**Annex X (normative)**

**Data exchange format for site assessment parameters**

1. General

This annex specifies the digital format for site suitability data exchange. The format shall be based on json file format (ISO/IEC 21778 [1]) and shall follow the specification in this document. The Universal Coded Character Set (ISO/IEC 10646 [2]) and UTF-8 encoding without BOM (Byte order mark) shall be used. The example file which follows this specification can be found in [4].

2. Top level keys

Ten top level keys shown in table X.1 shall be used. The value of each key is an object, which contains the information described in table X.1. Each top level key except for “Meta Data” corresponds to one sheet of the example data exchange format in MS Excel format [5]. The detailed descriptions of the corresponding objects are given in the next section.

Table X.1 The contents of the top level keys

|  |  |
| --- | --- |
| Top Level Keys | contents of the objects |
| Meta Data | Summary of the meta data such as wind climate discretization information, number and IDs of wind turbine and measurement devices, coordinate system |
| Project Information | General project information. |
| Turbine layout Summary | Summary of the turbine layout and estimated wind climate at the position of turbine. |
| Measurement Device Summary | Summary of the measurement devices. |
| WS Frequency | Sector wise and omni directional discretized frequency distribution of wind speed at each turbine positions and measurement device positions. |
| WS Weibull | Wind rose and sector wise Weibull parameters. (The Weibull parameters are fitted based on the discretized wind climate) |
| Ambient Mean TI | sector wise and omnidirectional ambient mean turbulence intensity as functions of wind speed |
| SD TI | sector wise and omnidirectional standard deviation of turbulence intensity as functions of wind speed |
| Extreme Ambient TI | omnidirectional extreme ambient turbulence intensity |
| Temperature | temperature at measurement device point |
| Shear | directional and omnidirectional wind shear exponent |
| Inflow Angle | directional and omnidirectional vertical inflow angle |
| CcT | turbulence structure correction parameter CcT |

3. Description of each object

The keys in the object “Meta data” are listed in table X.2. Table X.2 also shows the type and the description of corresponding values.

Table X.2 The keys in the object “Meta data”

|  |  |  |
| --- | --- | --- |
| keys | value type | description |
| Number of wind direction sectors | int | Number of wind direction sectors. This shall be 12 or 16 according to the local requirement. |
| Wind speed bin width | int | Wind speed bin width. This value shall be 1 or 2. If this value is 1, the bin width is 1m/s centered at each integer number of wind speed in [m/s], except for the lowest wind speed bin which is defined between 0m/s and 0.5m/s. If this number is 2, the bin width is 2m/s centered at each even number of wind speed in [m/s], except for the lowest wind speed bin which is defined between 0m/s and 1m/s. In both cases, the center wind speed of the highest wind speed bin is 40m/s. (see figure X.1) Thus, the total number of the wind speed bin is 41 when this value is 1, and 21 when this value is 2. |
| Number of measurement devices | int | The number of measurement devices (met masts and lidars) included in this data exchange file. |
| Measurement device IDs | array of string | The IDs of the measurement devices. The number of the elements of the array is equal to “Number of measurement devices” defined in this section. This IDs are used throughout this file. |
| Number of wind turbines | int | The number of wind turbines included in this data exchange file. |
| Wind turbine IDs | array of string | The IDs of the wind turbines. The number of the elements of the array is equal to “Number of wind turbines” defined in this section. This IDs are used throughout this file. |

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Figure X.1 The definition of the wind speed bins

The keys in the object “Project Information” are listed in table X.3. Table X.3 also shows the type and the description of corresponding values.

Table X.3 The keys in the object “Project Information”

|  |  |  |
| --- | --- | --- |
| Keys | value type | description |
| Project name | string | The project name |
| Project owner | string | The owner of the project |
| Project number | string | The project number (optional) |
| Name | string | Name of person & organization completing form |
| Date | string | Date when form was completed. The format of the date shall be (YYYY-MM-DD). |
| Revision number | int | the revision number in an integer number |
| Reason for revision | string | The reason for the revision |
| Country & state | string | The country and state where the project is to be built. It is recommended to use ISO 3166[3]. |
| Turbine Coordinates Datum | string | The coordinate datum used in this file. (e.g., WGS84) |
| Turbine Coordinates Projection | string | If projected coordinate system (e.g., UTM) is used, the projection method shall be specified here. In addition, the detail of the projection (e.g., the zone of the UTM) shall also be specified here. If projected coordinate system is not used (i.e., longitude and latitude are used as the coordinate, this field shall be “lon-lat”. |
| Accompanying report file name | string | The name of the accompanying report file name (if any). |
| Accompanying report revision number | string | The revision number of the accompanying report (if any). |

The keys in the object “Turbine layout summary” are the IDs of wind turbines and the values for them are the objects the keys of which are listed in Table X.4.

Table X.4 The keys in the objects of wind turbine IDs in the object “Turbine layout summary”

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| Project name | string | - | The project name |
| Easting, Latitude, etc | double | m or degree | easting in [m] or longitude in [deg] of the position of the wind turbine. This shall be in [m] when projected coordinate system is used and shall be in [deg] when longitude and latitude are used as the coordinate system. |
| Northing, Longitude, etc | double | m or degree | northing in [m] or latitude in [deg] of the position of the wind turbine. This shall be in [m] when projected coordinate system is used and shall be in [deg] when longitude and latitude are used as the coordinate system. |
| elevation | float | m | The elevation of the ground at the position of the wind turbine above sea level |
| Wind Turbine Manufacturer | string | - | The name of the manufacturer of the wind turbine. |
| model | string | - | The wind turbine model name |
| rated power | float | MW | Rated power of the turbine |
| rotor diameter | float | m | The diameter of the rotor |
| hub height | float | m | The hub height above ground level. |
| data source | string | - | The IDs of the metmast (see Table X.5) from which the wind climate is derived. |
| Ve50 | float | m/s | The extreme 3 second gust wind speed with the recurrence period of 50 years. |
| V50 | float | m/s | The extreme 10 minutes averaged wind speed with the recurrence period of 50 years |
| cov | float | - | The coefficient of variation (COV) of the extreme wind speed. This is only relevant when COV of the extreme wind speed may exceed 10%. |
| Air density | float | kg/m3 | Air density for extreme wind speed |
| Annual Average Wind speed | float | m/s | Annual average wind speed |
| Weibull scale parameter | float | m/s | The omnidirectional Weibull scale parameter |
| Weibull shape parameter | float | - | The omnidirectional Weibull shape parameter |
| CCT | float | - | The turbulence structure correction parameter |
| Annual mean wind shear | float | - | The omnidirectional annual mean wind shear. |
| TI15 | float | % | Annual average turbulence intensity at 15m/s wind speed. |
| sigma I | float | % | The standard deviation of the turbulence intensity at 15m/s wind speed, in [%] |
| Flow inclination angle | float | degree | The inclination of the wind velocity vector from |

The keys in the object “Measurement device summary” are the IDs of measurement devices and the values for them are the objects the keys of which are listed in Table X.5.

Table X.5 The keys in the objects of measurement device IDs in the object “Measurement device summary”

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| Easting, Latitude, etc | double | m or degree | easting in [m] or longitude in [deg] of the position of the wind turbine. |
| Northing, Longitude, etc | double | m or degree | northing in [m] or latitude in [deg] of the position of the wind turbine. |
| ground elevation | float | m | elevation of the ground at the position of the wind turbine above sea level |
| measurement device height | float | m | height above ground level where measurement device is located |

The keys in the object “WS frequency” are the IDs of wind turbines and the measurement devices. The values for them are the objects the keys of which are listed in Table X.4. The key “WS data occurencies” is required only when the object is one of the IDs of the measurement devices.

Table X.6 The keys in the objects of IDs of measurement device and wind turbine in the object “WS frequency”

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| WS frequency | 2D array of float (array of array of float) | % | Discretized frequency distribution of wind speed for each wind speed bin and wind direction sector, presented as 2D array (array of array). The element number of the inner array is the number of wind speed bins (either 41 or 21 depending on “Wind speed bin width”, see Table X.2). The element number of the outer array is equal to “Number of wind direction sectors”. The frequency shall be presented by using percent (i.e., the sum of the all the elements shall be 100.). |
| WS data occurencies | 2D array of int (array of array of int) | - | The number of 10 minutes data included in each bin of wind speed and wind direction. The format of the array is the same as “WS frequency”. This is only required for measurement devices. |

The keys in the object “WS Weibull” are the IDs of wind turbines and the measurement devices. The values for them are the objects the keys of which are listed in Table X.7.

Table X.7 The keys in the objects of IDs of measurement device and wind turbine in the object “WS Weibull”

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| WS Weibull scale parameter all directions | float | m/s | The scale parameter of the Weibull distribution which approximate the frequency distribution of wind speed for all wind directions. |
| WS Weibull shape parameter all directions | float | - | The shape parameter of the Weibull distribution which approximate the frequency distribution of wind speed for all wind directions. |
| WS Weibull scale parameter | array of float | m/s | The scale parameter of the Weibull distribution which approximate the frequency distribution of wind speed for each wind direction. The number of the element of the array is equal to “Number of wind direction sectors” (see table X.2). |
| WS Weibull shape parameter | array of float | - | The shape parameter of the Weibull distribution which approximate the frequency distribution of wind speed for each wind direction. The number of the element of the array is equal to “Number of wind direction sectors” (see table X.2). |
| WS Weibull frequency | array of float | % | The frequency of occurrence of wind direction (wind rose). The number of the element of the array is equal to “Number of wind direction sectors” (see table X.2). The sum of the values in all the elements shall be 100. |

The keys in the object “Ambient mean TI” are the IDs of wind turbines and the measurement devices. The values of them are objects the keys of which are listed in Table X.8.

Table X.8 The keys in the objects of IDs of measurement device and wind turbine in the object “Ambient mean TI”

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| Ambient mean TI all directions | array of float | % | The ambient mean turbulence intensity as function of wind speed for all wind directions. The element number of the array is the number of wind speed bins (either 41 or 21 depending on “Wind speed bin width”, see Table X.2). |
| Ambient mean TI | 2D array of float (array of array of float) | % | The ambient mean turbulence intensity as function of wind speed and wind direction, presented as 2D array (array of array). The element number of the inner array is the number of wind speed bins (either 41 or 21 depending on “Wind speed bin width”, see Table X.2). The element number of the outer array is equal to “Number of wind direction sectors”. |

The keys in the object “SD TI” are the IDs of wind turbines and the measurement devices. The value of them is an object the keys of which are listed in Table X.9.

Table X.9 The keys in the objects of IDs of measurement device and wind turbine in the object “SD TI”

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| SD TI all directions | array of float | % | The standard deviation of the turbulence intensity as function of wind speed for all wind directions. The element number of the array is the number of wind speed bins (either 41 or 21 depending on “Wind speed bin width”, see Table X.2). |
| SD TI | 2D array of float (array of array of float) | % | The standard deviation of the turbulence intensity as function of wind speed and wind direction, presented as 2D array (array of array). The element number of the inner array is the number of wind speed bins (either 41 or 21 depending on “Wind speed bin width”, see Table X.2). The element number of the outer array is equal to “Number of wind direction sectors”. |

The keys in the object “Extreme ambient TI” are the IDs of wind turbines and the measurement devices. The value of them is an object with only one key “Extreme ambient TI” the detail of which is shown in Table X.10.

Table X.10

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| Extreme ambient TI | array of float | % | Extreme ambient turbulence intensity as function of wind speed for all wind directions. The element number of the array is the number of wind speed bins (either 41 or 21 depending on “Wind speed bin width”, see Table X.2). |

The keys in the object “Temperature” are the IDs of the measurement devices. The value of them is an object the keys of which are listed in Table X.11.

Table X.11 The keys in the objects of IDs of measurement device in the object “Temperature”

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| Yearly mean ambient Temperature | float | degree Celcius | Measured yearly mean ambient temperature at the measurement device. |
| Days per year with at least 1 hour below -20 deg | float | day | Number of days per year with at least one hour below negative 20 degree Celcuis. |
| Temperature frequency | array of float | % | Discretized frequency distribution of temperature at the measurement site. The temperature bin is centered at each integer temperature in degree Celcius. The lowest temperature bin is centered at negative forty degree which include all the data below negative forty degree. The highest temperature bin is centered at positive fifty degree which include all the data above fifty degree. Thus, the number of the bin is 91 in total, meaning the number of the element of this array is also 91. |
| Temperature data occurrencies | array of int | - | Similar to “Temperature frequency” but shown as the number of 10 minutes value rather than the frequency. The bin setting is the same as “Temperature frequency”. |

The keys in the object “Shear” are the IDs of the wind turbines and the measurement devices. The value of them is an object the keys of which are listed in Table X.12.

Table X.12 The keys in the objects of IDs of measurement device and wind turbine in the object “Shear”

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| Shear all directions | float | - | The shear exponent calculated from all the wind directions. |
| Directional shear | array of float | - | The shear exponent as a function of wind direction. The number of the element of the array is equal to “Number of wind direction sectors” (see table X.2). |

The keys in the object “Inflow angle” are the IDs of the wind turbines and the measurement devices. The value of them is an object the keys of which are listed in Table X.13.

Table X.13 Table X.12 The keys in the objects of IDs of measurement device and wind turbine in the object “Inflow angle”

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| Inflow angle all directions | float | degree | The vertical inflow angle calculated from all wind direction data. |
| Inflow angle max | float | degree | The maximum vertical inflow angle. |
| Directional Inflow angle | array of float | degree | The vertical inflow angle as a function of wind direction. The number of the element of the array is equal to “Number of wind direction sectors” (see table X.2). |

The keys in the object “CcT” are the IDs of the wind turbines and the measurement devices. The value of them is an object the keys of which are listed in Table X.14.

Table X.14 The keys in the objects of IDs of measurement device and wind turbine in the object “CcT”

|  |  |  |  |
| --- | --- | --- | --- |
| Keys | value type | unit | description |
| Sigma 3/Sigma 1 | float | - | The ratio of the standard deviation of the vertical component of wind velocity () to the standard deviation of the longitudinal component of wind velocity (). |
| Sigma 2/Sigma 1 | float | - | The ratio of the standard deviation of the vertical component of wind velocity () to the standard deviation of the longitudinal component of wind velocity (). |
| CcT | float | - | The turbulence structure correction parameter CcT. |

Normative References

[1] ISO/IEC 21778:2017, Information technology — The JSON data interchange syntax

[2] ISO/IEC 10646:2017, Information technology — Universal Coded Character Set (UCS)

[3] ISO 3166, COUNTRY CODES

Example data sources

[4] sample json file

[5] sample excel spreadsheet