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|  | EMPLOYER’s REQUIREMENTS  Penamacor I  Appendix 3.04 – DC Cables | |
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|  | CLIENT | P2K Renováveis, Lda |
|  | TECHNOLOGY | GROUND MOUNTED PV PLANT |
|  | PHASE | EPC TENDER |
|  | DOCUMENT N° | KGA-2021-01-C-ER-APP3.04 |
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| **TABLE OF CONTENTS** |
| [1. INTRODUCTION 3](#_Toc78186450)  [1.1 OBJECTIVE AND SCOPE 3](#_Toc78186451)  [1.2 GENERAL REQUIREMENTS AND SPECIFIC STANDARDS 3](#_Toc78186452)  [1.3 DEFINITIONS AND Abbreviations 3](#_Toc78186453)  [2. SCOPE OF WORKS 4](#_Toc78186454)  [2.1 DESIGN LIFE 4](#_Toc78186455)  [2.2 REQUIREMENTS 4](#_Toc78186456)  [2.2.1 Design 4](#_Toc78186457)  [2.2.2 Off-Site Manufacturing and Testing 7](#_Toc78186458)  [2.2.3 Site Delivery and Acceptance 7](#_Toc78186459)  [2.2.4 On-Site Construction 7](#_Toc78186460)  [2.2.5 Testing and Commissioning 9](#_Toc78186461)  [2.2.6 Documentation 9](#_Toc78186462)  [3. PROJECT SPECIFIC REQUIREMENTS 9](#_Toc78186463)  [4. DEVIATIONS 10](#_Toc78186464)  **VERSION CONTROL**   |  |  |  |  | | --- | --- | --- | --- | | Version | Date Approved | Approved By | Notes | | A | 26/07/2021 | Mike Carter | Released for Penamacor I ITT | |  |  |  |  | |  |  |  |  | |  |  |  |  | |  |  |  |  | |

INTRODUCTION

OBJECTIVE AND SCOPE

This Annex defines the minimum technical requirements expected by the Employer in the delivery and installation of the DC Cables. The Contractor’s scope includes:

* Procurement of the DC Cables
* Factory Inspection and Testing
* Shipment to Site and unloading of the DC Cables
* Installation of the DC Cables and
* Site Inspection and Test.

GENERAL REQUIREMENTS AND SPECIFIC STANDARDS

National and international standards as well as the general requirements referred to 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 50521 | Connectors for photovoltaic systems |
| EN 50618 | Electric cables for photovoltaic systems |
| EN 61034 | Measurement of smoke density of cables burning under defined conditions |
| IEC 50262 | Cable glands for electrical installations |
| IEC 60228 | Conductors of insulated cables |
| IEC 60364 | Low-voltage electrical installations |
| IEC 62548 | Photovoltaic (PV) arrays - Design requirements |
| IEC 62738 | Ground-mounted photovoltaic power plants - Design guidelines and recommendations |
| IEC 62852 | Connectors for DC-application in photovoltaic systems - Safety requirements and tests |
| IEC 62930 | Electric cables for Photovoltaic systems |
| IEC 63225 TR | Incompatibility of connectors for DC-application in photovoltaic systems |

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 abbreviations that are specifically referred to in this Appendix:

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| Abbreviation | Definition |
| DC | Direct Current |
| LV | Low Voltage |
| UV | Ultraviolet |
| Large Projects | Projects greater than [50MWp] |
| String Cable | The cables from the PV module strings to the DC Combiner Box or inverter (as applicable) |
| Transfer Cable | The cables between DC Combiner Boxes and Inverters |

SCOPE OF WORKS

DESIGN LIFE

Plant Design Life as referred to in General Employer’s Requirements 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 |
| DCC-DE01 | DC Cables specifications and design shall be compliant with the Reference Standards, including the IEC standards. | 1 |
| DCC-DE02 | DC Cables specifications and design shall be suitable for the environmental conditions at the Site. | 1 |
| DCC-DE03 | DC Cables shall be sized for maximum current in continuous service as per applicable standard. | 1 |
| DCC-DE04 | All cables must withstand maximum shortcut current during the transient period of the actuation of the protections. | 1 |
| DCC-DE05 | The average of electrical losses of the DC system at STC conditions shall not exceed [1.0% ] of DC part of the Plant. | 2 |
| DCC-DE06 | DC Cable current ampacity calculation shall take into account the maximum anticipated current, downstream fuse rating and the derating factor of their installation (maximal ambient temperature, number of cables in the same trays/conduit/trench, soil thermal resistivity, maximum soil temperature etc.). | 1 |
| DCC-DE07 | DC Cables shall be correctly sized to minimize mismatch losses. | 1 |
| DCC-DE08 | Surge protection design:  • Modules DC cables induction loops shall be minimized, to prevent generation of inductive surges in the LV circuits, in accordance with IEC 60634 and IEC 62548 requirements.  • The distance between the two polarities (positive and the negative cables) shall be minimized as much as possible, between strings connectors and junction boxes and also between junction boxes and inverters. | 1 |
| DCC-DE09 | The connections between modules to form the Strings shall minimize the near shadings effects between the modules, (for example by connecting only modules in the same row so that near shadings affect only the shaded row). | 1 |
| DCC-DE10 | All DC cables shall:  • Be copper or aluminium-made specific double-insulation PV cables;  • Be UV resistant or protected from UV by appropriate means;  • Be ozone resistant;  • Have an enhanced resistance to heat and fire and with low smoke emissions;  • Operate in an extensive temperature range;  • Have enhanced resistance to friction;  • Have a minimum cross-section of 4mm². | 1 |
| DCC-DE11 | String cables up to the DC Combiner Box shall be:  • Suitable for outdoor use;  • Cold resistant;  • Halogen-free;  • Flexible class 5;  • 1.5kV DC (or 1kV in the event of a 1kV design) for voltage between conductors;  • Only in ducts if underground. | 1 |
| DCC-DE12 | Transfer Cables up to the inverters’ input shall:  • Have copper conductors or, for conductors with sections greater than 35mm², aluminium may be used;  • Have cross linked polyethylene (XLPE) insulation;  • Have polyvinyl-Chloride (PVC) bedding;  • Have galvanised Single Wire Armour (SWA) or Aluminium Wire Armour (AWA) armour/protection, if directly buried in the ground;  • Have polyvinyl-Chloride (PVC) sheath/jacket;  • Be rated 1.5kV DC (or 1kV in the event of a 1kV design) for voltage between conductors.. | 1 |
| DCC-DE13 | All underground cables must be rated AD7 class minimum and class AD8 (permanent submersion) in temperate countries such as the UK or where parts of the Site have a high level of underground water expected several weeks per year. | 1 |
| DCC-DE14 | In case of risk of termite presence during the Plant Design Life, electrical cable shall be termite resistant. | 1 |
| DCC-DE15 | DC Cable shall be selected (and installed) so that no damage is caused by water exposure, water ingress or condensation. | 1 |
| DCC-DE16 | The cable DC Connectors will fulfil at least the requirements of the international protection rating IP67 as defined in IEC 60529 and fulfil the safety requirements and tests of the EN 50521. | 1 |
| DCC-DE17 | Cable ways (trays, conduit, trench, framing channel, etc.) shall be designed to ensure the appropriate thermal performance of the cables installed therein. Cable ways shall not be loaded in excess of the manufacturer’s stated loading capacity. Bespoke designed cable ways, such as duct banks and in situ cast cable trenches, shall not be loaded beyond the capacity for which they were designed. Furthermore, in designing cable ways, the Contractor shall ensure a minimum of 10% spare capacity for future use. | 1 |
| DCC-DE18 | Unless armoured, DC Cables shall not be direct buried but will be contained in ducts. The Contractor shall ensure that an accurate record is kept of the location of all such buried cables. | 1 |
| DCC-DE19 | Spare ducts must be included in the design that allow replacement of any underground string cable without using the original duct or requiring trenching. | 2 |
| DCC-DE20 | Where cables between PV modules and inverters cannot be attached to existing structures, they shall be mounted on cable tray or buried underground in accordance with the requirement of this section. | 1 |
| DCC-DE21 | Cable trays and ladders must be of galvanised steel and of commonly available width. | 1 |
| DCC-DE22 | Exterior cable tray or ladders where used shall be covered with removable weather protective covers. | 3 |
| DCC-DE23 | Cables installation shall be mindful of appropriate segregation and separation of cables installed for different applications. Cables shall be considered to fall into one of at least four basic categories: HV power; LV AC power; DC power, control. Segregation of these categories shall always be maintained, preferably through appropriate spacing of cable ways. | 1 |
| DCC-DE24 | The Contractor shall supply and deliver all the DC Connectors necessary to link the PV Strings to the PV Modules and string inverters (if applicable). The DC Connectors shall comply with EN 50521 and IEC 62852. | 1 |
| DCC-DE25 | All combined female/male DC Connectors, including those connecting to PV Modules connectors, combiner boxes or inverters, shall be of the same model and manufacturer to guarantee a perfect compatibility. | 1 |

### Off-Site Manufacturing and Testing

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| ID | Requirement | Level |
| DCC-MFT01 | The cable type shall be tested to prove their Design Life for the Site environmental conditions. | 1 |
| DCC-MFT02 | For Large Projects, the Employer shall be entitled (at their cost) to request accelerated testing of the installed cables from the specific batches supplied. | 1 |

### Site Delivery and Acceptance

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| ID | Requirement | Level |
| DCC-DSA01 | DC Cables batch and type should be checked on delivery. In the case of multiple batches being delivered, the installation location of each type of cable should be noted on the as-built drawings. | 2 |

On-Site Construction

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| ID | Requirement | Level |
| DCC-OSC01 | The DC Cables installation shall be compliant with the applicable standards and the Manufacturer recommendations. The minimum cable bending radius used for all cables must comply with supplier specifications and applicable standards. | 1 |
| DCC-OSC02 | The DC Cables shall be installed so that no damage is caused by water exposure, water ingress or condensation. | 1 |
| DCC-OSC03 | Surge protection measures:  • Modules DC cables induction loops shall be minimized, to prevent generation of inductive surges in the LV circuits, in accordance with IEC 60634 and IEC 62548 requirements.  • The distance between the two polarities (positive and the negative cables) shall be minimized as much as possible, between Strings connectors and Junction Boxes and also between Combiner Boxes and inverters. | 1 |
| DCC-OSC04 | The DC Cables will be strapped to cable tray or on the parts of the mounting structure to support weight and not stress the Junction Boxes or cables themselves and to be constantly visible for maintenance purposes. | 1 |
| DCC-OSC05 | DC Cables may only be laid into framing channels in the event that the specific framing profiles’ design averts water stagnation. | 1 |
| DCC-OSC06 | DC Cables shall be tied or cleated to cable ways using materials specifically designed for this purpose. Cables shall be arranged neatly in cable ways and bundled, where and if appropriate. Conductive cable ties shall not be used on single-phase cables. Cable ties shall not be overtightened. Cleats and cable ties shall be UV resistant and suitable for outdoor installation. | 1 |
| DCC-OSC07 | Cable trays and cable ladders shall be installed as per the Standards. Cable trays and ladders shall be solidly earthed and a separate earth connection shall be made between sections where direction changes are made as per the Standards. | 1 |
| DCC-OSC08 | All cable ducts should be sealed where there is a risk of vermin infestation or degradation due to fauna and flora. The material used to seal the ducts should be fire resistant and take environmental conditions into consideration (i.e. UV light, rain, etc.). | 1 |
| DCC-OSC09 | Cables shall be supported along their entire length. | 1 |
| DCC-OSC10 | Where cables come into contact with sharp support structure edges, appropriate anti abrasion pads or conduit will be affixed to the support structure to prevent any damage to the cables during construction and operation of the plant. | 1 |
| DCC-OSC11 | In the event of cable bridging between adjacent mounting tables, the exposed part of the cable run shall be laid into an appropriate (in size and UV protection) conduit or spiral wrap. | 1 |
| DCC-OSC12 | All cable entries into enclosures shall use suitably sized glands (no foam or packing) and all conduits shall be grouted for sealing of open conduit ends. The use of expanding foam is not permitted for sealing open conduit ends. | 1 |
| DCC-OSC13 | Cables shall be clearly identified at both ends with a robust and weatherproof cable identification tag designed to last for the Plant Design Life. | 1 |
| DCC-OSC14 | The connections between modules to form the Strings shall minimize the near shadings effects between the modules, (for example by connecting only modules in the same row so that near shadings affect only the shaded row). | 1 |
| DCC-OSC15 | Boot lace ferrules shall be used where string cables are terminated into combiner boxes. | 1 |
| DCC-OSC16 | Cable terminations shall be checked that they are appropriate for the type and size of cable and shall be installed with equipment and dies specifically manufactured for the termination type. | 1 |
| DCC-OSC17 | Crimper calibration certificates should be provided. | 2 |

Testing and Commissioning

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| ID | Requirement | Level |
| DCC-TC01 | A visual inspection will be carried out as part of the Mechanical Completion Tests. | 1 |
| DCC-TC02 | A specific sample test to check the DC connector tightness shall be carried out at the site prior to signoff with the installation team. Should more than 2% of the sample be found to be non-compliant, a full check will be undertaken. | 1 |

### Documentation

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| ID | Requirement | Level |
| DCC-DOC01 | Design documentation:The Contractor shall provide the Design Documentation part relative to electrical design as per Appendix 5.1.1 to the Employer within 15 Days of the award of the Contract. | 2 |
| DCC-DOC02 | Pre-construction documentation:The following documentation shall be submitted by the Contractor before construction stage.   • Detailed design / calculation showing adequate ratings of all cables along their entire length  • Datasheets   • Installation manual   • Type test certificates to applicable standards and test reports   • Accelerated test certificates   • Bill of Materials   • Warranty terms | 1 |
| DCC-D03 | Final cable calculations shall be provided as part of the as-built documentation | 1 |

PROJECT SPECIFIC REQUIREMENTS

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

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| Section | Project Specific Requirement |
| On-Site Construction | If the PV Modules to be installed are bifacial modules, the Cables shall be installed in such a way that the amount of light reaching the back of the Modules is not reduced. |
| On-Site Construction | Cabling should be suitable for sheep grazing and geese, when needed, following and not limited to the specifications below:   * DC cables that are vertically mounted onto piles should be laid into corrugated HDPE conduits up to a height of 800 mm from the surface of the ground, * All exposed DC cables must be mounted and tied on the mounting structures so no part of the cabling is hung below 800 mm height from the surface of the ground * Wherever any kind of Combiner Box (e.g. string monitor boxes) is fixed on the mounting structures, apart from making sure all associated cabling is inside conduits as per above, a perimeter of a 800 mm range around the distribution box will be fenced with a 800 mm tall (above ground) welded-mesh 50x50 mesh size fence. The fence will be adequately but not permanently founded in the ground so it can be easily removed in the case of maintenance works. * All the open points underneath substations or inverter buildings that stand above the surface of the ground will be properly covered so any access to exposed cabling can be avoided. The description and technical drawings of the above requirements will need to be confirmed and approved by the Employer. |

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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