FEEDBACK REPORT

STAKE HOLDER CONSULTATION PROCESS OFFSHORE GRID NL	
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QUALITY CONTROL		
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Please note that the intention of this feedback report is to illustrate the overall discussion and results. The text should be placed in the greater context of transparency about TenneT 's consultation process. This text is not legally binding and could be modified during the stakeholder consultation process.

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1. Moments of feedback

Feedback	Abbreviation
Expert meeting 27.11.2014	EM01
Expert meeting 02.07.2015	EM06
Consultation website April	WS02
Consultation website May	WS03
Consultation website June	WS04
Consultation website July	WS05
Bi-lateral meetings	BL01

2. Feedback and action

Feedback	Feedback moment	Action
TenneT presented the current activities within the EU which should result into a new network code: "Requirements for Generators". This code includes requirements for Power Park Modules and will become mandatory for OWF. From the topics mentioned the compensation requirements were challenged and discussed in length. TenneT recognized the fact that the OWF would have less options to mitigate reactive power without the offshore infrastructure. OWF recognized the fact that what can be delivered by the turbines should be part of this requirements to realize the most economical solution. Parties emphasized the approach to use standard type of turbines and not require modified (and therefore expensive) models. TenneT recognized this concern, but will be bound by the new RfG and can only use discrete infrastructural equipment in an economical way. Parties proposed to have TenneT study a "typical" wind park with sensitivity analysis for the design of the concept and the requirements for the OWF regarding the compensation requirements. With respect of each other's responsibilities and flexibility TenneT accepted to further investigate how this item could be addressed in a proper way.	EM01	Discussed in expert meetings. Developments of the technical design did not show a need for extensive study on wind park model.
We agree with the comments stated in the Feedback report section 5.	WS02	Noted
From our quick review of the RfG draft that has been circulated (email 12/12/2014) we have some concerns about TenneT taking the maximum of the ENTSO-E Network Code RfG envelopes eg. for FRT and reactive	WS02	The WTG manufacturers have been part of

capability. Our concern is that such requirements applied to an offshore MV connection point (basically applicable at the end of the string) will be much more challenging to the PPM than if applied to the onshore PCC at HV. Since PPM has no possibility of installing additional equipment (eg additional reactive compensation) in order comply with the RfG requirements issues may be insolvable or in best case very costly.		the development of RfG. TenneT needs the requirements for a future stable transmission grid. The RfG requirements are different than the reactive power compensation requirements.
We do urge TenneT to consider the need for these requirements and assess the feasibility of PPM to provide the various services from a global perspective.	WS02	Noted
The Network Code does not cover power quality such as harmonic distortion. Could TenneT please elaborate on these requirements.	WS02	Addressed to in a separate position paper
In relation to power quality, we would not recommend that different PPMs are connected to the same transformer. The power quality issues will become very complex and potential converter interactions may jeopardize the stability of the WTGs.	WS02	In current grid connection design, one PPM is connected to one transformer
Here it should also be considered that resonances in export system and any neighboring PPM may influence the harmonic distortion beyond the control of the affected PPM.	WS02	Noted
As mentioned under SCADA we would also ask to have transient and power quality recorders for on-line measurement of the wind farm performance in the reference point in order to be able evaluate the compliance with codes. Generator will need to access to these fault recorders / power quality measurement in the PCCs.	WS02	Noted. Is taken into account.
For the stability of the system the reactive power range provided by the OWP and the grid connection system (220 kV-cable) at the onshore grid connection point is relevant. So the reactive power (capacitive) of the 220-kV-cable has to be taken into account when determining the reactive power range of the OWP. This leads to a reactive power range shift of the OWP towards the underexcited region. So unnecessary high demand regarding overexcited reactive power behavior of the OWP should be avoided in order to avoid stranded investments.	WS02	Taken into account. See position paper. No unnecessary high demands are applicable for the PPM's.
The ACM is expected to approve the offshore grid code in September	WS02	Correct

after which it will become legally binding. There seems to be a formal issue that, at the moment, the Electricity Act has no basis for an ACM decision on this code but the ACM is apparently willing to take the decision anyhow but it will only become legally binding at the moment the new Electricity Act is implemented.		
The Network Code does not cover power quality and transients.	WS03	It covers part of the scope.
TenneT has informed us that the specification of harmonic and transients will not be ready before end of 2015. This is late and problematic with regards to our assessment of the power quality requirements and risks in connection with the bid. Limits need to be specified in the tender documents.	WS03	Noted. Position paper on harmonics is planned for September meeting.
Another important issue is the back-ground harmonics. We understand that TenneT haven't planned any filter in the onshore substation. Experience from both UK and Danish projects is that large cable systems create harmonic resonances that will amplify background harmonics in transmission interface point. The experience from UK is that basically all projects have harmonic filters in the onshore substation in order to mitigate this. There is also a risk that these amplified background harmonics may be seen in offshore interface point between TenneT and OWF and have significant impact on compliance.	WS03	Noted
In any case background harmonics should be clearly specified together with the (incremental) limits applicable to the wind farms. Here neighboring wind farm emission should be included as well.	WS03	Noted. Position paper on harmonics is planned for September meeting.
Fulfilling the grid code is a combined responsibility of the wind farm owner combined with the substation owner.	WS04	Noted
It is important that TenneT shows that with the substation delivered is possible to fulfil the grid code in cost efficient way.	WS04	Noted
Experience shows that wind turbine manufacturers do not take responsibility for fulfilling the grid code. Which makes the possibilities limited for the wind farm owner to handle issues when not owning the OSS. General rule of thumb is that issues are less expensive to solve on the substation. Moreover, it might be the only place where these can be solved.	WS04	Discussed in expert meeting 2nd July. Solution is presented in the position paper.
Reactive power compensation: We advise TenneT to do a full market	WS04	During expert

study on reactive power compensation capabilities of the turbines (with and without the optional statcom) and perform a simulation including a worst case array cable. In this way TenneT can show whether the grid code can be fulfilled.		meeting of 2nd July, it is discussed and consented that the WTG to be applied are suitable.
It should be assessed whether installing reactive power compensation on the OSS is more cost efficient than installing statcoms on all turbines.	WS04	Addressed to in position paper Reactive Power Compensation.
Harmonics: Because harmonics problems often can only be solved on the OSS TenneT should show that the designed OSS should be able to comply with allowed harmonics levels. Depending on grid code(and headroom available) it might be necessary to have an harmonic filter on the OSS. If there is the chance that harmonics need to be compensated, for any particular turbine there should be room for it on the OSS in the onshore substation.	WS04	Noted. Position paper on harmonics is planned for September meeting.
Other requirements RfG/grid code: To give clarity on the requirements for the wind farm owner and comfort that these can be met, a check on the grid code/future RfG, etc. on whether (fail to ride through etc.) to show that fulfilling the grid code can be done with the current substation design. This would include an insight in the content in the (future) offshore grid code for the wind farm owner in the Netherlands. E.g. fault ride trough is managed by TenneT in the substation, but is included in the offshore RfG. At the moment it is not clear how the grid code is this translated into a proper grid code suitable for this situation?	WS04	Noted. Although the example given (fault ride through is managed by TenneT) is unclear. The TenneT offshore grid as well as the OWP offshore grid including WTGs need to comply c.q. facilitate the fault ride through.
Following the TenneT meeting of 27th Nov 2014 it is understood that TenneT will provide a paper in relation to the Grid Code / RfG compliance requirements which take notice of the fact that (i) the OWF will have no space at OSP to accommodate centralised solutions and (ii) the intent of the OWF developers, to minimise risk, is to employ standard WTGs rather than 'specials' – for example that may not be certified/certifiable.	BL01	The standard WTG should be able to fulfil the RFG requirement, as discussed during the expert meeting of 2nd July
We (OWF) would request that TenneT give consideration to transmission based solutions where this presents the most economical solution or the most sensible solution from a risk perspective. For example, in the UK the offshore transmission provider is responsible for provision of reactive	BL01	Most suitable and economical solution is discussed during

range, voltage control and power quality measures at the onshore interface point rather than at the offshore grid entry point – but options still exist in the UK to provide part capability in these areas from the OWF where this presents a more economical solution.		the expert meeting and described in the position paper.
When will TenneT new offshore code (RfG compliant) be available?	BL01	
We (OWF) have not attempted to provide commentary on the potential implications of different aspects of the RfG / TenneT Grid Code as this stage, this will be done following receipt of the paper referred to in the first bullet. When determining the rating of OSP switchgear on the LV side of the OSP then design interaction is required between TenneT and the OWFs – (i) obviously to understand the WTG fault contribution (ii) but also to ensure switchgear rating available/offered by WTG suppliers are adequate to accommodate design fault levels – for example, choice of TenneT OSP transformer impedance could have a material impact on WTG switchgear rating/cost/availability. We (OWF) seek close liaison with TenneT on such design issues.	BL01	Noted
Please note that we (OWF) need more information. Priority closely following 66 kV decision.	BL01	Noted
As discussed in the expert meeting the standpoint of TenneT will be altered. We will comment on the new standpoint. Agreed is that the most cost effective solution needs to be designed. In the experience of OWF it is in almost all cases more cost efficient to compensate reactive power on the substation. Statcom functionality in the turbine in zero load is likely to be more expensive and also losses are higher in turbines than in centralized solution. The required power purchase for compensation by the turbines need to be taken into account as well. Please note that in T2, OWF has made the recommendation to prepare space for items needed unexpectedly, reactive power compensation might be one of these unexpected items.	WS05	Point is discussed with all participants during the expert meeting of 2nd July. Statcom functionality at zero load is the exception and can be solved. Addressed to in position paper.
General reactive power control strategy It is understood that during normal operation, unity power factor at the onshore connection point is obtained primarily by switching on and of the 33kV onshore reactors/capacitors. For fine tuning the reactive power capability of the WTG converters is utilized. The WTGs are controlled with reference to the 66kV grid connection point on the offshore substation. What is the voltage/reactive power control strategy when using the WTGs for fine tuning the reactive power exchange, at the onshore connection point, when the reference point of the reactive power regulation of the WTGs is on the offshore substation?	WS05	TenneT will install an “onshore controller” to determine the OWP reactive power contribution. This will be “translated” to an offshore MVAr setpoint. It needs to be

Will TenneT provide some kind of 'plant controller' and how is this intended interfaced to PPM wind farm controllers. It's not clear when WTGs need to provide the additional reactive power as per the PQ-diagram.		investigated in further detail.
Reactive power capability and voltage dependency We need to point out that the voltage range on the platform need to be reduced in order avoid overvoltages elsewhere in the 66kV system or in the WTGs when operating in the required reactive power range. Because of the voltage rise or voltage drop along the string due to both active power and reactive power flow WTGs will see higher voltage at both MV side (Potentially >72.5kV) and at the LV side (converter terminals). Extreme voltage at converter terminals reduce the reactive power capabilities. We have studied this and will share our results with TenneT. If TenneT cannot adjust their requirements to fit the physics and the possible WTG performance, this will result in increased risks and increased costs for the OWF. In worst case: Can TenneT accommodate additional compensation on platform? We would like to stress that the RfG which apply to OWF need to be updated accordingly.	WS05	The reactive power and voltage are indeed depended. Everything mentioned is already recognized by TenneT and is being investigated with further grid calculations. Please provide us with the information as stated.
Reactive power at zero wind We understand that in case wind turbines cannot compensate the array cable network at no load, then TenneT can adjust the switchable compensation so that it is not needed. TenneT is kindly asked to clarify this in the decision paper. The current position paper still state the OWF need to maintain 0 Mvar at no load. We would like to stress that the RfG which apply to OWF need to be updated accordingly.	WS05	Noted
As an alternative to the requirement to achieve unity power factors (Cos phi = 1) at the onshore substation using a combination of equipment owned and operated by TenneT (fixed and switchable reactors onshore and offshore) and the reactive power capabilities of the wind turbine generators, would TenneT consider making it a condition that the OWF operator should achieve unity power factor only at the 66kV cable termination of each string (or sum of the OWF strings) thus the OWF owner has to compensate any reactive power effects (and also harmonic effects) only for their production. Then Tennet can decide the economic benefit of compensation of the connection from the offshore substation and its cable into the grid (and even determine that unity power factor at the onshore power station is not attractive).	WS05	For the lowest LCOE the complete offshore grid (TenneT and OWPs) should be approached as one electrical system. Most suitable and economical solution is discussed during the expert meeting and described in

The solution discussed 2 July 2015 was for TenneT to send setpoint signals for reactive power to OWF WTGs. When there are 2 windfarms per substation, this becomes more complicated. If strings are out of service (e.g. due to TenneT protection or switchgear fault) and the remaining strings do not have sufficient capacity to meet the reactive power demand, will there be any penalty / compensation scheme?		the position paper.
The compensation strategy is not very consequent: the WTG's are used to control the MVAR-band at 66 kV PCC and 380 kV connection point as well. If this is correct, then the +/- 0,1 pu control bandwith of the generators is probably too small to realize this.	WS05	**No, see position paper.**
We still miss the information from WTG manufacturers what are the abilities of the generators to deliver or consume this reactive power, also at low wind production. We need the real PQ-diagrams.	WS05	TenneT expects that all WTG manufacturers will be able to meet the requirements. But will not verify this further. The wind developers are can ask the manufacturers directly.
Full converter concepts are able to do this, but we fear that double fed induction generators cannot deliver sufficient reactive power under certain conditions, so that additional reactors are required.	WS05	Noted
How will this control strategy work out in practice? We think it will be necessary to do simulations with a network model, like Power Factory.	WS05	Correct. These simulations in Power Factory are already ongoing.
Do we understand correctly that TenneT will provide a setpoint to us (OWF) that we have to adhere to?	EM06	Yes; that is correct
Are you sure wind turbine manufacturers can provide wind turbines which can compensate? T: yes we are – in the case you'll find an example that cannot compensate we will adjust the configuration and the OWF will have to stay within a -0,1 – 0,1 pu bandwidth.	EM06	Yes; we are
Wind turbine manufacturers have been involved in the RfG discussion and know what to expect in the future. If they cannot provide a wind	EM06	Noted

turbine which can compensate they will have a disadvantage towards the rest of the market. We (OWF) are convinced they will make sure they provide such facilities to the wind turbines.		