POSITION PAPER

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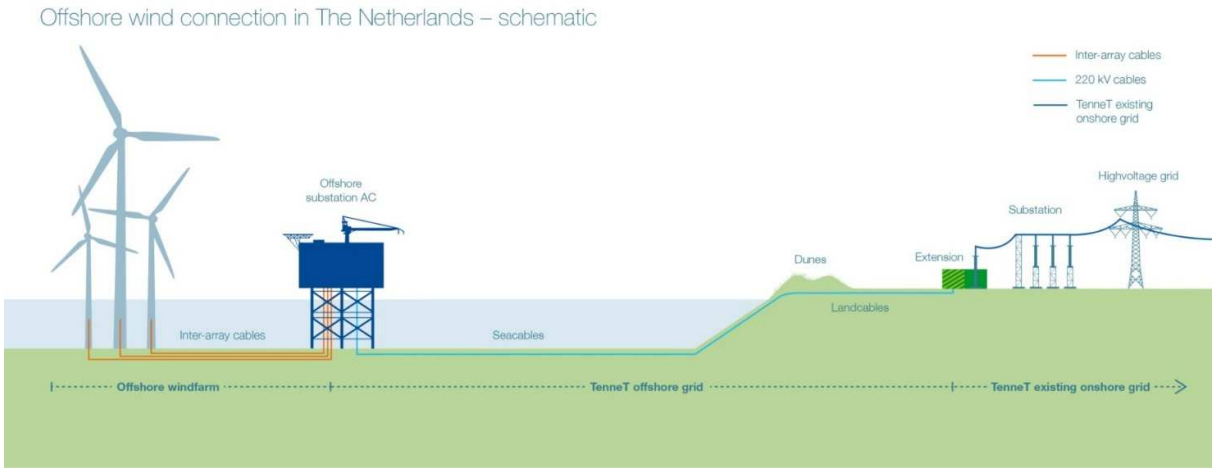
1. Background material

Literature used:
• Questionnaire as sent out to wind turbine generator suppliers (reactions from Siemens and Senvion). [Annex B]

2. Scope and considerations

Figure 1 below shows a schematic cross-section of the connection of an offshore wind farm to the onshore electricity grid. Wind turbines are connected through medium voltage “inter-array” cables (in orange) to the offshore Connection Point (CP)[1] at the offshore substation, from which electricity is transported to shore. TenneT is responsible for the grid connection up to, and including, the offshore substation and will take care for the supply and installation.



Schematic of the offshore electrical grid. Source: TenneT

The wind park, including the wind turbines and the array cables, up to the offshore CP at the switchgear installation on the offshore substation of TenneT, is to be supplied and installed by the owner of the Power Park Module (PPM). TenneT intends to standardise the offshore substations as much as possible for all five wind areas to be realised in the coming years in line with the Energy Agreement. This position paper describes the position of TenneT on the general design principles of the communication interface between the offshore CP and the onshore communication interface point and also on the PPM SCADA equipment needed to be installed on the offshore platform.

[1] The connection point (CP) between the offshore power park module and TenneT is specified [TenneT position paper ONL 15-061 T.3 Point of Common Coupling] at the cable termination of the inter-array cables and the switchgear installation on the platform.

General

The Energy Agreement requires a 40% cost reduction for offshore wind to be realised over the period 2014-2024. Realisation of this cost reduction is expected to require a combination of measures[2], including - but not limited to - standardisation of the offshore electrical infrastructure and larger capacity wind turbines within larger wind farms. TenneT contributes to this overall cost reduction target, through a strategic long term vision on the development of the offshore grid, focussing on the initial investments, but certainly also on operational expenses during the lifetime of its grid connections. In other words, reduce the contribution of the grid infrastructure to the LCoE of offshore wind farms. In this respect, equipment that does not need to be located offshore could be prevented.

Technical

Array cables will connect the wind turbines to the offshore substation. Fibre optic cable(s) will be integrated in the cable to be able to establish a network connection between the control system of the individual wind turbine generators (WTGs) and a central PPM SCADA (Supervisory Control And Data Acquisition) system. The location of this PPM SCADA system/equipment will be partly on the offshore platform, partly onshore;

Therefore, the network connection will need to be extended through the offshore substation, export sea cables, land cables and onshore substation to an onshore communication interface point between the TenneT onshore substation and the onshore SCADA room of the wind park owner (WPO).

Communication interface and PPM SCADA equipment on the offshore platform

TenneT identifies three different general communication principles to pass signals through from WTGs to shore and vice versa (further descriptions of these options can be found in Annex A):

1. Passive (all fibres are patched through one-on-one from array cables to export cables).
2. Multiplexing (fibres of array cables are patched to (at least two) multiplexing devices[3]. Onshore the signals will be fully de-multiplexed such that, on the communication interface point, all fibres will be available again for the PPM SCADA).
3. Switches (all fibres from array cables are patched to switches, where various redundant configuration are possible).

Options 1 and 2 will only allow the coupling of the WTGs to the PPM SCADA at the WPO onshore SCADA room. Also any required data and signals from the offshore substation can only be exchanged onshore. Option 3 introduces the possibility to connect data signals from the offshore substation directly to the PPM communication system through the switches.

PPM SCADA equipment installed on the offshore substation can also be roughly divided into three principles where each consecutive option requires more equipment offshore:

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[2] http://tki-windopzee.nl/files/2015-01/20141124_TKI_Roadmap.2015-2020_EZU_F%20(1).pdf
[3] Multiplexing based on (for example) wavelength-division multiplexing

a) Grid metering modules[4] (GMM) only (devices on which CT/VT outputs are connected and which convert the CT/VT signals to any data format / output to be agreed upon).
b) Power control modules (PCM) with separate or integrated GMMs possibly including one client system.
c) PCM's, GMM's and also PPM SCADA equipment like servers, clients, master control modules.

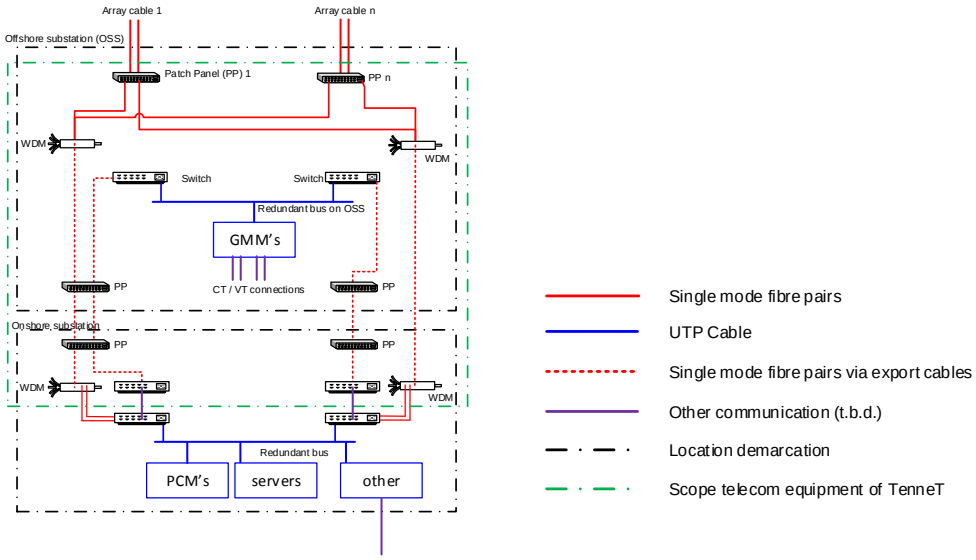
Communication options 1 and 2 can reasonably only be combined with PMM SCADA equipment option a), as all interfacing will need to be done onshore. With communication option 3 (switches) all three PPM SCADA equipment options are possible.

Considering above 6 options, following combinations are considered to be technical feasible. Risks and uncertainties are covered in the next paragraph:

- Option 2 (multiplexers) combined with Option a)
- Option 3 (switches) combined with Option a)
- Option 3 (switches) combined with Option b)

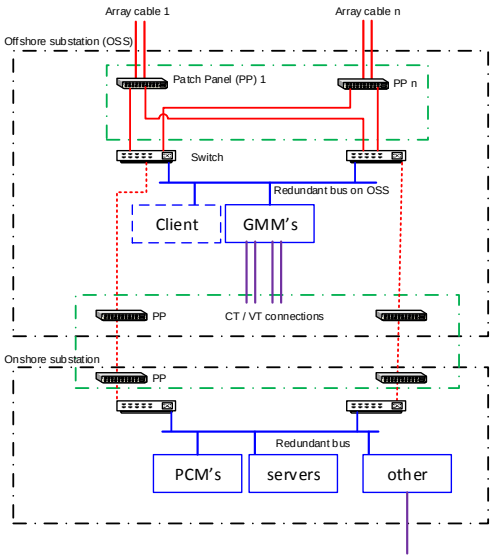
Option 1 is discarded as this option will require too many fibres in the export cable. Option c) is assumed not to be required considering current offshore wind farm designs.

As a general design principle to drive down costs, equipment should be installed onshore as much as technically possible. Obviously, option a) combined with either option 2 or 3 will lead to the minimum amount of communication and PPM SCADA equipment offshore.

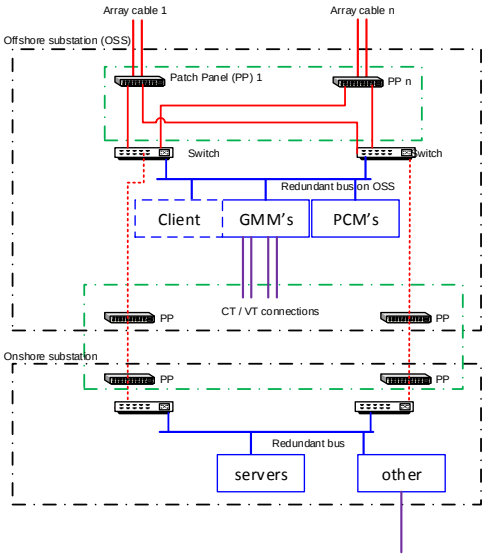


Option 2 – a

[4] The mentioned grid metering modules are for active and reactive power control of WTG's only. Grid metering modules for (certified) kWh measurements will be separate systems and these systems are covered in a separate position paper, T.9 - Metering



Option 3 – a



Option 3 – b

Ownership, access to equipment, space requirements

As the PPM SCADA system is part of the scope of the WPO, the WPO is owner of the equipment and shall have access to their equipment. TenneT will take care of the cabling on the platform to facilitate a coordinated platform design and efficient platform construction. Patch panels are considered to be part of the cabling scope. A second deviation to the ownership principle could be the ownership of

- the multiplexing system of option 2 and
- the GMM's of option a).

TenneT identified the possibility that these systems could be part of the scope of TenneT (including maintenance and condition monitoring). In this way, for option 2 combined with option a) access requirements to the platform by the WPO for SCADA or communication equipment is eliminated and WPO will have all required network and data connections available onshore.

For options 3 /a and 3 /b, equipment owned by the WPO will be installed on the offshore platform, which will require a separate room on the platform. Access to the platform and to this room is covered in a separate position paper [T.4 Access to platform]. For 3/a this equipment will be limited and is estimated to fit in 2 to maximum 4 cabinets[5]. For option 3/b more space is required which is dependent on the design and no estimate has been made for this option.

Required space on and access to the platform is summarized in the table below:

[5] Cabinets considered have typical dimensions of (h x w x d) 2000mm x 800mm x 1200mm.

Option	Description	Ownership		Required space / access
		TenneT	WPO	WPO
2 / a	MULTIPLEXING TenneT	Full	None	None
3 / a	SWITCHES + GMM	Only cables	Switches / GMM's	Yes: 2-4 cabinets
3 / b	SWITCHES + PCM/GMM	Only cables	Switches / PCM's / GMM's	Yes: # of cabinets >= 4 (t.b.d.)

Cost, uncertainties and risk

TenneT identified the uncertainties and risks as given in the table below.

Uncertainty	Effect on	Chance	Mitigation
Requirement of WTG supplier(s) to have at least PCM's and switches on offshore platform.	Option 2, 3 combined with a)	n/a	Market consultation of the necessity of this requirement is ongoing. The questionnaire sent to suppliers is attached to this paper (ANNEX B). Replies so far show that WTG suppliers are open to all three presented options, but have a preference for option 3 combined with either a) or b).
Increased delay times in the control loops due to larger distance between measurement (offshore), controller (onshore) and actuator (offshore: WTG).	Option 2, 3 combined with a)	n/a	As the communication interface will be by fibre optic cables in any option, delay times are expected to be within acceptable limits, even with a 60km export cable distance.

Risk	Effect on	Chance	Mitigation
Non-availability of export cable connection due to installation delays combined with a WTG type which requires PCM's on offshore platform.	Option 2, 3 combined with a)	very low	Mitigation only when occurs: in the very unlikely case that the OWP will install WTGs before an export cable connection is successfully commissioned by TenneT, TenneT can provide an emergency solution based on a wireless communication system. For option 1 and 2 additional temporary active communication equipment on the platform will be provided as well.
Non-availability of export cable connection due to damaged cable combined with a WTG type which requires PCM's on offshore platform.	Option 2, 3 combined with a)	Very low (redundant cable)	In the very unlikely event that both export cables (per platform) are out of service, no communication is possible between the onshore PCM's and the WTGs. Based on impact of this risk, mitigation measures will be determined in a later phase.
Failure of PPM	Option 2	Low	Regarding the legal consequences of failure,

communication and measuring equipment which is owned and operated by TenneT	combined with a)	(redundant and robust system)	TenneT and WPO shall make arrangements and agreements. These will be addressed to in the 'Customer Connection Agreements (in Dutch "Aansluit en Transmissie Overeenkomst" (ATO)).

Option 3 combined with b) is base case. Option 3 combined with a) and Option 2 combined with a) are expected to have a slightly positive impact on cost (reduction) because of the reduction of the offshore CAPEX as well as the OPEX during lifetime.

3. Position TenneT

Based on the internal TenneT evaluation and feedback received from WTG suppliers, TenneT has drawn the following conclusions:

- Option a) (GMM's only) will lead to the lowest amount of PPM SCADA and communication equipment on the offshore platform;
- Although option 2 (multiplexing) is technically feasible, there is only a minor benefit (no WPO SCADA and communication equipment on the offshore platform) which does not weigh up to the higher complexity, higher risks and uncertainties and lower flexibility of option 2 compared to option 3 (switches).

These considerations lead TenneT to the following position:

For the PPM SCADA and communication system (owned by the WPO), TenneT intends to make available on the five offshore platforms to be realised by TenneT up to 2023:

- A telecommunication room for each WPO to install his cabinets for switches and GMM's (max 4 cabinets, as defined above) including sufficient CT/VT connections and a redundant and uninterruptable power supply;
- Sufficient patch panels to connect the fibres of all array cable strings (maximum amount to be determined, but at least 6 fibres per string);
- Sufficient optical fibre pairs in both export cables to connect the main switches to the onshore communication interface point.

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4. Topic consultation

The expert meeting of 12-13 May, 2015 gives TenneT the opportunity to get feedback from developers on their position regarding "SCADA, communication interface and data links for offshore PPMs". The main goal of this meeting will be to assess whether TenneT's views as documented within this position paper, and background data above, are shared by the industry.

5. Annex A - Further description of communication principles

PASSIVE

In the offshore substation, the fibre pairs of each PPM string (max 3 pairs per string) are patched 1 on 1 onto the fibre optic cables inside the export cables (EXC). On the offshore substation only patch panels are required and this option is therefore completely passive. Onshore, on the communication interface point, for all PPM strings the fibres are available for the WPO to connect to his WTG SCADA system.

a. No active components on the offshore substation for the WTG SCADA communication system;
b. Maximum number of optical fibre pairs needed in EXCs (2x3 per PPM string: @66kV with 16 strings as a maximum = 2x48 | @33kV with 24 strings as a maximum = 2x72);
c. WTG switches at the end of a string just before the offshore substation shall have high power outputs to bridge the maximum of approx. 60km to the onshore communication interface point;
d. Required data from the offshore substation (at least voltage / current measurements and switchgear position information) are exchanged onshore (exchange interface to be specified in a later phase).

MULTIPLEXING

Fibres of each PPM string are patched to (at least two) multiplexing devices. The multiplexing technology will be based on wavelength-division multiplexing. On the offshore substation the following is required: a) patch panels and b) the WDM system. Onshore the signals will be fully de-multiplexed such that, on the communication interface point, for all PPM strings the fibres are available for the WPO to connect to his WTG SCADA system.

e. Simple (no 'intelligence') and reliable active components on the offshore substation for the WTG SCADA communication system;
f. Maximum number of optical fibre pairs needed in EXCs is reduced significantly compared to option 1 depending on the multiplexing factor.
g. No special WTG switches are required;
h. Required data from the offshore substation (at least voltage / current measurements and switchgear position information) are exchanged onshore (exchange interface to be specified in a later phase).

SWITCHES

In the offshore substation, the fibres of each PPM string are patched to switches (various redundant configuration are possible to be specified in a later phase). The configuration of switches shall have sufficient high power outputs which will be patched onto the fibre optic cables inside the EXCs. Onshore, on the communication interface point, these outputs will be available for the WPO to connect to his WTG SCADA system.

i. An important part of the PPM communication system will be based on the offshore platform.
j. Maximum number of optical fibre pairs needed in EXCs is reduced further depending on the configuration of switches on the offshore substation.
k. No special WTG switches are required;

Required offshore substation data (at least voltage / current measurements and switchgear position

information) could be exchanged directly on the offshore substation (exchange interface through the switches) or onshore.

6. Annex B - Questionnaire

Introduction

Within the offshore NL projects, TenneT's position is to limit access of the wind park owners (WPOs) to the offshore platforms as much as possible but this access limitation may reasonably not exclude any wind turbine generator (WTG) suppliers.

Two issues with regards to platform access and platform design which are directly related to the WTG type/manufacturer are:

1. the (WPO-owned) WTG SCADA and WTG control equipment which is required on the offshore platform;
2. Required telecommunication infrastructure from WTGs to the onshore WPO SCADA room/building via the offshore platform

TenneT is consulting the WTG market to receive the latest state-of-the-art information on requirements and options of above two items, such that TenneT will be able to take a position on these items.
The WTG supplier is kindly requested to provide information on the questions set out below or preferably give direct answers to these questions in red colour.

Questionnaire

Telecommunication system.

TenneT will provide a redundant telecommunication system from the offshore platform to onshore substation (two export cables per platform). Between TenneT and WPO there will be interfacing: 1) fibre optical cables from the WTG-strings to the offshore platform and 2) onshore communication interface from TenneT substation to WPO.

1. What is the typical telecommunication design within the WTG-strings to the offshore platform?
2. What is the preferred design (manufacturers standard) of the telecommunication system from interface point 1) to interface point 2)?
3. Is it feasible that the communication system for the WTGs between the interface points is completely installed and managed by TenneT (e.g. by patching all FO-fibres from the WTG-strings one on one or by using multiplexers)?

SCADA equipment

1. What SCADA equipment (for WTG operation and maintenance only, excluding wind farm power control modules which will be covered in a separate item below) shall be installed on the offshore platform in the typical suppliers standard?
2. If any: please indicate per equipment type if optionally this equipment may be installed onshore and what additional requirements are applicable (e.g. for telecommunication system).

Wind farm power control modules

For WTG control one or more wind farm power control modules will be required which will need current and

voltage measurement inputs from the switchgear where the turbine strings are connected (66kV or 33kV). This switchgear is owned, operated and maintained by TenneT. For the WTGs control, TenneT will make available either a) voltage and current measurements to be exchanged in a data-format (to be agreed) or b) the required current and voltage transformers. This may be current/voltage measurements in the outgoing feeders (per string) or in the incoming feeders (to be decided later).
To make available the voltage and current measurements, grid metering modules might be required onto which CT and VTs are directly connected.

1. With regards to the grid metering modules and wind farm power control modules: what is the typical design (suppliers standard) especially with regards to installation location?
2. Is it acceptable that the grid metering modules, which are obviously required to be installed on the offshore platform, are provided by TenneT (any required output / data format to be agreed upon)?
3. If suppliers standard is to install the wind farm power control modules on the offshore platform: please indicate if, optionally, these modules may be installed onshore and what additional requirements are applicable (e.g. for telecommunication system).
4. If not possible: please indicate what the specific (technical) reasons are which do not allow the wind farm power control modules to be placed onshore. If the reason(s) is/are risk related (e.g. risk on non-availability of export cable): are there any ways to mitigate these risks to acceptable limits?

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