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Vattenfall Wind Power Ltd

Thanet Extension Offshore Wind Farm

Annex B to Appendix 1 to Deadline 5 Submission: Applicant's response to ExQ2 2.3.3

Relevant Examination Deadline: 5

Submitted by Vattenfall Wind Power Ltd

Date: April 2019

Revision A

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Date of Approval:	April 2019
Revision:	A

Revision A	Original Document submitted to the Examining Authority
N/A	
N/A	
N/A	

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1 Introduction - Substation layout for TEOWF

This document has been prepared to outline in more detail the technical justification for the type of and size of substation proposed for Thanet Extension. It explains why an onshore substation connecting a wind farm to the transmission system requires a larger substation size compared with a demand load substation (such as those used at Olympic Park, London). The document also explains that the selection of switchgear insulating medium (gas or air) has negligible impact on the substation size, when compared with the design and layout constraints related to the other equipment that is required to provide a Grid Code compliant wind farm connection including the redundancy required to be factored into the design by transmission standards.

A wind farm substation is different from other onshore substations in many ways. Unlike a demand load substation, a wind farm substation comprises multiple voltage levels; as well as highly complex equipment, including multiple types of filtering and dynamic/passive reactive compensation equipment used to stabilise the power flows from the wind farm. This equipment is varied in terms of size, voltage level and insulating medium, requiring a range of design and safe maintenance access considerations when fixing the primary layout of a substation. For a wind farm grid connection, the overall substation size is predominantly governed by the physical size of the equipment used to stabilise the power flows from the wind farm, which is roughly the same size whether air-insulated switchgear (AIS) or gas-insulated switchgear (GIS) technology is selected.

2 Technical Note in support of Applicant's response to Examination Authority Questions – EXQ2

2.1 Question 2.3.3 (c) – dated 10 April 2019

1 Following ASI1, the ExA remains concerned that this is a larger land area than that required to construct and secure a substation and to provide replacement land for the Border Force compound. The justification for subjecting this entire land area remains unclear. The Applicant is asked to provide a summary, drawing as required on existing application and examination documents but addending such new information as is required to fully justify the case for CA for all of this land. This should include a fuller technical justification of the Applicant's assertion that the choice of GIS or AIS technology for the substation will not materially affect the land requirement.

2.2 Applicant's Response 2.3.3 (c)

2 The question of technology selection between gas-insulated switchgear and air-insulated switchgear is limited to the type of circuit breaker / switch employed. This equipment is used to isolate circuits/elements of substation equipment in the event of faults, as well as provide flexibility in the running arrangement of the wind farm electrical network. As the name suggests, air-insulated equipment uses air as the insulating medium between the phase conductors and earth, whereas gas-insulated switchgear uses sulphur hexafluoride (SF6) as the insulating medium. As the insulating properties of these gasses is superior to air, the separation between the phase conductors and earth can be reduced for GIS.

3 However, a typical substation also comprises switchgear and other equipment to ensure the stable transfer of power. The Thanet Extension Onshore substation will contain additional equipment for the transformation of electricity from the selected export voltage (66-220kV) to 400kV, as well as additional equipment required to condition the power prior to export to the grid as well as provide network support services to National Grid. This equipment is predominantly outdoor equipment and is connected together via the switchgear. The overall substation size is predominantly governed by the physical size of this equipment used to stabilise the power flows, which means that the overall substation area is roughly the same size whether air-insulated switchgear (AIS) or gas-insulated switchgear (GIS) technology is selected. A summary of the equipment that will be required is given below;

4 ***Transformers*** - these are the largest items of equipment to be located at the substation. They are used to transform the voltage from the selected export voltage to the transmission voltage of 400kV. NGET design standards (eg Security and Quality of Supply Standards (SQSS); National Grid Technical Specifications) for offshore transmission systems require projects such as Thanet Extension to provide two transformers at the onshore substation to provide redundancy in the event of an outage on either unit. Transformers of the rating applicable to Thanet Extension are insulated using oil. Due to the potentially fire hazardous and environmentally sensitive nature of the insulating medium, transformers tend to be laid out in such a way to provide adequate spacing to other equipment to prevent the risk of further substation damage in the event of a transformer fire. Additionally, the transformer foundations include a large perimeter bund to allow the capacity oil within the transformer to be contained in the event of tank rupture.

5 The transformer tank is also the largest, indivisible load that requires delivery and installation at the substation, containing the core and windings of the transformer. The substation layout therefore has to take account of the delivery of and installation onto the tank plinths located within the bunded foundation, as well as the build-up of transformer coolers, pipework and accessories around the main tank itself.

6 The layout, spacing and fire-zoning of these transformers are therefore primary driving factors for overall substation primary layout. In addition to the main step up transformers, ***additional transformers*** are required to connect specialised equipment that operate at fixed voltages (such as the power converters comprised in static synchronous compensators (Statcom) or Static Var Compensators (SVC), and auxiliary LV supplies). While these transformers may be smaller than the step-up transformers, they use a similar design and therefore require the same consideration of tank delivery/installation, oil containment and fire zoning.

7 In addition to the transformers, ***shunt reactors*** at the site will pose similar design considerations to that of the main transformers. Shunt reactors are used to compensate the charging current of the long export cables and are similar in design to transformers, with a larger main tank containing a core and windings insulated by mineral oil that is cooled by circulating it via radiators located on or adjacent to the tank. These reactors would tend to be located at the export voltage level, and connected to the export circuit it is compensating. As is the case for the transformers, the layout and positioning of this equipment will need to take account of the same design considerations as for the transformers.

8 ***Dynamic reactive compensation (DRC)*** will also be required to provide fast-acting control of reactive power to the transmission system in order to meet requirements of the Grid Code around voltage support. It is usual to have a DRC system per step up transformer to ensure system security is maintained.

9 The DRC system is a complex arrangement, comprising a static compensator (Statcoms/SVC) that is typically containerised as well as passive reactive compensation in the form of air-cooled reactors. The Statcoms/SVCs tend to come in lower voltages (1000V-13.9kV depending on the supplier) with the passive reactors tending to be in the range of 13.9-33kV (hence the potential need for the addition transformers to the step up transformers referenced above). The dynamic reactive compensation system is marshalled by a dedicated containerised switchgear system (usually GIS) which requires the different passive and dynamic elements of the system to be located together and a consolidated system compound. Due to the shunt reactors being air-cored, the DRC system layout needs to take account of substation boundaries and equipment/substation access routes/internal roads to ensure emf levels are outside of the DRC compound remain within limits. The result of this is that quite extensive spacing is required between the DRC equipment and the internal compound and boundary fencing.

10 ***Harmonic filters*** will also be required at the substation to improve power quality prior to export of power onto the grid in addition to compensating for the amplification effect of the wind farm offshore network on harmonic current already present on the system. The exact design of harmonic filters is heavily dependent on the detailed design and nature of the harmonics that require filtering, but typically comprise of a large capacitor bank connected in series with an air-cored reactor and resistor unit. Again, one filter is typically specified per transformer circuit and can connect either at 400kV or the export voltage, again, heavily dependent on the detailed design of the filtering solution. All equipment comprised in the harmonic filter is out door and air-insulated, requiring due consideration of electrical clearances and EMF emissions in terms of its siting, proximity to boundary fences and internal access routes/roads.

11 In addition, suitable access routes and space around each piece of equipment is needed to allow for safe maintenance access and for certain component parts to be replaced during the project lifetime. These need to be considered in the overall layout of the substation.

12 ***Number of Circuits*** – the number of circuits required is governed by the number of circuits connecting to the offshore windfarm and the amount of equipment required within the substation to make it compliant with National Grid standards. For safe maintenance of the equipment, the electrical connection to each piece of equipment needs to be deenergised separately, and hence needs to be on an individual circuit.

13 ***AIS vs GIS - space*** – Whilst the applicant acknowledges there are potential space savings from the use of GIS, as well as other potential advantages such as slightly better protection in coastal areas, the impact of these savings in space terms are limited on the overall land required for the Thanet Extension substation.

14 To this end it may be determined by the Applicant, during detailed engineering that GIS is an optimal solution for the Thanet Extension onshore substation. However, the Applicant in making such a design decision will also be required to take note of potential drawbacks with the selection of such technology such as circuit proximity to other circuits, increased complexity of substation internal cable routing/gas insulated line routing, use and management of sulphur hexafluoride (SF6) – the gas used in GIS equipment.

15 Where a substation’s primary use is to amalgamate multiple circuits or for a dedicated demand load (eg Olympic Park), GIS can have a significant impact on the overall substation footprint where GIS is installed in a centralised single or multi-storey building. However, the addition of a significant amount of outdoor equipment for a wind farm substation (e.g. reactive compensation and harmonic filtering) sees this benefit significantly eroded. Indeed, in such cases where lots of underground cables need to be routed from outdoor equipment to a compact, centralised switchgear building, the cabling congestion around the substation can result in issues in relation to circuit security (i.e. a fault on a circuit can damage an adjacent circuit).

16 A multi-storey GIS building is not practical for a wind farm. Whilst a multi-storey GIS building may be practical for a central London substation, a windfarm substation transfers significantly more power and at significantly higher voltage levels. This makes equipment larger, heavier and more sensitive to movements; meaning buildings require larger foundations and reinforced floors. For the power demands of Thanet Extension, this makes a multi-storey building less practical from an environmental and construction perspective.

17 ***AIS vs GIS – noise*** – The Applicant notes that there is no significant noise difference between AIS and GIS - any reduction is negligible compared to other substation noise sources (reactors, transformers). All substation noise sources will be subject to detailed noise studies, as noted in Document Reference 6.3.10 - Noise and Vibration – Environmental Statement Volume 3 Chapter - (PINs Reference APP-066) and the accompanying information: Document Reference 6.5.10.1 Annex 10-1 - Onshore Noise and Vibration Technical Report - (PINs Reference APP-121), and Document Reference 6.5.10.2 Annex 10.2 - Onshore Noise and Vibration Supporting Information - (PINs Reference APP-122)

18 A series of Figures below demonstrate the layout of elements of the substation. The design process has not yet been concluded. These show in particular additional equipment required for an offshore windfarm that would not be required for other forms of substations.

19 ***Conclusion*** – To summarise, the onshore substation connecting a wind farm to the transmission system is highly complex comprising multiple voltage levels as well as multiple types of filtering and dynamic/passive reactive compensation equipment. This equipment is varied in terms of size, voltage level and insulating medium, requiring a range of design considerations when fixing the primary layout of a substation.

20 While the selection of GIS over AIS would have the effect of reducing the footprint taken up by the circuit breakers within the substation, the footprint saving for this equipment is negligible when compared to the design and layout constraints related of the other equipment that is required to provide a Grid Code compliant wind farm connection with the redundancy required by transmission design standards.

21 The Applicant notes that RAMAC considered at CAH2 that the required area for the substation can be reduced from 8.5 acres (as is the current design) to 2.3 acres and that the number of circuits may be greatly reduced. However the Applicant disagrees with this conclusion for the reasons highlighted above. For the reasons set out above, having a substation area of 2.3 acres would not be feasible, and a reasonable area required based on the design code requirements is 8.5 acres. There is no material difference in land requirements for either a AIS or GIS substation. Indeed, this is comparable with other wind farms of similar size and voltage, e.g. Rampion, where the onshore substation is situated in a 7 hectare (17.30 acre) site.

2.3 Applicant Response 2.3.3 (c) –Onshore Windfarm Substation Layout (2x 400/66kV Tx)

22 A typical onshore substation layout which is freely available on the internet is shown in Figure 1. The size of the transformer and harmonic filters are identified. The figure shows that the size of the equipment governs the space required, rather than the separation distances of the air insulated busbars connecting to the equipment (which require greater separation than gas insulated connections).

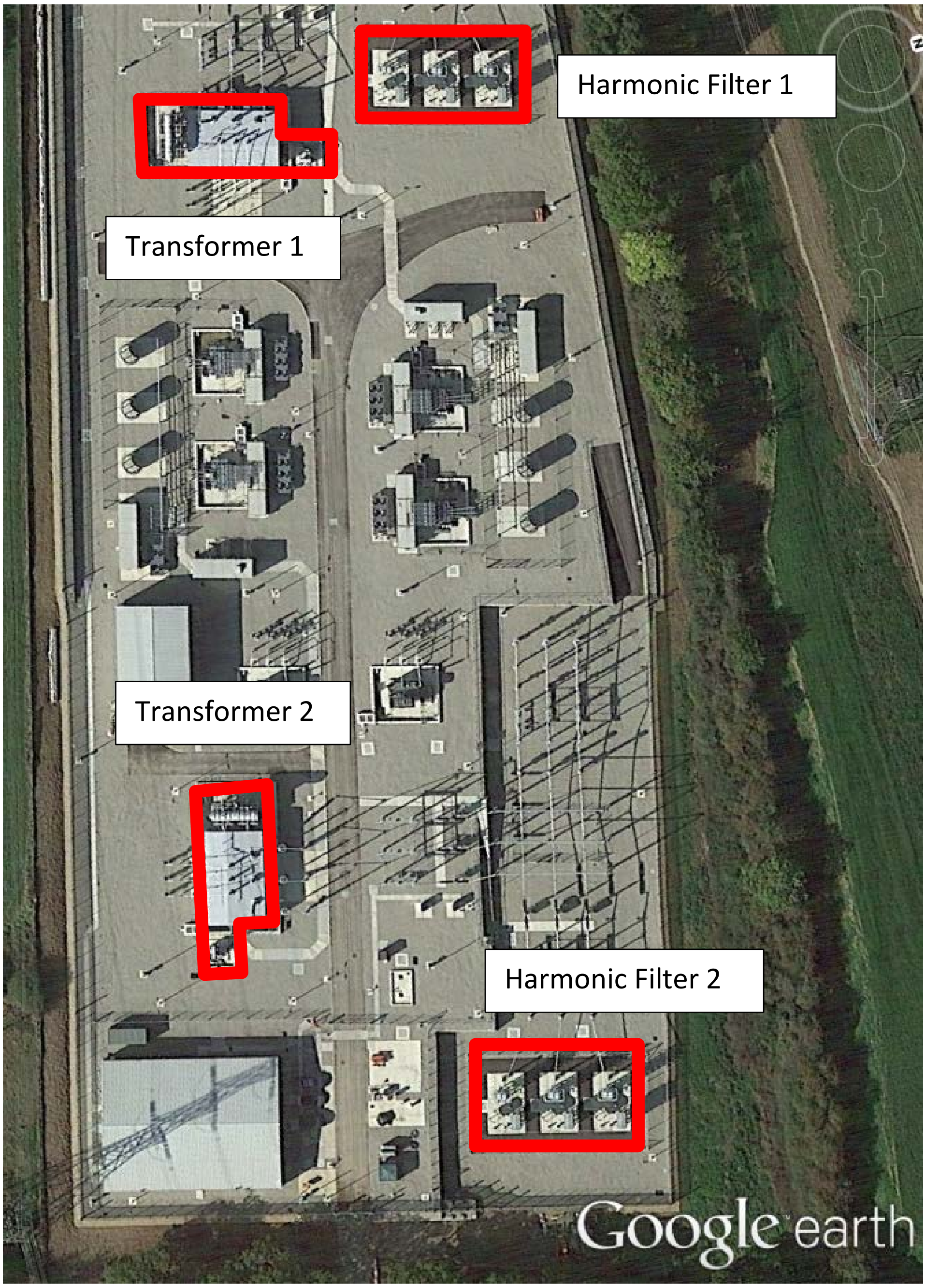

Figure 1: Indicative Layout – 2 x 400/132kV Transformers.

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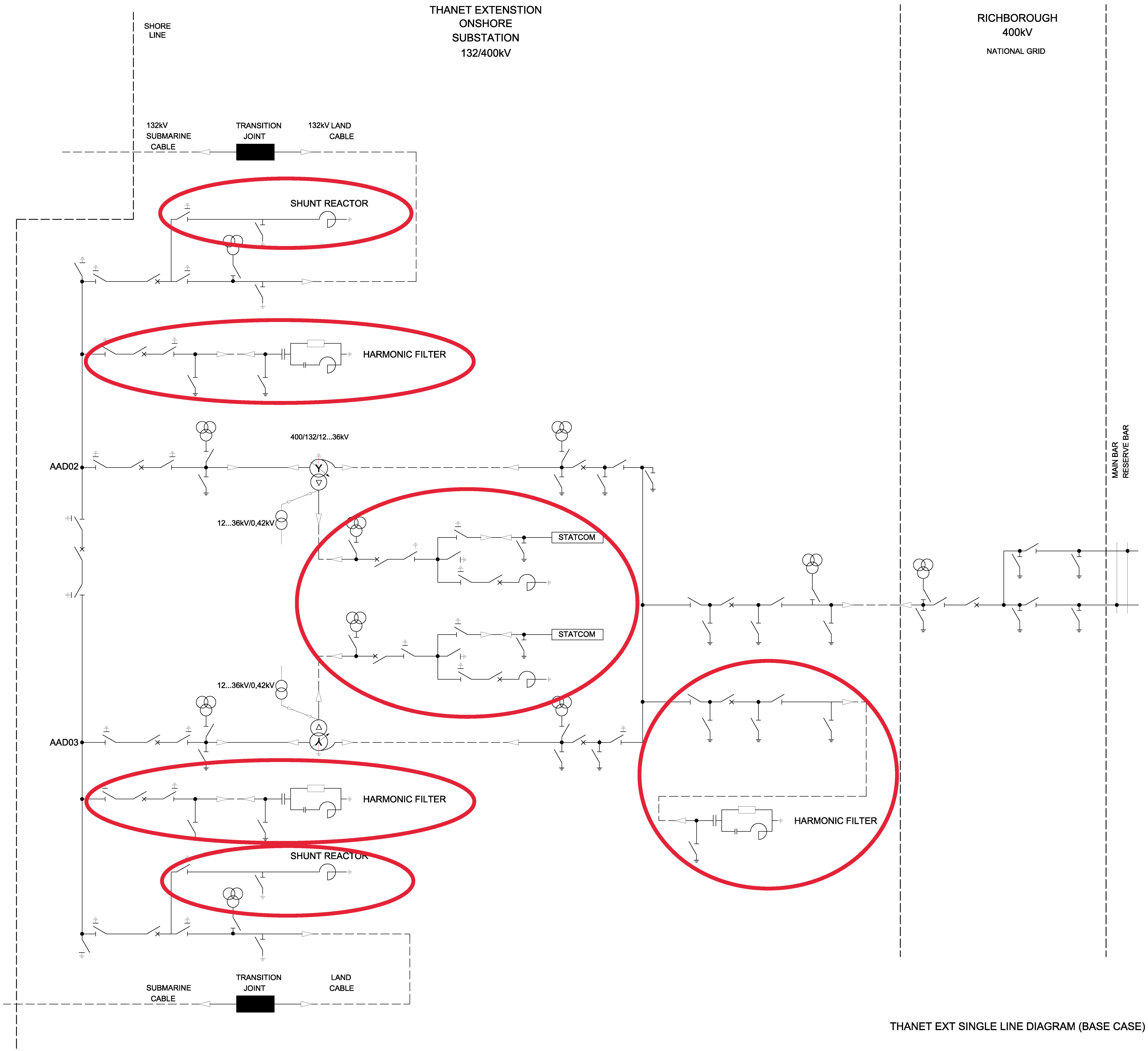
2.4 Applicant Response 2.3.3 (c) – Indicative Single Line Diagram

23 Figure 3 shows an indicative layout (single line diagram (SLD)) for the Thanet Extension onshore substation. Exact equipment and layout will be determined by detailed engineering.

24 The Equipment depicted in the SLD includes

- 5 x 400kV Circuit Breakers
- 7 x 132kV Circuit Breakers
- 2 x Transformers
- Harmonic Filters / Shunt Reactors / Statcoms to comply with National Grid Code

25 The additional equipment required for a wind farm connection compared with a dedicated demand load (eg Olympic Park), is shown circled.



THANET EXT SINGLE LINE DIAGRAM (BASE CASE)