Assignment – Electrical Aspects

OE44170 –Offshore Renewable Technologies 2025

Description of the exercise

The goal of this assignment is to complete a series of exercises related to the topic of electrical infrastructure for offshore renewable sources. Completing this assignment will give you the confirmation that you have understood the course material and address the following learning objectives (LO):

LO1: Explain the main impact of large-scale (offshore) wind power on power systems

LO2: Perform basic design calculations for offshore wind electrical infrastructure

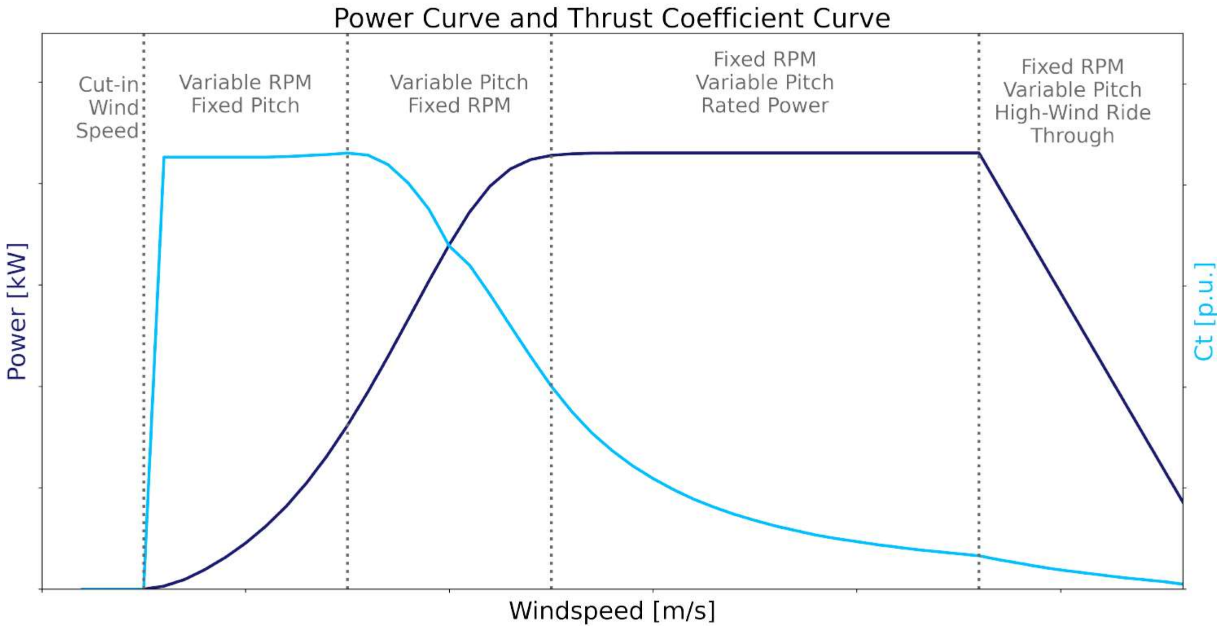
LO3: Understand the basic considerations in electrical infrastructure design

LO4: Be aware of offshore wind project development and construction aspects

Each of the LO is covered in a separate part. It is expected that you use the provided data and templates in Excel for the required calculations (files available in Brightspace). The total number of points for all questions combined is forty (40), with the possibility to receive one (1) bonus point at the end.

Part 1: Grid Integration of Offshore Wind *[12 pts]*

The integration of large-scale wind power has many impacts on the power system. For example, the variability of the wind means that the power production of wind turbines and wind parks vary as well. An overview of the power curve and the thrust curve of a modern wind turbine is provided below. The overview indicates five operational areas, from left to right I, II, III, IV and V.



Please answer the following questions.

- ➢ What is the challenge of operational area I for power systems? *[1 pts]*
- ➢ What are two challenges of operational area III for power systems? *[2 pts]*
- ➢ What are two benefits for power system operation of area V compared to a 'hard cut-out' at a high wind speed, as is the case for older wind turbines? *[2 pts]*

Offshore wind parks consist of a cluster of wind turbines. The power production by such a cluster of wind turbines is dependent on the wake effects: the power production of wind turbines may be reduced in the wake of other turbines. In the Excel file, tab 'WTG Yield Wake', the wake effect for a wind park of 80 WTGs is provided for wind speeds, measured at hub height, between 0.5 and 28.5 m/s.

- ➢ For this wind park, at what wind speeds are the wake effects negligible? *[1 pts]*
- ➢ Explain for operational areas II, III and IV what impact the wake effects have on power production of an offshore wind park. Consider the thrust curve as part of your answer. *[2 pts]*

In the past decade, wind turbines have become much larger. This is true for the generator sizes [MW], but even more for the rotor diameters [m] which have become larger also relative to generator size. Compare two identical wind turbines with a fixed capacity [MW] but with different rotor sizes.

- ➢ Discuss two opportunities of a larger wind turbine rotor for a wind park owner. Include the operational areas of relevance in your answer. *[2 pts]*
- ➢ Argue if a larger rotor could be beneficial from a power system operation point of view. Consider power variations and power forecast errors in your answer. *[2 pts]*

Part 2: Inter-Array Cabling Losses *[11 pts]*

Please consider the following information regarding the inter-array cabling types.

Inter Array Cabling Types

	Type [mm^2]	Ampacity [A]	Conductor resistance [Ω/km]	Phase operating voltage [kV]	Cost [€/m]
Cable 1	400	424	0.101	66	145 - 160
Cable 2	630	584	0.063		165 - 180
Cable 3	800	750	0.037		240 - 255

The type indicates the cross-section of the aluminium conductor [mm^2]. The ampacity is the maximum current [A] the cable type is designed to handle. Assume you are using 20 MW offshore wind turbines.

For the calculation, assume that every wind turbine operates at *cos φ* = 0.95 and do not consider any wake losses (conservative estimate).

- Calculate the nominal current per wind turbine *[2 pts]*
- Determine the maximum number of wind turbines that can be connected to Cable 1, Cable 2 and Cable 3 without exceeding the ampacity. *[2 pts]*

Assume that you want to use the cheapest cable type where possible. Review the Excel file, tab 'IAC' and, using your answers above, complete all yellow cells.

- What is the annual electricity loss as a percentage of the yield of the WTGs on the string? *[3 pts]*

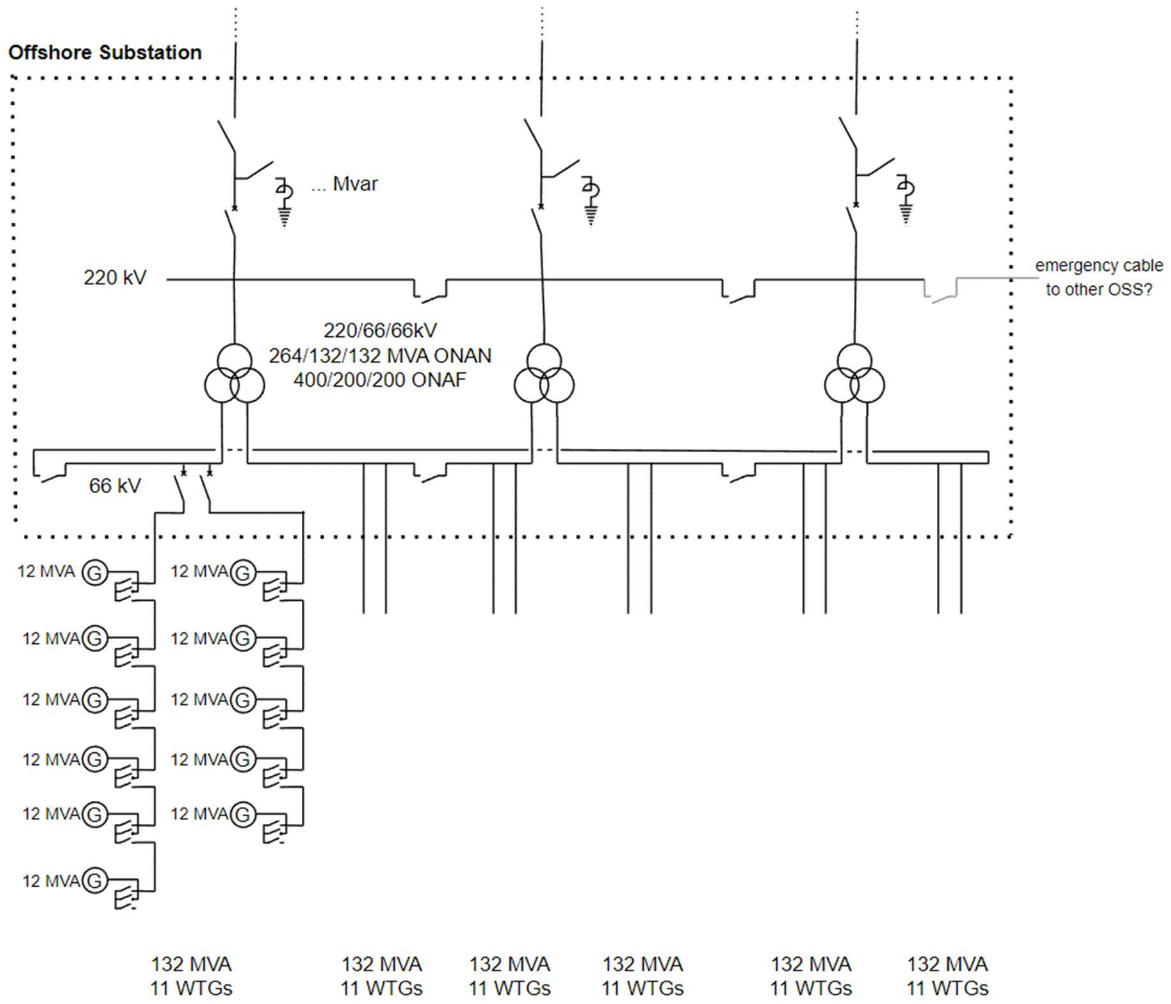
Assume that the voltage level of the cables would be 132 kV instead of 66 kV and that the conductor resistance would be the same.

- How many WTGs of 20 MW could be connected to Cable 1 if it would be at 132 kV? *[2 pts]*
- How much would the annual losses on the wind turbine string be reduced if the voltage level would be increased to 132 kV, everything else being equal? Explain your answer *[2 pts]*

Part 3: Offshore Wind Park Electrical Design *[7 pts]*

You are asked to evaluate the electrical design for a wind farm. A part of the single-line diagram of the offshore wind park is provided below. From the bottom to the top is shows the wind turbines, the inter-array cabling, the offshore substation, and the export cabling towards the onshore grid. The design is built up of modular blocks: only two of the total of twelve wind turbine strings are shown. For the oil-filled power transformers, two ratings are shown using different cooling setups:

- Oil Natural Air Natural: only natural convection and airflow cool the transformers
- Oil Natural Air Forced: ventilators force extra air to flow, cooling the transformers better



Assume that one of the export cables has an electrical fault and is out of service (N-1).

- ➢ What should be the capacity [MVA] of the export cable circuits? *[2 pts]*
- ➢ What is the level of redundancy [%] in the offshore substation transformers? Support your answer using a short calculation. *[2 pts]*

On the right in the single-line diagram, an option is indicated for an emergency connection to another substation. The emergency cable would be strong enough to keep the substation and the wind turbines energized in case all export cables from the offshore substation to shore would be out of service.

- ➢ Discuss three factors that you would consider in your decision to build that connection or not *[3 pts]*

Part 4: Offshore Wind Park Development and Construction *[9 pts]*

You are asked to develop a new offshore wind project that will be visible from land. The project is developed in a country that does not have offshore wind yet. Although there is general support for offshore wind, your project may face opposition from different stakeholders. The different stakeholders include

1) the national government
2) the local government
3) a nature conservation society
4) local fishermen
5) the local port
6) the grid company that will connect the wind park

- For each stakeholder, list a possible risk that your project may pose for the stakeholder *[3 pts]*
- For each stakeholder, list a possible gain or opportunity that your project could provide *[3 pts]*

You have managed your stakeholders well and you have a permit to build the project. The construction of the project will consist of different phases. Argue in what order the phases should be *[3 pts]*:

- The wind turbines
- The offshore substation
- The wind turbine foundations
- The onshore substation with the grid connection
- The inter-array cables between the wind turbines
- The export cables between the offshore and the onshore substation

Feedback *[1 pts]*

Offshore Renewable Technology is a new course. As your lecturers, we are motivated to learn with you and improve going forward. Therefore, we very much appreciate feedback on our work.

- Please provide your constructive feedback to the ORT-course thus far – it can be on lectures, course material, assignments and you are also welcome to make suggestions *[1 pts]*

Please note: constructive feedback can be positive or critical, but in any case, it should be phrased in a helpful, specific and kind way (in Dutch: Behulpzaam, Aardig, Specifiek (BAS)).

To encourage you, the student team providing the most valuable feedback will be given a bonus point!