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|  | EMPLOYER’s REQUIREMENTS  Penamacor I  Appendix 3.01 - PV modules | |
|  | A picture containing outdoor  Description automatically generated | |
|  | CLIENT | P2K Renováveis, Lda |
|  | TECHNOLOGY | GROUND MOUNTED PV PLANT |
|  | PHASE | EPC TENDER |
|  | DOCUMENT N° | KGA-2021-01-C-ER-APP3.01 |
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INTRODUCTION

OBJECTIVE AND SCOPE

This Annex defines the minimum technical requirements expected by the Employer with respect to the PV modules. The Contractor’s scope includes:

* Procurement of the PV Modules
* Factory Inspection and Testing
* Shipment to Site and unloading of the PV Modules
* Site Installation and
* Site Inspection and Testing.

GENERAL REQUIREMENTS AND SPECIFIC STANDARDS

National and international standards as well as requirements within the ER General Conditions all apply to this scope of work. Where there is conflict between these requirements, the more onerous should apply unless a deviation has specifically been raised and agreed in Section 4.

In addition, the Contractor’s attention is brought to the following standards that are specifically referred to in this Appendix:

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| Standard | Reference |
| EN 50380 | Marking and documentation requirements for Photovoltaic Modules |
| IEC 60352-2 | Solderless connections - Part 2: Crimped connections – General requirements, test methods and practical guidance |
| IEC 61215 Ed 2 | Terrestrial photovoltaic (PV) modules - Design qualification and type approval |
| IEC 61701 | Photovoltaic (PV) modules - Salt mist corrosion testing |
| IEC 61730 | Photovoltaic (PV) module safety qualification |
| IEC 61853 | Photovoltaic (PV) module Performance - performance testing and  Module energy rating |
| IEC 62446 | Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance |
| IEC 62716 | Photovoltaic (PV) modules - Ammonia corrosion testing |
| IEC 62782 TS | Cyclic (Dynamic) mechanical load testing for photovoltaic (PV) modules |
| IEC 62788-2 | Measurement procedures for materials used in photovoltaic modules - Part 2: Polymeric materials - Frontsheets and backsheets |
| IEC 62790 | Junction boxes for photovoltaic modules - Safety requirements and tests. |
| IEC 62804 | Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation |
| IEC 62915 TS | Photovoltaic (PV) Modules - Retesting for type approval, design and safety qualification |
| IEC 62938 | Non-uniform snow load testing for photovoltaic (PV) modules |
| IEC 62979 | Photovoltaic module bypass diode thermal runaway test |
| IEC 63126 TR | Guidelines for qualifying PV modules, components and materials for operation at high temperatures |
| IEC 62941:2019 | Terrestrial photovoltaic (PV) modules - Quality system for PV module manufacturing |

DEFINITIONS AND Abbreviations

General definitions and abbreviations can be found in Appendix 1.01 (Definitions and Abbreviations).

The Contractor’s attention is brought to the following terms and abbreviations that are specifically referred to in this Appendix:

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| Term / Abbreviation | Definition |
| Bifacial PV Module | PV Module that is able to convert light captured on both rear and front sides into electrical energy. |
| EL Testing | Electro Luminescence Testing |
| Frame | Means the metallic frame of a PV Module. |
| Independent Tester | Has the meaning given in PVM-MFT01. |
| Junction box | means the box where the electrical connections are made to the module itself, usually including bypass diodes |
| LeTID | Light and elevated Temperature Induced Degradation |
| Module | Module means a photovoltaic (PV) module, and “Modules” shall be construed accordingly. |
| Module efficiency | Module efficiency is defined as the ratio of the module output power to the incident irradiance perpendicular to the surface of the PV module including the frame. |
| NOCT | Normal Operating Cell Temperature |
| PID | Potential-induced degradation |
| STC | Standard Test Conditions |
| Sample Products | Has the meaning given in PVM-MFT01. |
| Testing Criteria | Has the meaning given in PVM-MFT01. |

SCOPE OF WORKS

DESIGN LIFE

Plant Design Life as referred to in the ER General Conditions applies to this scope of works.

REQUIREMENTS

In the tables below, specific requirements are listed for design, construction, testing and (if applicable) commissioning. The column level refers to the requirement below:

* Level 1 – Full compliance is obligatory,
* Level 2 – Compliance may be adjusted by inclusion of a deviation in section 4 if agreed with the Employer,
* Level 3 – Compliance is not rigidly required but is advised.

Design

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| ID | Requirement | Level |
| PVM-DE01 | The supplied Modules shall comply with the general design of the Project as defined in the ER General Conditions and in particular with any Permit restrictions. | 1 |
| PVM-DE02 | Wherever possible, Modules to be supplied for the Project shall be of the same type and from a single manufacturer. The Module manufacturer shall comply with the following:i. ISO 90001 – Quality management systemii. ISO 14001 – Environmental management system; andiii. ISO45001 / OHSAS18001 – Occupational health and safety. | 1 |
| PVM-DE03 | The module supplier should be listed by Bloomberg New Energy Finance as meeting their Tier 1 criteria on the date of signature of the EPC contract. | 1 |
| PVM-DE04 | The Modules shall be produced by the Module Manufacturer itself. Any batch produced by a third party will be rejected. | 2 |
| PVM-DE05 | The Modules shall fulfil the requirements of the International Electro-Technical Commission (IEC) standard IEC61215 and shall be of Class ll. | 1 |
| PVM-DE06 | Construction material shall be monocrystalline or polycrystalline silicon cells | 2 |
| PVM-DE07 | The average power tolerance of the Modules must be positive. | 1 |
| PVM-DE08 | The Power of each Modules must be measured by Manufacturer in the manufacturing plants according to IEC 61215 standard with a AAA class measuring machine and a measurement uncertainty of 2.5% or less. | 1 |
| PVM-DE09 | Module efficiency shall be not less than [TBC] % at STC and corresponding cell efficiency shall not be less than [TBC] % at STC. Module efficiency is defined as the ratio of the module output power to the incident irradiance perpendicular to the surface of the PV module including the frame. test | 1 |
| PVM-DE10 | Modules shall have a linear Peak Power warranty and shall guarantee, as a minimum, 98 % of initial peak power at STC after the first year of operation and 84.8% after 25 years. Additionally, Modules shall have a minimum product warranty of 12 years. | 2 |
| PVM-DE11 | The rear Junction Box (connection box) of the Modules shall include by-pass diodes to protect against partial shading and module overheating as well as flying leads fitted with IP67 rated pin type Multi-Contact (MC) 1500 V rated connectors or equivalent. | 1 |
| PVM-DE12 | The precise connector brand and type shall be specified to allow matching connectors to be used on the associated string cables. | 1 |
| PVM-DE13 | The PV Module cable length must be suitable for connecting alternate PV modules together in the chosen portrait or landscape configuration (i.e. connecting PV Modules 1,3,5,7…8,6,4,2). | 2 |
| PVM-DE14 | The Modules shall be capable of operating under extreme temperature (-10°C to +50°C) and humidity (15% to 95%) conditions and will be designed to ensure the highest possible reliability in operation and to ensure minimum and efficient required maintenance over the lifetime of the system. | 2 |
| PVM-DE15 | Each PV module shall permanently and prominently display a technical characteristics plate as required by IEC 61215 and IEC 61730. | 1 |
| PVM-DE16 | Specifications for Modules shall also be provided at Nominal Operating Cell Temperature (NOCT) indicating percentage power loss as a function of temperature. The percentage power loss shall not exceed 0.5% per degrees Celsius (°C) away from STC. | 1 |
| PVM-DE17 | Full current intensity–voltage characteristics (I-V curves) will be provided at 25°C for a minimum of four different levels of irradiance between 200 W/m2 and 1000 W/m2. | 1 |
| PVM-DE18 | The solar cells within the modules shall be protected from mechanical stress and moisture via encapsulation in a plastic material of high clarity that is sufficiently flexible to allow contractions and expansions. This material shall be free of bubbles and cracks. | 1 |
| PVM-DE19 | The front surface of the encapsulation of the Modules shall be protected with tempered high transparency safety glass of low iron content and shall have a manufacturer-applied anti-reflective coating. The glass cover shall have strong resistance to heavy shocks, thermal stress and high wind loads. | 1 |
| PVM-DE20 | The Modules must be certified for resistance to a minimum suction pressure of 2400 Pa (wind speed of 130 km/h with safety factor 3) and a minimum increased distributed mechanical load of 5400 Pa on the front glass surface (wind, snow and ice). | 1 |
| PVM-DE21 | The PV laminate (glass / encapsulant + solar cells / rear side) shall be surrounded with a metal frame made of stainless steel or aluminium alloy. The frame shall be placed to protect the edges of the glass cover of the PV modules and to facilitate support and mounting. | 2 |
| PVM-DE22 | The construction of the frame of each PV module shall be adequate to allow for thermal contractions and expansions of the glass cover of the PV module. | 1 |
| PVM-DE23 | To avoid galvanic corrosion due to electrolytic action between different materials, any contact between different metals (apart from stainless steel bolts and washers, in a way that the validity of the modules warranties is not affected) in the Module frame must be fully electrically isolated. | 2 |
| PVM-DE24 | The active electrical components within each PV module shall be electrically insulated from the metal casing (frame), the rear cover and the front glass surface. The insulation must withstand 1500 Volts DC between the short-circuited module output leads and the metal frame and the rear and front covers. The insulation resistance after application of this voltage for 5 seconds must be greater than or equal to 1 ΜOhm. | 2 |
| PVM-DE25 | Where a non-standard fixing method is used (e.g. a Tracker speed clamp), written approval from the PV Module Manufacturer of the specific fixing method for the supplied PV Module shall be provided. | 1 |

### Off-Site Manufacturing and Testing

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| ID | Requirement | Level |
| PVM-MFT01 | The Employer shall be entitled to conduct an inspection of the manufacturing plants during the manufacture of PV Modules for the Project (Pre-shipment inspection). This will include access to the flash testing and other quality inspection processes. The Contractor will provide without additional charge, all reasonable facilities and assistance for such inspections. |  |
| PVM-MFT02 | The Contractor agrees that prior to shipping the Modules, the Contractor shall instruct, at the Contractor’s sole cost and expense, TUV SUD, CEA, RINA or any other independent third party agreed to by the Employer and the Contractor (the “Independent Tester”) to conduct pre-shipment tests of the Modules at the manufacturer’s factory or other certified laboratories. The number of Modules to be tested per Container (the “Sample Products”) shall be determined according to ISO 2859-1 sampling procedure applied to every Container of Modules to be delivered by the Contractor under this Contract.The inspection shall mainly consist of a visual inspection of the Modules, a measurement of their power output (with the following details for each tested module: serial number, module type, package number, Voc, Isc, Pmpp, Vmpp, Impp, FF, test date, record date) and EL test in accordance with IEC testing criteria (the “Testing Criteria”). | 2 |
| PVM-MFT03 | All the Sample Products will be subject to EL Testing. The Independent Tester will evaluate images for cell damage and micro-cracks according to industry accepted standards. The EL images shall be provided by the Manufacturer for all Sample Products under general inspection. | 1 |
| PVM-MFT04 | All the Sample Products will be subject to PID Testing according to IEC 62804. These tests will be carried out by the Independent Tester. | 1 |
| PVM-MFT05 | Supplied modules of PERC or PERT technology shall be subject to LeTID Testing. The test method will be submitted in advance to the Employer for approval. A standardised method, if available, will be preferred. | 1 |
| PVM-MFT06 | If, in the Independent Tester’s opinion, any of the Sample Products fail to meet the Testing Criteria, then the Contractor shall replace the Container containing the failed Sample Products with a substitute Container of new Modules and the testing procedure in the above clauses shall be repeated for the replacement Container. | 2 |
| PVM-MFT07 | The Contractor shall provide the results of each test performed by the Independent Tester to the Employer prior the Modules being shipped. | 1 |
| PVM-MFT08 | The Contractor will supply PV Modules that have been manufactured less than six (6) months before arrival on Site. | 2 |

### Site Delivery and Acceptance

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| ID | Requirement | Level |
| PVM-SDA01 | The Contractor shall ensure each container seal is not broken, or otherwise tampered with, and matches the unique identifier recorded by the manufacturer or Independent Tester at the manufacturing facility. The Contractor shall ensure photographic evidence of each seal is obtained and available for review by the Employer. | 1 |
| PVM-SDA02 | During the unloading of the pallets from the containers, the Contractor shall ensure restraints and strapping have remained intact and no evidence of shifting, sliding, or impact of the pallets is present within the container. The Contractor shall also inspect each pallet for signs of damage to the packaging and check if any shock sensor has been activated. The Contractor shall ensure photographic evidence of each container and pallet is obtained and shall promptly notify the Employer if any deficiency is observed. The Employer, in its sole determination, may approve the affected product, request that it is replaced, or request that additional testing is performed prior to installation. If a deficiency with respect to the manufacturer’s approved packaging standard operating procedures, evidence of damage, or another deficiency as described above is observed, an inspection of a modules sample from the container shall be conducted according to PVM-MFT01 and PVM-MFT02. | 1 |
| PVM-SDA03 | If any of the Sample Products fail to meet the Testing Criteria, then the Contractor shall have all the PV Modules in the container tested at his cost and only those that pass the Testing Criteria used in the Project. For the avoidance of doubt, any individual module that fails to meet the Testing Criteria shall be replaced with a conforming product. The Contractor shall provide the Employer with the serial numbers of all rejected PV Modules and confirm/denote that such PV Module was either i) not installed in the project or ii) individually tested and met all the test criteria described herein. | 1 |

On-Site Construction

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| ID | Requirement | Level |
| PVM-OSC01 | Modules must be handled carefully during the transportation and construction activities to prevent any micro-crack damage to the Modules. | 1 |
| PVM-OSC02 | Modules must be installed in accordance with the module installation manual. | 1 |
| PVM-OSC03 | The Contractor shall implement a specific handling instruction and sufficient training of the workforce taking into account the specific PV Modules, the skills and experience of the workers and the recommendations of the Module Manufacturer. The Contractor shall have visually inspected each Module before installation and shall regularly check that the Modules are not being damaged by the way they are handled and / or installed. | 1 |
| PVM-OSC04 | The Contractor will be responsible for replacing any PV Module damaged by it or its subcontractors. | 2 |
| PVM-OSC05 | For the grounding of anodized Module frames, grounding shims or clamps shall be used to ensure the Module is conductively connected to the mounting rack and thus incorporated into the potential equalisation of the Structure. | 1 |
| PVM-OSC06 | Should the aggregate peak power of the modules installed not reach the aggregate power level contracted for the Works, then the Contractor shall substitute the affected Modules in order to reach the total aggregate contract installed power requirement. | 1 |
| PVM-OSC07 | All Modules shall be barcoded and those barcodes scanned so an exact location for each module to a row and position level can be established and supplied to the Employer. The format of such data shall be in excel format as agreed to by the Employer. | 1 |

Testing and Commissioning

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| ID | Requirement | Level |
| PVM-TC01 | A visual inspection will be carried out as part of the mechanical completion tests. The visual inspection rejection criteria for the quality check at the Module delivery are the following:  • Corrosion issue in the cell or on the frame  • The wires are not properly insulated or there is a risk of electrical shock  • Connectors damaged deformed or cracked  • The junction boxes are damaged, not securely connected  • Glass:o Dirt area > 50mm2o Scratches with L>30mmo Crack crossing the entire thickness  • Cells: Any visible cracks or breaks on the cells  • Cells: String, cell misalignment of more than 1.5mm  • Backsheet:o Dent> 50mm2o Any scratcho Failure of adhesive bonds;o Bubbles or de-laminations forming a continuous path between a cell and the edge of the module;Make note of and/or photograph the nature and position of any cracks, bubbles or de-laminations, etc. which may worsen and adversely affect the module performance in subsequent tests. | 1 |
| PVM-TC02 | After commissioning, a thermographic analysis by drone survey will be performed by the Employer to evaluate possible defect or breakages happened during construction. | 3 |

### Documentation

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| ID | Requirement | Level |
| PVM-DOC01 | The following Module specifications shall be submitted by the Contractor before construction stage.  • Datasheets  • Installation manual  • Type test certificates to Applicable Standards and test reports:o IEC61215 test report and certificateo IEC61730 test report and certificateo IEC61701 test report and certificateo IEC62716 test report and certificateo independent LID test resultso independent IAM test resultso independent PID test results  • Accelerated test certificates  • Proposed module Bill of Materials  • Warranty terms | 1 |
| PVM-DOC02 | A minimum of 10 days prior to each delivery of Modules to the Site, the Contractor shall provide   • a Bill of Materials “BoM” (or if relevant multiple BoMs) detailing the subcomponents used in the manufacture and the manufacturing location of each subcomponent for that delivery. A list linking each PV module serial number with its respective BoM shall be provided prior to Commissioning.  • EL inspection for each PV module.  • Manufactured date for each PV module. | 1 |
| PVM-DOC03 | Upon delivery of the modules to site, the Contractor shall submit factory flash test reports in electronic format (Excel files) which shows the performance data at STC for each PV module (with the following details: serial number, Module type, package number, Voc, Isc, Pmpp, Vmpp, Impp, FF, test date, record date, BoM). The Contractor shall provide a summary spreadsheet containing the totals of all the spreadsheets and the full plant capacity; | 1 |
| PVM-DOC04 | Results for all other tests carried out on site or by the Independent Tester shall be provided as they become available. | 1 |

PROJECT SPECIFIC REQUIREMENTS

If relevant, the following project specific requirements should be considered.

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| Section | Project Specific Requirement |
| Design | The Modules shall be of a brand stated on the KGAL Whitelist. |
| Design | The Modules shall be Bifacial PV Modules. |

DEVIATIONS

The following deviations have been proposed during the tender phase and agreed with the Employer.

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| Section | Deviation |
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1. LeTID Test requirements

PERC PV Modules may be tested either in accordance with section A.1 or A.2 with a minimum sample size per BOM of [8].

Results from the power measurements of a reference module should also be displayed in the test report.

* 1. Testing in Accordance with IEC61215-2:2016

Tests shall be carried out in a climatic chamber following the IEC61215 edition 2 with the following specific conditions:

* Temperature: (75 ± 2)˚C
* Monitoring of electrical circuitry of the modules at Idark = Isc,stc - Imp,stc
* Minimum 2 cycles with duration 162 hrs each
* Inclusive Measurement of the IV curve at Standard Test Conditions (STC) according to IEC

60904:2006 (included Initial and Final)

* If criteria (Pn – Pn-1) / Pn > 0.01 is fulfilled, further climate chamber cycles shall be undertaken.

The Test shall be passed if:

where

* P0 is the power measurement prior to testing but after stabilization according to
* IEC 61215-2:2016
* Pn is the power measurement after cycle n
* Pfinal is the final power measurement after the last cycle
* n is the number of cycles undertaken
* m is the number of PV modules tested per Bill of Materials
  1. Testing in Accordance with TÜV Rheinland procedure 2pfg

Tests shall be carried out in a climatic chamber according to 2pfg2689/04.19 with the following specific test conditions:

* Temperature: (75 ± 2) ˚C
* One cycle of 300 hours with appliance of a current: two times (Isc, initial - Impp,initial)
* IV curve and electroluminescence measurements before and after stress are

included

The Test shall be passed if:

where

* P0 is the power measurement prior to testing
* P1 is the power measurement after testing
* m is the number of PV modules tested per Bill of Materials