Power Matrices and Annual energy recovered for SurfPower

Reference Number: SP-003-03222016-ED

West Coast Wave Initiative
University of Victoria

Director:
Dr. Brad Buckham
Project Manager:
Dr. Bryson Robertson
Author
Dr. Helen Bailey
PO Box 3055 STN CSC
Victoria BC V8W 3P6
Canada

Phone: 250-472-4065
Fax: 250-721-6323

Website: uvic.ca/wcwi
Email: wcwi@uvic.ca

Abstract

SurfPower is a buoyancy floating pontoon that reacts against the seabed to pressurize fluid which is transported to shore to generate electrical power. Four different configurations are considered, these are:

1. An *original* design
2. The same *original* design which also incorporating an ESM.
3. A design that has been obtained from an optimization experiment including the ESM
4. A design chosen by the developer from the optimization study using additional cost and manufacturing ability criteria that also incorporates a massless fence on the top of the pontoon and the ESM.

The mean power and the annual energy recovered for 85 different seastates for these four SurfPower configurations are presented in this report. The annual energy recovered is based on an Amphitrite Bank location off the West Coast of Vancouver Island and the total annual energy recovered is presented in the following table. All the numerical simulations have been run to the IEC Technical Standard, TC114.

Configurations	Annual Energy Production (MWh)
SP Original with No ESM	993
SP Original with ESM	1119
SP Optimal configuration with ESM	1937
SP configuration with fence & ESM	1215

Sensitivity testing has been conducted to ascertain how much the time domain seastate representation of a spectral seastate results in variation in the mean power. 30 different simulations were ran for a single spectral seastate representation and the mean power recovered varied by 8.6% uncertainty for 2 standard deviations (95% confidence) of the mean power in the seastate tested.

Table of Contents

Introduction

The SurfPower WEC is being developed by Seawood Designs Inc and is composed of a floating buoyancy pontoon reacting against a hydraulic cylinder that is fixed at one end to the seafloor. Further details about the design and its development have been presented in the following reports:

- EMS, October 2014.
- Full Power matrix for 3 different SurfPower configurations, July 2015
- Power Matrices for and annual energy recovery for 3 different SurfPower configurations – Part II: New seastate spectrum, October 2015.

The seastates have been re-run for 1200 seconds with additional frequency and directional bins. This makes the numerical simulations fully comply with the IEC Technical Standards TC114. The SurfPower configurations tested are presented in Table 1.

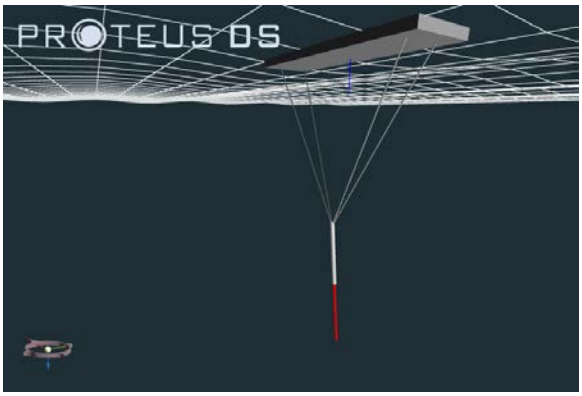

Figure 1: An image of the SurfPower WEC

	EMS	PTO Force	Stroke	Width	Fence
Configuration	[-]	[N]	[m]	[m]	[m]
SP Original with No EMS	No	1000000	2.25	6.7	0.0
SP Original with EMS	Yes	1000000	2.25	6.7	0.0
SP Optimal configuration	Yes	1906250	2.109375	10.6875	0.0
SP configuration with fence	Yes	1000000	2.25	9	0.3

Table 1: SurfPower configurations specifications

Results

The total annual energy production for the four SurfPower WECs is presented in Table 2. This is based at Amphitrite Bank where the annual hours of occurrence are presented in Table 3.

Table 2: The annual energy recovered for the different SP configurations

Configurations	Annual Energy Production (MWh)
SP Original with No EMS	993
SP Original with EMS	1119
SP Optimal configuration	1937
SP configuration with fence	1215

Table 3: Annual hours at Amphitrite Bank

Hs\Te	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5
0.25	0	0	0	0	0	0	0	0	0	0
0.75	0	48	87	27	33	15	0	0	0	0
1.25	39	570	774	399	222	39	0	0	0	0
1.75	57	324	549	513	210	117	36	0	0	0
2.25	9	156	258	378	477	156	54	3	0	0
2.75	3	60	174	261	477	174	54	15	3	0
3.25	0	27	69	72	255	198	108	18	0	0
3.75	0	6	51	81	111	87	81	18	0	0
4.25	0	0	6	48	72	66	93	42	0	0
4.75	0	0	12	33	27	54	51	24	3	0
5.25	0	0	0	15	21	33	36	12	9	0
5.75	0	0	0	9	12	12	12	6	24	3
6.25	0	0	0	0	9	3	9	9	9	6
6.75	0	0	0	0	3	0	3	12	6	0

Power recovered from the different SurfPower configurations

The total mean power from each of the seastates is presented for each of the four configurations in this section for a 20 minute simulation. The time domain representation of each of these seastates was identical for the different SurfPower configurations simulated.

Table 4: Mean Power recovered [kW] for SurfPower without EMS

Hs\Te	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5
0.75		7	6	4	5	4					
1.25	36	44	39	37	35	28					
1.75	83	86	80	78	65	61	56				
2.25	130	125	118	116	104	99	91	81			
2.75	191	178	170	162	138	122	119	104	106		
3.25		227	203	196	174	162	150	136			
3.75		266	247	231	214	195	193	161			
4.25			287	268	239	233	203	201			
4.75			344	315	272	271	243	228	205		
5.25				339	308	289	263	243	221		
5.75				358	327	303	287	264	248	227	
6.25					352	313	311	281	251	242	
6.75					375		326	296	277		

Table 5: Mean Power output [kW] for "*Original SurfPower*"

Hs\Te	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5
0.75		15	12	11	14	13				
1.25	49	59	60	58	56	43				
1.75	94	101	98	95	87	82	77			
2.25	141	132	133	131	120	115	108	98		
2.75	194	185	179	175	155	135	133	120	119	
3.25		230	211	203	185	176	162	153		
3.75		268	249	238	221	205	200	174		
4.25			287	271	246	238	213	208		
4.75			346	298	277	272	247	230	209	
5.25				336	311	293	267	248	229	
5.75				360	328	303	287	265	250	233
6.25					352	313	311	285	257	245
6.75					376		327	294	276	

Table 6: Mean power recovered [kW] for *optimal SurfPower*

Hs\Te	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5
0.75		19	11	11	12	8				
1.25	59	85	83	94	86	69				
1.75	147	164	167	174	156	141	139			
2.25	209	209	235	233	213	205	196	179		
2.75	298	310	313	308	271	236	233	216	218	
3.25		379	364	359	335	315	295	265		
3.75		435	431	420	401	368	366	317		
4.25			507	473	445	435	388	376		
4.75			583	564	492	482	445	414	380	
5.25				596	553	527	479	447	410	
5.75				625	588	545	526	479	457	417
6.25					626	555	558	504	461	443
6.75					664		585	529	501	

Table 7: Mean Power recovered [kW] for the SurfPower with Fence configuration

	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5
0.75		27	27	22	26	21				
1.25	68	71	69	64	64	55				
1.75	121	114	104	103	94	90	85			
2.25	177	154	146	142	131	120	117	105		
2.75	229	208	197	185	164	143	142	129	127	
3.25		257	230	219	194	187	169	160		
3.75		293	269	251	238	219	213	183		
4.25			309	290	257	250	226	218		
4.75			363	335	294	287	263	241	218	
5.25				350	326	309	280	260	235	
5.75				378	343	315	296	279	258	241
6.25					368	327	325	298	267	256
6.75					393		338	304	287	

Annual power recovered for Amphitrite Bank

The annual energy recovered for the Amphitrite Bank location is presented for the four SurfPower configurations below.

Table 8: Annual power recovered for each seastate [MWhr] for SurfPower with no EMS

Hs\Te	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5
0.75	0.34	0.51	0.10	0.17	0.06				
1.25	25.00	30.32	14.61	7.78	1.08				
1.75	27.80	43.83	39.79	13.72	7.11	2.03			
2.25	19.45	30.38	43.83	49.66	15.37	4.93	0.24		
2.75	10.70	29.56	42.26	65.62	21.20	6.45	1.56	0.32	
3.25	6.13	13.99	14.08	44.24	32.14	16.18	2.45		
3.75	1.60	12.62	18.68	23.78	16.96	15.65	2.91		
4.25		1.72	12.86	17.18	15.36	18.87	8.43		
4.75		4.13	10.40	7.34	14.65	12.40	5.46	0.62	
5.25			5.08	6.46	9.52	9.47	2.92	1.99	
5.75			3.23	3.92	3.64	3.44	1.59	5.95	0.68
6.25				3.17	0.94	2.80	2.53	2.26	1.45
6.75				1.12		0.98	3.55	1.66	

Table 9: Annual Energy recovered, per seastate [MWhr], for the "SurfPower Original"

Hs\Te	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5
0.75		0.71	1.07	0.30	0.48	0.19				
1.25	1.91	33.79	46.38	23.21	12.32	1.69				
1.75	5.38	32.75	54.02	48.54	18.29	9.58	2.78			
2.25	1.27	20.62	34.24	49.52	57.02	17.88	5.82	0.29		
2.75	0.58	11.13	31.21	45.65	73.73	23.52	7.17	1.81	0.36	
3.25		6.20	14.53	14.58	47.27	34.90	17.50	2.75		
3.75		1.61	12.70	19.31	24.52	17.83	16.20	3.14		
4.25			1.72	13.02	17.71	15.70	19.82	8.74		
4.75			4.15	9.83	7.48	14.68	12.58	5.51	0.63	
5.25				5.04	6.53	9.66	9.60	2.98	2.06	
5.75				3.24	3.94	3.63	3.45	1.59	6.01	0.70
6.25					3.16	0.94	2.80	2.57	2.32	1.47
6.75					1.13		0.98	3.53	1.66	

Table 10: The annual energy for each seastate [MWhr], for the SurfPower Optimal configeration

Hs\Te	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5
0.75		0.93	0.96	0.29	0.40	0.12				
1.25	2.28	48.55	64.23	37.52	18.99	2.70				
1.75	8.39	53.16	91.67	89.03	32.70	16.49	5.01			
2.25	1.88	32.58	60.60	88.24	101.41	32.01	10.56	0.54		
2.75	0.89	18.60	54.38	80.33	129.20	41.06	12.58	3.24	0.65	
3.25		10.24	25.12	25.83	85.40	62.29	31.84	4.77		
3.75		2.61	21.98	34.05	44.54	32.01	29.66	5.71		
4.25			3.04	22.69	32.02	28.71	36.05	15.80		
4.75			7.00	18.61	13.29	26.02	22.71	9.95	1.14	
5.25				8.94	11.61	17.39	17.26	5.36	3.69	
5.75				5.62	7.05	6.54	6.31	2.88	10.97	1.25
6.25					5.63	1.67	5.02	4.54	4.15	2.66
6.75					1.99		1.76	6.35	3.01	

Table 11: The annual energy per seastate [MWhr] for the SurfPower with Fence

Hs\Te	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5
0.75		1.30	2.35	0.61	0.85	0.32				
1.25	2.66	40.56	53.57	25.64	14.14	2.15				
1.75	6.92	36.96	57.30	53.06	19.73	10.59	3.06			
2.25	1.59	24.01	37.66	53.49	62.44	18.73	6.30	0.31		
2.75	0.69	12.45	34.31	48.27	78.28	24.87	7.66	1.93	0.38	
3.25		6.93	15.84	15.78	49.60	37.08	18.25	2.88		
3.75		1.76	13.72	20.37	26.39	19.08	17.22	3.30		
4.25			1.86	13.93	18.49	16.48	21.02	9.16		
4.75			4.36	11.06	7.93	15.49	13.40	5.79	0.65	
5.25				5.26	6.86	10.18	10.08	3.12	2.11	
5.75				3.40	4.12	3.78	3.56	1.67	6.20	0.72
6.25					3.31	0.98	2.92	2.68	2.40	1.53
6.75					1.18		1.02	3.65	1.72	

Sensitivity

30 runs of the SurfPower Fence configuration were conducted in the 1.75m@10.5s seastate. The spectral shape remained constant but the random variations within the seastate and the number of frequency and directional bins were varied. A histogram showing the results of the sensitivity test is presented in Figure 2. It would be expected that 95% of all values fall within the mean value plus or minus 8.6% of the mean value represented by the green lines in the figure.

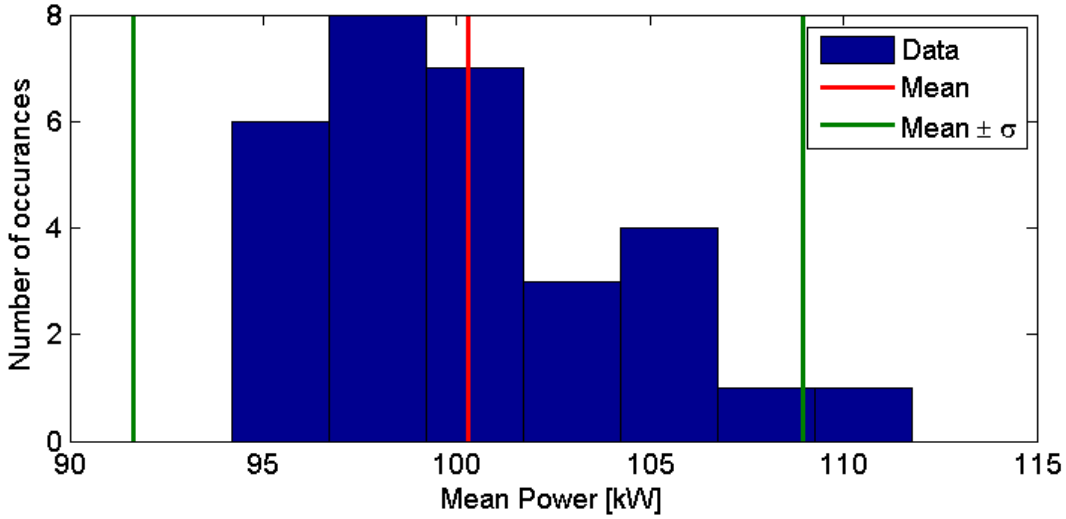

Figure 2: Histogram of mean power output