The Security and Quality of Supply Standard (SQSS) modification review workgroup, named GSR020, has evaluated the proposal requesting acceptance for single transformer offshore substations above 90MW as SQSS-compliant.

The conclusion accepted by the SQSS Review Panel is that offshore wind power plants with at least two offshore transmission modules are compliant with the standard. The implications are positive for cost reduction, as the decision opens up a range of solutions delivering good value for money across different sites. However, the agreement is not without controversy: therefore, it is beneficial to explore the good practices and lessons learned within the group and how this helped it to come to fruition.

Summary of findings

- The new interpretation of the standard allows single transformer offshore platforms above 90MW to be considered SQSS-compliant without a design variation.
- Conventional solutions based on double transformer offshore substations may be preferred for some projects and are not precluded by GSR020 conclusions.
- Two power transformers are still required in offshore transmission systems (OTS) because 50% of the capacity must remain available at all times.
- When not sharing a foundation with a wind turbine, the offshore transmission module comprises an open-deck single-transformer offshore substation.
- A broader review of the offshore parts of the SQSS is widely acknowledged as ideal, but there seems to be little interest in conducting such a review within the current industry context.

Recommendations

- ORE Catapult should gather evidence of the progress of single transformer offshore substations through the Cost Reduction Monitoring Framework.
- The SQSS GSR020 participants could analyse the positive outcome of the workgroup and share best practice with the industry.
- Pay attention to the terms ‘standalone’ or ‘integrated’, because they are used with different meanings: they describe the integration of the single transformer platform either with a wind turbine or the overall OTS solution.
- The development of similar solutions for single transformer offshore substations by other equipment manufacturers would be welcome as a necessary step towards ensuring the appropriate level of competition.
The background

In a sustained global context of low fossil fuel prices, the new political agenda has reconsidered subsidies for renewable electricity sources in the UK. There is scope for continued innovation and research, provided that the technology proposals under evaluation are aimed at reducing the levelised cost of energy (LCoE).

With regard to offshore wind, the UK Department of Energy and Climate Change has shown commitment to further Contract for Difference (CfD) allocation rounds during this parliament.

This is positive, although the delivery of these allocation rounds has been explicitly linked to “the industry meeting the Government's conditions on cost reduction”. Bearing this in mind, the last strike prices of c.£115/MWh seem to set a ceiling for bids to be put forward in the years to come.

In this context, utilities, manufacturers and research organisations are working on novel solutions to decrease offshore wind LCoE. The Cost Reduction Monitoring Framework, delivered by ORE Catapult to the Offshore Wind Programme Board (OWPB), keeps an objective track on progress.

As previously stated, the endurance of the industry depends on its ability to deliver and show progress in the overall objective of cost reduction.

With regards to grid connection costs, cable systems and offshore substations are the main areas under consideration. Greater capacity cable systems are being investigated with increased voltage, cross sectional area, and enhanced dynamic controls.

Meanwhile, considered novel solutions involving offshore substations range from radically different turbines and collector systems, to realistic exercises of value engineering affecting the offshore transmission system (OTS) as a whole.

Such innovative proposals have recently been focused on a number of issues, including the number of transmission circuits within onshore substations forming part of offshore transmission systems; the number of power transformers onto offshore platforms; and the cost effectiveness of auxiliary systems such as permanent back-up diesel generators, associated fire suppression systems or helipads.

However, projects incorporating these novel ideas still need to comply with grid codes if funding is to be secured. For projects in pre-final investment decision (pre-FID) stages of development, a key piece of regulation is the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS). This standard establishes a coordinated set of criteria and methodologies that transmission licensees use in the planning and operation of NETS.

The fact that relevant chapters of this standard are based on analyses conducted a decade ago imposes its own challenges to technologies beyond state-of-the-art, such as those under consideration within the scope of this paper.
The challenge

Manufacturers and developers have proposed new systems to decrease offshore wind grid integration costs. Some of these proposals suggest the simplification of the offshore equipment and, in particular, a reduction of the number of transformers on each platform. However, prior to GSR020, the prevailing interpretation of the SQSS prevented the use of single transformer installations above 90MW.

Heavily involved in the optimisation of a number of projects under development, Siemens Transmission & Distribution formally requested a review of the relevant sections of the standard. The request was raised to the System Operator (SO), as National Grid SO is the administrator for the SQSS on behalf of the transmission network licensees.

The manufacturer claimed that comparison of a state-of-the-art two-transformer offshore substation, with an installation using two of the lower cost single transformer, modules would show a positive cost benefit analysis (CBA) over the lifetime of the windfarm. The alternative offshore substation configurations proposed by the manufacturer, and subsequently evaluated by the GSR020 workgroup, are shown in Figure 1:

Subfigure 1.a shows the single line diagram of a conventional OSP-based solution with a single platform, two transformers and the MV circuits connected with an open interconnection.

Subfigures 1.b, c and d show alternative arrangements with single transformer modules (platforms) that incorporate HV, MV or no interconnection between the modules respectively.

According to the figures provided by the manufacturer, the capital expenditure (Capex) savings for a 500MW reference project were between £20 million and £30 million for single transformer-based designs, when compared with conventional OSP-based solutions.

1 At this point, there is benefit in noting the different terms coined for concepts which propose to use the same foundations for turbines and substations, notably Siemens’ Offshore Transmission Module (OTM); Dong’s Distributed Substations; ABB’s Distributed AC Power Collection Systems; and OWPB’s Lightweight Offshore Substation Designs.

There are significant differences between these proposals, but it is common to all of them to consider single transformer offshore platforms for power ratings above 90MW.
By the time the SQSS modification proposal was pushed forward, one offshore wind developer had already raised a design variation request for a 600MW project aiming towards FID in early 2016. Bearing in mind previous workgroup experiences, it seemed sensible to take alternative routes to check whether offshore transmission module (OTM)-like solutions were to be accepted as SQSS compliant.

With similar design variation requests in the making for another two developments around 500MW and 1,000MW, ‘do nothing’ was not a valid approach for the Authority and the SO.

The approach

The NETS SQSS Review Panel agreed that a workgroup should be established to progress the modification proposal raised in relation to single transformer offshore substations. National Grid, alongside Siemens, agreed on the Terms of Reference and workgroup membership was sought shortly after.

The GSR020 workgroup was formally convened targeting the Modification of Clause 7.8.1.1 to Allow Single Transformer Offshore Substations of Capacity Greater Than 90MW. It was established with the clear intention of improving previous workgroup experiences, and the first meeting resolved to have the workgroup conclusions report ready for the NETS SQSS Review Panel by the end of 2015.

There were a number of early agreements on controversial issues that helped to set the working group on the right path:

- The [OffGEP capacity definition in the] SQSS does not necessarily require modification, but its interpretation has to be unified and agreed throughout the industry;
- Reactive compensation issues will not be considered in the cost benefit analysis (CBA) comparing the current requirement and new solutions;
- A minimum of 50% OTS capacity shall be available at all times; hence, a connection with one transformer for the whole OTS is unacceptable;
- Single transformer offshore solutions are a new design option, showing lifetime economic benefit in some projects, and will not diminish future connection requirements.

Open and positive discussions were held on both the input assumption values and the methodology for the CBAs used to support the evaluation.

Variables such as failure probabilities, mean time to repair, energy prices and cost of capital were discussed to agree both the mean value (default assumption), and the range to be considered within the sensitivity analyses. The practicalities of the spreadsheet delivering the calculations for the CBAs in all the scenarios were also reviewed by members.

Siemens provided the workgroup with quality reference material in the form of spreadsheets and graphical representations. This facilitated focusing the discussions on the key issues and encouraged members to put quality time into the analyses and return comments in a timely manner. Face-to-face meetings were convened when a relevant piece of work was to be discussed, which ensured productive meetings and rapid progress.
As a consequence of all that, detailed CBAs for the 500 and 750MW options were agreed and early results began to prove that the lifetime economic benefit, which the stakeholders had claimed was feasible, was correct.

The results

The net present value (NPV) of a baseline project was the metric chosen by the workgroup for the evaluation. It was calculated for each alternative described above (see Figure 1, as illustrated on page 3) and the results were presented as the NPV differences between each of the three OTM-based options and the state-of-the-art conventional OSP based design.

The results obtained for a 500MW offshore wind baseline project are summarized graphically in Figure 2 (as illustrated on page 6). The green bars represent savings corresponding to the design based in OTMs with a HV interlink between the single transformer platforms. Similarly, light blue and yellow bars represent savings for the alternatives with MV interlink and no interlink between OTM modules respectively.

Therefore, each group of green-blue-yellow bars represent the NPV savings for a baseline project moving from a conventional OSP based solution to one of three novel designs with HV, MV or no interlink between OTMs.

Compared to the default input assumptions, the calculations showed lifetime savings of £30.6m, £31.6m and £26.8m for the three novel solutions. These NPV improvements correspond to Capex savings of £23.5m, £23.5m and £25m respectively.

These Capex savings stated by the manufacturer are highlighted in Figure 2 by a red box, while the correspondent NPV improvements are noted by a golden box.

Moreover, the robustness of these results was checked by a number of sensitivity analyses. The input parameters were taken one-by-one to a less favourable scenario and the NPVs were recalculated in each of them.

The worst case scenario is obtained when all the input assumptions are taken to the less favourable end of the range agreed by GSR020 members. The results in this scenario are pointed out in the dark blue box in Figure 2 and still show NPV savings of £25.9m and £34.8m for the OTM interlinked options. On the contrary, this worst case scenario shows a cost increase of £2.1m for the design with no interconnection between OTMs when compared to the conventional OSP-based design.

It should be noted that the Capex savings were not checked by the workgroup: they were provided by the manufacturer and are based on calculations made for a real project. These savings were broken down to roughly £9m in structure, £7.5m in lifting works and £7m in constructing a jacket.

Another developer also stated that, according to the assessments made for his close to 1,000MW project, the single transformer solution was expected to create savings of almost £40m against traditional OSP. However, these two projects are likely to use the same manufacturer.
The GSR020 was asked if any member had a rough calculation of the difference in Capex between original single platform solution and single transformer solution, using a different manufacturer. Unfortunately, nobody could give a figure and concerns were raised that the whole exercise seemed to be focused on one supplier.

However, the developers informed the working group that, during their initial design exercises prior to submitting connection applications, they made their own analysis with multiple suppliers and various designs and concluded that the single transformer platform designs will introduce savings.

All in all, the GSR020 workgroup agreed the input assumptions and the CBA methodology and transformed the Capex savings claimed by the manufacturer and developers into NPV values. The lifecycle economic benefits of single transformer platforms were accepted in the terms described and the open industry letter, guidance note and final report were made publicly available.

The GSR020 was formally closed by crossing the modification proposal out of the NETS SQSS Modification Register in the last SQSS Review Panel of 2015. The early and successful closure agreed for the SQSS GSR020 workgroup has been welcomed by the developers involved as well as by the wider industry. It has demonstrated how a wide group of offshore wind stakeholders can work together successfully to unlock cost reductions by the review of standards in force.

1 http://www2.nationalgrid.com/UK/Industry-information/Electricity-codes/SQSS/Modifications/GSR020/
Conclusion

Single transformer offshore platforms above 90MW are now SQSS compliant, provided that two transformers are installed in the offshore transmission system. Conventional solutions based on previous interpretations of the standard are by no means precluded by GSR020 conclusions, and will possibly be favoured in some developments depending on the project specifics. When not sharing a foundation with a wind turbine, the solution proposes an open-deck single-transformer offshore substation (see Figure 3).

![Image of offshore wind projects](image)

- a) 90 MW single transformer platforms operational in Robin Rigg (EoN)
- b) 294 MW single transformer platforms under consideration for Beatrice (SSE)

**Figure 3: Evolution of single transformer substations in offshore wind projects**

The different terms being used for proposed solutions to place wind turbines and substations onto the same foundation should be noted. Siemens’ offshore transformer module (OTM), Dong’s distributed substations, ABB’s distributed AC collection systems and OWPB’s Lightweight Offshore Substation designs all refer to related but different concepts. Similarly, terms such as ‘standalone’ or ‘integrated’ are used with different meanings. They can describe the relation of the single transformer platform either with the wind turbine or with the overall electrical layout.

In a broader context, a fundamental review of SQSS chapters affecting offshore wind grid integration is widely acknowledged as necessary and is likely to be conducted in due course.

Looking towards the future of such innovations, ORE Catapult will continue to engage with the industry through the Cost Reduction Monitoring Framework, the OWPB, and other initiatives and projects in order to promote appropriate level of competition, analyse root causes for the positive outcome of the workgroup and share best practice with relevant stakeholders.
Recommended reading


Beatrice Project Update within Open4Business supply chain event & Beatrice offshore windfarm decommissioning program, SSE, September 2015

Cost-benefit analysis on reactive power compensation from offshore wind farms, National Grid, July 2015


Distributed Substations – A cost efficient multi-platform topology, DONG, March 2015


Transmission cost reductions – concepts for offshore substations, Alstom, June 2015
Author Profile

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