SEATWIRL®

Questions and Answers (Tech Tuesday, November 10, 2020)

1) **Q: What is the biggest challenge of scaling up from S1 to S2?**

   A: When scaling up the wind turbine you also increase the forces on the structure. The dynamics of a significantly larger structure is more challenging than for a smaller. It does not scale linearly with size. Remember that the S2 is approximately 30 times bigger than the S1. We are mitigating this through performing thorough in-house analyses. The S2 is also designed to become a commercial product with all challenges that follow being compliant with rules and regulations to a higher extent than for a prototype as the S1.

2) **Q: How high waves can S2 handle? We have had storms with above 10 meters high waves on the Swedish west coast and above 20 meters high waves at the Norwegian west coast?**

   A: The advantage of a spar solution is that it is relatively insensitive to waves, horizontal motions are limited as the wave "passes" by the slender spar. The wind turbine is being designed site specific, the first unit will be withstanding the actual wave height at site in Norway, but newer WTs will be able to withstand higher waves.

3) **Q: What are the dimensions/diameter of a 10MW rotor?**

   A: A 10MW wind turbine would have a diameter of 135m and a height of 110m (approximately).

4) **Q: How large is the clearance of the sea surface? Can it meet requirements of 25-30 meters clearance to the sea, also with the max angle?**

   A: The air gap between blades and water surface is appr. 15 m at calm sea with 0 deg heel.

5) **Q: Has the capacity factor been proved with S1? Or is the capacity factor number taken from HAWT's?**

   A: The capacity factors we use are calculated for each specific design and site, based on our VAWT technology.

6) **Q: Why can VAWT reach 30MW when HAWT cannot? What is the physical rational behind that?**

   A: Reference is given to the following documents: - F. Ottermo, H. Bernhoff. An upper size of vertical axis wind turbines DOI: 10.1002/we.1655 (2013) - S. Eriksson, H. Bernhoff, M. Leijon. Evaluation of different turbine concepts for wind power DOI:10.1016/j.rser.2006.05.017 (2006)

7) **Q: What are the losses of spar buoy rotating against the water?**

A: This depends on spar buoy diameter, surface area and rpm. Weighing everything together we expect our LCOE (Levelized Cost of Energy) to be very competitive.

8) **Q: What are the most challenging structural problems?**

A: Since we have a rotating structure and we want it to last over a long lifetime, fatigue becomes an issue to address. It is important to work with materials with high stiffness and low weight. At the same time, we ensure we are well below the fatigue limit by performing extensive simulations and analysis. One advantage is that during the rotation of the rotor, a VAWT does not have additional fatigue load due to gravity, the gravity load is constant during operation.

9) **Q: Is the fatigue loading challenging? It seems that VAWTs are exposed to extra challenging fatigue loading due to the torque and thrust changing a lot during the rotation.**

A: See answer to question no 8.

10) **Q: What is the nominal healing angle at rated wind speed?**

A: Maximum healing angle at operation is about 5 degrees and at storm condition 10 degrees.

11) **Q: What protects the turbine during storm conditions? And how do you handle overwind shutdown?**

A: If the experienced or forecasted environmental conditions exceeds the operational limits the control system of the wind turbine will perform a controlled shutdown of the turbine utilizing the mechanical brake if needed. Once the turbine has come to a complete stop a mechanical rotor lock is engaged which will prevent the turbine from rotating.

12) **Q: When scaling towards 30MW do you plan on just increasing the diameter? Seems like it could be beneficial.**

A: See answer to questions no 3 and 6.

13) **Q: What's the reason for three blades on a VAWT?**

A: Three blades is a compromise between reducing fatigue loading and keeping the overall weight of the rotor low. Two blades increase torque variation, four blades mean additional weight. HAWT's face the same challenge.

14) **Q: What happens if mooring cables break if you have a cluster of turbines?**

A: Mooring design is performed according to existing DNV GL rules and regulations. To have "backup" lines for the mooring is basically a risk/economy evaluation. This evaluation will depend on each park configuration and environmental conditions.

15) **Q: Will sea movement be used as source of power?**

A: No, we are only utilizing the wind.

16) **Q: What is the draft (depth) of the Spar for a 10, 20 and 30MW unit?**

A: These numbers are not published yet.

17) **Q: How do you intend to install it, given that deep harbors are few and far between?**

A: We haven't disclosed our installation method yet, but we are not planning on using deep water harbors for installation.

18) **Q: When will you have the 1MW prototype in the water? And when will we see the 10MW unit spin?**

A: The S2 1MW pilot will be installed in 2022. No date set for a 10 MW or other size unit yet.

19) **Q: Do you see physical damage and business interruption scenarios being reduced or increased versus other floating turbine designs?**

A: Both being reduced due to simpler design and fever moving parts.

20) **Q: What is the capacity factor of S1?**

A: The S1 turbine has a rated power of 30 kW. Operating all the time, that is equivalent to 10-13 normal households (5000 kWh/year/household).

21) **Q: What is the major difference in ecological impact between S1, S2 and your competitor's solution?**

A: Compared to a bottom-fixed structure we have less impact on the seabed. S1 and S2 use traditional anchors, 3 off for each turbine. There are indications that VAWT are more friendly for seabirds, however this remains to be verified.

22) **Q: What is larger? Does it mean larger in all dimensions or could it mean wider but not necessarily higher or could it mean a greater number of blades with a narrower spacing or different in any other fashion?**

A: Length, area and volume scale differently, so depending on what dimensions are scaled, scaling is made differently.

23) **Q: When do you see the commercialization of the S2? And the upscaling?**

A: We plan to commercialize the S2 once the S2 pilot unit is installed and evaluated. We are already looking at scaling our design.

24) **Q: A challenge with vertical wind turbines is that the force on the blades constantly changes during the rotation and that it can create fatigue problems in the construction. How have you solved that problem and how do you know that it works overtime when e.g. S2 is in production?**

A: See answer to question no. 8

25) **Q: What are the expected/planned sizes of the units in terms of MW?**

A: We are looking into both smaller and larger sizes. We are currently looking into a smaller S0 unit in the range of 100-300kW and a larger SX unit in the range of 3-8 MW.

26) **Q: What are typical dimensions for a given MW unit?**

A: See answer to question no 16

27) **Q: Do you collaborate with any wave power companies that can supplement your products at sea today or can your product also generate electricity via wave power? The same applies to solar cell.**

A: We see other renewable energy sources, such as solar and wave power as possible partners in future energy mix applications. Our design uses wind as the sole source of energy.

28) **Q: Where do you see your first market being?**

A: We have several interesting markets. The first market will be a combination of where we get advantageous project conditions, site permissions, suitable location, project financing and incentive plans for renewable energy.

29) **Q: What are the plans of recycling hardware?**

A: Steel parts recycled as steel. Carbon fiber components, as we are using, are commercially recyclable today, in contrast to glass fiber blades which today are being used as landfill at end-of-life.

30) **Q: Many of your competitors are in one way or another backed by deep pockets. Competitors are also already on their way to scaling up to handle very large turbines. How will you be able to compete given that your larger designs are estimated to reach market at the earliest 2025?**

A: We are designing something unique, that no-one has done before. Our competitors are at different readiness levels and we are monitoring their ventures of course. However, we are focusing on our task, which is to design the most competitive solution for the future of floating offshore wind. We will be able to offer a game-changing solution for clean energy at a reasonable cost (LCOE, Levelized Cost of Energy).

31) **Q: What is the present height over sea of the prototype, and what will be the height of S1 and coming generations?**

A: The overall height of the S2 is appr. 55 meters from the still water line. Regarding the height of other SeaTwirl designs please turn to answer of questions no. 3, 16 and no. 22.

32) **Q: How big will the "risk zone" be around the turbine cluster?**

A: The risk zone may vary depending on the requirements and legislation governing each specific installation site.

33) **Q: What is the estimated lifetime for a S2 turbine? How long time do you expect it to be working offshore? How often do you need to perform service and which parts are expected to be replaced most often (and how often is that)?**

A: The intended testing period of the S2 pilot is 5 years, based on the permit we are given at the site. A commercial unit should have a life of 25-30 years. We are not intending on replacing any significant components.

34) **Q: What is the durability of the bearing? …and how is it possible to change bearing?**

A: See answer to question no 33.

35) **Q: How does the risk analysis look like regarding ships crashing into a turbine cluster?**

A: A HAZID will be performed for each site prior to installation.

36) **Q: Why isn't S1 in duty at the entrance of Lysekil? It should be very good marketing for SeaTwirl to see it "in action".**

A: The S1 was built, and is being used, for testing purposes only. Hence it is only operated when personnel are present for operation and monitoring of performance.

37) **Q: In your simulations, how do you take sea state into account?**

A: Sea state is included in many of the simulations we perform of the S2.

38) **Q: How you do handle marine growth on the spar buoy?**

A: Marine growth is something that we are taking into consideration. However, we are not ready to disclose how yet.

39) **Q: I like the S2 installation site, even if the depth might be > 80m. Will Greenmountain DC take use of the power produced?**

A: We have a power purchase agreement with Haugaland Kraft who will buy the electricity we produce and distribute in their grid.

40) **Q: Having the gearbox close to the water surface may not be positive in all aspects since it also ends up in a more corrosive environment. Even if you think a structure is safe regarding corrosion that is not always the case. What are your thoughts on this?**

A: All sensitive components are located within the generator house and hence protected from the surrounding environmental conditions. Humidity and temperature will also be regulated inside the generator house which further reduces the risk of corrosion.

41) **Q: It was presented that the HAWT can be upscaled to 30 MW. What kind of future technology developments are assumed in this estimation?**

A: See answer to question no 6.

42) **Q: How far off the coast is it profitable to install the turbines (of course depending on the numbers and size of turbines)?**

A: As you mention yourself, this is completely dependent on the size of the turbines and of the offshore wind farm. As costs come down over time, we will be able to reach sites further away from the coastline. Today, anything less than 60 km offshore is considered to be "near-shore" following IEA (International Energy Agency).