy obtained from PV modules and achieve the renewable energy mix target.

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Author Contributions

O.A.R was responsible for the conceptualization, validation, resources, data curation, software development, and project administration. O.A.R. and A.Fu. jointly contributed to the methodology, formal analysis, investigation, original draft preparation, review and editing, visualization, supervision, and funding acquisition. N.M.L., A.P., H.H., A.F., and L.S. contributed to the investigation, data curation, review and editing, and validation of the manuscript. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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