Multibody Simulation of a Floating Wave Energy Converter

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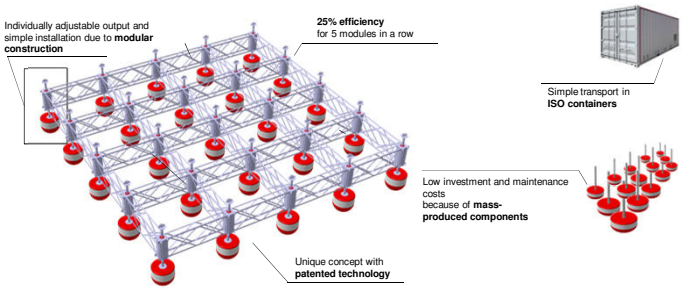
ABSTRACT

SINN Power is a German developer of a patented wave energy converter (WEC). The company is part of the CUTEC Institute at Technical University Clausthal and supported by a grant from the Federal Government of Germany. SINN Power's vision is to use the wave power plant to supply people from coasts all over the world with affordable, reliable and sustainable electricity from the ocean.

The SINN Power WEC consists of a rectangular formation of evenly space point absorbers. They are supported by an overarching framework. Generators attached to the framework convert the heave motion of the point absorbers into electric power. The framework is held up only by the electric torque of the generators.

For the WEC to operate in an economically profitable way, the geometry and the control need to be optimized for each specific location. This optimization progress can be done digitally using multibody simulations. Using this method, favorable wave climates can be identified.



OBJECTIVES

- Simulation of ocean wave climates
- Calculation of the resulting forces on each point absorber
- Build-up of a modular MBS model with simple control systems
- Simulation of the multibody system behavior
- Calculation of the power output
- Variation of geometry and control parameters to maximize power output

MODEL

The wave climate is simulated using the Matlab Toolbox WAFO [6]. A 3-dimensional wave field is generated for a given amount of time.

The hydrodynamic parameters of a floating body are calculated in frequency domain using the open source BEM solver NEMOH [1]. The reliability of the results was confirmed by a simulation run with WAMIT at a cooperating university.

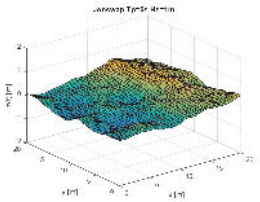


Figure 2. 3-dimensional wave field, calculated with WAFO [6].

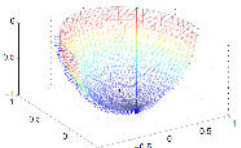


Figure 3. Generated mesh for calculations with BEM Solver NEMOH

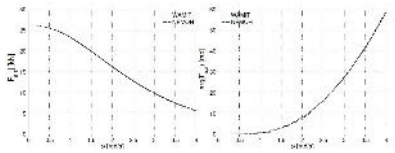


Figure 4. Results for the excitation force in heave direction for the geometry of the point absorber, found with BEM solver NEMOH [1], compared with results found with WAMIT [2].

The external force on each point absorber results from the wave elevation.

When the hydrodynamic heave forces exceed the gravity force of point absorber, lifting rod and structure, the body moves in upward direction. When the sea level drops, the point absorber moves down. By applying electric torque on the generators during the next upward motion of the point absorber, the structure is gradually lifted.

SINN Power obtains empirical data on the friction forces of the bearing of the lifting rod, the gear and the generators on a test bench of a single module of the WEC.

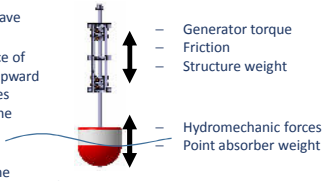


Figure 5. Sketch of a single module of the WEC with resulting forces

By inputting the plant geometry and control data, a Simulink model [8] is automatically generated.

The simulation can be visualized using the SimMechanics Explorer. The power generation of each module is added up.

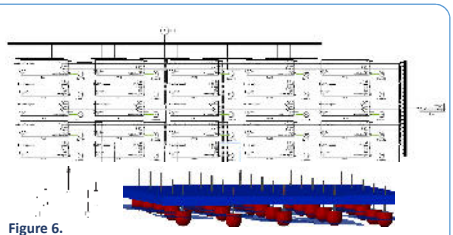


Figure 6. Simulink model for a 5x5 modules WEC and visualization in SimMechanics Explorer [8]

Significant wave height Hs [m]	Peak Period Tp [s]											TOTAL
	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	
0,5	0	2	11	20	13	4	1	0	0	0	0	51
1,5	0	0	9	48	73	48	17	4	1	0	0	200
2,5	0	0	3	28	75	80	45	15	4	1	0	251
3,5	0	0	1	12	45	67	50	22	7	2	0	206
4,5	0	0	0	4	21	42	37	19	6	2	0	131
5,5	0	0	0	1	9	20	22	15	6	2	1	76
6,5	0	0	0	1	3	9	12	9	4	2	1	41
7,5	0	0	0	0	1	4	6	5	3	1	0	20
8,5	0	0	0	0	1	2	3	3	2	1	0	12
9,5	0	0	0	0	0	1	2	2	1	1	0	7
10,5	0	0	0	0	0	0	1	1	0	0	0	3
11,5	0	0	0	0	0	0	0	1	0	0	0	1
TOTAL	0	2	24	114	241	275	196	98	37	12	2	1000

Figure 7. H_s / T_p table of a North Atlantic coast site

The power generation of the WEC at a local site is predicted using actual wave data.

Through iterative calculations, the geometry and the control strategy is optimized for every specific wave climate.

The electricity generation cost is the target variable to be maximized.

Using global wave data, the power output of the WEC is estimated for every region in the world. By multiplying a power table of the WEC with a local H_s / T_p table, the average annual power output is calculated.

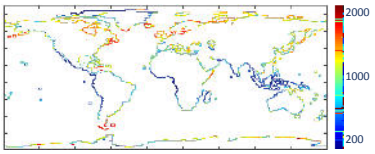


Figure 8. Prediction of average power output for coastal regions using global wave data [7].

CONCLUSIONS

With the designed simulation model, rough estimations of the WEC power generation are feasible. Optimal plant configurations can be identified. For a good performance of the WEC, short wave lengths and moderately high wave heights are favorable. When the waves are too long, there is not enough relative movement between each point absorber and the structure is not lifted. When the structure cannot be lifted, there is no stroke movement and no power generation.

By increasing either the number or the distance of modules the performance in long wave climate can be improved.

Using smart control systems, it is also possible to realize a floating structure resting still on the water.

Hs [m]	Tp [s]										
	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5
0,5	327	228	37	0	0	0	0	0	0	0	0
1	1704	1293	784	538	178	39	0	0	0	0	0
1,5	3359	2153	1505	875	490	293	148	24	0	0	0
2	3873	3894	2254	1908	1169	673	414	174	58	0	0
2,5	5078	4415	3034	1979	1949	1166	708	394	202	60	0
3	0	5024	3497	2513	2239	2004	1354	736	398	213	93
3,5	0	5986	4145,5	2805	2373	1918	1511	1031	663	332	126
4	0	0	5138	3122	2568	2161	1827	1322	843	620	284
4,5	0	0	0	3960	2996	2354	1957	1513	1134	759	418
5	0	0	0	4281	3424	2768	2335	1873	1380	942	557
5,5	0	0	0	0	3488	2870	2331	1897	1573	1220	839
6	0	0	0	0	3694	2918	2448	2158	2045	1638	928
6,5	0	0	0	0	4259	2981	2713	2402	2049	1597	1047

Figure 8. Average power output of a single WEC module as a function of significant wave height and peak period

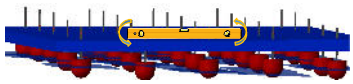


Figure 9. With effective control systems it is possible to keep the framework in balance

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