Marine Energy Conversion Technologies: Lowering the Levelized Cost of Energy through Control Systems, Materials Research, and Systems Engineering.

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Overview

Marine Energy Conversion (MEC) technologies (a.k.a. Marine Hydrokinetic (MHK)) development is following a similar trajectory to the wind energy industry towards commercialization. Over the last several decades, installed capacity for wind energy systems have seen tremendous growth throughout the world. Wind technologies have moved from experimental to full-scale systems deployment at scales required to make the levelized cost of energy (LCOE) competitive. Although MEC technologies are still at relatively nascent stages of development, they are expected to follow a similar development trend throughout the U.S., Europe and beyond. These technologies, spanning a wide range archetypes and sizes, range from emergent floating bouy-like devices that transfer wave motions to mechanical power and electricity, to submerged marine turbines, like wind turbines that extract kinetic energy from currents, are at the forefront of exploiting potentially vast energy resources found in waves and tidal currents. A key challenge for this suite of MEC technologies will be to reduce the LCOE to ranges that seek to be cost competitive.

A U.S. Department of Energy techno-economic assessment study of marine energy technologies, including several current energy converter (CEC) point designs and several wave energy converter (WEC) point designs [1], demonstrated that levelized costs are at least an order of magnitude higher than those for solar and wind. This study identified cost drivers and cost-reduction pathways to make marine energy technologies more economically competitive through innovations, e.g., advanced control strategies and advanced materials. WEC point designs, in particular, have relatively high levelized costs because, in contrast to CEC point designs that are similar to wind turbine technologies, they have no technology analogues. More recent work to improve the performance of WECs via advanced control strategies has shown the potential to greatly increase the amount of energy produced by WECs [2]. While these advanced control studies do not yet consider the full complexity of WEC power generation, some rough initial projections for the potential of improved control strategies to reduce LCOE of WECs can be made. Addtionally, the general effect of materials and coatings on LCOE presents an opportunity to determine their impact on the manufacture, operation, maintenance, and repair of devices used in the marine environment. By using the proper material and coatings, savings may be found in weight reductions through light weight durable materials along with improved resistance to biofouling and corrosion [3, 4].

Methods

Here, we use the comparison of advanced WEC control strategy performances presented in [2] to update the LCOE calculations performed for the RM3 WEC device considered in [1]. The RM3 is a two-body point absorber device, as shown in Figure 1. The LCOE estimates for the RM devices originally presented in [1] assumed that the devices employed a simple “resistive” control strategy. Two high-performing advanced control strategies assessed in [2] were model-predictive control (MPC) and linear quadratic (LQ) control. By assuming that the relative performance of control strategies observed for the device studied in [2] is representative of WECs in general, we can make some rough estimates about the potential reduction in LCOE of the RM devices resulting from more advanced control strategies. For this study, we use two factors from [2] to update RM LCOE calculations: average annual energy production (AEP) and maximum power take-off (PTO) force. Table 1 shows the average percent increase (versus resistive control) in AEP and maximum PTO force for the MPC and LQ control strategies.

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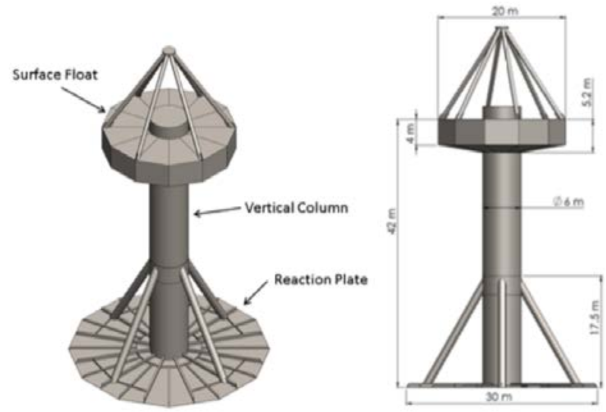

Figure 1 *- Reference Model 3 (RM3) wave energy converter (WEC) device (reproduced from [1]).*

Table 1 *- WEC control strategy relative performance.*

	Average % Increase	Resistive	MPC		LQ	
		[united]	[united]	% Increase	[united]	% Increase
AEP	177%	15.50	46.1	197%	39.8	157%
Max PTO force	249%	739	2653	259%	2500	238%

Results

By updating the LCOE calculations for the RM devices, we obtain the new LCOE estimates shown in Table 2. As a result of increase in PTO force, the PTO portion of the CAPEX is assumed to increase at a prorated rate. However, the increase in AEP more than offsets this increased cost. OPEX is assumed to remain unchanged, and the LCOE for the RM3 device is predicted to drop from 1.41 $/kWh to 0.58 $/kWh (a reduction of 59%).

Table 2 *– Relative CAPEX, OPEX and LCOE for RM3 (10-unit array).*

	Resistive control	Advanced control
PTO (CAPEX)	$4,937,000	$17,212,694
Total CAPEX	$61,173,000	$73,448,694
OPEX	$3,294,700	$3,294,700
LCOE	1.41 $/kWh	0.58 $/kWh

Conclusions

The growing research area of Marine Hydrokinetics (MHK), also referred to Marine Energy Conversion (MEC), offers a substantial new renewable energy resource. The wave and tidal flow resources throughout the world offer an energy source that is both close to many large population centers, may be predicted with reasonable certainty (similar in spirit to wind energy resources), and draws upon existing construction and maintenance industries across both the offshore oil and gas platform industry, as well as expertise that can leverage decades of work in the wind energy industry.

The step-change in cost of energy predicted in this simple study shows the potential for MHK devices to attain economic viability through technological innovation. Further work is needed both to realize these technological gains and better understand their effect on cost of energy.

References

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