Task Force MOG 2

14.10.2022

Agenda

9:30 - 10:00 ■ **Connection requirement**

- Feedback ad-hoc technical workshop 16/09
- Overview feedback received from stakeholders

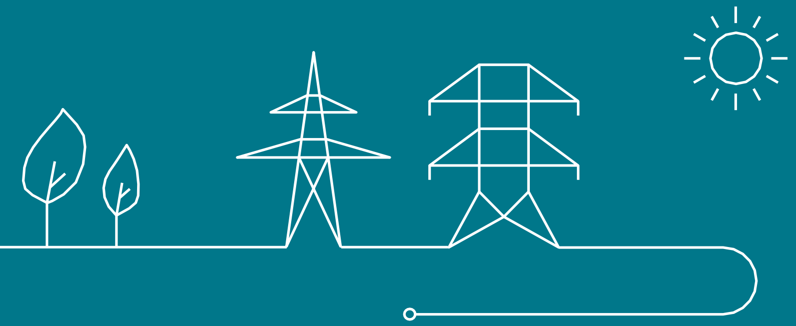
10:00 – 11:00 ■ **Dynamic & Harmonic**

- Presentation of voltage control & MVar concept for MOG 2

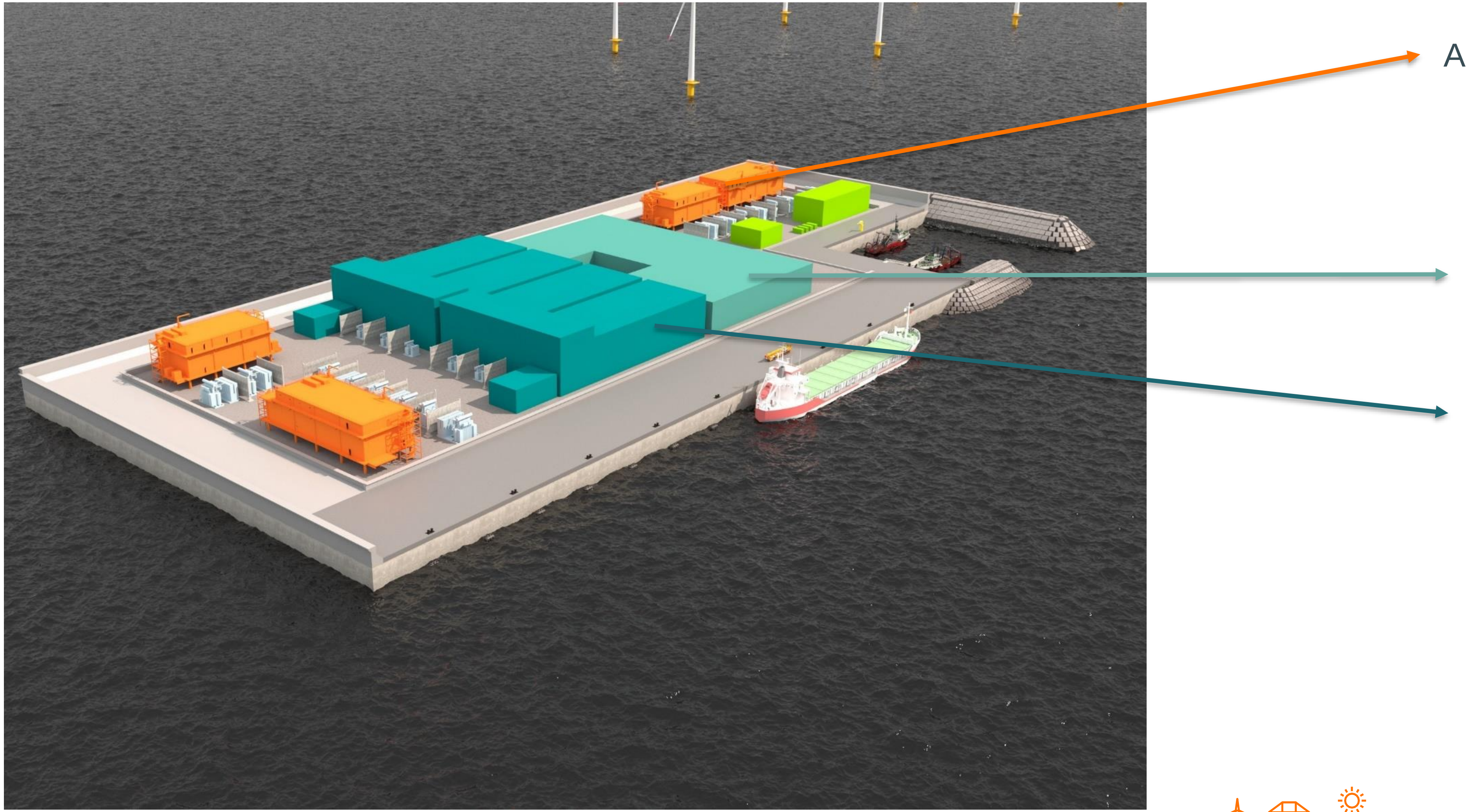
11:00 – 12:00 ■ **Market & grid design - workshop**

- BOP presentation on grid and market design for integration of offshore wind energy in the Princess Elizabeth zone
- Presentation of MOG 2 and Nautilus projects in the framework of the Federal Development Plan

Connection requirements



Energy Island Design: potential layout



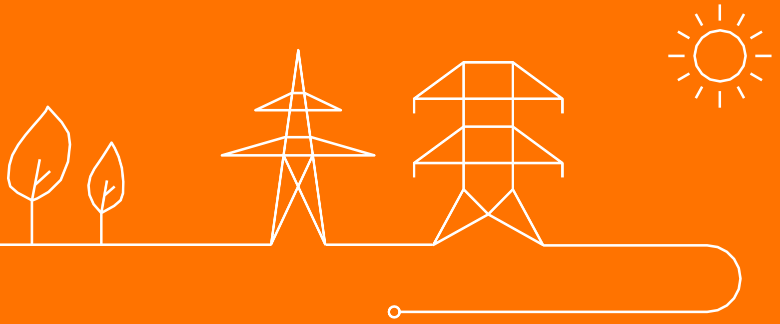
AC substations

DC substations

DC converter

Initial Feedback ad-hoc technical workshop

Davy Verwilghen, Tom Trappeniers



Process overview

- A technical workshop took place on 16/09
- The goal of the workshop was to introduce design choices made by Elia, and to discuss with potential investors about other design elements
- Written feedback was received on 7/10/2022 from 4 parties
- The following slides are covering some of the key aspects being discussed
- A next technical TF will be organised in December 2022 to follow up on all open items. A more high-level feedback will be given during the main TF MOG2

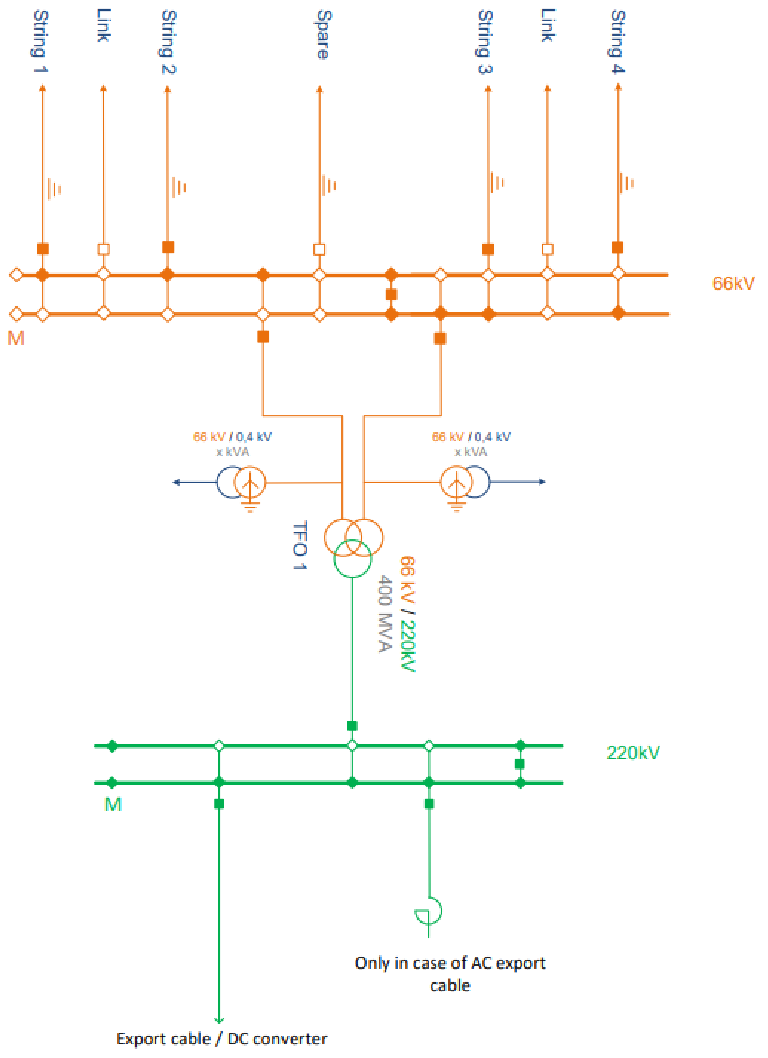
Interarray voltage level: 66 kV vs 132 kV

- Elia explained reasoning behind the reference voltage level of 66kV at previous task force meetings
  - WTG and cable technology not timely **and** widely available for PEZ timing (2027-2029)
- Preliminary review of more recent feedback from User Group confirms benefits already identified, e.g.
  - Reduction of number of interarray cables, reducing complexity of cable landings on island
  - Reduction of total interarray cable length, resulting in reduction environmental impact (although limited)
  - Potential valorisation of technological advancements
- Minister of Energy has sent out letter to relevant stakeholders in the sector to request the technological readiness of 132 kV in the timeframe of the development of the PEZ, results are pending
- Elia will evaluate the additional feedback and share this assessment to confirm the final approach
- **In any case, the choice cannot be left open**
  - A change at this stage will have impact on timing, cost and technological risk

Interarray cable design and configuration

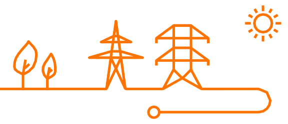
- Interarray cable design:
  - Elia proposal: 4 strings of 90MW/string + 1 spare that are connected to the GIS 66kV
  - Feedback User Group: Please clarify the distribution of spare bays
  - **Conclusion: 1 spare bay per 700 MW seems feasible (but to be confirmed)**
- Looping of strings
  - Elia question: Looping of strings foreseen?
  - Feedback User Group: some yes, some no
  - **Conclusion: to be further investigated (likely both allowed)**
- Property and maintenance border at 66kV GIS cable compartment, in accordance with IEC62271-209

350MW building block



Other feedback on connection requirements

- Circuit breaker at first WTG (+ VT)
  - Elia proposal: integrate a Circuit Breaker + Voltage Transformer at the first Wind turbine generator to reduce the operational interface
  - Feedback User Group: Circuit breaker at first Wind turbine generator is not a standard design
  - **Conclusion: to be further investigated**
- Voltage control
  - Feedback User Group: can we receive more insights?
  - **Conclusion: see part 2 of this Task Force**
- Short-circuit current
  - Elia proposal: 8kA, 3s
  - Feedback: can this be reduced?
  - **Conclusion: to be further investigated**

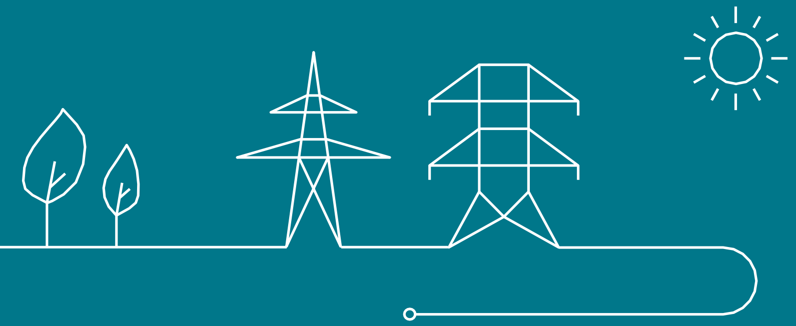


Some quick wins

- Initial Elia proposal: Optical fibers 24f / OWF
- **New proposal: 48f / OWF incl. split for redundancy**
- Initial Elia proposal: Power supply 1x 230Vac
- **New proposal: 2x 230Vac UPS**

Dynamic & Harmonic

Fortunato Villella



4 main clarifications will be potentially defined in the technical requirement for 1st tendering of MOG 2 OWF

① **Forced oscillations:** this phenomena must not lead to critical consequences for BE/EU system ▶ **[Introduction provided in TF MOG 2 24/06]**

② **Process for data sharing & model validation:** need for process definition on data and model sharing from asset owner to perform conformity study

③ **Coordination of design study:** need for coordinated simulations/studies to perform conformity study

▶ ④ **Voltage control:** adjustment of voltage and MVar capabilities (owner of step-up transformer shift from OWFs (MOG 1) to Elia for MOG 2) **Today**

The output of pre-design studies* might require additional adaptations

**Pre-design study are performed to prepare the clarification for technical requirements required for the OWF MOG 2 tendering*

Agenda

Goals & Context

Voltage Control in MOG 2

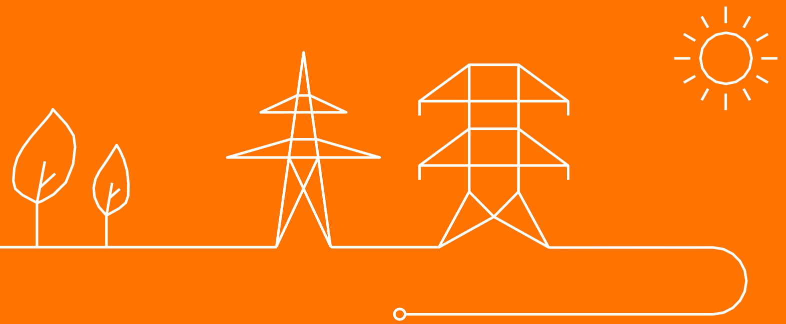
- Structure of existing offshore connection
- Hierarchical Voltage Control Philosophy for the MOG 2
- Distributed Controllers based Voltage Control Scheme

Proof of Concept voltage control in MOG 2

- Setup of simulation
- Combination analyzed
- Dynamic behavior study

Conclusions and proposal for technical requirements adaptations

Goal and Context



Goal and context of ‘Wind Farm Voltage Control and MVar’ study

Goal of this study

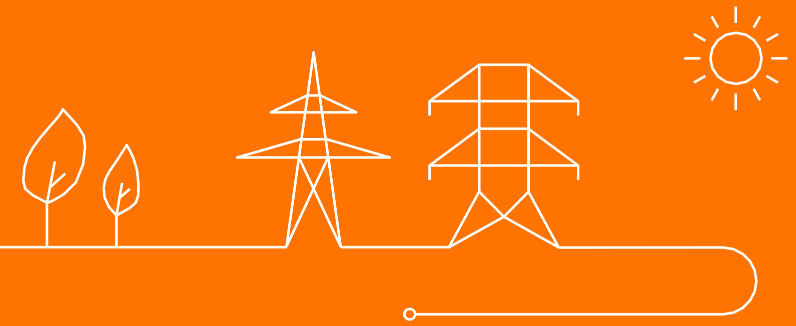
- **Assess major impacts on voltage control** for MOG 2 compared to MOG 1 and **define needed adaptation to requirements**
- **Assess the impact** on existing technical requirements
- Present and discuss the **assessment performed by Elia for MOG 2** and principles foreseen around voltage control

Context

- **Presentation** provided in **User Group June 2020** and feedback received from the stakeholders to improve the communication speed for voltage management (compared to MOG 1)
- Presentations with wind parks vendors were organized and positive feedback received. **Suggestion to validate study** with detailed model from vendors
  - *An **ad-hoc technical workshop** organized to tackle the discussions on data /measurements (16/09/2022)*
  - *The previous study (2020) **was extended to a Proof of Concept** with more detailed models from vendors (see next slides)*

This presentation describes the proposal of modifications for technical requirement related to voltage control

Voltage Control in MOG 2

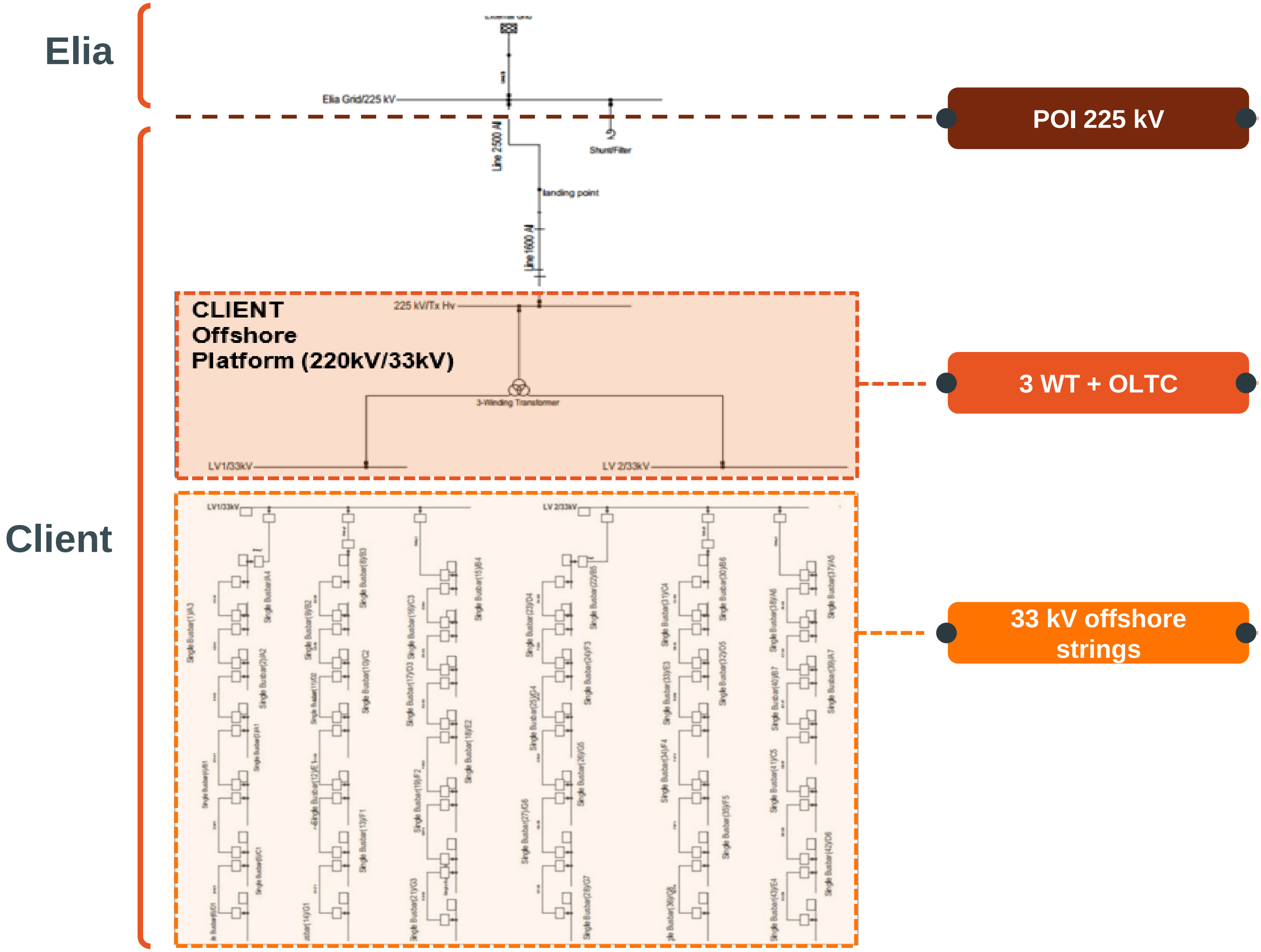


Structure of existing offshore connection in MOG I

Reminder

POI: Point of Interface
3 WT:3 Wind Winding Transformer
OLTC: On Load Tap Change Transformer

Structure MOG I



The Point of Interface (POI) is at 225kV
and is connected to the client via an export cable or directly via a 3WT

A 3WT connects to the export cable at the offshore platform

The 3WT and the export cable belong to the client.

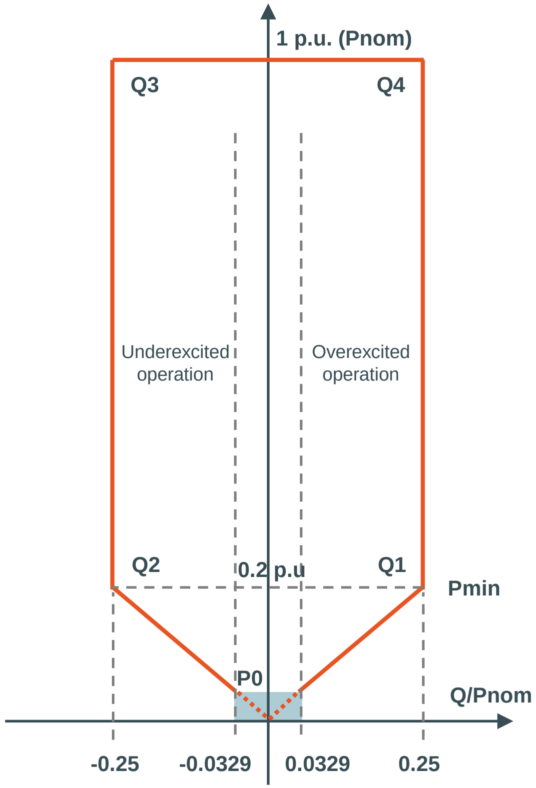
Internal network (40-50km of 33kV cables) connects the turbines to the 3WT

- highly capacitive (to be compensated)
- voltage profile not constant throughout the string (can vary up to 2-3%)
- cable sections strongly optimized to reduce cost

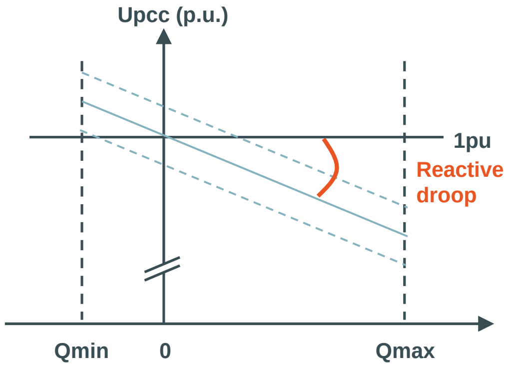
- **No static compensators** available offshore (no shunt)
- **Reactive power control** made **dynamically** by the wind generators (control 220kV POI) also without wind (STATCOM mode)
- **OLTC controls 33kV bus-bar voltages** (~1pu +/-1%) fast (~10-60s)

Voltage requirements for offshore parks (recent parks on MOG 1 and STEVIN)

Capability curve



Voltage droop control



Voltage range

Range	Duration
0.85 pu – 0.90 pu	60 minutes
0.90 pu – 1.118 pu	Unlimited
1.118 pu – 1.15 pu	20 minutes

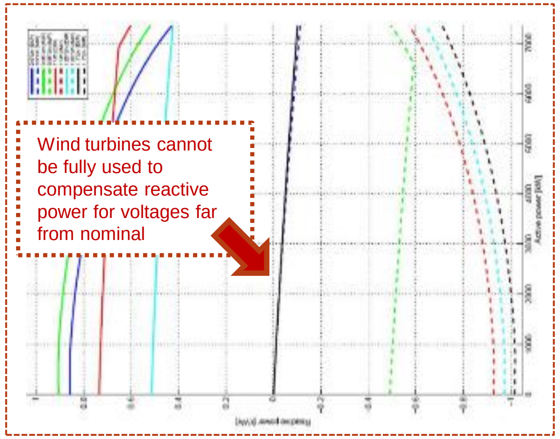
Requirements can be met at the POC (220kV/150kV) without extra considerable investments by the client

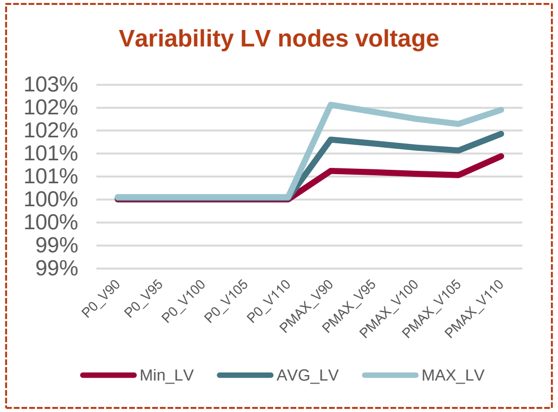
Can the same **requirements be met at 66kV** in the **MOG2 structure**?

Structure of an existing offshore park and main design limitation

- **Current parks can comply with ELIA requirements thanks to a precise control of the MV=33kV**
  (via their platform TFO tap changer)

- Should the MV (66kV in the MOG2) **not be controlled at a good voltage level, the client should**:
  - **Install transformers** or reactive **power compensators** → need space / platform
  - **Potential increased size** of its wind generators
  - **Oversize the internal network** (to handle higher currents for lower voltages)
  - Or **not comply with ELIA requirements** → ELIA has to take care of the compensation and dynamic voltage control

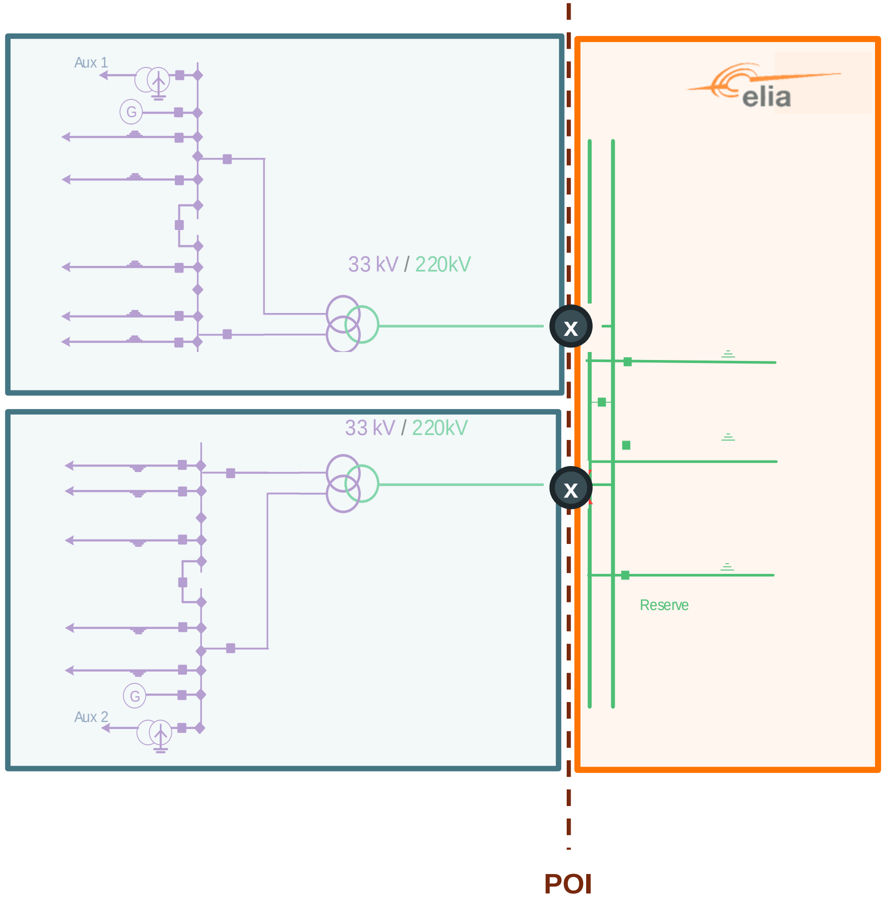

Wind turbines cannot be fully used to compensate reactive power for voltages far from nominal



Maintaining good 66kV voltage level is of fundamental importance to allow full usage of wind generator reactive capabilities

Fundamental difference for voltage control between MOG 1 and MOG 2

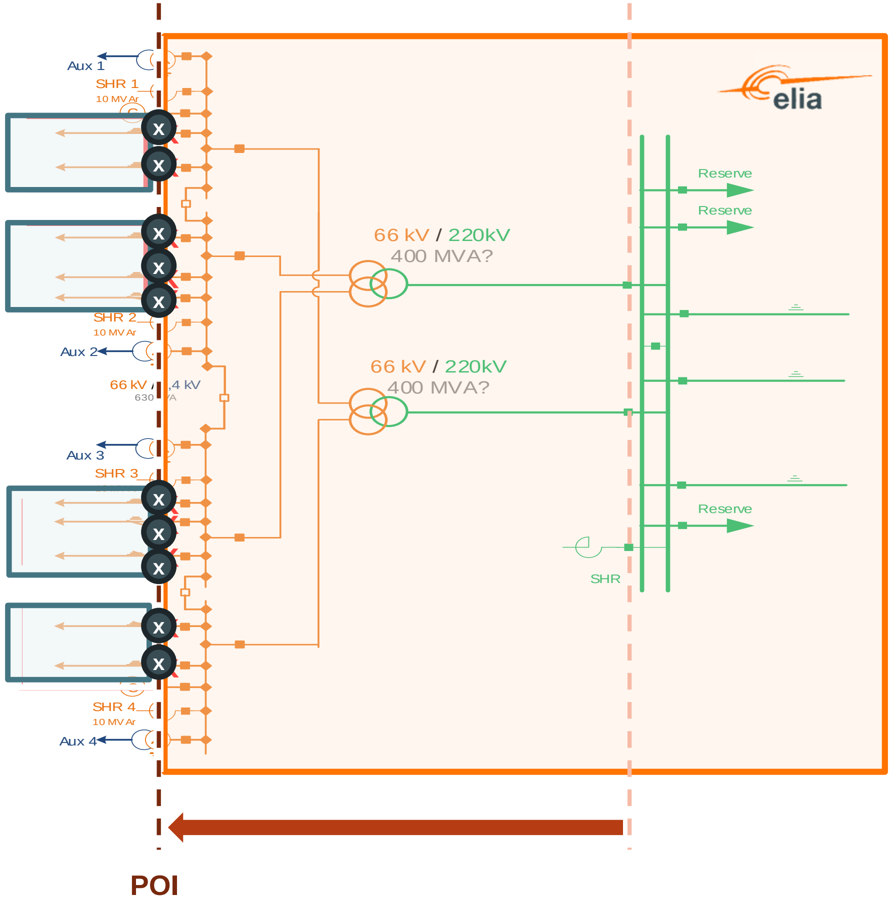
Voltage control MOG I



Main differences

- **Change in client connection point**
- **3 Winding Transformer managed by Elia**

Voltage control MOG 2



Legend

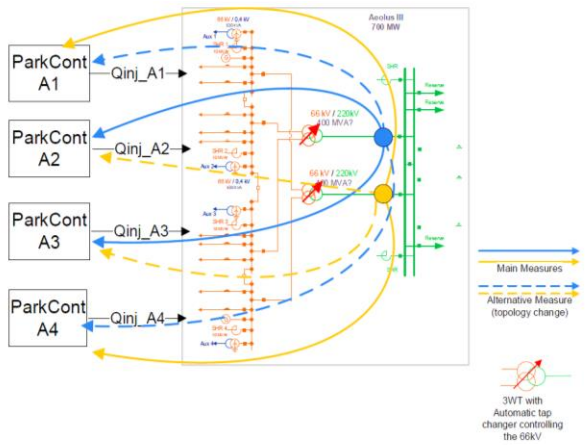
ⓧ client connection point

Not final SLD, for illustration purpose only

MOG 2 Voltage Control Scheme - Distributed Controller Based on 220kV Voltage Measurements

- **66kV** should be kept at **as constant as possible** via automatic OLTC. Tradeoff between accuracy and speed to:
  - Keep voltage as much as possible to 1pu
  - Generate reasonable number of tap changes in line with lifetime. The **active and reactive injection** for each 66kV busbar of the 220kV/66kV/66kV TFO **should be equilibrated** to avoid too large differences of voltage on the two 66kV busbars
- Each park controls its 66kV Q-injection based on the measure of 220kV 3WT to which it is connected
- The **parks should be able to receive a measure** from ELIA of the 220kV voltage HV side of the 3WT to which it is connected
- **Speed** and **quality of measurement** should be adapted for **control purposes** (better than MOG 1)
- **Different parks should react in similar way** to the voltage input

→ additional or more stringent requirements on response time and value of droop may be imposed



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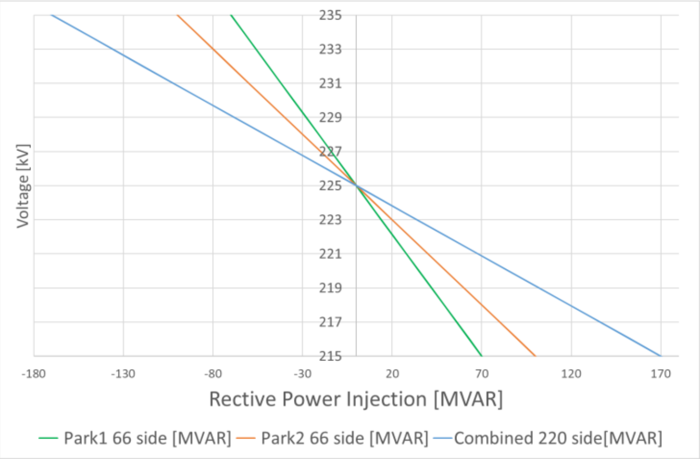
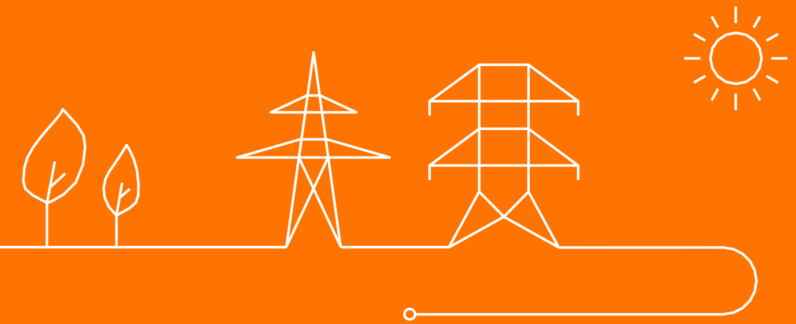


Feedback from the vendors & wind park developers

- New approach without Master controller must be based on high performance communication/measurements
- Using a single vendor on the same TFO should not cause problems
- Using multi-vendor parks on the same TFO may cause interaction
- Request to perform a confirmation of the concept via simulation with non-generic vendor specific models

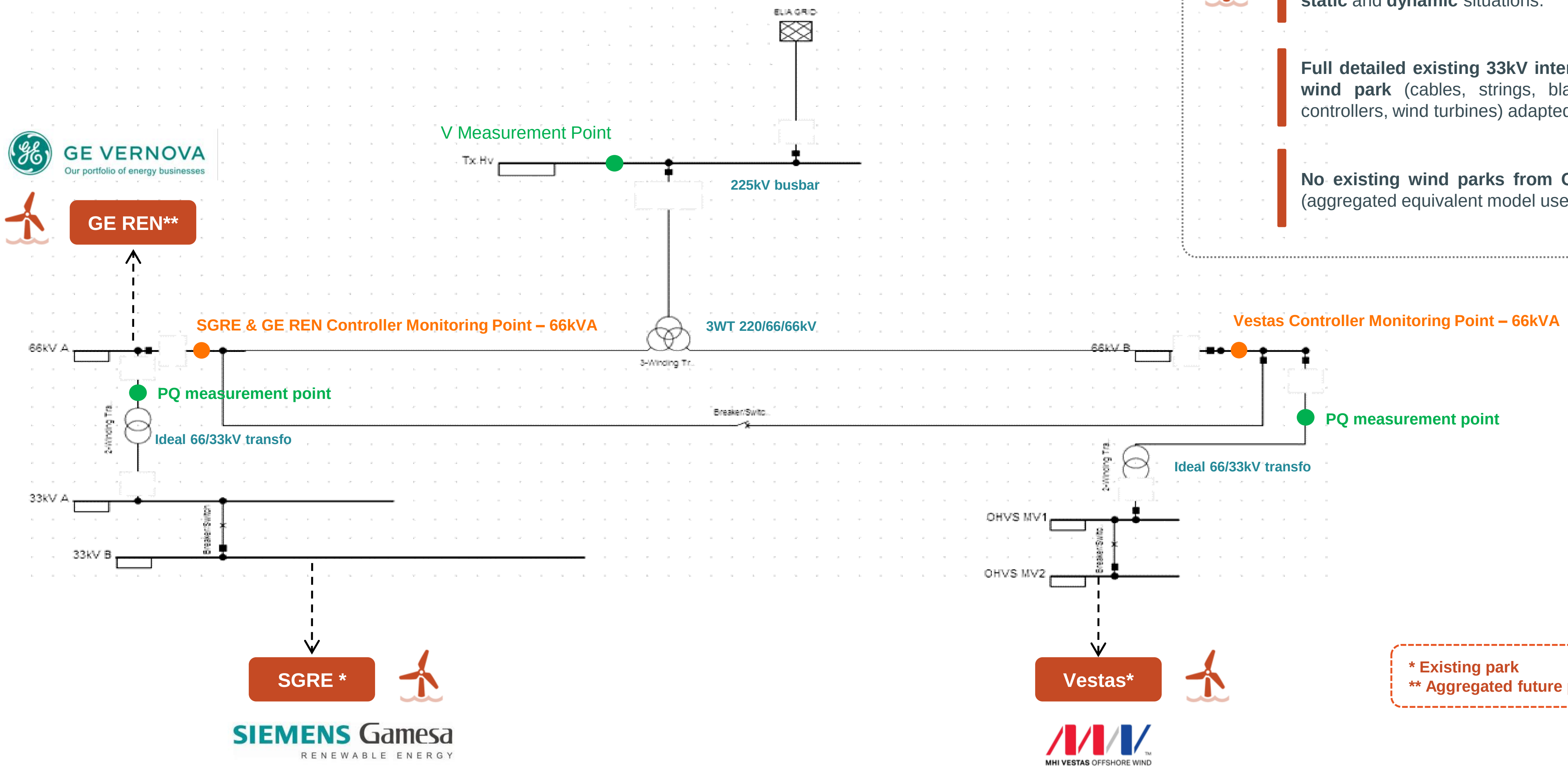
The results of the simulations will be shared in the remainder of the presentation

Proof of Concept of voltage control in MOG 2 with vendor models



RMS dynamic simulation setup used with model from vendors

Simulation setup



Wind pars are simulated in **combinations of 2 parks from different vendors** at a once for observations in **static** and **dynamic** situations.

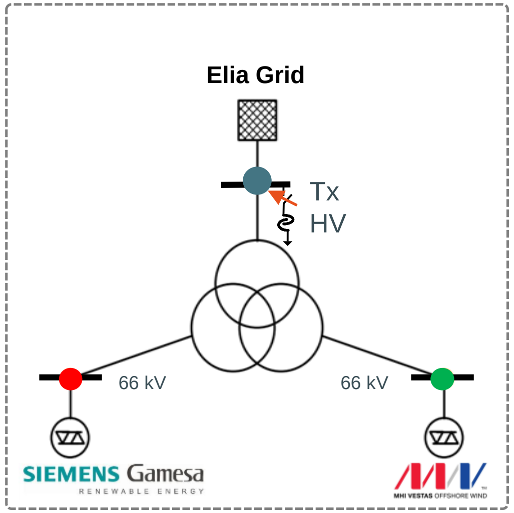
Full detailed existing 33kV internal network of the wind park (cables, strings, black boxed dynamic controllers, wind turbines) adapted to 66kV network

No existing wind parks from GE REN (aggregated equivalent model used)

*** Existing park**
**** Aggregated future park**

Setup constructor 1 – constructor 2

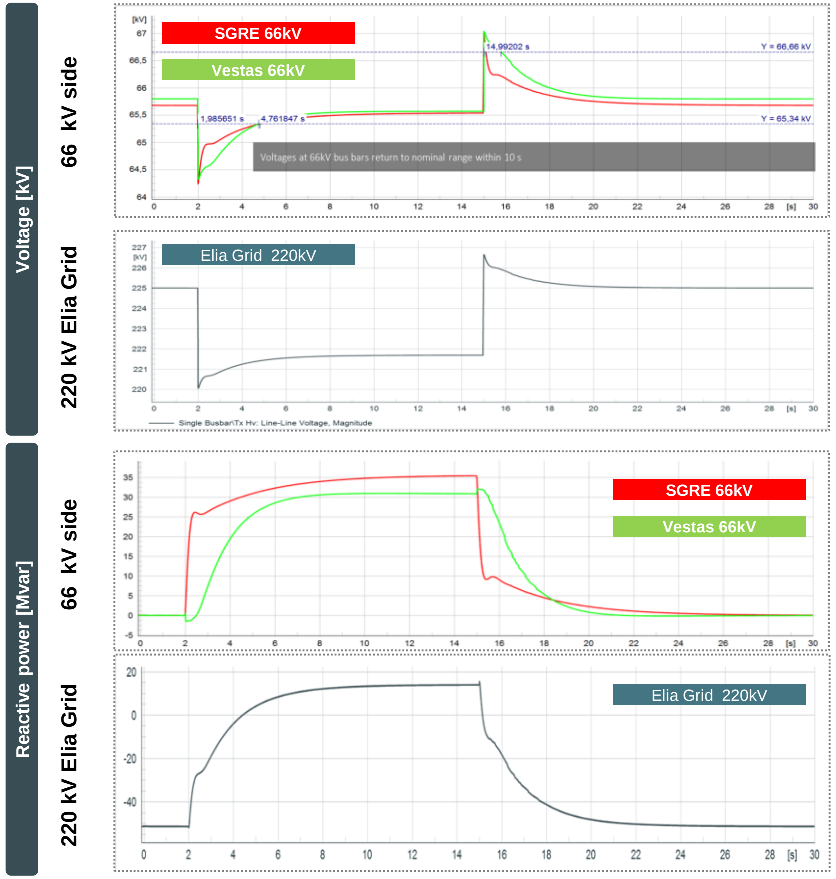
Case 1/3



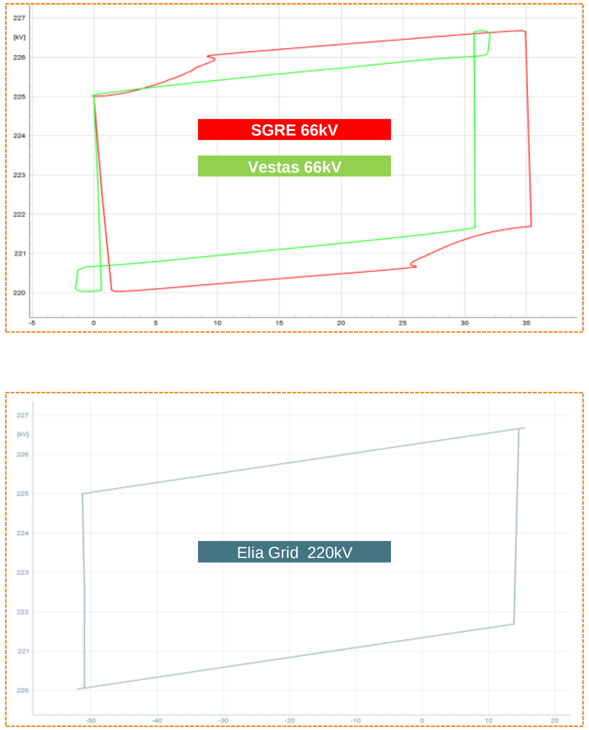
200 MVAr shunt reactor switched at TxHV

- Switch ON: 2 s
- Switch OFF: 15 s

Simulation results



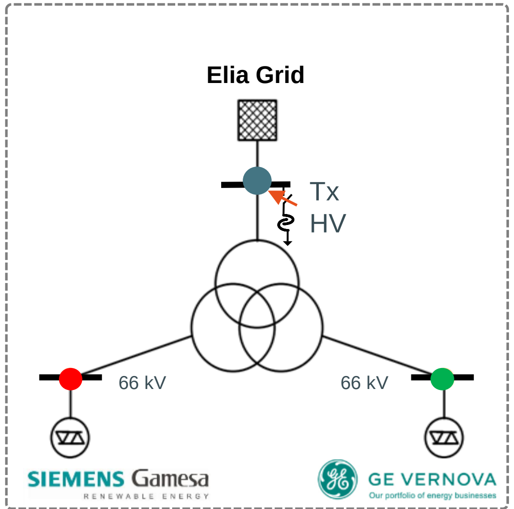
Q-U diagram



Stable dynamic behavior observed in this first case with no interactions between the two different vendors

Setup constructor 1 – constructor 3

Case 2/3



200 MVAr shunt reactor switched at TxHV

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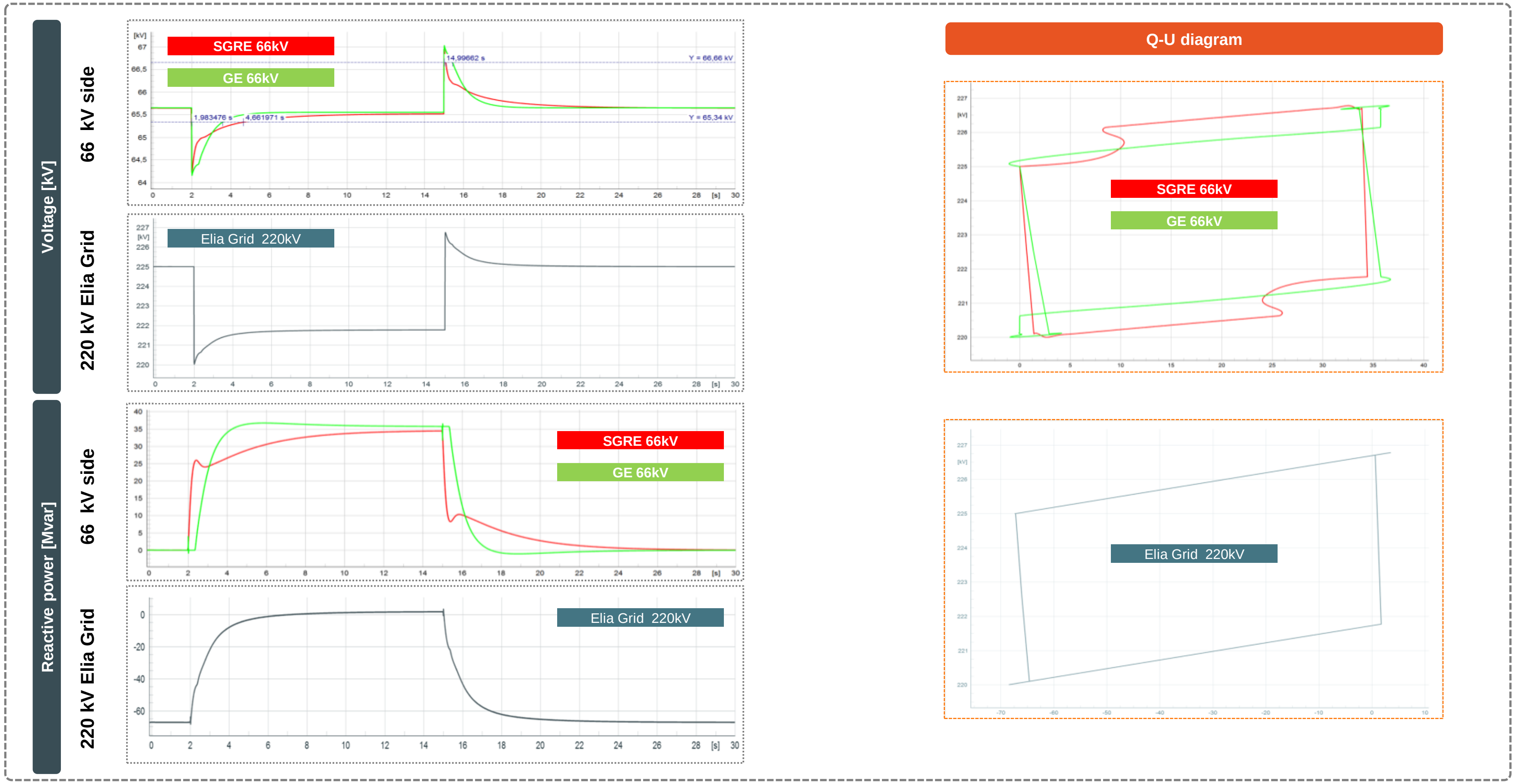
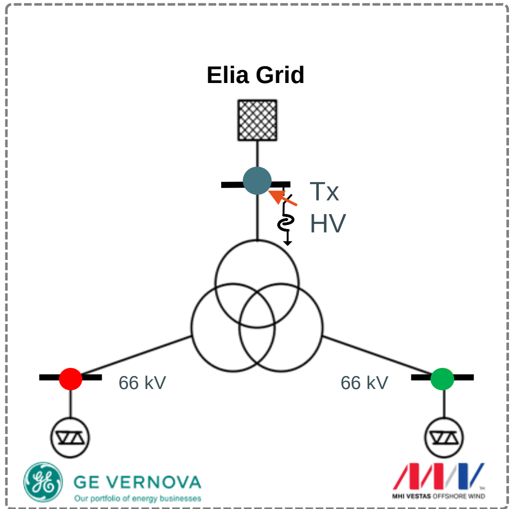
Simulation results



Stable dynamic behavior observed in this case as well with no interactions between the two different vendors

Setup constructor 2 – constructor 3 and conclusions of all variants

Case 3/3



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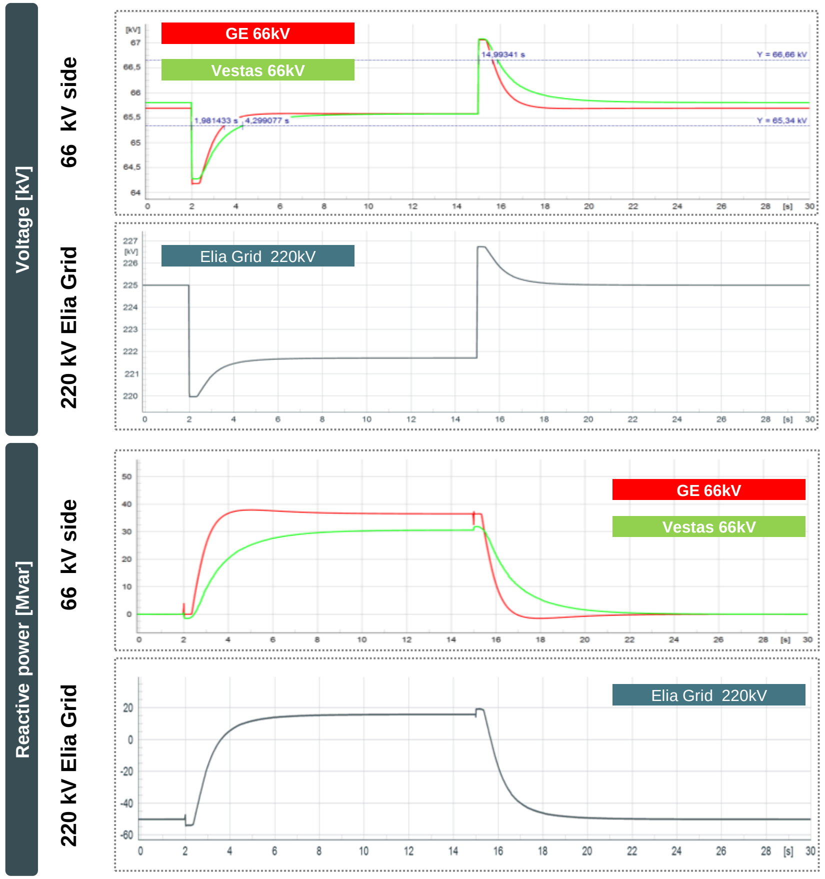
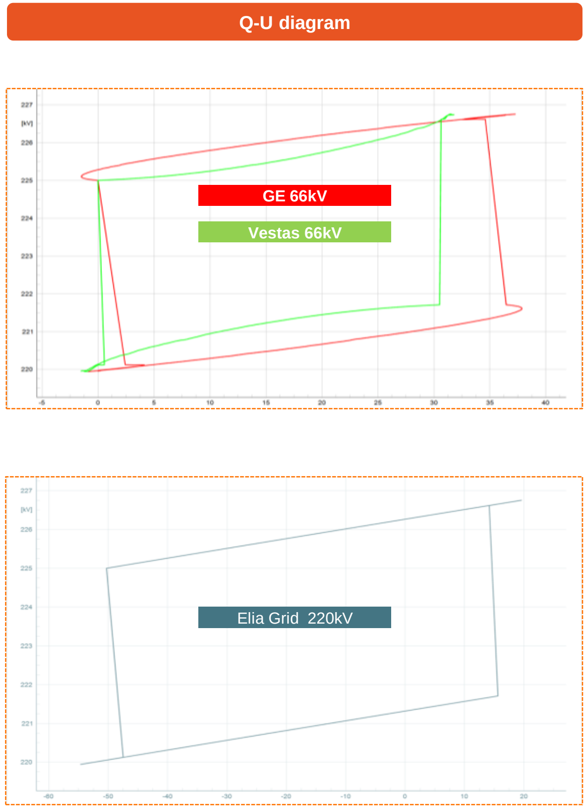
Simulation results



Q-U diagram



Main conclusions

- In **all** the different **simulations** with all combinations of two different vendors, **stable dynamic behavior is observed**
- **No negative interactions** from the parks are observed
- **Overall the voltages** show a **stable behavior**
- **Parks provide reactive power** support proportional to their capacities and also droops

Lessons learned MOG2 Voltage control proof of concept

- **Time response** and **droop value** for the future wind park **should** be in the **same range** as currently defined in the **existing requirement**
- 66kV busbar should be operated at a voltage close to the nominal value with an OLTC allows maximum **availability of reactive power** for Elia and **avoid oversizing of the converters**
- The **solution** is **robust against errors** in the measurement chain even if performances will be impacted

Lessons learned (return of experience & studies) from MOG1

- **Capability to switch remotely** and **online between Voltage and Q control modes** is necessary to allow correct activation of change in reactive power from ELIA
- **Conformity process** of new OWF **will be required** for validation of performance including EMT simulation on done ELIA side on and on site tests
- To ensure good performance for the voltage control, Elia should **transfer measurement to wind park significantly faster than MOG 1 (~hundred ms)**
- **Risk of Transient Overvoltage** following elimination of fault closed to large HVDCs & OWFs **requires**
  - **High Voltage Fault Ride Trough capability** and
  - Capability to **enable/disable remotely & online Fast Reactive Current injection with independent characteristics** for low and high voltage

Proposal of adaptations for technical requirements based on Voltage Control study

1. Reduce the range of voltage for which the wind park shall be able to deliver/absorb reactive power:

- From +/-10% of the nominal value to +/-5% of the nominal value (this is valid for 66kV connection)
- **No impact** on equivalent behavior at 220kV **for ELIA**
- In line with what is done for MOG 1 by the park owners
- **Significant reduction of cost for the clients** as no oversizing of converter is needed

2. Change of the voltage control droop principle - based on a measure of voltage coming from ELIA (220kV) and reactive injection of the park at 66kV

- **No impact on the client** control system (same specifications)
- Feasiblity confirmed by study and exchanges with vendors
- Allow **reducing complexity for ELIA** (no master controller is foreseen)

3. Adapt the droop characteristic by adding deadband on voltage

- Already existing in specifications of MOG1 park (even if not explicitly required for MOG I requirements)
- Existing in other TSO specification = VDE (German standard)
- **Allows flexibility** to reduce possible interactions (should they appear even if the simulation has shown no interaction risk)
- **No impact on client cost** as a de-facto standard

All the above proposed adjustments will reduce complexity for Elia and the cost for the client and Elia compared to MOG 1

Proposal of adaptations for technical requirements based on ReX or existing available capability

4. Clarify the behavior of the wind park when a new set-point of reactive power is sent by ELIA

- Current technical requirement doesn't include the required details
- Already implemented for MOG 1 (agreed with the clients during final commissioing phases)
- **Modification based on feedback from clients to be more clear for technical requirements**

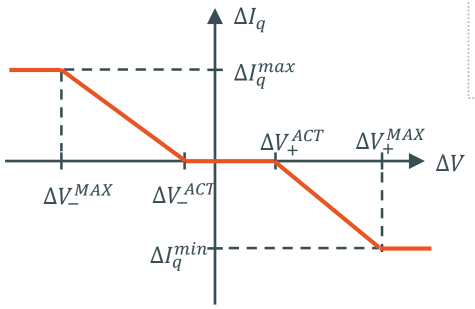
5. Clarify the requirement for Fast Reactive Current Injection

- Capability to disable/enable the function remotely and online (TBD with vendors)
- Independant characteristics for low voltage and high voltage
- Already included in the Belgian Grid code after commissioning of MOG 1 wind parks

6. Clarify the requirement for High Voltage Fault Ride Through Capability

- Post-fault overvoltages are caused by the wind parks themselves as speed of adaptation of current injection is limited
- This will reduce the risk of trip of wind parks in case of severe short circuits nearby

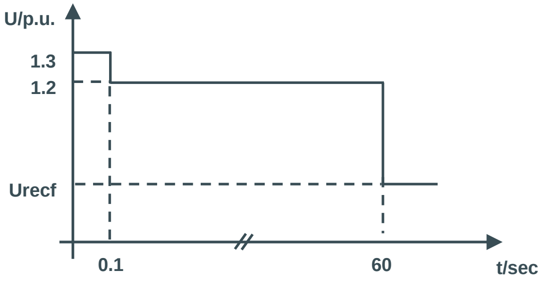
Fast Reactive Current Injection



$$\Delta I_q = \frac{I_q - I_q^{pre-fault}}{I_q^{pre-fault}}$$

$$\Delta V = \frac{V - V^{pre-fault}}{V^{pre-fault}}$$

High Voltage Fault Ride Trough Capability



All the above proposed adjustments* in OWFs connection requirements related to their Voltage & MVar control capabilities **are proven feasible based on standard vendor features** confirmed by MOG I or other European TSOs experience.

* *expected for Fast Reactive Current Injection Enable/disable*

Thank you.