Sheepwash Solar Energy Project

Grid Connection Assessment

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Executive Summary

This report has been prepared by Artios Energy Ltd for Origin Power Services Ltd, to assess the best location in relation to the electrical grid for a solar energy farm comprising of 50MW of solar generation and with 15MW of battery energy storage, located 2km west of Marden, in Kent, England. The project has a connection agreement with UK Power Networks (UKPN) for a connection at 132kV on the nearby 132kV line.

Connection options

Due to the size of the project, a connection at 33kV would only be feasible at a 132/33kV substation, the closest being around 8.5km away, and not the nearby 33kV lines, as it would require a double circuit. A connection at 132kV is feasible using a single circuit. The nearby 132kV line therefore would be suitable for connection. This is also the proposed connection in the connection agreement.

Connection analysis

The nearby 132kV line appears to have adequate capacity to accommodate the connection of the project. The connection agreement indicates that some minor uprating works are required. The Pembury 132/33kV substation offers good export capacity, but it is further away, at 8.5km, and would require a significant amount of works to connect, with increased costs and timescales.

Works and timelines

The works to connect to the nearby 132kV overhead line involve: a 132kV metering breaker on site; 100m of 132kV cable from site to the nearest overhead line tower; cable termination to connect to the 132kV overhead line; uprating of the 132kV line conductor; and protection and intertrip installation.

The closest the project substation is to the 132kV line, the smaller the length of cable and excavation required, which minimises the amount of works and timelines, and reduces the cost. Longer cable routes would also increase the energy losses, at cost to the grid company and consumers.

A connection to a 132/33kV substation would require a much greater cable route length, with increased costs and timescales. A cable route would probably follow public roads, leading to traffic disruptions during installation. Using an overhead line would have a significant visual impact.

The connection date is March 2023. A connection to a location further away will extend the timescales by at least a year. An overhead line would need at least 5 years to complete, due to consents process.

Costs

The costs for a connection at the 132kV line are given in the connection agreement, at around £2.5m. Some of these costs are fixed, and do not depend on the location of the project, but some depend on the project location. The cost for laying 100m of cable is around £196k, but if the project was further away, the cable installation cost would increase by around £1m per km. A 132kV overhead line, for longer distances, would add £500k per km. A cable route length of more than 500m would also require a breaker at the 132kV line, for an additional £1m. These significantly add to the total costs.

Similar cost increases would be expected for a connection at a 132/33kV substation, and potentially more if a 33kV connection was made using a double 33kV line, as it would probably require a 132/33kV transformer at the connection point.

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List of acronyms

Acronym	Full term
BSP	Bulk Supply Point (132/33kV substation)
GSP	Grid Supply Point (400/132kV or 275/132kV substation)
LTDS	Long Term Development Statement
MVA	MegaVoltAmpere
MW	Megawatt
NGESO	National Grid Electricity System Operator
NGET	National Grid Electricity Transmission
UKPN	UK Power Networks

1 Introduction

1.1 General

This report has been prepared by Artios Energy Ltd for Origin Power Services Limited, to provide a grid connection feasibility study for the Sheepwash Solar Energy Project (the Project), and assess the connection point in the grid connection offer. This study aims to review the current grid situation and the available capacity, identify any ongoing or required transmission reinforcement works, and inform Origin Power Services Limited on the optimal connection location options, works and timescales.

The Project is a solar energy farm with 50MW of solar generation and 15MW of battery energy storage, located around 12km south of Maidstone, and 2km west of Marden, in Kent, England. The location of the Project and of the local grid is shown in the figure below.

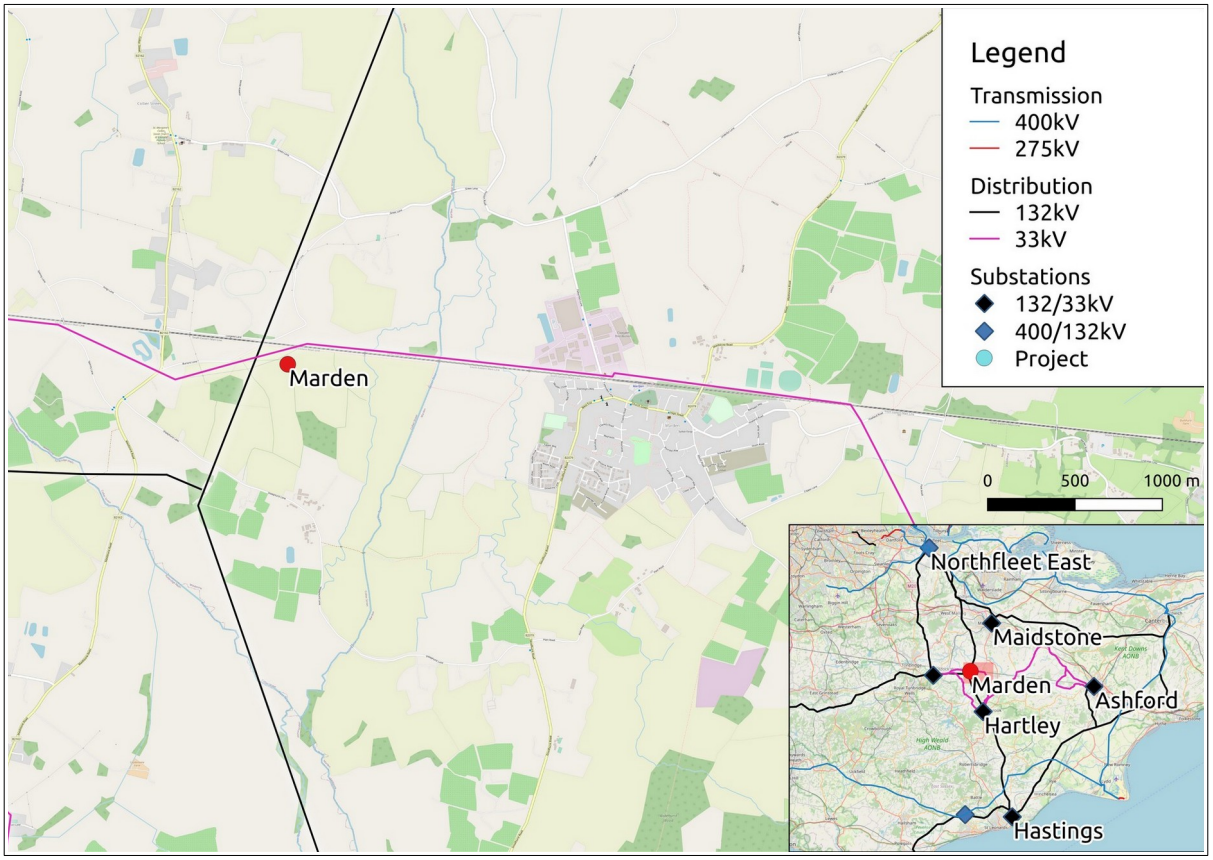

Figure 1-1: Project location and local grid

The local distribution network is owned and operated by UK Power Networks (UKPN), while the local transmission network is owned by National Grid Electricity Transmission (NGET) and operated by National Grid Electricity System Operator (NGESO).

1.2 Project background

The Project has a connection agreement with UK Power Networks (UKPN) for a connection at 132kV on the nearby 132kV line [1], which is seen in the map in Figure 1-1. The works include around 100m of 132kV cable and other electrical equipment to connect the Project to the 132KV overhead line. UKPN will also increase the operational temperature of the 132kV overhead line to allow higher thermal capacity to accommodate the capacity of the Project.

Origin Power Services Limited has asked Artios Energy to assess the Project location against the proposed connection point and the network capacity, and confirm that the Project location and the point of connection are the optimal in terms of grid capacity, connection works and costs, or otherwise.

1.3 Data used and assumptions

To perform the feasibility study, Artios Energy has used publicly available information published by UKPN and NGESO, including the UKPN heat maps [2] and Long Term Development Statement (LTDS) [3], and NGESO Ten Year Statement [4], a, as well as in-house data.

2 Connection analysis

2.1 Connection profile

Given the planned export capacity of the Project, at 50MVA, a connection at 33kV would require a direct connection to a 33kV substation, as the distribution 33kV lines cannot normally carry more than 30-35MVA. Furthermore, a connection at 33kV would require a double overhead line or cable to carry the full output of 50MVA, thus increasing the works and costs, and extending the timescales for consents of overhead lines.

A connection at 11kV would not be possible, given the very low carrying capacity of 11kV lines, and the detrimental effect a 50MVA connection would have on 11kV and LV customers (primarily residential and small scale commercial). Thus only a connection to a 132/33kV Bulk Supply Point (BSP) substation would be suitable, so that power is exported directly to 132kV.

A distribution connection at 132kV therefore appears to be the most feasible option, as it would require a single line or cable. Distribution 132kV lines in UKPN's area can typically carry at least 105MVA, so they would be suitable for the connection of 50MVA export capacity. Similarly, a connection at a 132kV substation busbar would be feasible, utilising a single 132kV line or cable, and offer even higher capacity.

Artios Energy has therefore examined the available capacity of the grid in relation to a connection at nearby 33kV BSP substations, or 132kV lines and busbars.

2.2 Local Grid overview

The local distribution network consist of a 132kV overhead line around 100m to the west of the Project, running north to south from Northfleet East 400/132kV Grid Supply Point (GSP) substation to Pembury BSP, too the west of the Project. There is also a disused section that used to run to Hastings 132/33kV BSP to the south, via Hartley. From Hartley, a 132kV line runs to Hastings BSP and finally to Ninfield GSP, to connect at 400kV

There is also a nearby 33kV line, around 100m north of the project, running east to west, from Marden Primary 33/11kV substation to Pembury BSP. However, as discussed above, overhead 33kV lines are not suitable for a 33kV connection due to low thermal capacity. The closest feasible 33kV assets therefore are at Pembury BSP, 8.5km to the west. The next closest appropriate 33kV point is at Hartley BSP, around 10km to the south.

➔ The closest feasible connection point is the nearby 132kV overhead line. Other feasible connection options are at least 8.5km away.

The local distribution and transmission assets as described above can be seen in Figure 1-1 in the previous section, and the wider network in Figure 2-1 below.

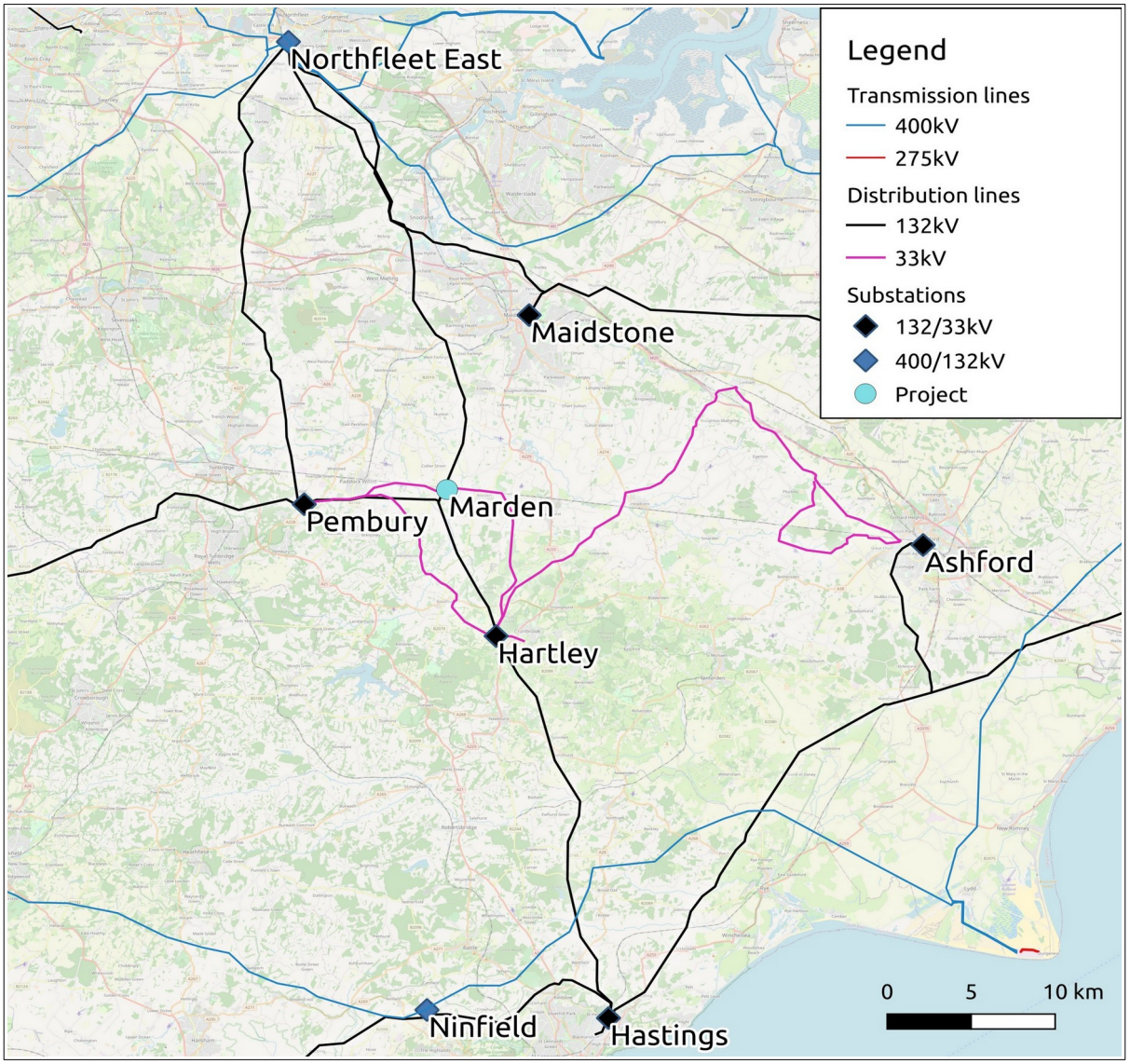

Figure 2-1: Local distribution and transmission grid

2.3 Transmission reinforcements

There appear to be no ongoing or planned transmission reinforcements in the area. The connection offer notes that a Statement of Works will be made to NGESO to determine whether the connection will trigger any reinforcement works, and this will be notified to the Project. However, no transmission reinforcements are expected to be required for the connection.

2.4 Connection options analysis

As discussed, the first most feasible connection option is to the nearby 132kV line 100m to the west, that runs from Northfleet East 400/132kV substation in the north to Ninfield 400/132kV substation in the south.

The 132kV line is rated at 460A in summer, which corresponds to 105MVA. To estimate the current power flow along the line, the total generation flowing out of Pembury has been assessed against the capacity of the three 132kV lines connecting it to Northfleet East GSP, one of which is the 132kV line under consideration.

The generation flowing out of Pembury includes all the generators connected at Pembury, Tunbridge Wells and Dormansland BSPs (for simplicity, it is assumed that the interconnection to other GSPs is normally open, so all the power flows through Pembury). The total generation contracted is 51MW, according to the 2020 LTDS [3], with an additional 81MW in connection offers pending acceptance. This would give a worst case power export of 132MW, to flow along three lines rated at 105MVA each. It is therefore expected that there is adequate thermal capacity on the 132kV line to accommodate the connection.

However, it is noted that the connection agreement refers to the need to uprate the 132kV line to higher operational temperatures to accommodate the connection. This is probably to ensure proper operation and avoid overloads during line outages. In any case, the connection agreement indicates that a connection to the 132kV line is feasible with minimal reinforcement works.

➔ The nearby 132kV line seems to have adequate capacity to accommodate the project, although the connection agreement indicates some minimal uprating works.

The next available option would be a direct connection to the 132kV breaker busbar at Pembury. Since this is more interconnected, it would offer better export capacity, without the need to uprate the line. But given the distance from the project, around 8.5km away, the costs of the additional works would greatly outweigh any benefits.

➔ The Pembury 132kV substation offers better export capacity, but as it is further away, at 8.5km, the additional works required to connect would outweigh the benefits.

The nearby 33kV lines are rated at 20MVA, so they are not adequately rated, as noted before.

3 Connection options, works and timelines

3.1 Proposed connection options

Based on the grid analysis in the previous section, it is concluded that the best potential connection option is a direct connection to the nearby 132kV overhead line. The next best option would be a connection to a BSP substation around 9km away to the west or south.

The following sections analyse the required distribution and transmission works for each option, and the expected timescales.

3.2 Connection works

The works for connecting to the nearby 132kV overhead line are already described in the Project's connection agreement, and are the following:

- 132kV metering breaker on site.
- Install 100m of 132kV cable from site to the nearest overhead line steel tower.
- Install cable termination and wood-pole leads to connect to the 132kV overhead line.
- Uprate the 132kV conductor to operate in higher temperature/capacity.
- Set up an intertrip between the Project and Northfleet East GSP.

These works are illustrated in the simple diagram below.

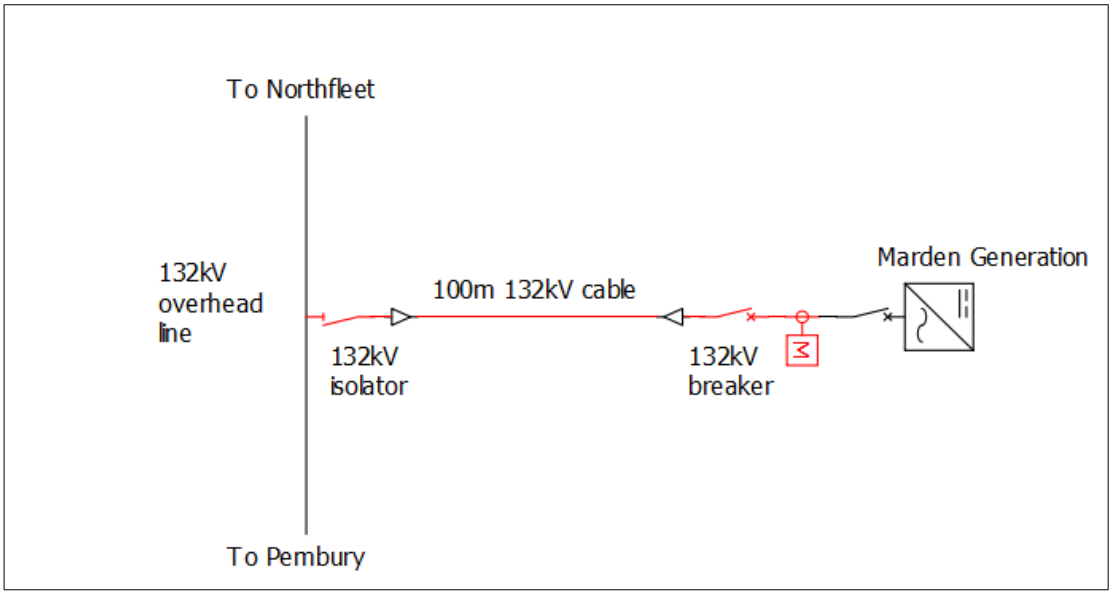

Figure 3-1: Diagram of connection works

The works are the minimum required to connect the Project to the nearby 132kV line, by means of 100m of cable. At the point of connection to the 132kV lines, a cable termination will be needed, to switch to overhead conductors, and two H-pole constructions with an

isolator would be needed to raise the conductors up to the 132kV line tower. An inter tripping scheme is also to be installed between the Project and Northfleet East GSP, to disconnect the Project under abnormal network conditions (faults or overloads).

3.3 Assessment of alternative works

It can be seen from the above that the closer the Project substation is to the 132kV overhead line, the smaller length of 132kV cable and excavation is required. This represents financial savings to the Project and shorter timescales for connection. It also corresponds to savings for UKPN and its consumers by reducing distribution network losses.

Furthermore, according to the connection agreement, if the cable route length is more than 500m, then an additional circuit breaker will be needed at the point of connection to the 132kV overhead line, to protect from the cable charging currents due to its length. This would increase the costs to the Project. Thus the ideal proximity of the project to the overhead lines should be within 500m. The costs are discussed in Section 4.

➔ The closer the Project is to the 132kV line, the lower are the connection cost to the project, and the network losses for UKPN.

An alternative would be to connect to either Pembury or Hartley BSP substations, at 132kV or even at 33kV, but they are both around 9km away from the Project, to the west or south respectively. This would require a long connection route, which would significantly increase costs and it would also lead to higher losses on the distribution network, at cost to the consumers. The costs are discussed in in Section 4.

➔ A connection to the nearest 132/33kV substation would increase the costs to the Project, and the power losses for the grid.

In addition, a cable route would most probably follow public roads, to avoid the need to obtain multiple easements. A longer cable route, either for a 132kV or a double 33kV cable, would lead to disruptions to the public highway for the duration of the cable installation. On the other hand, a new long overhead line would require long timelines to consent, at least 5 years, and it would introduce some visual impact, especially a double wood pole 33kV line.

➔ A connection to the nearest 132/33kV substation would involve cable installation works along public roads, with traffic disruptions, or increased visual impact if overhead lines were used.

3.4 Timelines

The connection date is determined by the equipment delivery timelines, the construction time, and the completion date of any required transmission reinforcements (none in this case). Therefore, the larger the volume of works, e.g. the longer the routes, the longer are the construction timelines, and the later the connection date.

The connection date for the Project as set out in the connection agreement is 31 March 2023 [1]. This is assumed to take into account 6 months for detailed design, one year for the 132kV equipment procurement, and around 6 months for the installation works.

Slightly longer cable lengths are not expected to increase the timeline, but once the cable length extends beyond a couple of kilometres the timelines will extend accordingly. If a connection is made to the nearest 132kV BSP substation, this would extend the timelines to the following year. A connection via a 132kV overhead line would need at least 5 years including consents.

➔ The connection timelines are determined in part by the amount of cable installation, and the closer the Project is to the 132kV lines the shorter the timelines for connection.

➔ A connection further away to a 132/33kV substation would likely extend the timescales by at least a year, up to 5 if a 132kV overhead line was used.

4 Costs

4.1 Current connection costs

The Project will have to pay the costs for all the distribution works required to allow the connection to the grid. These include all the works described in Section 3.2 above, plus additional works on-site to allow connection. The connection agreement provides a breakdown of the works and costs [1], which is summarised below.

Item	Cost
132kV breaker compound on-site	£1,431,800
Cable installation	£195,800
Connection to 132kV line	£94,200
Uprating 132kV line	£448,130
Protection and intertrip	£271,370
Administration charges	£104,300
Total	**£2,545,600**

Table 4-1: Cost breakdown

Of the above items, the 132kV compound on-site, protection and intertrip and administration charges are considered more fixed, regardless of the point of connection, and would most probably apply for every connection arrangement. They cannot be reduced, as the on-site works are the standard for generation connections, and the intertrip costs would apply to any connection under Northfleet East GSP.

The costs for cable installation, connection to the 132kV line and uprating of the line are more flexible costs, and greatly depend on the point of connection and the amount of works required. For a different project location, further away from the 132kV line, the cable costs would increase almost proportionally to the length of the route, so for 1km away from the lines the cable installation costs would increase by at least £1m, or by around 40% overall.

➔ As the distance from the line increases, the cable installation costs increase, by around £1m/km. Close proximity to the line greatly reduces the costs.

In addition, as noted above, and in the connection agreement, a cable length more than 500m would require a circuit breaker to be installed at the point of connection to the line. This would increase the cost by at least £1m. The most cost optimal distance of the Project from the lines is therefore within 500m.

➔ For any cable length more than 500m, a circuit breaker would be required to connect to the line, adding an extra £1m to the costs.

4.2 Alternative connection arrangements

An alternative to cable, in order to reduce costs if the location of the project was further away from the lines, would be to install a 132kV overhead line from the project to the point of connection to the existing one. However, similarly to the case with cable, the further away the project, the higher the connection costs, which would increase by about £500k per km, which is around 20% of the overall cost.

➔ Even if 132kV overhead line was used to reduce costs for longer distances, it would still add £500k per km.

Finally, if a different connection point was selected, i.e. a 132kV busbar at Pembury or Hartley BSPs, apart from the additional costs of the cable or overhead line route discussed above, it would also require a 132kV breaker at the connection point, with costs similar to those described above for the 500m long cable case. A 33kV connection to the relevant 33kV busbars would require a double 33kV cable and would have comparable costs, if not higher, as an additional 132/33kV transformer would most probably be required at the BSPs.

➔ A connection to a BSP 132kV busbar would incur similar cost increases as above in terms of cable length and equipment at the point of connection. These might be even higher for a 33kV connection.

4.3 Conclusion

Based on the above it is concluded that in term of costs the most cost-efficient option is a location in close proximity to the 132kV lines, which reduces the cost of 132kV cable or overhead line from the Project, and also reduces the cost of equipment required to connect to the grid.

➔ The current location of the Project is ideal to minimise the connection costs.

5 Summary

5.1 Introduction

This report has been prepared by Artios Energy Ltd for Origin Power Services Limited, to provide a grid connection feasibility study for the Project, and assess the location of the Project in relation to the electrical grid.

The Project is a planned 50MW solar farm with 15MW of battery energy storage located 2km west of Marden, in Kent, England. It has a connection agreement with UK Power Networks (UKPN) for a connection at 132kV on the nearby 132kV line from Northfleet East 400/132kV substation to Pembury 132/33kV substation.

5.2 Connection options

Due to the size of the Project at 50MVA, a connection at 33kV would require a double circuit, and a direct connection to a 33kV substation, as the 33kV distribution lines cannot usually carry more than 30MVA. This would exclude the nearby 33kV lines.

A connection at 132kV is more feasible, as a single 132kV line can usually carry around 105MVA, so a single circuit would be needed to connect to the existing grid. This also allows a direct connection to existing 132kV overhead lines, as they have more carrying capacity, and could more easily accommodate the 50MVA of export. The nearby 132kV line would be suitable for connection.

Thus, the most feasible and cost effective option would be a connection at the nearby 132kV overhead line. This agrees with the connection arrangements presented in the connection agreement. The next feasible connection options are the Pembury and Hartley 132/33kV substations to the west and south, at a distance of around 9km.

5.3 Connection analysis

The nearby 132kV line is rated at 105MVA, and seems to have adequate capacity to accommodate the connection of the project, with a minimal amount of works to connect due to the close proximity. However, the connection agreement indicates that some uprating works are required to allow operation at higher temperature and higher capacity.

The Pembury 132kV substation offers good export capacity, but as it is further away, at 8.5km, it would require a great amount of works to connect, which would lead to increased costs and timescales.

5.4 Works and timelines

The works to connect to the nearby 132kV overhead line are described in the Project's connection agreement, and involve: a 132kV metering breaker on site; 100m of 132kV cable from site to the nearest overhead line tower; Cable termination to connect to the 132kV overhead line; uprating of the 132kV conductor to operate in higher temperature/capacity; and protection and intertrip installation works.

The works indicate that the closer the Project substation is to the 132kV overhead line, the smaller length of 132kV cable and excavation is required, which minimises the amount of works and timelines, and reduces the cost for the Project (see next section). Longer cable routes would also increase the energy losses, at cost to the consumers.

A connection to one of the 132/33kV substations would require a much greater cable route length, with increased costs and timescales. In addition, a cable route would most probably follow the public highway, to avoid the need for easements, and it would lead to some traffic disruptions for the duration of the cable installation. If a 132kV (or double 33kV) overhead line was used instead of a cable, this would have a detrimental visual impact on the landscape.

The connection date in the connection agreement is 31 March 2023, presumably including 6 months of design, one year for equipment lead times, and six months for the works. A connection further away to a 132/33kV substation would likely extend the timescales by at least a year. A 132kV overhead line would need at least 5 years to complete, due to the long consenting process. The proximity to the 132kV line therefore reduces the timelines.

5.5 Costs

The connection costs for a connection at the 132kV line are given in the connection agreement, at around £2.5m. Some of them are fixed, and do not depend on the location of the Project, like the on-site 132kV breaker (£1,432k), and the protection and intertrip works (£271k), which apply to any connection under Northfleet East GSP.

However, other costs depend on the Project location and the length of the connection works. The cost for laying 100m of cable is around £196k, but if the Project was further away, the cable installation cost would increase by around £1,000k, or 40% of the overall costs, per km of cable route. Furthermore, a cable route length of more than 500m would also require a metering breaker at the point of connection to the 132kV line, for an additional £1,000k.

If a 132kV overhead line was used to reduce costs for longer distances, if the Project was located further away, it would add £500k per km, or 20% of the total.

Similar cost increases would be expected for a connection at one of the 132/33kV substations, and potentially more if a 33kV connection was made using a double 33kV line, as it would probably require an additional 132/33kV transformer at the connection point.

6 References

[1] UK Power Networks, 8600019908_Marden_Generation_Quote_Lite_04.12.20-signed, 04 December 2020

[2] UK Power Networks, DG Mapping Tool, May 2021

[3] UK Power Networks, South Eastern Power Networks plc Long Term Development Statement, 30 November 2020

[4] National Grid Electricity System Operator, Electricity Ten Year Statement 2020, November 2020

Artios Energy Ltd

Artios Energy Ltd is a renewable energy consultancy, with professionals having over 10 years of experience in all aspects of electrical connections of renewable energy projects, from the initial design to final grid connection. You can get in touch with us using contact details below.

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