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|  | EMPLOYER’s REQUIREMENTS  Penamacor I  Appendix 3.03 - Single axis trackers | |
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|  | CLIENT | P2K Renováveis, Lda |
|  | TECHNOLOGY | GROUND MOUNTED PV PLANT |
|  | PHASE | EPC TENDER |
|  | DOCUMENT N° | KGA-2021-01-C-ER-APP3.03 |
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INTRODUCTION

OBJECTIVE AND SCOPE

This Appendix defines the Employer’s minimum technical requirements for the delivery and installation of the single axis trackers. The Contractor’s scope includes:

* The design, supply and transportation of all equipment referred to here to the installation location;
* Transportation, handling and installation of all equipment which is in line with Manufacturers’ recommendations and which does not compromise the warranties of any piece of equipment;
* The construction and foundation of Trackers as necessary;
* The supply and construction of control systems, instrumentation, weather stations, network communications, power systems, drive trains and mechanical parts necessary for proper functioning of the Tracker system;
* The fixing of the Modules to the mounting Tracker;
* The full testing and commissioning of the provided equipment and works.

GENERAL REQUIREMENTS AND SPECIFIC STANDARDS

National and international standards as well as the general requirements referred to within the Employer’s Requirements 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 1990 | Eurocode basis of structural design |
| EN 1991 Eurocode 1 | Actions on structures |
| EN 1992 Eurocode 2 | Design of concrete structures |
| EN 1993 Eurocode 3 | Design of steel structures |
| EN 1997 Eurocode 7 | Geotechnical design |
| EN 1998 Eurocode 8 | Design of structures for earthquake resistance |
| EN 1999 Eurocode 9 | Design of aluminium structures |
| EN ISO 1461 | Specifications and test methods on hot dip galvanised coatings on fabricated iron and steel articles |
| EN ISO 14713-1 | Guidelines and recommendations for the protection against corrosion |
| EN 10346 | Continuously hot-dip coated steel flat products for cold forming - Technical delivery conditions” |
| EN 1090 | Execution of steel structures and aluminium structures |
| ISO 9223 | Corrosion on Metals and Alloys |
| IEC 62817 | Photovoltaic systems - Design qualification of solar trackers |

References above to international standards shall be taken to include a national prefix where applicable (e.g. *EN 1991* shall be taken as *IS EN 1991* in Ireland, and *EN ISO 1461* shall be taken as *BS EN ISO 1461* in UK).

References above shall be taken to include the national annex document, if it exists, which applies at the place of the installation location.

Each reference shall be taken to include all applicable parts and sub-parts (e.g. *EN1991* shall be taken to include parts -1-1, -1-2, -1-3 etc.)

The applicable version of each reference shall be taken to be the version in force at the place of installation location at the time of contract execution.

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 or Abbreviation | Definition |
| Tracker | Means the system comprising a tracking Structure, its power train, drive train, control device, communications and any other attached electro-mechanical parts. |
| Tracker System | Means a Tracker or group of Trackers together with its collective control system (hardware and software), network infrastructure, weather stations, and SCADA interface. |
| Structure | Means the mounting structures as described in 2.2.1“Structures” shall be construed accordingly |
| Superstructure | All parts of the structure which are above ground |
| Foundation | The structure which transfers loads from the superstructure to the ground |
| Pile | The type of foundation which is driven or bored through the ground to transfer loads from the structure to the ground. It may also comprise an integral part of the superstructure. |
| Drive Train | The drive train includes all components of the Tracker System that transfer mechanical motion to the payload interfaces, including all axes of rotation. Typically, this would include gears, motors, actuators, hydraulic/pneumatic rams, transmission, and linkages. The drive train does not include the electronic controls or the payload interface. |

SCOPE OF WORKS

DESIGN LIFE

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

[A Corrosion Design Life of [40] years shall apply to the design, specification and fabrication of corrosion protection systems to facilitate potential life extension of the project without the need for replacing structures.]

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 [xxx] if agreed with the Employer,
* Level 3 – Compliance is not rigidly required but is advised.

Design

|  |  |  |
| --- | --- | --- |
| ID | Requirement | Level |
|  | **Tracker architecture and main functional requirements** |  |
| SAT-DE01B | The Contractor shall optimise the structural form and layout (tracker type, range of motion, modules mounting format, structure height, ground clearance, row-to-row spacing, maintenance track width and maximum row length) to achieve the most economically advantageous performance at optimum EPC price.  The Contractor will use 1V Trackers (i.e. one module in portrait) | 1 |
| SAT-DE02 | The Tracker shall support modules so that the module height, Tracker spacing and layout complies with constraints set out in the documents in Appendix [6.03] (Planning approval and Conditions). | 1 |
| SAT-DE03 | The tracker shall be designed for normal operation with a full range of motion for wind speeds up to at least [60 km/h gust at 10m reference elevation]. | 2 |
| SAT-DE04 | Wind speed ramp-up rate for stow system design shall be determined by the Contractor based on site conditions, but the adopted value shall be not less than 1 m/s/min (gust at 10m reference height). | 2 |
|  | **Tracker testing, certification and independent reviews** |  |
| SAT-DE05 | If the Tracker system is not certified to meet IEC62817, the Tracker supplier shall:   * Provide test reports for any aspects of the Tracker system which have been tested to IEC 62817 requirements * Provide commentary on all gaps in compliance with IEC 62817   As a minimum, the Tracker system shall have successfully completed IEC 62817 testing for accelerated mechanical cycling and environmental testing. | 2 |
| SAT-DE06 | The variant of the Tracker system and its component parts which are to be installed at the Project shall be the same, or substantially the same, as the system and components listed in any testing, certification or sales information provided by the Tracker supplier.  The Tracker supplier shall highlight any differences in components between the version tested / certified / marketed and the version which shall be installed at the Project. The Tracker supplier shall provide a description of any differences for the Employer to review. The varied system or components shall not be any lower performance, durability or strength, not require additional maintenance than the tested / certified / marketed system and components. | 1 |
|  | **Tracker performance requirements** |  |
| SAT-DE07 | Tracking accuracy shall be [2°] in winds up to [10 km/h] (mean speed at 10m). | 2 |
| SAT-DE08 | Normal tracking, without restriction on range of motion, shall be possible in wind conditions up to at least [50 km/h] (gust speed at 10m). | 2 |
| SAT-DE09 | The Tracker shall be capable of a rotational speed of no less than [30°/min]. | 2 |
| SAT-DE09 | The Tracker shall be designed to be maintenance-free, besides annual visual inspection and replacement of any consumables. | 1 |
| FS-DE12 | Design and detailing of the structure shall be adapted to accommodate the topography at the installation site, without the need for *ad hoc* amendments or changes to the design made during construction. If necessary, adjustable length parts should be included in the design to allow structures to be adapted to terrain without cutting, extending or forcing parts together during construction. | 2 |
| FS-DE13 | The surface and edges of the Structure shall be smooth and consistent. Sharp edges from cutting or from galvanising defects shall be removed.  Finishes shall be designed and manufactured to meet the design operational life (as set out in 2.1) with regular maintenance. | 1 |
| FS-DE14 | The Structure should, where practicable, include provisions for DC cable routing and cable securing. | 2 |
|  | **Tracker structural design (general)** |  |
| FS-DE04 | Load-bearing parts of the Structures shall primarily comprise structural steel materials.  Aluminium materials may be used for module clamps.  Polymer materials may be used in load-bearing assemblies, subject to review and acceptance by the Employer. As part of its review, the Employer may request that the Contractor substantiates the choice of material in the form of material properties, production specifications, and/or testing which demonstrates the strength or durability of the material.  Timber and other materials are not permitted as part of load-bearing systems. | 1 |
| FS-DE16 | Permanent loads, wind loads and snow loads acting on the structure shall be determined using the applicable parts of Eurocode EN1991.  Design load combinations given in Eurocode EN1990 shall be used, with applicable combination factors (e.g. for combined wind and snow etc.).  Partial safety factors for loads shall be taken from Eurocode EN1990. | 1 |
| FS-DE17 | Permanent loads shall be determined by considering:   * Module self-weight, with reference to the supplier data sheet * Bundled string cable weight allowance (except for uplift case) * An allowance for the weight of any ancillary equipment (combiner boxes / inverters) if its support is integrated as part of the PV support structure. | 1 |
| FS-DE18 | If the snow zone for the installation location cannot be clearly determined from national snow load maps because of the resolution of the map, the zone with the higher snow load shall be adopted.  Snow shall be assessed based on the altitude of the highest part of the array. | 1 |
| FS-DE08 | The structure shall be designed and installed such that deflection, movement and vibrations do not adversely affect the support of PV modules, nor degrade the performance of PV modules. | 1 |
| FS-DE09 | Relative movement between adjacent structures shall be limited so that damage is not caused to string cables passing between structures. | 3 |
| FS-DE10 | The Structures shall support PV modules at the prescribed position and tilt angle and shall maintain this condition even after a 50-year extreme loading event (the Serviceability Limit State event – SLS – as defined in EN1990) without any damage needing maintenance or repair. | 1 |
| FS-DE10 | The Structures shall safely support PV modules and remain static even after an Ultimate Limit State (ULS) event (that is, the 50-year extreme event plus factors of safety). After this event, some repairable deformation and yielding of the Structures and needed maintenance may be permissible, provided that modules remain undamaged. | 1 |
| FS-DE16 | Partial safety factors for loads shall be based on KFI = 1.0 according to EN1990 Reliability Class / Consequence Class 2.  *[Or subject to Skyray approval, for a refined design with a trusted supplier can reduce as follows:*  Partial safety factors for loads may be reduced using KFI = 0.9 according to EN1990 Reliability Class / Consequence Class 1.] | 1 |
| FS-DE28 | Calculations shall be produced to prove the static design of the entire structure, including all load-bearing components and assemblies between the PV module surface and the ground. | 1 |
| FS-DE29 | All structural profiles / members shall be proven, with checks of all applicable failure modes such as:   * Flexural buckling due to axial force * Flexural torsional buckling due to bending * Local buckling modes due to bending, applicable to cold-formed steel profiles * Plastic failure due to bending * Shear * Web crippling and web buckling * Axial tension and compression   Cold-formed steel parts are susceptible to local buckling modes which can limit the effective strength of the part. Cold-formed steel parts shall be checked using rules in EN1993-1-3 and -5, or with an appropriately detailed buckling analysis model. | 1 |
| FS-DE30 | All parts of connection assemblies shall be proven, with checks of all applicable failure modes including but not limited to:   * Localised bending, prying, shearing, bearing, and tensile failure of metal plates * Bolt shear and tension failure   Connection assemblies may be designed by load testing, provided that standard requirements are met and sufficient safety margins are included for testing uncertainty and sample size. | 1 |
| FS-DE31 | The structure shall be designed to remain in equilibrium at the Ultimate Limit State (ULS, as defined in Eurocode) load level without rupture, buckling or other type of structural failure.  The structural shall be designed to remain elastic at the Serviceability Limit State (SLS, as defined in Eurocode) load level without yielding or permanent deformation. | 1 |
|  | **Tracker wind design – aeroelastic stability and dynamics** |  |
| SAT-DE10 | Aeroelastic instability shall be considered as an Ultimate Limit State (ULS). The trackers shall remain aeroelastically stable up to and including the gust wind speed associated with the static wind ULS design. | 1 |
| SAT-DE11 | Tracker aeroelastic stability shall be substantiated by multi-row, scale-model, aeroelastic wind tunnel testing.  The aeroelastic wind tunnel test report shall be submitted to the Employer for review. The aeroelastic wind tunnel testing and report shall meet the following requirements:   * Applicable range of geometry (module chord length and tilt, structure length, height, clearance and row spacing) shall be stated in the report and shall cover the geometry of the proposed installation; * Scaling method and issues should be reported; * Scale model stiffness, mass moment of inertia, frequency and damping shall be selected to correspond to the targeted full-scale design; * Minimum of 6-row array, with instrumented models being used (or swapped in to) the first, second, third and final rows as a minimum; * Minimum 12 azimuth direction sectors (6 with symmetry) tested; * Wind shear profile in the wind tunnel and its relationship to full scale terrain categories should be reported; and * Wind speed reference height should be reported.   Zoning of the proposed array into areas of different stow angle due to sheltering effects will be accepted provided that it is substantiated with test results.  The report shall confirm critical wind speeds for all initial tilt angles in the tracker range of motion.  The wind tunnel test report should discuss uncertainty levels. Where the report recommends a safety margin on aeroelastic critical wind speed to account for model/testing uncertainty, this shall be adopted. Where the report does not recommend a specific safety margin, a safety margin of at least 10% shall be used for design. | 1 |
| SAT-DE12 | Dynamic properties for use in the aeroelastic wind tunnel study shall be derived from full-scale structure testing.  Frequency (f, Hz) and damping (ζ, %) shall be determined from so-called ‘pluck testing’ of a full-scale tracker.  Stiffness (GJ/L, Nm/rad) may be based on load-deflection testing or, if it is clearly on the safe-side, by more basic numerical analysis of the structure. If stiffness is determined by numerical analysis, the stiffness contribution from modules shall be excluded.  Stiffness at large displacement levels is typically much lower than the apparent stiffness at low displacement levels. During the pluck test, a sufficiently large displacement shall be used so that stick-slip friction of bearings is overcome. In this context ‘large displacement’ is more than 20-30°. | 2 |
| SAT-DE13 | Insofar as aeroelastic critical wind speed is characterised by an allowable peak-to-peak tip rotation, the tracker shall be design for inertial loads associated with that rotation and in any case the peak-to-peak rotation shall be limited to 30°. | 2 |
| SAT-DE14 | Static wind pressures shall be augmented by dynamic amplification factors (DAFs) based on the tracker dynamic properties. | 2 |
|  | **Tracker wind design – static pressures** |  |
| FS-DE19 | The characteristic 10-minute average basic site wind speed for the installation location assessment shall consider:   * Basic wind speed from EN1991-1-4 national annex * 50-year return period (i.e. cprob = 1.0)   In case altitude is a parameter in the assessment of site basic wind speed, the altitude at the highest part of the array shall be adopted.  If a directional approach is adopted for wind design:   * the highest directional factors within the 90° sector ±45° from the module azimuth shall be used for uplift and downforce design, * a directional factor of 1.0 shall be used for wind friction assessment | 1 |
| FS-DE20 | The characteristic site peak wind pressure assessment shall consider:   * Orography assessment (if orography is significant according using EN1991-1-4) * Terrain category / roughness * Reference height equal to the highest part of the structure * The approach given in the applicable national annex to EN1991-1-4. | 1 |
| SAT-DE15 | Pressure coefficients shall be derived from wind tunnel testing. The test report shall be submitted to the Employer for review. The testing and report shall meet the following requirements:   * Applicable range of geometry (module chord length and tilt, structure length, height, clearance and row spacing) shall be stated in the report and shall cover the geometry of the proposed installation; * Scaling method and issues should be reported; * Minimum of 6-row array, with instrumented models being used (or swapped in to) the first, second, third and final rows as a minimum; * Minimum 12 azimuth direction sectors (6 with symmetry) tested; * Sufficient density of pressure taps to obtain in-stationary / peak local pressures at module scale, especially at the structure’s tips. * Wind shear profile in the wind tunnel and its relationship to full scale terrain categories should be reported; and * Wind speed reference height should be reported.   Zoning of the proposed array into areas of different wind load due to sheltering effects will be accepted provided that it is substantiated with test results. | 1 |
| FS-DE24 | In case terrain slope exceeds 5° (8.7%), two cases of pressure coefficients shall be analysed:   * Horizontal wind flow – the tilt of the module surface relative to the horizon shall be used * Wind flow parallel to the ground – the tilt of the module surface relative to the terrain slope shall be used.   The more onerous of the two cases shall be used for design. | 2 |
| FS-DE25 | In case terrain slope exceeds 5° (8.7%), sheltering assumptions shall only be used with independent wind engineering advice. Otherwise structures in these zones should be considered as fully exposed to wind without sheltering benefit. | 2 |
|  | **Tracker geotechnical design** |  |
| FS-DE32 | The Contractor shall submit a procedure for pile load testing, and a procedure for interpretation and use of the pile load testing results.  The pile load testing procedure shall outline:   * Type of pile profile(s) to be tested * Depth(s) of pile to be tested * Number and approximate locations of proposed tests * Testing method (load levels, points of load application, method of load application, point of displacement measurement, method of measurement, hold time for each load level)   A minimum of 0.5 locations/Ha, and not less than 10 locations in total, shall be tested. A higher testing rate is necessary if especially heterogenous results are expected.  If more than 10% of the site is expected to require pre-drilling, load testing of pre-drilled piles should also be conducted.  If testing is used directly to validate a specific pile design, then testing shall use the same pile profile and depth as the proposed structures. Test loads in this case shall be derived from the design extreme loads, and safety factors based on the sample size using correlation factors in Eurocode EN1997. At the ‘unfactored’ load level, lateral deflection at ground level shall not exceed 10% of the effective pile diameter, and uplift shall not exceed 3% of the effective pile diameter.  If testing is used to derive an analytical model of the ground conditions, then testing may use a selection of pile profiles and depths broadly similar to the propose structures. Test loads should be selected so that soil properties at the unfactored and factored load levels are well understood. Lateral pile test results shall be back-analysed using analysis software such as “L-pile” to determine the apparent soil properties for design. Factors of safety shall be applied according to EN1997. The worst case or, if there are enough data points, the 5%ile results shall be used for design of the piles for the proposed structure. In this case, the vertical pull-out strength can be back-analysed by more basic manual geotechnical calculations. Piles shall be designed so that at the ‘unfactored’ load level, lateral deflection at ground level shall not exceed 10% of the effective pile diameter, and uplift shall not exceed 3% of the effective pile diameter. | 2 |
| FS-DE33 | The Contractor shall review all pre-existing geotechnical desk studies and investigation reports provided by the Employer and consider the ground conditions in its structure design. | 1 |
| FS-DE34 | The Contractor shall address the impact of any:   * Significant volume-change potential of the soil (and make allowances in its pile design for ineffective depth of soil due to shrinkage) * Frost-heave potential * Pile driveability risk | 1 |
|  | [Bespoke requirements should be added in case of foundations other than driven or pre-drilled piles] |  |
|  | **Tracker durability** |  |
| FS-DE35 | All the structural steel elements shall be hot dip zinc galvanised, or continuously zinc galvanised or Magnelis ® coated. Piles subjected to highly corrosive soils may require additional protection. | 1 |
| FS-DE36 | Corrosion design of steel exposed to soil shall be assessed using the Romanoff method, or another quantitative method if agreed by the Employer. | 2 |
| FS-DE37 | Hot dip zinc galvanised components which are batch-galvanised in a zinc bath shall comply as a minimum with EN ISO 1461.  Hot dip zinc galvanised components which are fabricated from continuously galvanised sheet shall comply as a minimum with EN ISO 10346.  Magnelis® (zinc-aluminium-magnesium alloy) shall comply as a minimum with EN ISO 10346.  In all cases, coating thickness shall be selected according to the project Corrosion Design Life (see 2.1 Design Life) and annual zinc loss according to EN ISO 12944-2 class [C3 – note may be C2 to be confirmed by Geotechnical survey].  A combination of corrosion protection measures is permitted, provided that no bimetallic corrosion can be assured. | 1 |
|  | [Consider adding project-specific minimum zinc and magnelis thicknesses, and/or maximum annual corrosion rates in the first year which could be measured between PAC/FAC.] |  |
| FS-DE39 | Structures shall be designed and executed according to recommendations in EN ISO 14713-1 to ensure that, as well as use of coatings, good principles are used to protect against corrosion. | 1 |
| FS-DE40 | All connections including bolts, nuts, washers and associated fixings shall be of hot dip galvanized steel only for M10 or greater, or stainless steel A2, A4 or higher grade depending on the corrosion classification of the Site location. All frame fixings are required to be in metric specification. All module clamps shall either be aluminium or stainless steel A2 or A4. In the event that the contractor makes use of framing suppliers or equipment that are not [in the KGAL Whitelist], the Employer will consider the use of these provided that the contractor engages and pays for the appropriate Independent Third Party Technical Advisor approval. | 2 |
| FS-DE41 | The interface and materials at the interface between the module and the Structure shall be designed to prevent bimetallic corrosion and shall comply with any Module Supplier requirements for corrosion. | 1 |
| FS-DE42 | The Structure shall avoid accumulation of water or moisture within the Structure and shall accommodate an adequate flow of water off the Structure. | 1 |
|  | **Tracker - PV module interface** |  |
| SAT-DE16 | The support locations and attachment of modules shall comply with module supplier requirements as shown in module supplier document [installation manual], or with specific deviations agreed in writing by the module supplier and warranted by the module supplier. | 1 |
| FS-DE06 | Mounting Structures, clamps and other equipment interfacing with the Modules shall be approved for use by the Module Manufacturer. The approval shall be site-specific and confirmation from the Module Manufacturer and confirm that the associated warranties remain valid for the full warranty period. | 1 |
| FS-DE26 | Maximum module wind pressure and wind suction shall be checked using peak local pressures. The Contractor shall ensure that the design value (i.e. factored extreme) wind pressure does not exceed the module supplier tested, allowable, warranted pressure. | 1 |
|  | **Tracker drive train and mechanical** |  |
| SAT-DE17 | The Tracker drive train shall be [distributed (independent) / twin-row / centralised (ganged)]\*. | 2 |
| SAT-DE18 | The Tracker drives shall be [self-powered / powered from the solar PV strings / powered by site auxiliary supply]\*. | 2 |
| SAT-DE19 | The Tracker motion shall be actuated by [slew gear / linear actuator / pulley]\*. | 2 |
| SAT-DE20 | Maximum torque (or force) on the tracker drive shall be calculated for the stow wind speed plus at least [3 m/s] and shown to be lower than the maximum operating torque (or force) for the drive. | 1 |
| SAT-DE21 | Maximum torque (or force) on the tracker drive shall be calculated for the design extreme wind speed and shown to be lower than the maximum holding torque (or force) for the drive. The wind speeds and safety factors on loads and resistance shall be the same as for the structural design, assuming that the drive forms part of the load-bearing structure.  The holding torque (or force) resistance of the drive shall be based on physical load testing of samples. | 1 |
|  | **Tracker system electrical system** |  |
| SAT-DE22 | Lightning and surge protection should be suitable for the conditions anticipated by the lightning protection study. Communication equipment should be protected by Class II surge protection as a minimum. | 2 |
| SAT-DE23 | Earthing installed on the trackers should satisfy the requirements defined in the earthing study and the trackers should be connected to the earthing network in accordance with the earthing study recommendations. | 2 |
| SAT-DE24 | The tracker system battery specification shall be selected such that tracking operations can continue for a minimum of 3 days without charge. | 2 |
| SAT-DE25 | All electronic components within the tracker control system, weather stations and motor boxes shall be housed and sealed appropriately to achieve a minimum IP65 rating. Motors / gearboxes / drives shall be sealed to prevent the ingress of dust, sand and grit. | 1 |
| SAT-DE26 | Materials for cables, housing, connectors and any other non-metallic parts shall be selected to withstand UV for the duration of the project design life without degradation of functional performance and without becoming embrittled. | 1 |
| FS-DE15 | The Structure must include a method of providing equipotential bonding between all exposed metal components of the mounting Structure as well as all exposed metal components of the Modules. The components of the equipotential bonding network shall be chosen to minimise the occurrence of galvanic corrosion between dissimilar metals. | 1 |
|  | **Tracker control, weather station and network communications** |  |
| SAT-DE27 | The control system shall be designed to operate automatically without any user intervention. Remote STOP and restart shall be possible, via SCADA interface. Local manual STOP and restart shall be possible. Local manual STOP shall override any remote commands | 1 |
| SAT-DE28 | The Tracker communications network shall be [wireless / hard-wired]. | 2 |
| SAT-DE29 | Software and software updates shall be provided for the duration of the project life without fees. | 1 |
| SAT-DE30 | Central controller, tracker controller and weather stations shall be networked wirelessly using ZigBee or LoRa protocols. Antenna types, frequency bands, transmitter power, and component locations shall be selected so that components operate well within their wireless range and provide a high-reliability wireless network. The wireless communication system shall be designed to minimise the possibility of radio jamming, interference, or malicious attacks. | 2 |
| SAT-DE31 | As a minimum, the control system shall send the following signals to the project SCADA:   * Tracker operational mode (normal operational, backtracking, move to stow, stowed, fault) * Tracking setpoint angle * Actual tracking angle * Wind speed (gust and mean) * Wind direction * Battery state | 2 |
| SAT-DE32 | The tracker control shall be interfaced with multiple weather stations to provide redundancy and to detect high wind. A minimum of four weather stations shall be installed. | 1 |
| SAT-DE33 | Trackers shall respond to worst wind speed readings across the site rather than zoned to a local weather station, unless a zoned approach can be substantiated and approved by the Employer. | 2 |
| SAT-DE34 | Tracker weather station anemometers shall be:   * ultrasonic type; * mounted at height H ≥ 4m above ground; * preferably mounted at the top of a mast, or otherwise on a horizontal boom at least 5D from the face of the mast (where D is the mast diameter); * mounted in a location without any obstacles, except for the PV array, within a radius of 10H; * generally located at convex corners of the array perimeter, so as to allow good quality measurement of wind speeds upwind of the PV array; * Commissioned and calibrated by trained installers.   Weather station layout shall be agreed with the Employer. | 2 |
| SAT-DE35 | Preferably at least one high-quality weather station at 10m above ground would be installed to provide reference speeds at 10m. After 6-12 months of commissioning the weather stations, preferably the tracker weather stations would be correlated to the high-quality 10m mast. | 3 |
| SAT-DE36 | The Owner may use the tracker weather station data as grounds for a warranty claim in the event of damage to the structures. The instruments should be calibrated by qualified independent technicians as part of commissioning, to the satisfaction of both parties. | 1 |
|  | **Tracker stow system design** |  |
| SAT-DE37 | Insofar as the Tracker is not designed to withstand all wind conditions throughout the full range of motion, trackers shall be designed to move to a wind-safe stow angle before design extreme wind speeds are reached.  This requirement does not apply to the Array Technic DuraTrack tracker. | 1 |
| SAT-DE38 | The Tracker shall have an active wind stow system using a high angle, nose-down philosophy to avoid aeroelastic instability.  This requirement does not apply to the Array Technic DuraTrack tracker. | 1 |
| SAT-DE39 | The tracker supplier shall demonstrate good system integration for the different component parts, specifications and parameters of the stow system. The following parameters and specifications shall be coordinated to result in a reliable stow system:   * Stow trigger wind speed * Site wind ramp-up speed * Wind speed correction between tracker height and mast height * Anemometer polling frequency * Wind speed averaging period * Network communication time lag * Tracker / drive rotational speed specification (under load) * Aeroelastic stability critical wind speed, with safety margin * Structural dynamic and static design * Rotational/tilt tolerances and second-order rotations   The coordination of the different system parameters and specifications shall be substantiated in an engineering report.  This requirement does not apply to the Array Technic DuraTrack tracker. | 1 |
| SAT-DE40 | In case of sensor failure, controller failure, weather station failure, network failure, or critical lower battery power the trackers shall be designed with a failsafe system which moves modules to the wind-safe stow angle.  This requirement does not apply to the Array Technic DuraTrack tracker. | 1 |
|  | **Warranty** |  |
| SAT-DE41 | Electro-mechanical parts: 5 years  Structural and load bearing parts: 10 years  Corrosion protection: [25 years / full project design life[[1]](#footnote-2)]  If measurements between PAC and FAC show that corrosion rates (μm/year) exceed the rate which would cause the corrosion protection to be consumed before the end of the project design life, this shall be treated as a defect under the contract even if functionality of the system is not compromised in the short-term. | 1 |
| SAT-DE42 | Warranty shall commence at the date of project Provisional Acceptance. |  |
| SAT-DE43 | Tracker supplier shall inspect the Trackers prior to Take Over and provide written confirmation of the validity of the warranty, or else state any specific snagging work required as a warranty condition. |  |

### Off-Site Manufacturing and Testing

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| --- | --- | --- |
| ID | Requirement | Level |
| FS-MFT02 | The scope for FAT shall be defined by a combination of reference to applicable international standards (e.g. EN1090 conformity assessment for structural components) and by reference to supplier’s specific test procedures and check sheets that are agreed upon with Employer prior to award of subcontracts. | 1 |
| FS-MFT03 | The Contractor shall provide a detailed program for planned FATs prior to manufacturing and shipping; and the Employer, or the Employer’s representative shall be entitled to witness these FATs. | 1 |
| FS-MFT04 | The below specifies a minimum list of Structure FATs. The Contractor is not limited to these and should also complete any additional tests as per its internal processes.   * material test certificates * fasteners: material declaration * weld visual inspections * visual inspection and quantity * dimensional check of profile cross sections, profile lengths, and positions of holes/attachments, confirming compliance with design and applicable standards * galvanizing check (visual condition and thickness measurements) * pre-shipment inspection | 2 |

### Site Delivery and Acceptance

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| --- | --- | --- |
| ID | Requirement | Level |
| FS-DSA01 | Upon reception on site of the elements of the Structure, the Contractor shall inspect them and verify galvanization thickness and absence of any trace of corrosion. Non-compliant components shall be rejected. | 2 |
| FS-DSA02 | The Contractor shall inspect for any shipping, handling or storage damage. Non-compliant components shall be rejected. | 1 |
| FS-DSA03 | Materials shall be stored in such a way that they are raised off the ground and covered.  Storage locations and methods shall prevent materials from being covered in mud, water or any substances which may cause damage. | 1 |
| FS-DSA04 | The Contractor shall obtain and keep material production certificates and traceability information for all structural profiles. the Employer reserves the right to audit this information. | 1 |

On-Site Construction

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| --- | --- | --- |
| ID | Requirement | Level |
| SAT-0SC01 | Prior to installation commencing, the Contractor will provide confirmation either that the organisation carrying out the installation is an “approved installer” according to the Tracker OEM or that the warranty will remain in force if this is not the case. | 1 |
| FS-OSC01 | Prior to installation of any components, the Contractor shall finalise and submit for approval an installation manual and any other procedures required for completion of the work.  The design information, installation manual, and any installation procedures may be contradictory. In the event that any discrepancies are detected during installation, installation work shall be halted until the discrepancy is resolved by the author, the information has been revised, and the revised information approved by the Employer. | 1 |
| FS-OSC02 | The contractor shall provide a procedure to be followed in the event of pile refusal.  The procedure may include:   * a tolerance for pile embedment depth * a method and acceptance criteria for lateral and pull-out testing of piles which have met refusal * remedial requirements, such as pre-drilling or alternative foundation types   The pile depths, tolerances, and any methods contained in the procedure must coordinate with the static design assumptions so that all the installed piles comply with the approved design. | 1 |
| FS-OSC03 | The contractor shall maintain a pile installation log, identifying all deviations from the target depth, position, inclination, azimuth/twist, or any other aspect of installation quality.  A course of action for each type of deviation shall be agreed with the Employer and the Contractor shall track and record the completion of those actions in the same log. | 2 |
| FS-OSC04 | Structure installation shall strictly follow the approved design drawings, installation manual and procedures (e.g. ramming, pre-drilling, refusal). | 1 |
| FS-OSC05 | On rammed piles, the top of the piles shall be protected after ramming with durable coating paint (piles must be clean and dry before painting and product application instructions must be followed).  The contractor shall submit product details of the proposed galvanisation touch-up paint, demonstrating that it is compatible with the corrosion protection system and meets long-term durability requirements. | 1 |
| FS-OSC06 | The surface and edges of the Structures shall be smooth and consistent. Finishes shall be designed and manufactured to meet the design operational life (as set out in 2.1) with regular maintenance. | 1 |
| FS-OSC07 | All structures shall be continuously bonded and grounded to the earthing system. | 1 |
| FS-OSC08 | The Contractor shall attach all Modules to the Structure in a manner approved by the Module Manufacturer. | 1 |

Testing and Commissioning

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| ID | Requirement | Level |
| FS-TC01 | A visual inspection will be carried out as part of the Mechanical Completion Tests. The Contractor shall notably:   * control that all the Structure components (such as bolts, screws etc..) are installed; * verify overall setup distances, surfacing, alignment and completeness of the assembly; * verify galvanization thickness, the absence of any trace of corrosion and rectify scratches or defects; * verify proper alignment of the Structure and the module rows; * if applicable, verify that all module fasteners and module clamps have been installed properly; * verify that the supplier quality certificates of steel and galvanisation of the Structures are in accordance with applicable standards included those defined in the Technical Specifications of the Plant; * verify earthing of the Structures; * verify the compliance of the Module installation with the Module installation manual. | 1 |
| FS-TC02 | Acceptance tests.  The checklist shall include:   * Distance between the tables and the tables tilts are within contractual values. * The Structures and the foundations are free from visual defects and correspond to contractual specifications. * All the Structure components (such as bolts, screws etc..) are installed in accordance with design information (or agreed variations) * Sample check of at least 5% of bolt torques * The screws and bolts are free from any visible corrosion trace. * All the Modules are installed, are free from defects and the Modules correspond to contractual specifications. * The Modules are properly and durably attached to the Structures. * The Modules assembly system is free from defects and correspond to contractual specifications. | 1 |
| FS-TC03 | On Provisional Acceptance, all parts of the Structures shall be entirely free of corrosion. In case of corrosion traces, the parts concerned shall be replaced. Application of durable coating paint is accepted for limited corrosion traces below 1 cm² (except for screws and bolts with corrosion at the reception on site, which must be replaced in any case). Attention shall be paid to the risks of galvanic corrosion (between different metals or coating). | 2 |
| FS-TC04 | To prevent accelerated corrosion, any Structure components which are covered by mud or other substances shall be washed before Provisional Acceptance. | 2 |
| SAT-TC01 | Each tracker shall be individually commissioned and subjected to functional testing including:   * Manual / local operation and STOP/START * Connection with network and SCADA system * Rotation through the full range of motion, and correct end-stops * Correct response to stow command | 1 |
| SAT-TC02 | Tracker control system shall be tested on commissioning and include as a minimum:   * Test for normal operation * Test for wind stow (be simulating wind over stow threshold) * Test for loss of communications * Test for loss of weather station / controller power * Test for low battery stow * A check for actual tracking angle vs anticipated tracking angle for tracker availability measurement purposes. | 1 |

### Documentation

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| ID | Requirement | Level |
| SAT-DOC01 | Tender stage   * Detailed Tracker specification (in form of IEC62817 Table 1) * IEC 62817 certified test report (if exists) * UL 3707 certified test report (if exists) * UL 2703 certified test report (if exists) * Any third party vendor’s technology due diligence reports or bankability reports (if exists) * Test reports demonstrating any partial compliance with IEC62817 if the Tracker is not fully certified to IEC62817. (conditionally required, see SAT-DE05) * Commentary on all gaps in compliance with IEC 62817 (conditionally required, see SAT-DE05) * Data sheets * Confirmation of any project-specific options / differences from the standard offering | 1 |
| FS-DOC01 | Pile load testing documentation:  The Contractor shall provide the following documentation at least 4-weeks before commencing testing.   * Procedure for pile load testing * Procedure for interpreting and using pile load testing results | 1 |
| FS-DOC02 | Pre-construction documentation:  The following documentation shall be submitted by the Contractor before construction stage, at least 8-weeks before respective construction dates.   * Structural calculations * Pile load testing report and results interpretation * Geotechnical calculations * Corrosion design specifications and calculations (atmospheric and soil corrosion) * Detailed design drawings   + Site layouts and piling plans   + Structure general arrangement drawings   + Component-level fabrication drawings   (Detailed connection geometry, torque specifications, profile cross-section dimensions, material grades, and corrosion protection coating specifications shall be present on at least one of these drawings)   * Installation manual * Module Manufacturer warranty approval of clamps / connection interface. * Datasheets * Procedures in case of pile refusal * Galvanisation / coating touch-up product details and application procedure * Type test certificates to applicable standards and test reports * Bill of Materials * Warranty terms   Depending on design the design approach adopted, the Contractor shall also submit the following conditionally required information at the same time:   * Wind tunnel test report (conditionally required, see FS-DE22) * Substantiation of wind loading blockage assumptions in case of low ground clearance designs (conditionally required, see FS-DE23) * Material properties, production specifications, and/or testing relating to use of polymer materials used in load-bearing assemblies (conditionally required, see FS-DE04). * Module Manufacturer approval of non-standards attachment locations (conditionally required, see FS-DE05) * Module Manufacturer approval of direct contact with galvanised steel (conditionally required, see FS-DE41) | 1 |
| SAT-DOC02 | Pre-construction documentation, specific to single axis trackers:  The following documentation shall be submitted by the Contractor before construction stage, at least 8-weeks before respective construction dates.   * Aeroelastic wind tunnel test report (requirement SAT-DE11) * Static wind tunnel test report (requirements SAT-DE15) | 1 |
| FS-DOC03 | FAT programme:  Draft version shall be provided within 15 days of the award of the Contract. The programme may be resubmitted as and when test dates are finalised. | 1 |
| FS-DOC04 | Factory Acceptance documentation:  FAT certificates completed during the manufacture, assembly and testing of all the materials shall be forwarded to the Employer for approval prior to installation on Site. | 1 |
| FS-DOC05 | Mechanical Completion documentation:  The Mechanical Completion Tests results relative to the Structures as per [Appendix 4.3] Mechanical Completion shall be provided to the Employer within 10 Days after completion of the Mechanical Completion Tests. | 1 |
| FS-DOC06 | As-built structural drawings  The detailed structural drawings showing piling, framework assembly and module attachment method shall be provided to the Employer immediately after successful completion of the Mechanical Completion Tests. They need to show inter-row spacing and shading angle as well as array tilt and orientation. | 1 |
| FS-DOC07 | Commissioning documentation:  The Contractor shall provide copies of its own completed inspection plans, including checks on dimensions, angles, visual condition, corrosion protection thickness, and connection torques.  The Contractor shall provide a declaration of conformity, confirming that the structures meet all design requirements. | 1 |

PROJECT SPECIFIC REQUIREMENTS

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

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| Section | Project Specific Requirement |
| TBC | TBC |

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. Longer corrosion warranties will be considered favourably during the tender phase. [↑](#footnote-ref-2)