The Influence of a Transmission System on the Ocean Grazer Wave Energy Converter Performance

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1 Abstract

The Ocean Grazer exploits the energy potential in our oceans by creating a wave energy converter. In order to have an optimal power extraction, a transmission system with an adaptable ratio is needed to account for the variety of sea states. This research looks at the influence of a transmission system with an adaptable ratio, and the influence of a location, on the performance of the Ocean Grazer wave energy converter. The study shows that a transmission system with a ratio that is adaptable for every incoming wave creates the highest efficiency. The location where the wave energy converter is placed significantly influences its performance because a location determines the incoming waves throughout the year. The location also determines the requirements of maintenance and transportation of energy, which indirectly influences the performance of the wave energy converter.

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3 List of Abbreviations

- Ocean Grazer (OG)
- Wave Energy Converter (WEC)
- Power Take-Off (PTO)
- Capture Width Ratio (CWR)

4 Introduction

There is an increasing demand for renewable energy due to the limited amount of fossil fuels available on our planet. Detailed analysis showed that the potential of different ocean energy sources is greater than our global annual energy demand (Melikoglu, 2018).

The Ocean Grazer (OG) project attempts to make use of this potential energy in the ocean. The OG is a renewable energy device that generates energy from waves while also storing the generated energy as potential energy in an ocean battery. The storage of renewable energy is important due to the unreliable and intermittent nature of wind, wave and solar energy (Coppez, Chowdhury & Chowdhury, 2010).

The OG project has been under development at the University of Groningen since 2014. Ocean Grazer B.V. was created in 2019 to commercialize the product ("Ocean Grazer - Offshore hybrid renewable energy harvest and storage device", 2021).
At the moment, the OG project is working on its third design. Figure 1 shows the impression of the OG 3.0 design, which combines the OG project with an offshore wind turbine to store energy from both systems in one design. This spreads out the costs of the system and improves its feasibility.

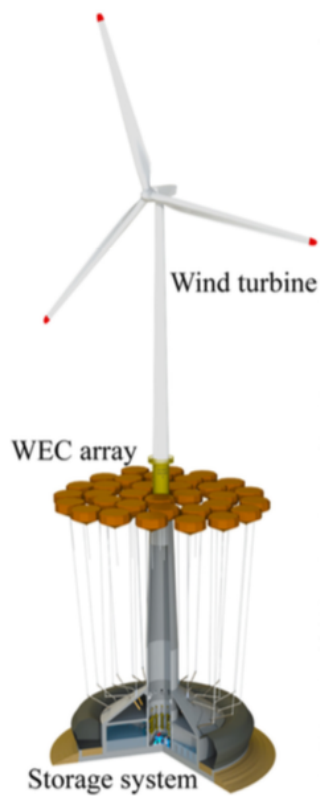


Figure 1: Impression of Ocean Grazer 3.0 design by Ocean Grazer B.V. (Wei et al., 2019).

Figure 2 shows the function structure of the OG 3.0 design. The design has three main purposes: capturing energy, storing energy and generating electricity. This research focuses on the wave energy converter (WEC) array, shown in the yellow box.

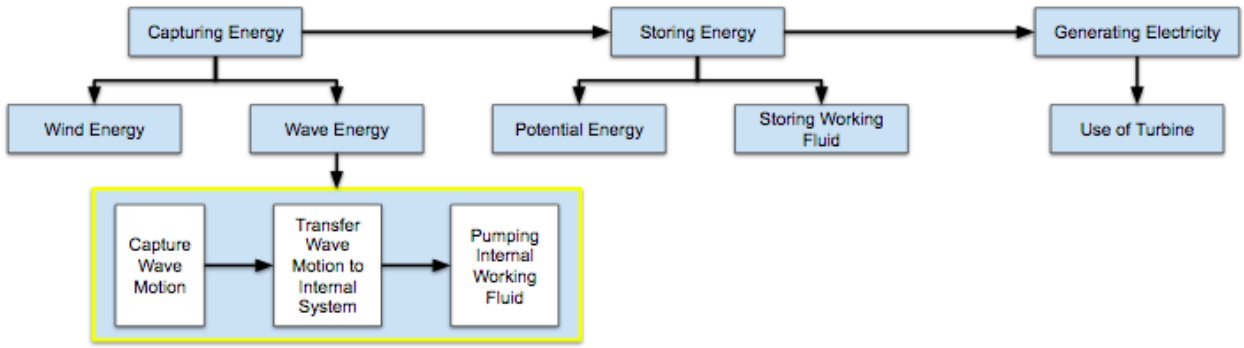


Figure 2: Function structure of the Ocean Grazer (Bechlenberg, 2018).

Figure 3 shows a schematic of the power take-off (PTO) system in the WEC. The WEC array consists of several buoys in the ocean that move up and down with the waves. The vertical movement of the buoys is used to pump working fluid, in a closed system, from a reservoir at atmospheric pressure to an outside flexible bladder. Working fluid pumped into this bladder is stored at the pressure of the surrounding ocean water, which creates a pressure difference between the bladder and the reservoir. Hydro-turbines are used to convert the pressure difference into electricity when it is most needed.

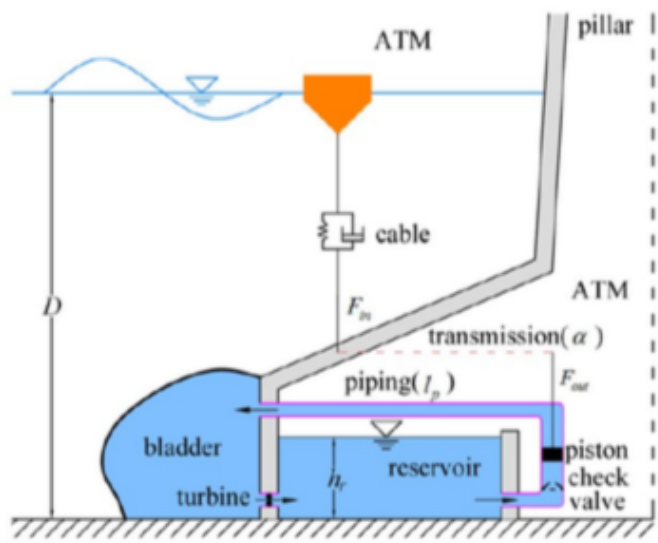


Figure 3: Schematic of the power take-off system. (Wei et al., 2019)

The buoys are linked to a piston via a cable with a transmission system in between. The transmission system makes sure to convert the vertical movement of the buoys into a force that pumps the working fluid from the reservoir into the flexible bladder. The transmission system has an adaptable transmission ratio that ensures an optimal power extraction in different locations and sea states. This is needed because waves vary in height, period and, consequently, in how much power they contain. A transmission ratio is the ratio between the force coming into the system, and the force going out.

5 Problem analysis

Assigning a transmission ratio to regular sinusoidal waves is relatively straight forward (Wei et al., 2019). Unfortunately, realistic sea states have irregular waves. These are waves that vary in height and period (Neill and Hashemi, 2018). Determining the optimal transmission ratio gets more difficult in these irregular waves because waves of varying heights and periods contain different amounts of power. The physical representation of the transmission system is not yet known, but a range of transmission ratios and corresponding power extraction of the WEC is found in a simulation (of a non-linear frequency domain model) done by Wei et al., 2019.

The inputs of this model are the floater design, significant wave height (average wave height of the one-third highest waves), peak period, transmission ratio range, and the eighteen different buoys in the array. The model creates a set of irregular waves of 5000 seconds long, which is the simulation time, for each combination of significant wave heights and peak periods. Each set of waves is split up into time windows of two times the peak period. For all time windows, the power extraction is calculated for the range of transmission ratios and the different buoys in the WEC array. The output of the model is a dataset containing the power extraction by the WEC for the combination of all sea states, transmission ratios, buoys and time windows.

Alva Bechlenberg, a PhD student who is a part of the OG research group, encountered a problem. The model calculates the power extracted for a given transmission ratio range per sea state, but the dataset is not informative about what the transmission ratio does to the performance of the WEC array. Rather, this has to be found by filtering the dataset. Alva Bechlenberg has written a different code to find results, which is time consuming and, therefore, costly. Besides that, it is also unclear what the influence of the location of the WEC array is on the performance. Data on sea states in four locations in the Atlantic Ocean is available, but an overview of this data and what it means for the WEC array is lacking.

5.1 Problem statement

After analysing the problem, the concluding problem statement is:
The influence of a transmission system with an adaptable ratio on the performance of the OG WEC array in different locations and sea states is unclear. The data to find this is available, but an overview is lacking.

5.2 Other stakeholders

Drs. Wout Prins and Prof. dr. Antonis Vakis are both project managers of the Ocean Grazer research project. They are continuously working on improving the design of the WEC and are interested in the results of this project.
Martijn van Rooij, co-founder and chief technological officer of the Ocean Grazer B.V., is a potential stakeholder of this research. He is mainly focused on developing the ocean battery at the moment. Since this research is focused on the WEC, he could benefit from this research in the future when the WEC is developed and implemented in practice.

6 Research scope

In order to finish the project in time, clear boundaries need to be established about what is and is not included. The dataset from the simulation will be used to study the effect of a transmission system on the performance of the OG WEC array. A brief literature research will be done to define performance measures. Using the performance measures to compare the OG WEC to other WECs on the market is not part of the research scope for time purposes.

Data on sea state occurrence for different locations is also available and used in this research to study the effect of a location on the performance of the OG WEC. In this research, only one location is used to show the results. Mainly due to the limited availability of data and for time purposes.

Information found in literature that proves to be relevant to include in the research will be applied accordingly.

6.1 Research objective

Now that the scope of the research is defined, the research objective is:
Find the influence of a transmission system with an adaptable ratio, and the influence of a location, on the performance of the OG WEC array by designing a tool that will transform the available data into an overview of the performance of the OG WEC array under varying transmission systems and sea states.

6.2 Research questions

Main question
What is the influence of having a transmission system with an adaptable ratio on the performance of the OG WEC array in different sea states and locations?

Sub questions

1. How is the performance of the OG WEC array measured?
2. What data is needed to show the performance of the OG WEC array?
3. How is the influence of the transmission system measured?
4. What data is needed to show the influence of the transmission system on the WEC array performance?
5. How are different locations relevant to the performance of the OG WEC array?
6. What data is needed to show the influence of the locations on the WEC array performance?

7 Literature research

A paper by (Babarit et al., 2012) uses the mean annual power absorption as one of the performance measures to compare a selection of wave energy converters. The mean annual power absorption is obtained by multiplying the absorbed wave power matrix (in kW) with a scatter diagram for a location. A scatter diagram shows the annual probability of occurrence of different sea states. The outcome is summed up, which gives the mean annual power

absorption (in kW). The mean annual power absorption will be a performance measure used to judge the influence of the different transmission systems on the performance of the OG WEC array. (In estimating the feasibility of the WEC or comparing the OG WEC array to other WECs on the market, it is not enough to just use the annual absorbed power. That is why the paper also uses the annual absorbed energy per characteristic mass, per characteristic surface area and per unit of characteristic PTO force. Including these measures are outside of the scope of this research, but they can be considered in future studies.)

Scatter diagrams are useful because they show what sea states occur with a certain frequency throughout the year at a given location. Drs. Wout Prins, a project manager for the OG project, has created a dataset with the significant wave height and peak period for four locations in the Atlantic Ocean. The measurements were taken every hour for nearly a full year in 2011. This dataset is used in this research to show the performance of the OG WEC array as if it were placed in these locations.
Choosing a location to place a WEC is dependent on several factors. First of all, a location determines the range of sea states that occur throughout the year. The WEC can be designed to be most efficient in sea states that occur most frequently and/or sea states with the highest energy density. Knowing the most extreme sea states is also important, because high and steep waves are likely to damage WECs. While calm sea states are ideal to perform maintenance. Another factor is the distance to shore. After generating energy, it has to be transported back to shore, regardless of the type of energy.
The depth of the seabed also influences the waves. There is a rough distinction between a deep and shallow sea. A deep sea is deeper than one half of the wavelength and the seabed has a negligible effect on the waves. A shallow sea on the other hand reduces the wave power due to absorption, breaking or reflection by the seabed (Neill and Hashemi, 2018).
The geographic location of the ocean plays a role as well, as can be seen in figure 4. For instance, waves in the Atlantic Ocean have more space to gain power than waves in the North Sea (Pecher and Kofoed, 2017).

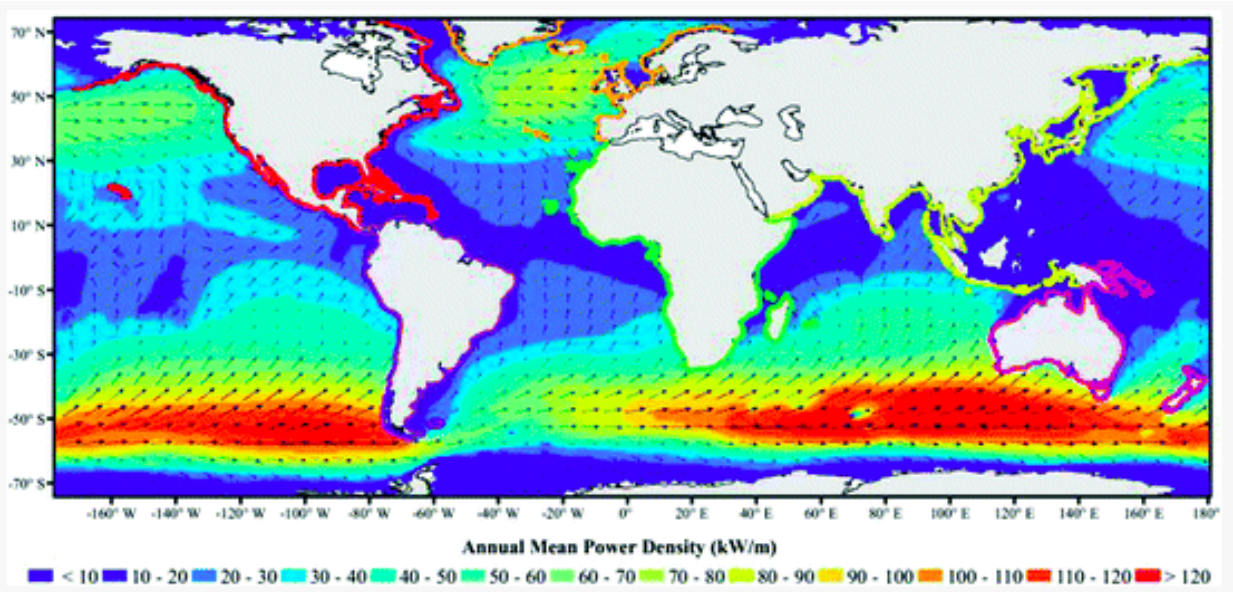


Figure 4: The global annual wave power availability (Pecher and Kofoed, 2017).

Another paper by (Babarit, 2015) lists the performance of different WECs by reviewing performance results obtained from literature. Performance, in this paper, is quantified using the capture width ratio (CWR). The CWR is obtained by first dividing the power produced by the WEC (in kW) by the available wave power (in $\frac{kW}{m}$). After that, this fraction is divided by the characteristic dimension of the WEC, often the width of the device. According to Wei et al., 2019, the OG WEC array is 60 meters wide. This is another performance measure used to judge the influence of the different transmission systems on the performance of the OG WEC. Furthermore, the CWR is useful because it shows both the overall efficiency and the efficiency per sea state for the WEC array.

As mentioned above, one of the parameters to calculate the CWR is the available wave power. The following formula, to calculate the available power in a sea state per meter width, was found in Falnes, 2007.

$$J = \frac{\rho g^2 T_p H_s^2}{64\pi}$$

Where:

- J is the available wave power in Watts per meter.
- ρ is the density of the sea water, which is 1030 kilograms per cubic meter.
- g is the acceleration of gravity, being 9.81 meters per second squared.
- T_p is the peak period of the wave in the sea state in seconds.
- H_s is the significant wave height in meters.

An assumption is made for the depth of the sea. Namely, that the seabed is at least one half of the wavelength deep. The seabed has a negligible effect on the wave in this scenario.

8 Method

A matlab tool is created to reach the desired objective as stated earlier. Figure 5 shows an overview of what the tool does.

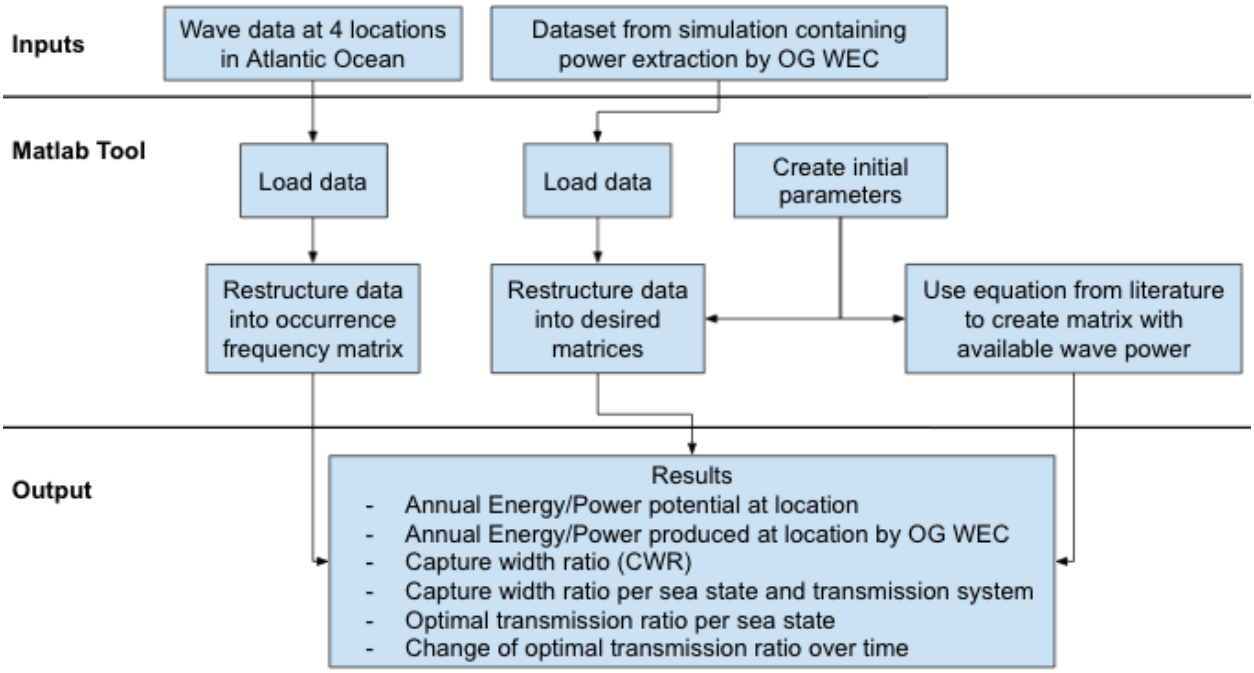


Figure 5: An overview of the method of the research project.

8.1 Wave data

One input of the model is the dataset with wave occurrence data for the four locations in the Atlantic Ocean as shown in figure 6. The wave occurrence data is loaded and transformed into a matrix that shows the fraction of how often a certain sea state occurs in that location. A sea state is a combination of a significant wave height (in meters) and a peak period (in seconds). The result is displayed as a scatter diagram. For time purposes, all results are shown only for the location of buoy 64045. That is the most northern buoy in figure 6, with coordinates 59°10' N 11°40' W.

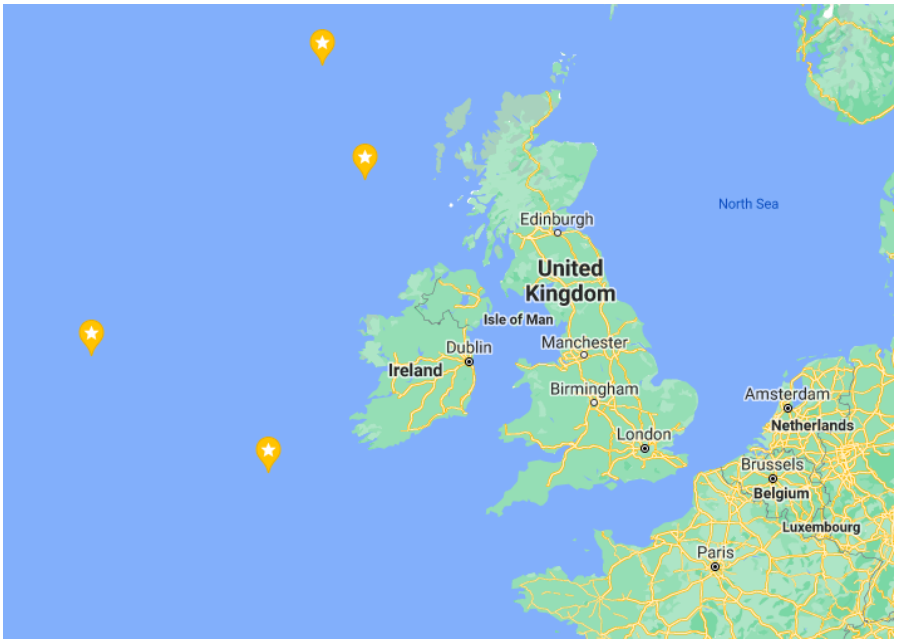


Figure 6: The data on wave occurrence is measured at the four locations marked with a star.

8.2 Data from simulation

Another input is the dataset from the simulation of the non-linear frequency domain model. The model, talked about earlier and created by Wei et al., 2019, provides a five dimensional dataset of the power extracted for a range of significant wave heights, peak periods, transmission ratios, buoys and time windows. The dataset from the simulation is filtered to show the power extraction of the OG WEC array for three different transmission system scenarios.
The first scenario has a transmission ratio of 1, which essentially means that there is no transmission system. The incoming force is equal to the outgoing force. The second scenario is a transmission system with a uniform transmission ratio for the whole simulation, but the ratio can be changed. In practice, this means that the optimal transmission ratio is chosen for the average of the waves that is forecasted to come in for at least the next 5000 seconds (length of the simulation). The third scenario is a transmission system with a varying transmission ratio during the simulation. In practice, the ratio can be changed for every incoming wave.

8.3 Equation from literature

Lastly, the equation to calculate the available wave power is taken from literature. The equation for the available wave power is used to create a power matrix with the available wave power in each sea state. Several initial parameters, values or vectors, are used for calculations in the tool. It contains the gravitational constant and the density of water to calculate the available wave power. It also contains vectors for the range of significant wave heights, peak periods and transmission ratios.

8.4 Outputs

With the scatter diagrams and the power matrices created from the data, the following is done.

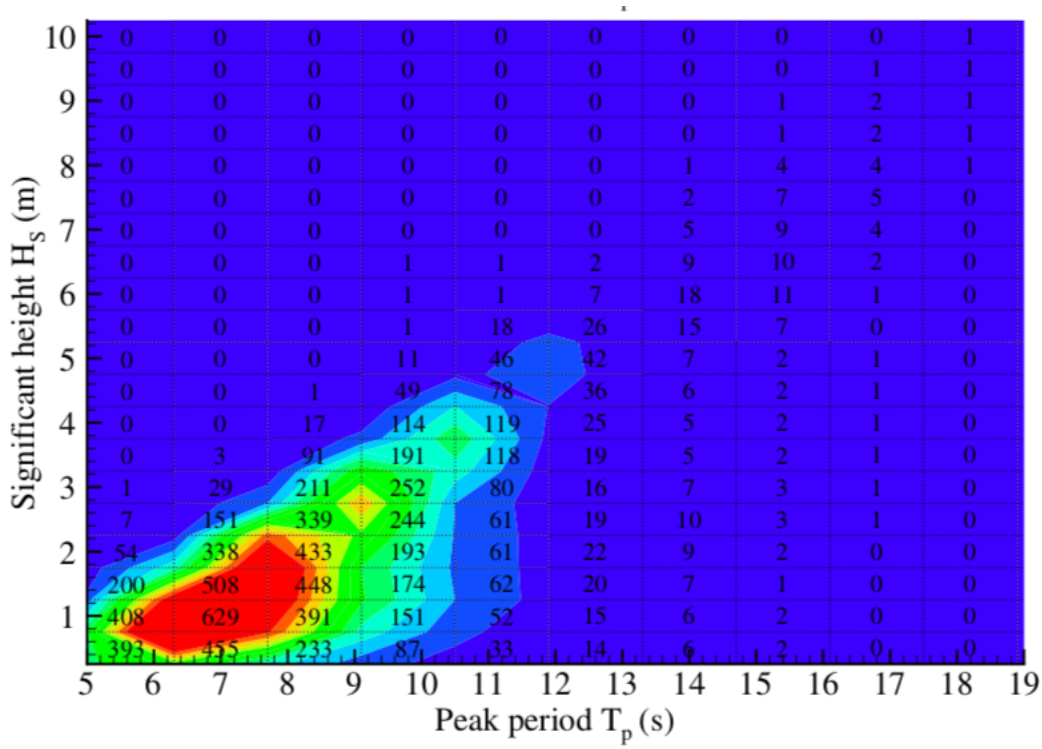
- The power matrix for the available power is multiplied with the scatter diagram, which gives the annual power available per sea state at buoy 64045. The annual power availability matrix can also be summed up to give the mean annual power availability in that location. This annual power availability matrix is also multiplied by the number of hours in a year [$(365.25\frac{days}{year})(24\ \frac{hours}{day}) = 8766\ \frac{hours}{year}$] to give the annual energy available per sea state at buoy 64045. Again, summing up the matrix gives the total annual energy available in that location.
- The same is done with the OG WEC power matrices for the different transmission system scenarios. The power matrix for each scenario is multiplied with the scatter diagram at buoy 64045 to give the annual power extracted by the OG WEC array at buoy 64045. Summing up the matrix gives the mean annual power extracted in that same location. Multiplying the matrix for the annual power extracted with the number of hours in a year, gives the annual energy production by the OG WEC array per sea state at buoy 64045. The summed up matrix gives the total annual energy production by the OG WEC array.
- As mentioned in the literature research, the capture width ratio is used to measure the efficiency of a WEC. Therefore, the total power production for the three different transmission system scenarios is each divided by the product of the available wave power and the characteristic dimension of the OG WEC array (60 meters). These values, fraction or percentage, essentially shows how much of the passing wave is effectively absorbed by the WEC array in each scenario.
- The CWR is also calculated for every single sea state by dividing the power matrix for each scenario by product of the available wave power and the device width. The resulting matrix, with the CWR for each sea state, gives insight into the efficiency of the OG WEC in different sea states.
- Besides the power matrices, the tool creates a matrix showing the optimal transmission ratio per sea state. A plot is also made of the optimal transmission ratio against the time, to give an illustration for the rate at which the ratio needs to be changed in the transmission system with a real time varying ratio.

9 Validation

The matlab tool will be validated by taking existing data from literature where the desired output is already known. The known output will be compared with the output of the matlab tool, which will either give the same or a different result. The tool is valid when both outputs are the same, but if they differ the tool must be revised.

The tool is validated with the results from the paper (Babarit et al., 2012). One of the scatter diagrams is replicated as well as one of the power matrices from a WEC mentioned in the paper. The scatter diagram is multiplied with the power matrix and summed up, which is identical to the method used in the paper. The result gives the annual mean absorbed power. The annual mean absorbed power by the floating heave-buoy array (F-HBA) at location EMEC is **362 kW.**

Figure 7 shows the replicated scatter diagram of the wave data statistics at location EMEC. A close look at the scatter diagram on the left shows that not each step for the peak period has its own column with values. This made replicating the scatter diagram difficult because the values for each peak period step had to be estimated.



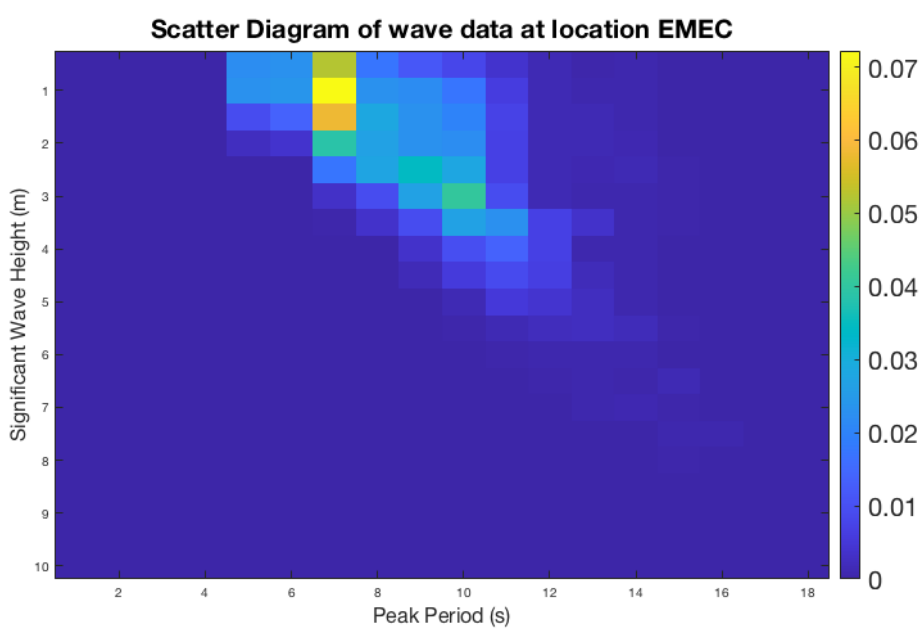


Figure 7: (top) Scatter diagram at location EMEC found in (Babarit et al., 2012). (bottom) Replicated scatter diagram in the matlab tool.

Figure 8 shows the replicated power matrix of the absorbed power by the F-HBA.

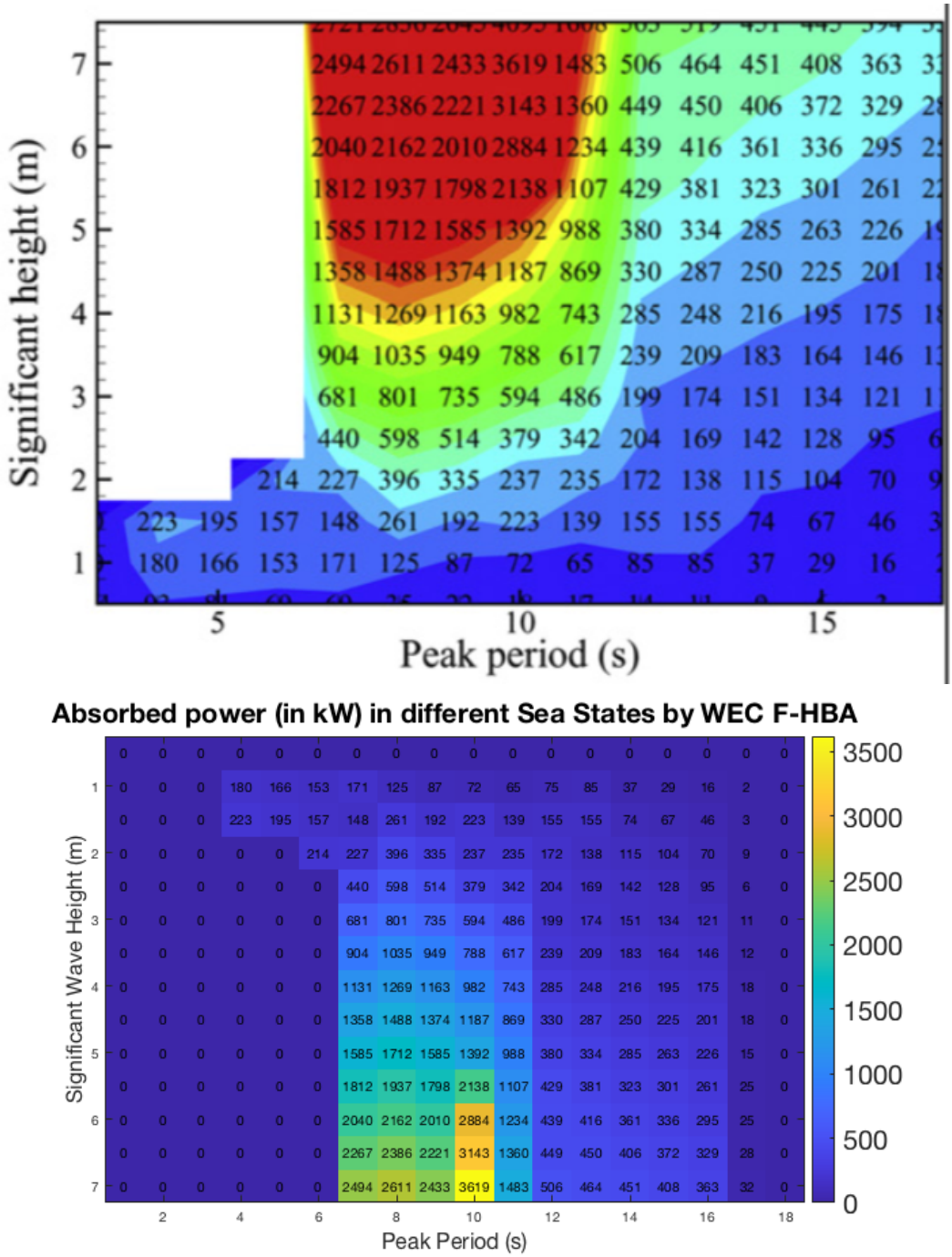


Figure 8: (top) Power matrix of the absorbed power by the F-HBA retrieved from (Babarit et al., 2012). (bottom) Replication of power matrix in matlab tool.

Multiplying figure 7 & 8 and summing up the result gives a mean annual absorbed power of **320 kW**. The replicated value is **11.6%** lower than the value in the literature. The replicated result, however, lies within the same order of magnitude and the difference can likely be attributed to

the replication of the scatter diagram, which proved to be difficult as mentioned before. The matlab tool can, therefore, be considered valid.

10 Results

After creating and running the matlab tool, the following results were obtained. Figure 9 displays the scatter diagram at buoy 64045. The brighter the colour, the more frequent that sea state occurs. At buoy 64045, a sea state of 3 meters high and a period of 9 seconds occurs the most throughout the year. The dark blue areas occur rarely or not at all.

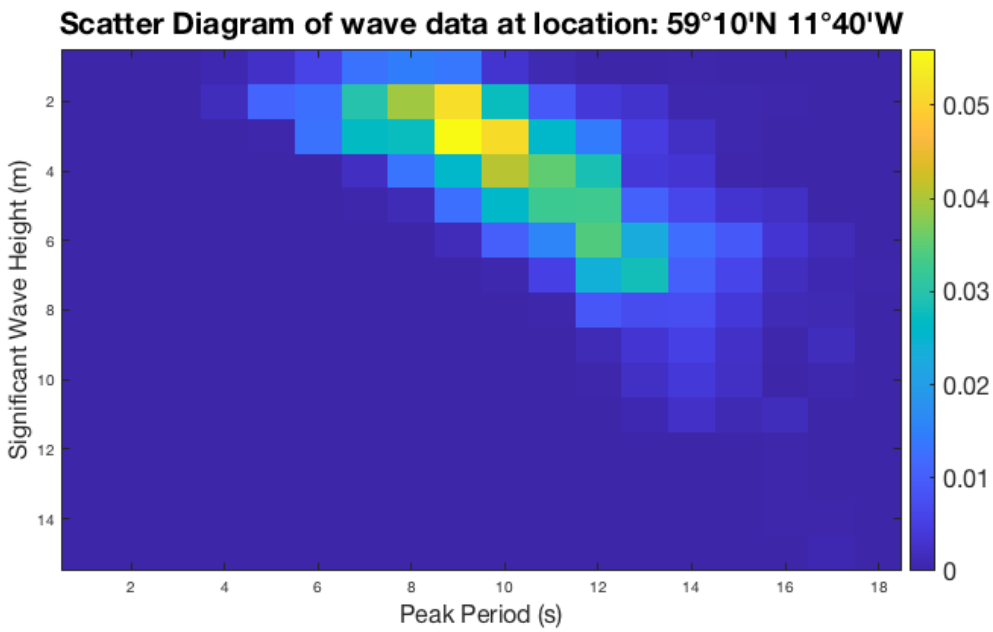


Figure 9: Scatter diagram at location 59°10' N 11°40' W that shows the occurrence frequency of different sea states throughout a year.

Figure 10 shows the available wave power (in kW/m) for different sea states. The yellow area in the bottom right of the figure contains the most power, while the dark blue, top left area contains the least power. As described in the formula calculating the available power, the significant wave height has a quadratic relationship with the power. Meaning that when a wave is double the height, it has four times the power available. The period of the wave is linearly related to the wave power. A wave twice as long contains twice the available power.

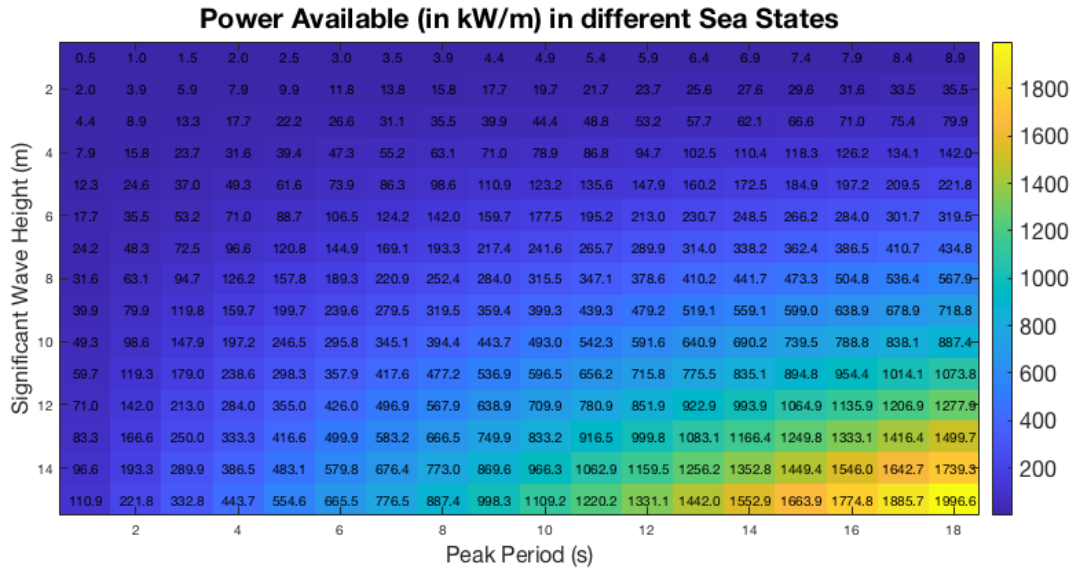


Figure 10: Power matrix showing the available power in different sea states in kW/m.

Multiplying the previous two figures as mentioned in the method shows the annual power potential at buoy 64045 for each sea state. The matrix is shown in figure 20, and can be found in the appendix. Summing up the matrix gives a mean annual power potential of **127.7 kW/m**. When the previous matrix is multiplied by the number of hours in a year, figure 11 is obtained. Notice here that a sea state of 7 meters high and with a period of 13 seconds has the highest annual energy potential, while that sea state does not occur most frequently. The sea state with the highest annual power potential also has the highest annual energy potential. Summing up figure 11 gives a total annual energy potential of **1120 MWh/m** at buoy 64045.

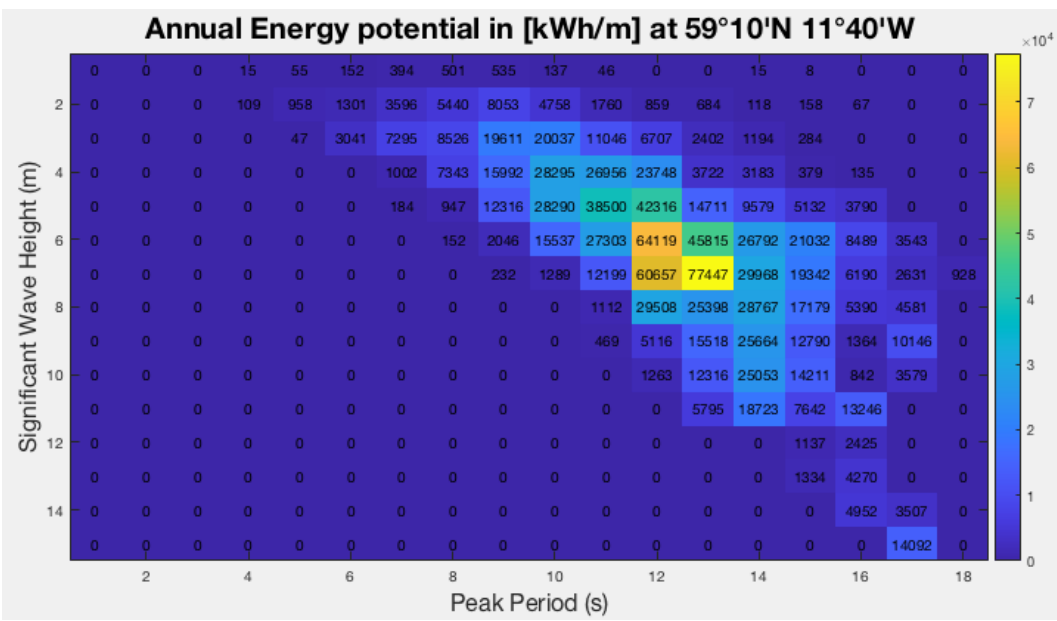


Figure 11: Matrix showing the available energy in a year at location 59°10' N 11°40' W for different sea states.

Figure 12 displays a similar result as figure 11, but these matrices are results for the OG WEC array in the first scenario, where there is no transmission system. Figure 21 in the appendix shows the annual power production per sea state, with a summed up mean annual power production of **90.6 kW**. Figure 12 shows the annual energy production per sea state, with a summed up total annual energy production of **794.0 MWh**. The CWR for this scenario is **1.18%**.

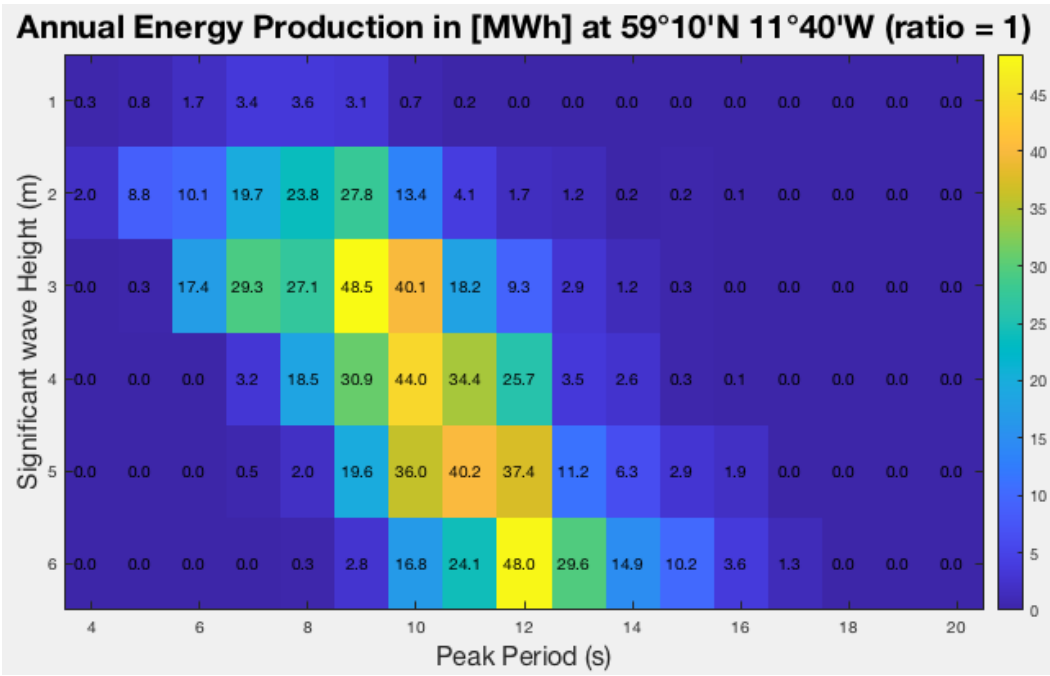


Figure 12: Annual energy production for different sea states at location 59°10' N 11°40' W, with a transmission ratio of 1.

Figure 13 shows the result for the OG WEC array in the second scenario, where there is a transmission system with a uniform ratio. Figure 22 in the appendix shows the annual power production per sea state, with a summed up mean annual power production of **933.6 kW**. Figure 13 below shows the annual energy production per sea state, with a summed up total annual energy production of **8184 MWh**. The CWR for this scenario is **12.2%**.

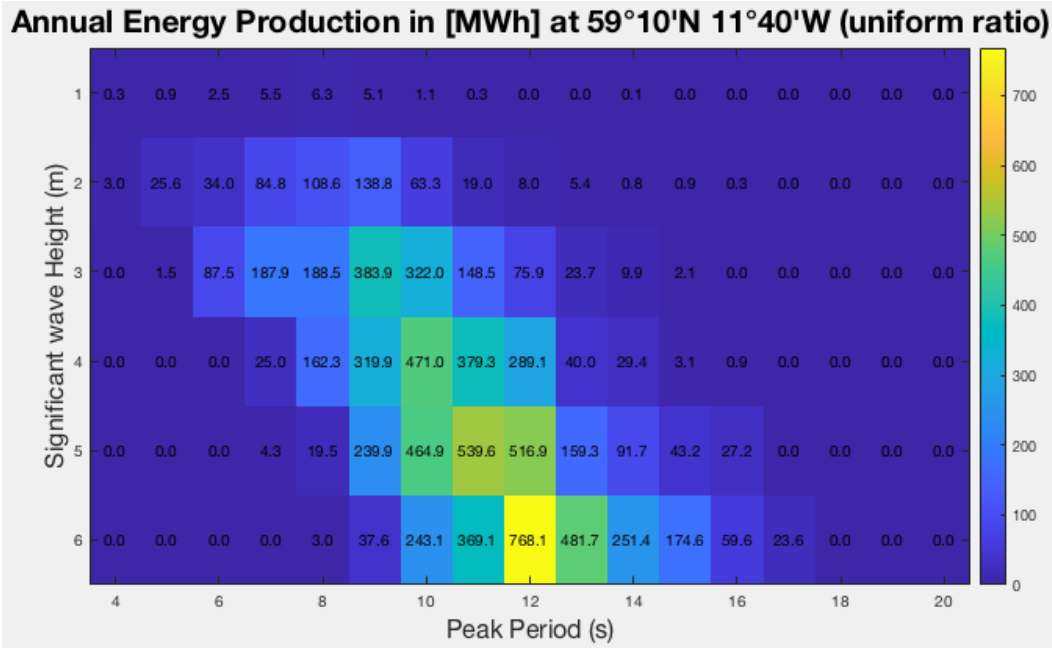


Figure 13: Annual energy production for different sea states at location 59°10' N 11°40' W, with a uniform transmission ratio.

Figure 14 shows the result for the OG WEC array in the third scenario, where there is a transmission system with a varying ratio. Figure 23 in the appendix shows the annual power production per sea state, with a summed up mean annual power production of **1698 kW**. Figure 14 shows the annual energy production per sea state, with a summed up total annual energy production of **14881 MWh**. The CWR for this scenario is **22.2%**. (The matrix with power extracted with a varying ratio is within range of Alva's results. The results in this paper are slightly lower, but Alva said that was not out of range. Alva does not use the CWR to compare scenarios, but since this is done in literature it was logical to use the CWR here.)

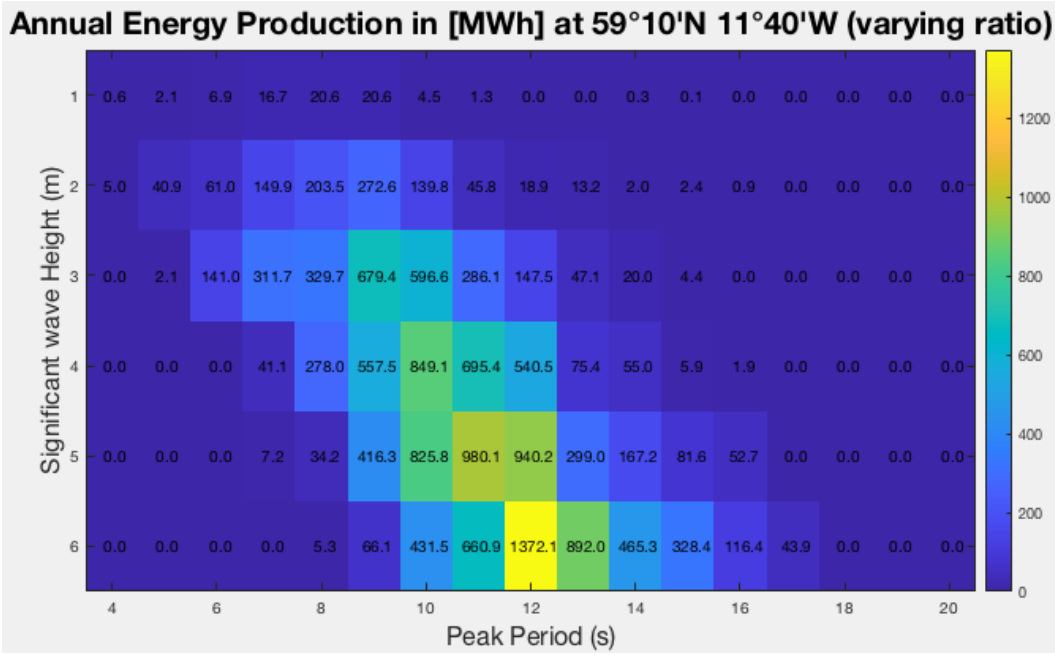


Figure 14: Annual energy production for different sea states at location 59°10' N 11°40' W, with a varying transmission ratio.

Figure 15 displays the CWR of the OG WEC in different sea states for the scenario with no transmission system. The WEC is most efficient in waves with a small height and a small period in this scenario.

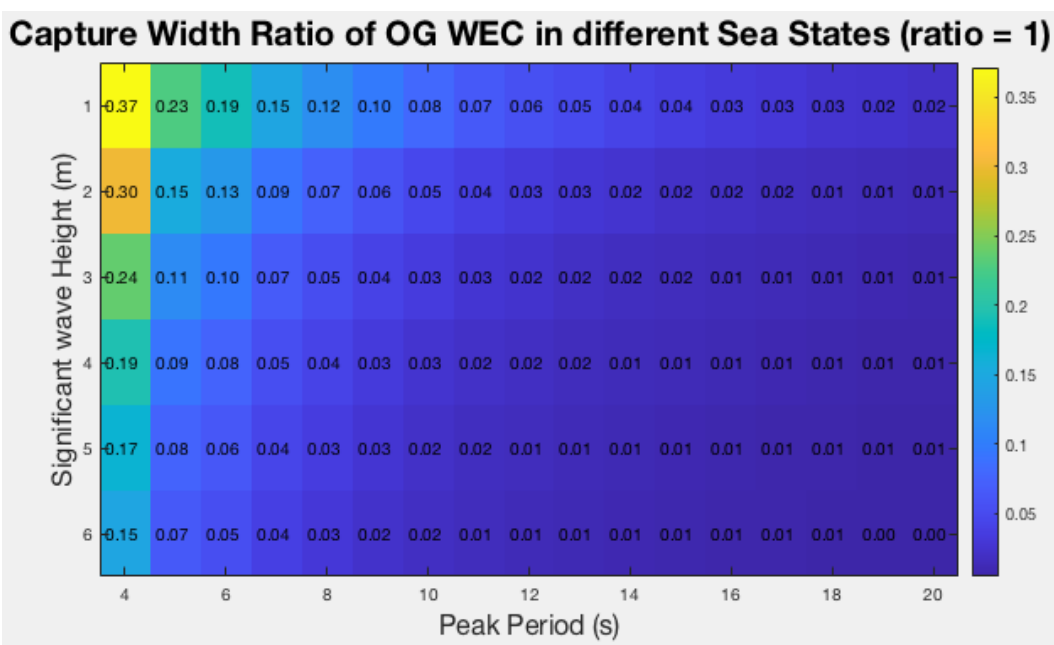


Figure 15: The CWR of the OG WEC in different sea states for a transmission ratio of 1.

Figure 16 shows the CWR of the OG WEC in different sea states for the scenario with a transmission system with a uniform ratio. The decline in efficiency when the peak period becomes bigger is still present, however the efficiency for higher waves has gone up.

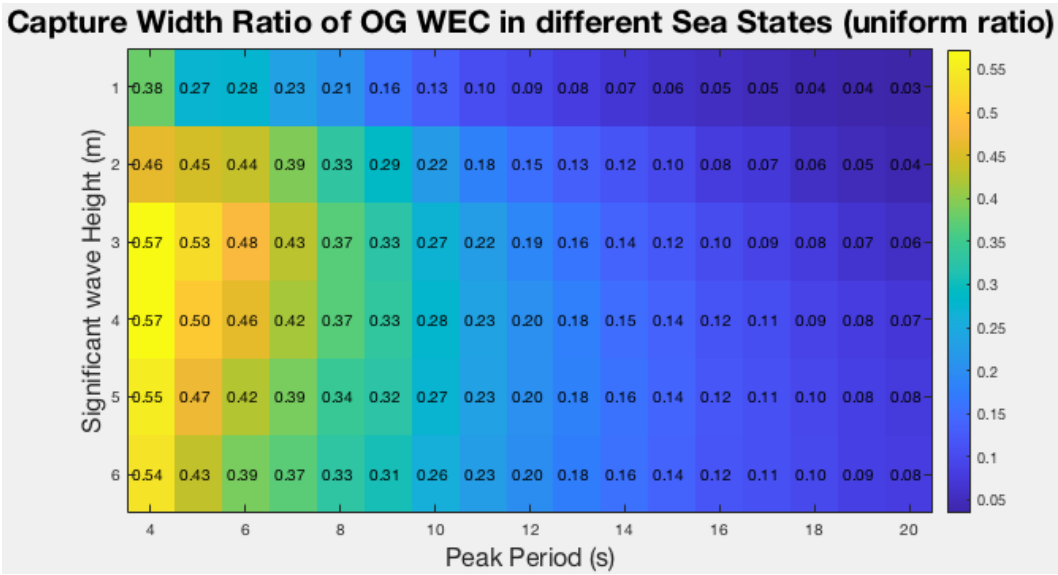


Figure 16: The CWR of the OG WEC in different sea states for a uniform transmission ratio.

Figure 17 shows the CWR of the OG WEC in different sea states for the scenario with a transmission system with a varying ratio. The efficiency for every individual sea state is higher than in figure 16, but the trend of a declining efficiency when the period gets bigger is still present.

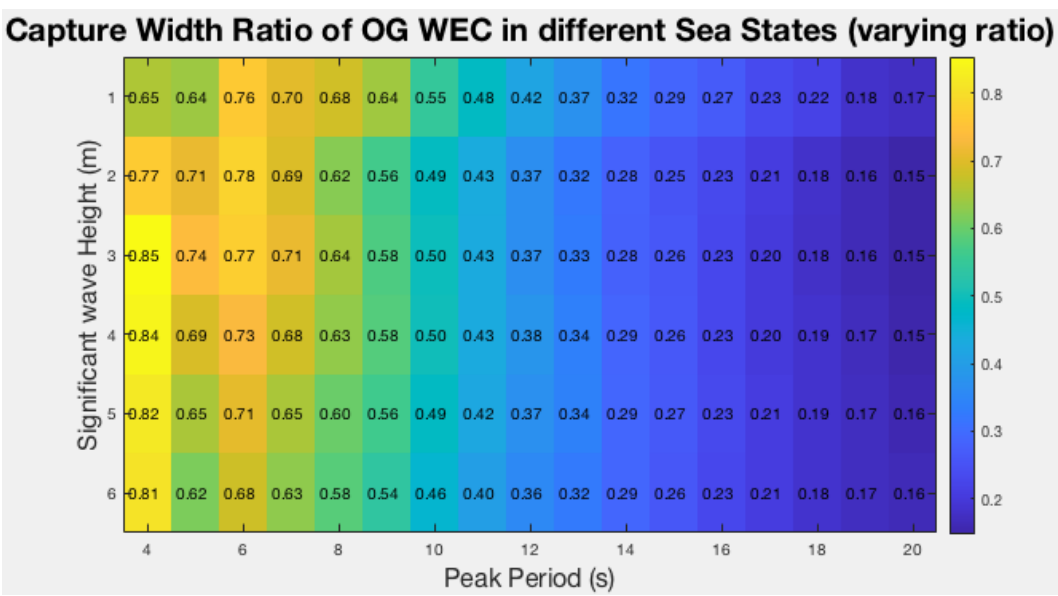


Figure 17: The CWR of the OG WEC in different sea states for a varying transmission ratio.

The optimal transmission ratio for each individual sea state is visible in figure 18 It is noticeable that the ratio does not change significantly anymore from a peak period of 9 seconds and higher for the same significant wave height.

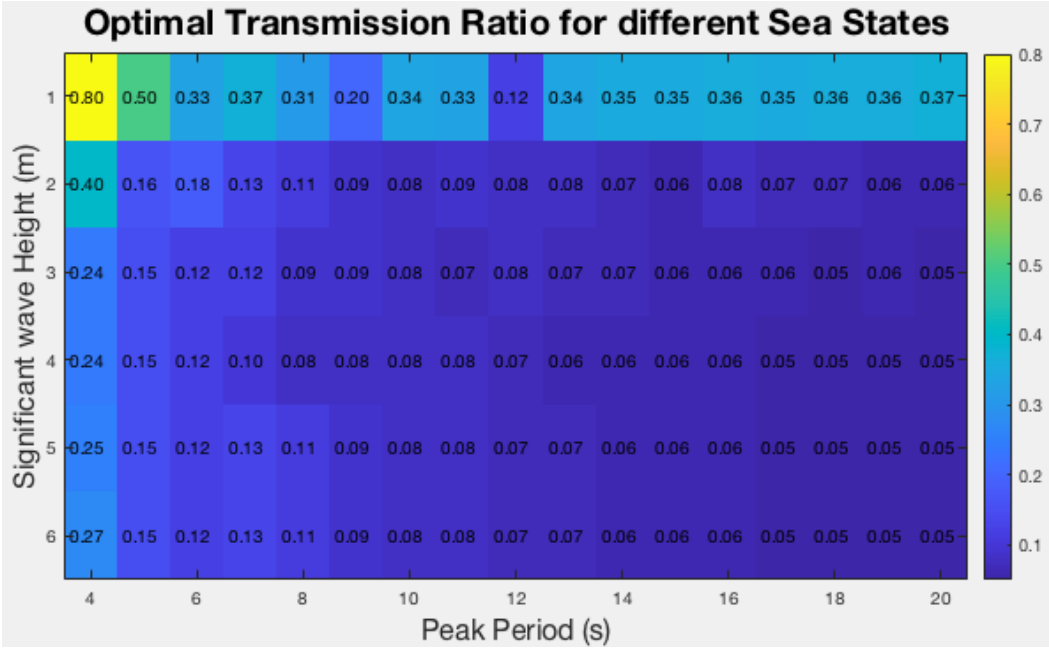


Figure 18: This image shows the optimal transmission ratio for each sea state.

Figure 19 is a plot with on the y-axis the optimal transmission ratio, and on the x-axis the time in seconds. This plot gives, for the scenario with a varying transmission ratio, an indication for the length of the time interval between two different transmission ratios. In the plot it is visible that the ratio is changed in the order of tenths of seconds.

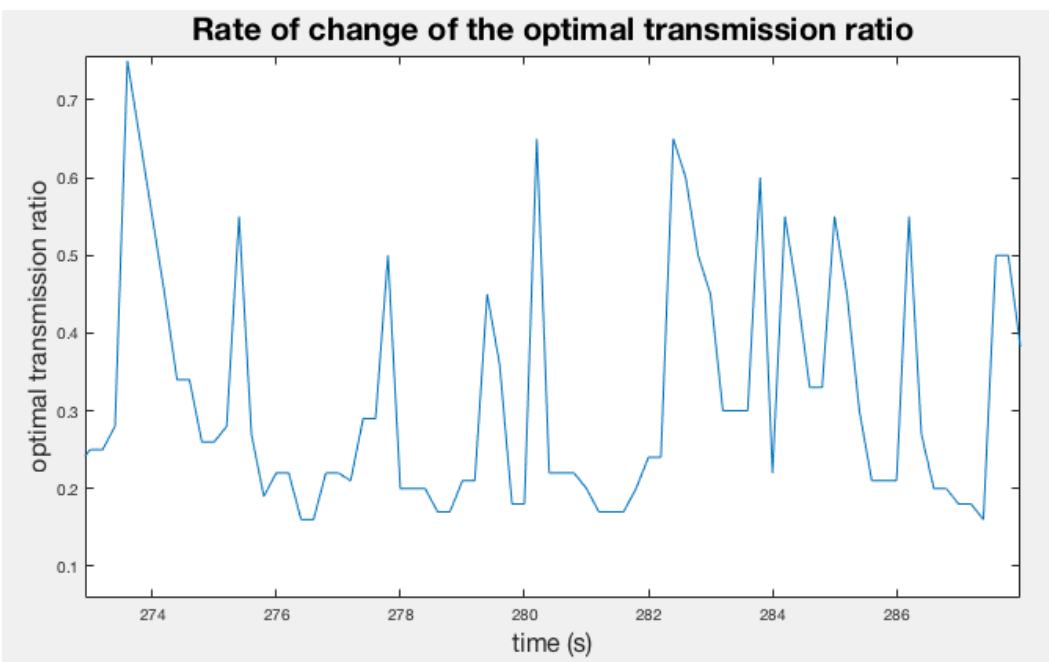


Figure 19: This plot shows the change of the optimal transmission ratio over time. It is a fragment of 15 seconds from a 5000-second plot (length of the simulation).

Table 1 gives an overview of the results for the three different transmission system scenarios that were discussed above.

Transmission system	Mean annual power production [kW]	Annual energy production [MWh]	Annual power available at buoy 64045 [kW/m]	Annual energy available at buoy 64045 [MWh/m]	Characteristic dimension of WEC [meter]	CWR
Ratio = 1	90.6	794.0	127.7	1120	60	1.18%
Uniform ratio	933.6	8184	127.7	1120	60	12.2%
Varying ratio	1698	14881	127.7	1120	60	22.2%

Table 1: An overview of the results for the three transmission system scenarios for the OG WEC array.

11 Discussion

11.1 Results

Location
As mentioned in the literature research, the location of the WEC has a significant influence on the waves going through that WEC. The scatter diagram reinforces the literature, because it shows that not all sea states occur equally frequently and some don't occur at all. Waves occur mostly on the diagonal of the scatter diagram. High waves with short peak periods and low waves with long peak periods are thus very rare or non-existent. Besides the type of waves in a location, other factors mentioned earlier, such as the distance to shore, sea depth and extreme weather conditions, have a significant influence on the performance of the WEC. This information has to be taken into account when choosing a location and designing the WEC.

Transmission systems
The three different transmission system scenarios show significant differences. For the OG WEC array without a transmission system, the CWR is 1.18%. A transmission system with a uniform ratio gives a CWR of 12.2%, while a transmission system with a varying ratio gives a CWR of 22.2%. It can, therefore, be said that it is more efficient to have a transmission system with a ratio that can be varied for each individual wave coming into the WEC array.

Looking at the CWR for each sea state it is also clear that the transmission system with varying ratio is the most efficient. A noticeable trend that can be seen in all three scenarios is that the CWR decreases when the peak period increases. In other words, the WEC array becomes less efficient with an increasing wave period.

The CWR for all three scenarios could be higher in practice, because the simulation only goes up to a significant wave height of 6 meters. This means that the power extraction for waves of 7 meters and higher is considered to be zero, while the CWR does take all available waves into account. If the OG WEC array is able to extract power from waves of 7 meters high, and higher,

the CWR will go up in all scenarios. The magnitude of this increase will have to be shown by calculations, another simulation or with an experiment, but this is outside of the scope for this research.

The matrix showing the optimal transmission ratio for each sea state shows that the ratio does not change significantly as the peak period is larger than 9 seconds. While the ratio stays equal, the amount of power in a wave does increase with an increasing peak period. It seems plausible that this phenomenon causes the inefficiency of the OG WEC array in waves with large peak periods. In this case, it would be logical to redesign the transmission ratio range.

The figure that plots the optimal transmission ratio over the time is important for the design requirements of the transmission system with a varying ratio. It is clear that the varying ratio is the most optimal in terms of power extraction, but it does not say anything about the feasibility of designing such a transmission system. As mentioned in the results, the time interval between two different transmission ratios is in the order of tenths of seconds. It could be challenging to create a transmission system that can achieve this, but this again lies outside the scope of this research.

11.2 Limitations

A simulation of a model always aims to represent reality as accurately as possible. The results always contain a degree of uncertainty compared to practical results. It is, therefore, important to keep in mind that the results from this research could differ from the practical results.

Another limitation of the research is the validation of the matlab tool. While one part of the matlab tool has been proved valid, another part remains difficult to validate. Creating the scatter diagrams from wave data has not been done within the OG research group before. Within the two months of conducting this research, it was not possible to receive a dataset that is used to create a scatter diagram in the literature.

12 Conclusion

The performance of the Ocean Grazer WEC array is measured using both the annual power absorption and the capture width ratio. Three different transmission system scenarios are used to examine the optimal system. The data used to obtain the results are the available wave power and the power absorbed by the Ocean Grazer WEC array under varying sea states and transmission ratios.

Data on waves in different locations and literature research is used to show the influence of different locations on the Ocean Grazer WEC. The location of the Ocean Grazer WEC directly influences the sea states going through the WEC, which, in turn, affects the performance of the WEC. The location determines, besides the sea states, the requirements of maintenance and transportation of energy to its destination, which indirectly influences the performance of the Ocean Grazer WEC.

In conclusion, a transmission system with an adaptable ratio has a positive influence on the performance of the Ocean Grazer WEC. A transmission system with a transmission ratio that can be adapted for each incoming wave results in the highest power extraction by the Ocean Grazer WEC.

13 Further research

As mentioned earlier, the simulation to get the power matrices only considers a maximum significant wave height of 6 meters. It will be interesting to examine what happens to the CWR with a simulation for the full range of significant wave heights.

The different transmission systems proved to have varying outcomes in terms of performance. The cost and design requirements of these systems are not yet taken into account. It might turn out that the most efficient transmission system, the one with the varying transmission ratio, is too expensive or impossible to make. Further research into this matter is, therefore, desired.

The performance measures chosen in this research are only used to compare different scenarios for the OG WEC. It would however, be interesting to compare the performance of the OG WEC with other WECs on the market.

For this research, only one location is used. Looking at different locations to place the OG WEC is another research possibility that can be of value. As mentioned in the literature research, many variables in different locations have an influence on the performance of a WEC.

A last suggestion for further research is to look into a transmission system or ratio that is more efficient when it comes to extracting power from waves with a large peak period. It could be beneficial since waves with a larger peak period contain more power.

14 References

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15 Appendix

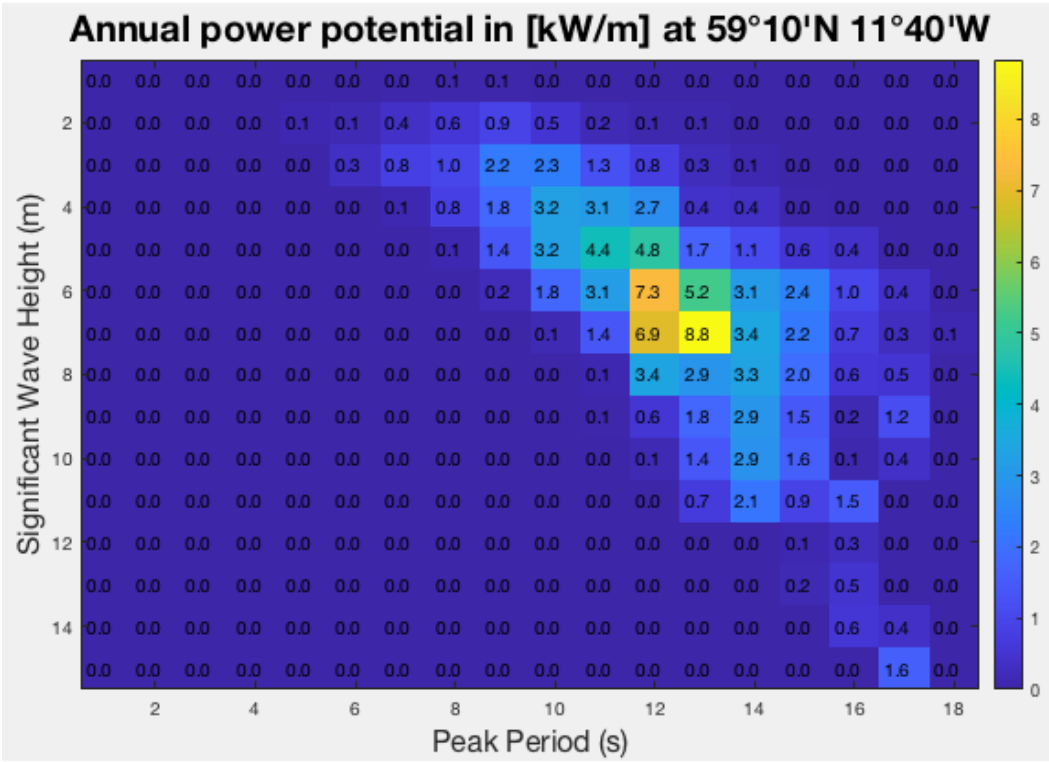

Figure 20: Power matrix that shows the annual available power for each sea state at location 59°10' N 11°40' W.

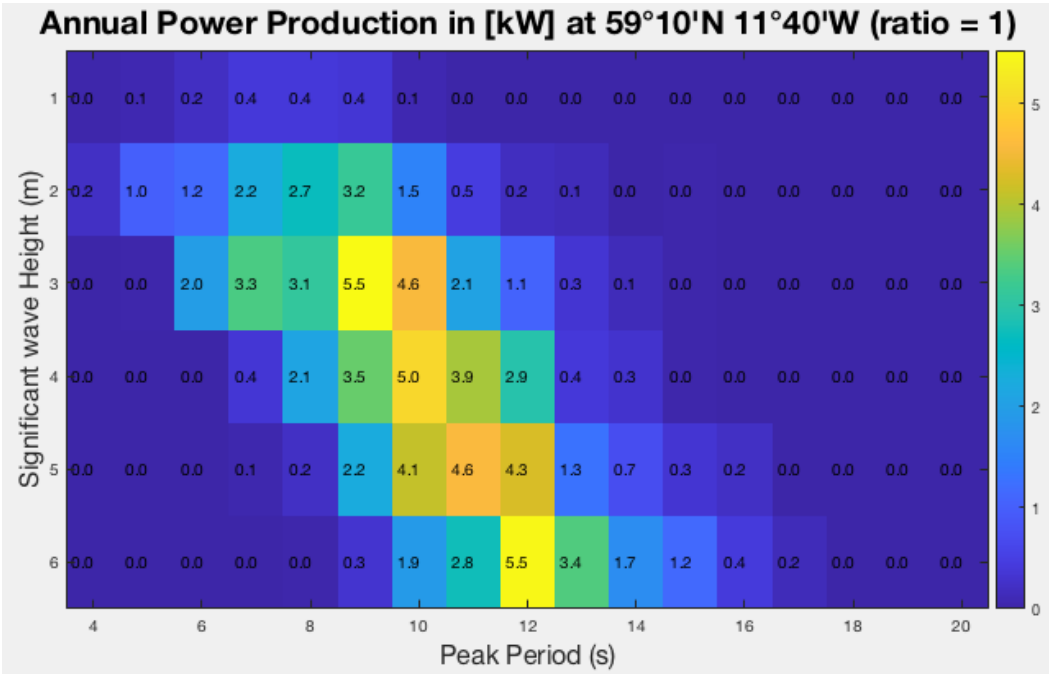

Figure 21: Annual power production for different sea states at location 59°10' N 11°40' W, with a transmission ratio of 1.

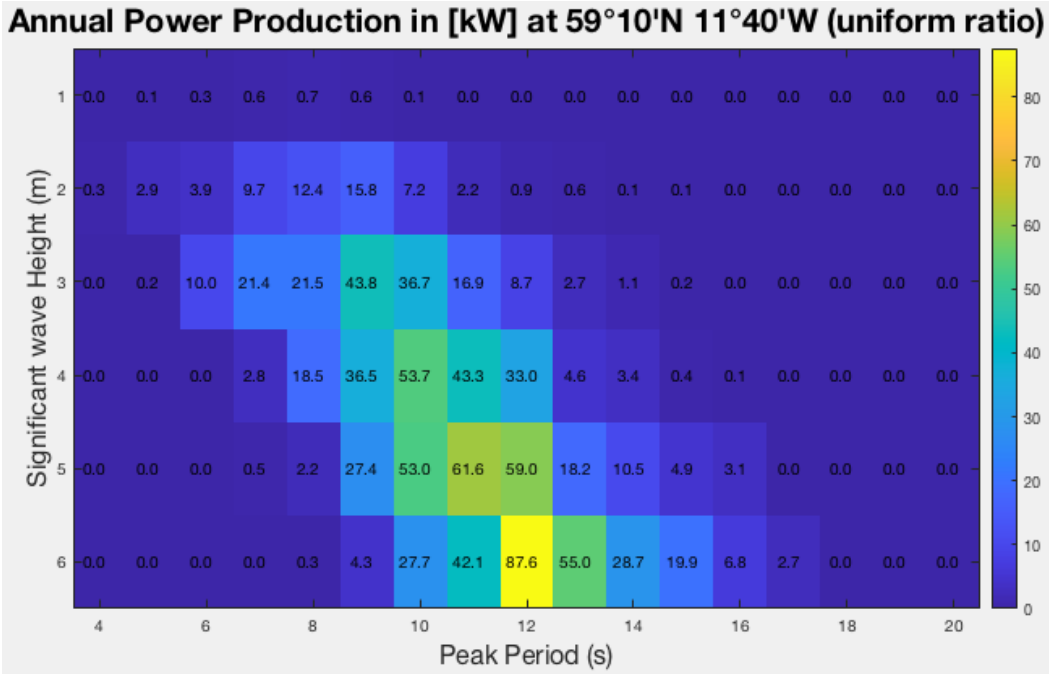

Figure 22: Annual power production for different sea states at location 59°10' N 11°40' W, with a uniform transmission ratio.

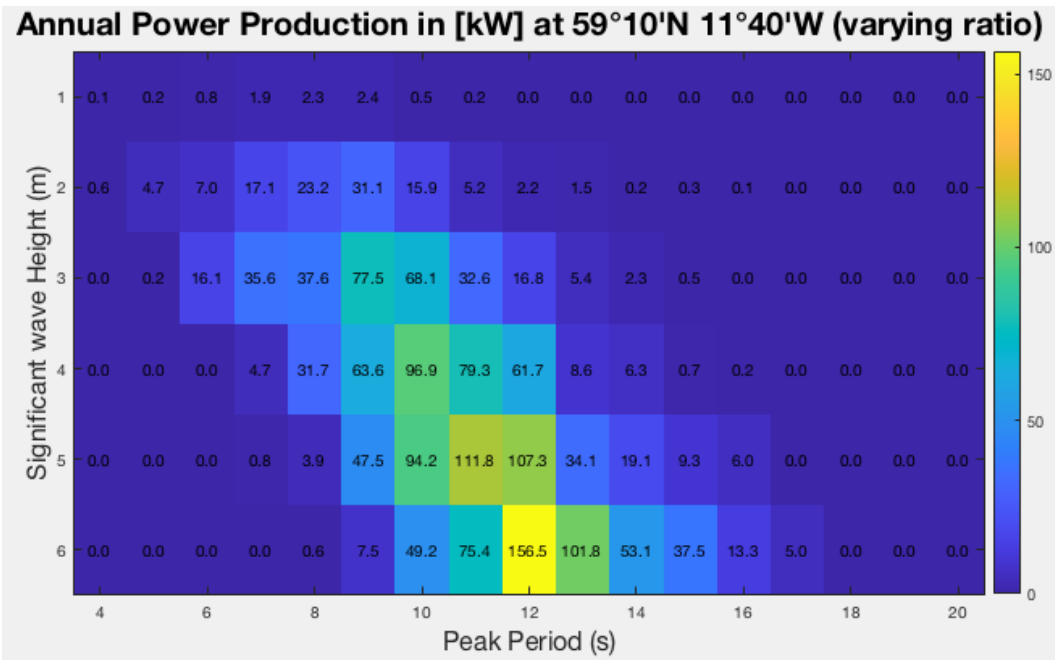

Figure 23: Annual power production for different sea states at location 59°10' N 11°40' W, with a varying transmission ratio.