Back of the envelope calculations on the proposed Swansea Bay Tidal Lagoon

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Abstract

This note presents some simple back of the envelope calculations on the power potential of the Swansea Bay Tidal lagoon as per the proposal submitted for planning permission in early 2014. The purpose of this note is to do a quick and crude reality check on the numbers presented by the developers. It is not intended as an in depth analysis or criticism as I have neither the information or the time to carry this out.

1. Introduction

This note looks at the proposed tidal lagoon for Swansea Bay, South Wales. This note presents a quick check on the data presented by the developers about the project.

2. Data

The following data was available from the website `http://www.tidallagoonswanseabay.com/`.

- Annual power output – 420 GWhours
- Area of lagoon – 11.5 km^2
- Daily generating time – 14 hours
- Average tidal range neap – 4.1 m
- Average tidal range spring – 8.5 m

The following data was derived from the above data:

- Mean power generation – 48 MW

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From the data on tidal range quoted above it is obvious that the tidal amplitudes for the port of Swansea have been used in the analysis (taken from standard tide tables). In my analysis I have used data from the same source but have taken the data from Port Talbot where the tidal amplitude is slightly larger (approximately 2% greater and thus the expected power will be approximately 4% larger using the data assumed herein). My reason for doing this is that the water level at Port Talbot is likely to be more representative of the water level at the entrance of the lagoon than the water level at Swansea. I took my water level data from [1].

Throughout this analysis I make the assumption that the water level outside of the bay remains unaltered by the presence of the lagoon. This is a big assumption and would be unacceptable for a detailed engineering analysis.

3. Method

This analysis I will base on 53 weeks of elevation data starting on 1 January 2018 (the year the project is due to start). The nodal factor of the dominant M_2 tide in 2018 year is approximately ~ 1.02 and so tides will have a slightly higher range than average over the lifetime of the lagoon [1]

When it is impossible to do more detailed calculations, for want of technical detail, I like to calculate upper bounds to problems using the information to hand (e.g. [2]). A simple upper bound may be calculated from the data given by assuming that the water level inside the lagoon is the same as that outside the lagoon at high tide. This is then stored until low tide when all the potential energy from the water inside the lagoon is converted to power. The lagoon is then shut off and when high tide is reached the lagoon is flooded again all the potential energy of the water outside is converted to useful power. Carrying this out for the water level data for Port Talbot and for the area of the proposed lagoon one calculates a theoretical maximum mean power of 123 MW.

Now sadly we cannot use all of this power. The key reason is that it takes a finite time to fill and empty the lagoon. Thus we must start to empty the lagoon before we have actually reached low water outside the lagoon. This makes a big difference to the power output. Prandle [3] found that with the most favourable configuration it was only possible to generate 0.37 times this theoretical maximum[2]. This brings the mean power one could generate over a year down to 45 MW. Prandle found that this limit was typically around double that predicted for real tidal turbine schemes. Part of the reason for the 0.37 factor being overly optimistic is the inherent inefficiency of the turbine[3]. In general, the lower

[1]The nodal factor models the long term variation in the tidal amplitudes as the plane of the moon's rotation around the earth varies on an 18.6 year cycle. It varies between 1.04 and 0.96. As a very rough first approximation the power from a tidal lagoon will vary with amplitude squared – so the power generated in 2023 when the nodal factor is a minimum at 0.96 would be approximately 89% of the power calculated for 2018. By contrast in 2033 the power will be $\sim 4\%$ larger than the 2018 figure.

[2]This can be improved by pumping (see [4]) but there appears to be no plans for this at the Swansea site. This limit can also be exceeded if a river flows into the basin topping up the water in it (e.g. [5]).

[3]The water still has some velocity when it comes out of the turbine – thus all the energy has not been extracted from it.

the difference in water level the lower the efficiency of the turbine and in this case we are generally going to be dealing with rather small water level differences (not only compared to hydro-electric dams but even compared to La Rance or the proposed Severn Barrage). I would suggest 80% is a representative efficiency over the range of different heads which the turbine will have to operate. This brings the estimate of upper bound to the power of the Swansea lagoon down to 36 MW.

4. Discussion on intermittent nature of power output

Tidal power will be intermittent over the course of a day – no power generation takes place when the gates are closed and water is either being held in, or held out, of the lagoon. An important variation in power also takes place over the fortnightly spring/neap tidal cycle[6]. The difference in power might simply be approximated as being proportional to the tidal range squared which would imply that on spring tide the facility would produce 4.2 times the amount of power it does at neap tide. However, in fact this ratio is likely to be rather larger as discussed in the next paragraph.

It is claimed that power generation will take place for 14 hours a day. This is plausible although it suggests that, on for instance ebb generation, generation will start 2.5 hours after high tide when the water level difference between inside and outside the lagoon is just over 3 meters at a typical spring tide and about 1.5 meters at a typical neap tide. A head of 1.5 meters is very small for commercial power generation and because there will be large turbine inefficiencies. Thus, the difference in the power between spring and neap tide is likely to be greater than the 4.2 times suggested in the previous paragraph since it will be more efficient to operate the turbines with the bigger head there is at spring tide.

5. Conclusion

This note has carried out some quick calculations of the power potential of the proposed Swansea Bay tidal lagoon. In general, despite making optimistic assumptions where possible, the resource estimated herein is about 75% of that calculated by the developers. Great caution should be applied to the figures in this note as all the calculations are very approximate and I have not had detailed design information about the facility on which to base my analysis.

References

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