POSITION PAPER

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1. Background Material

LITERATURE USED:
• None

2. Scope and Considerations

For the roadmap offshore wind 2030 (routekaart windenergie op zee 2030) TenneT is tasked with the connection of several offshore wind farms up to 2030. The wind farm zones 'Hollandse kust West' and 'Ten Noorden van de Waddeneilanden' will be connected with TenneT's previously established and consulted standardized 700 MW grid connection concept. Due to its size and distance to shore, a new grid connection concept has been established for the wind farm zone IJmuiden Ver. The figure below shows a schematic cross-section of this new grid connection concept. Wind turbines are connected through 66 kV “inter-array” cables (in orange) to an offshore (HVDC) converter station. Using 2 GW high voltage (525 kV) export cables (in green) the electricity is transported to shore. TenneT will be responsible for the offshore grid, from the onshore substation up to and including, the offshore substation. TenneT intends to create a new standard HVDC grid connection concept for both connections to IJmuiden Ver and potential future far shore wind farms.

This paper describes how TenneT, as the offshore grid connection owner, proposes to deal with the control & protection design at the 66 kV side.

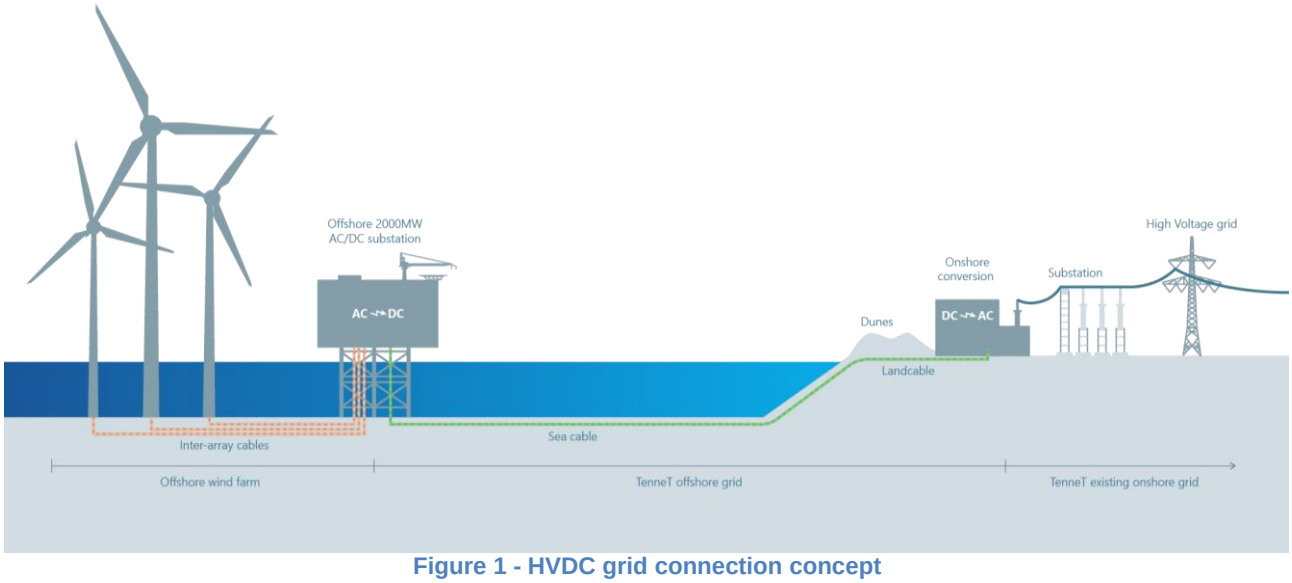

Figure 1 - HVDC grid connection concept

3. Control and Protection design 66 kV

Following the single line diagram (SLD) of the complete grid connection system (GCS) for IJmuiden Ver, as presented in position paper T01, this paper elaborates on the detailed aspects for the area of common interest between TenneT and OWF: the 66 kV switchyard of the converter platform. The paper focuses on the following three aspects:

i. Detailed SLD for the 66 kV switchyard
ii. Ownership and O&M boundaries between TenneT and OWF
iii. Protection functions across the 66 kV interface

3.1 Detailed SLD of 66 kV switchyard

As described in position paper T01, there will be four 66 kV buses in total for the platform bipole converter station, therefore two 66 kV buses per converter pole. The number of bays for the connection of inter-array cables from the OWF shall be based on 6+1 bays per 66 kV bus (generator block), as described in position paper T11. One of them will be an universal connection bay.

Figure 2 illustrates the detailed SLD of the 66 kV switchyard of one of the two converter poles. As can be seen in the figure, TenneT proposes the use of a double busbar topology. This means that the unavailability of a single busbar disconnector does not lead to the unavailability of the whole generator block but only the connected bay.

It shall be possible for TenneT to combine two cable strings into one 66 kV GIS bay on the platform, in case the maximum current per string is below 625A.

The auxiliary power system of the complete bipole converter station will be fed by two main power sources during normal operation. Two 66 kV bays, as a minimum, will be reserved in total for this purpose; one from each pole.

The switchyard at the valve side of the converter transformers is not essential for the wind farm operation, therefore omitted from the figure below.

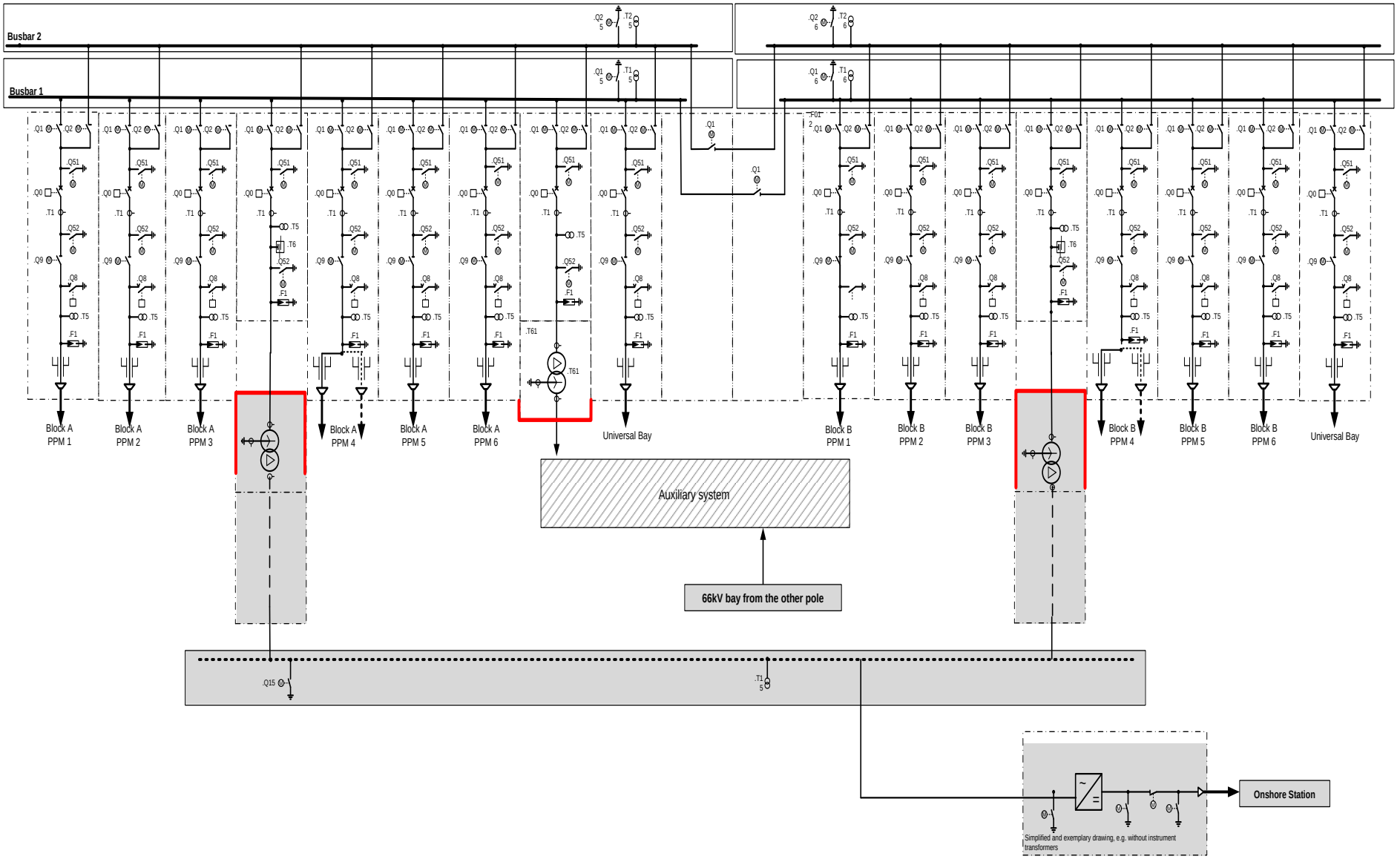

Figure 2: Detailed SLD for 66 kV switchyard of one converter pole

3.2 Boundaries between TenneT and OWF

Focus is given in the following aspects:

1. **Supply**: TenneT will supply the complete 66 kV equipment on the converter platform. However, no part of the 66 kV cable system (up to the cable termination) will be supplied by TenneT.

2. **Ownership**: TenneT will own the complete 66 kV equipment on the converter platform. However, no part of the 66 kV cable system (up to the cable termination) will be owned by TenneT.

3. **Operation of bays**: TenneT intends to keep the operational philosophy regarding the operation of bays for the offshore platforms in the Netherlands, similar to the current practice for the operation of switchgear onshore for the connected parties. This means that the switchgear installation with connections to the OWF will be fully operated by TenneT, as the owner of the switchgear.

   This solution is common practice for customer connections within TenneT. The dispatch centre of TenneT is 24/7 manned and can be contacted. Based on the request of the OWF, switching actions can be carried out by the system operator of TenneT. Thus a uniform way of working (which is already applicable for other connected parties) can be applied for all offshore connections with clear uniform procedures for all parties involved.

4. **Maintenance of bays**: TenneT will be responsible for the maintenance of the bays.

3.3 Protection

TenneT will be responsible for the protection equipment on the platform for the OWF strings and will design, install, operate and maintain the protection system. This has advantages in terms of installation and maintenance activities that can now be performed by TenneT personnel only. The protection system and its settings will be aligned with the OWF.

This (standard) protection system will be based on a fully redundant concept with two protection relays from a different manufacturer in every outgoing feeder bay. It may also be that the second protection function is not based on a relay, but instead is incorporated in the HVDC protection logic. However, this remains to be developed during detailed engineering phase. This A-, and B-protection system concept will enable a higher availability performance and reduce possible financial risks. Furthermore, it is expected to exchange C&P equipment after approximately 15-20 years and with the A-, and B-protection system concept it should be possible to exchange IED´s without shutting of the string.

Based on TenneT's experience with the existing HVDC-based offshore grid connections, distance protection (measurement of the fault impedance) seems to work more efficiently than overcurrent protection. In addition, distance protection is more effective as a backup protection function (compared to overcurrent protection) when it comes to busbar faults.

Without exception this protection concept will not work without voltage measurements because the system has to detect the fault direction (line side or busbar side). TenneT needs the backwards fault “zone” as a backup for the busbar protection. For the OWF it is beneficial to have more than one protection zone to protect the cables between the turbines.

The figure below illustrates an indicative arrangement for the protection of the 66 kV bay. It must be noted that the detailed features (e.g. number of CT's, type of cores) of the figure are not fixed and will be developed during the detailed engineering phase.

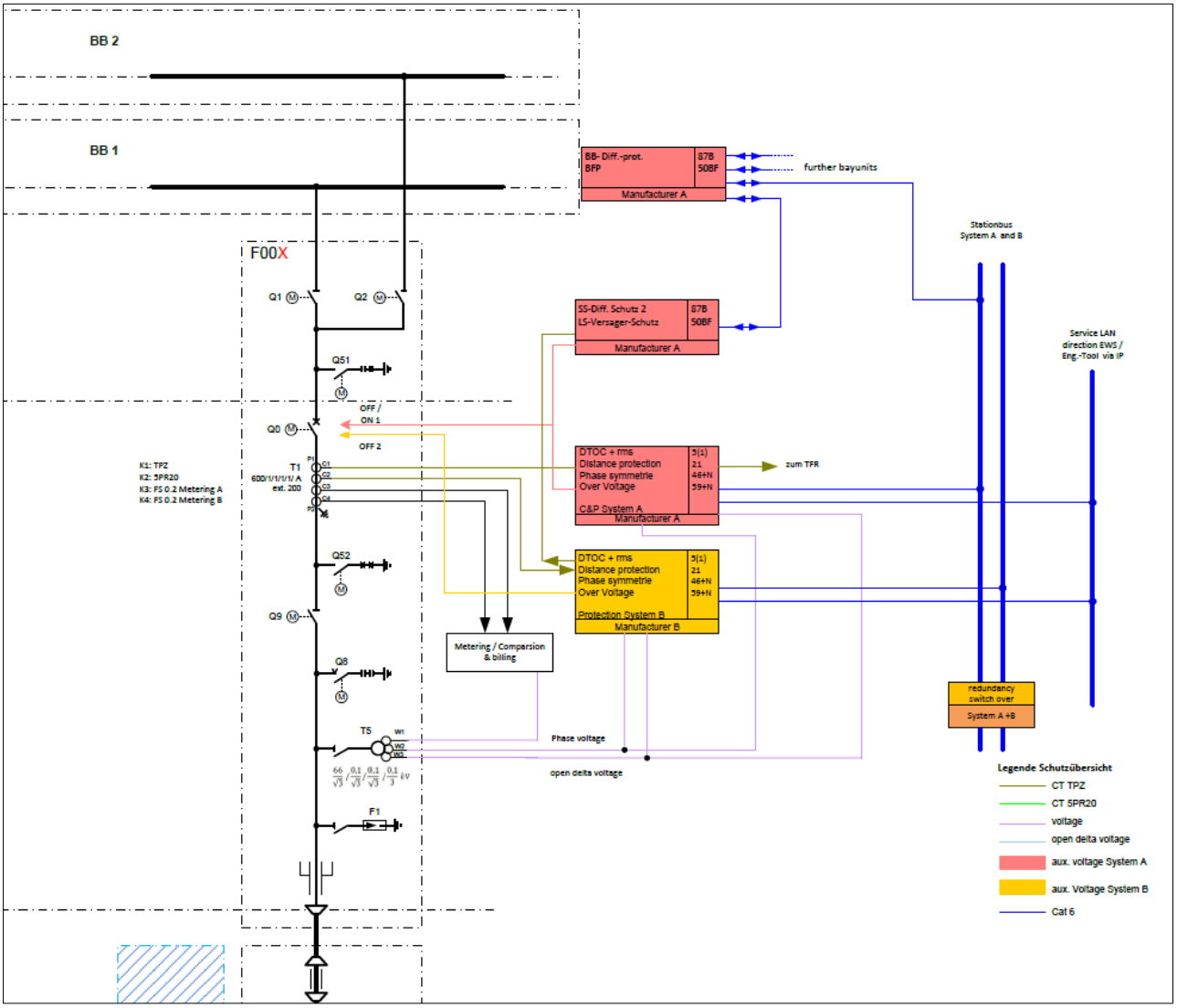

Figure 3: Protection principal diagram at 66 kV bays

4. Position TenneT

The position of TenneT can be summarised as follows:

TenneT proposes a standardised approach for the detailed representation of the 66 kV switchyard on the converter platforms.

TenneT will standardise the operation of the 66 kV bays for the offshore platform, similar to the current practice in the Netherlands for the operation of switchgear onshore (and offshore) for the connected parties, where the switchgear installation with connections to the OWF is fully operated by TenneT, as the owner of the switchgear.

TenneT will standardise the protection equipment of the OWF inter-array cable strings to the TenneT offshore converter platforms. This will be done by implementing a standardised, fully redundant protection system with distance protection as the main protection function for the cable strings.

The protection settings will be aligned with the OWF.