Optimal sizing of a hybrid OTEC-diesel system with battery energy storage for fish farming application

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1) Mathematical modeling of the proposed standalone hybrid system
2) Optimal sizing to minimize the LCOE and ensure uninterrupted operation

Introduction

- Aquaculture is the fastest-growing food production system in the world, and it is expected to meet most of the growing demand for food in the future.
- Fisheries and aquaculture farms need a smooth and reliable power supply.
- The aquaculture industry, traditionally reliant on diesel, has the potential to reduce greenhouse gas emissions by transitioning to renewable energy sources.
- Ocean Thermal Energy Conversion (OTEC) generates electricity using the temperature difference between deep cold and surface warm ocean waters and can provide a consistent energy source for offshore fish farms.

System Configuration

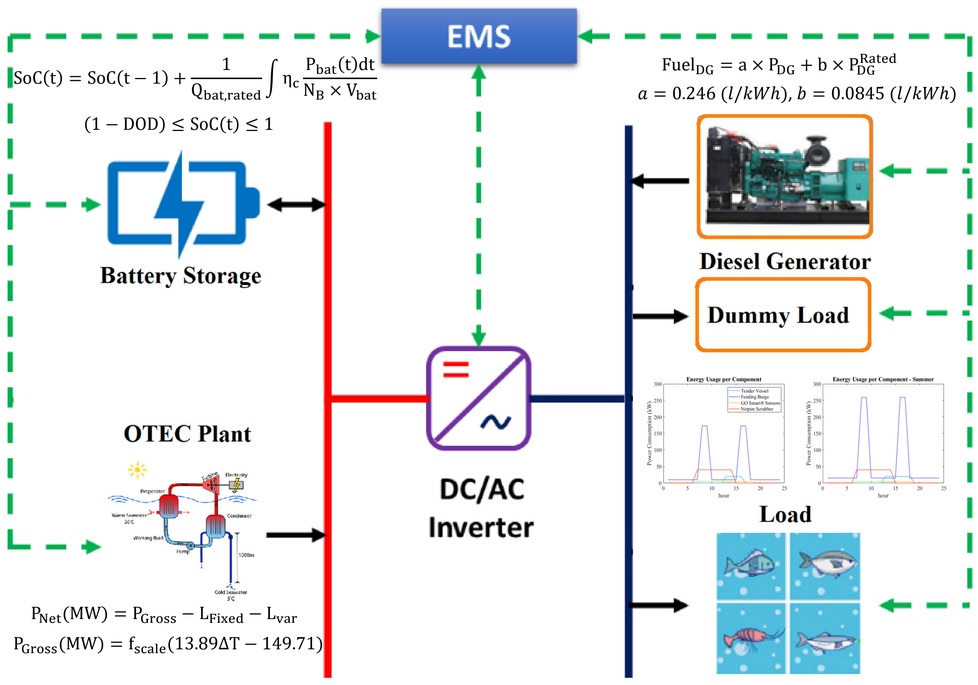

Figure 1. Schematic diagram of the proposed hybrid renewable energy system

Techno-Economic assessment

Evaluate system's reliability:

$$LPSP = \frac{E_{shortage}}{E_{load}}$$

$E_{shortage}$: *Annual energy shortage*

E_{load} : *Annual energy load*

$$RI = 100\% - (LPSP \times 100)\%$$

We need RI = 100%, therefore we need to have a diesel generator

Evaluate Levelized Cost of Energy of the system:

$$LCOE = \frac{I_0 + \sum_{n=1}^{N}\left(\frac{C_n}{(1+r)^n}\right) + C_{reinv}}{\sum_{n=1}^{N}\left(\frac{E_{utilized}(1-d)^n}{(1+r)^n}\right)}$$

I_0 : Investment cost ($).

C_n : Operation/maintenance (O&M) and fuel cost ($) in year n

C_{reinv}: Reinvestment cost ($).

$E_{utilized}$: Annual energy utilization of the system (kWh).

d : Annual degradation rate (9%) in the efficiency of OTEC and BES.

r : discount rate (0.5%/year) .

N: Lifetime of the project (25).

Table 1. Specifications and associated costs of the components

Description	OTEC	BES	DG
Unit Cost ($/kW$)	$61980 \times (Plant\ size\ (MW))^{-0.349}$	190	230
O&M Cost	5.5% of unit cost	2% of unit cost	0.1 $/h
Fuel Cost (including delivery)	-	-	11.12 $/G

RESULTS

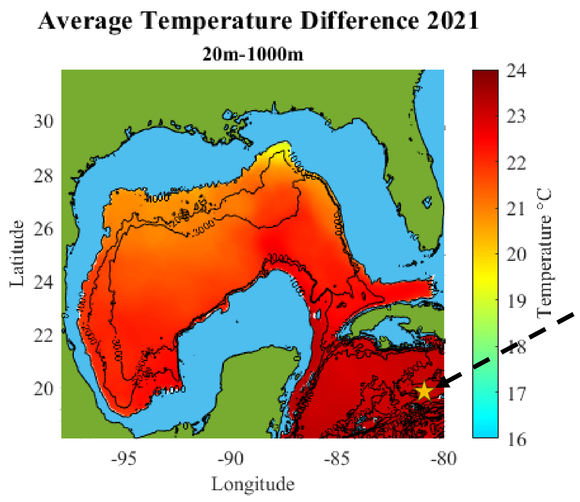

Figure 2. Mean temperature difference between warm (20m) water and cold (1000m) water in Gulf of Mexico and western Caribbean using daily HYCOM thermal data

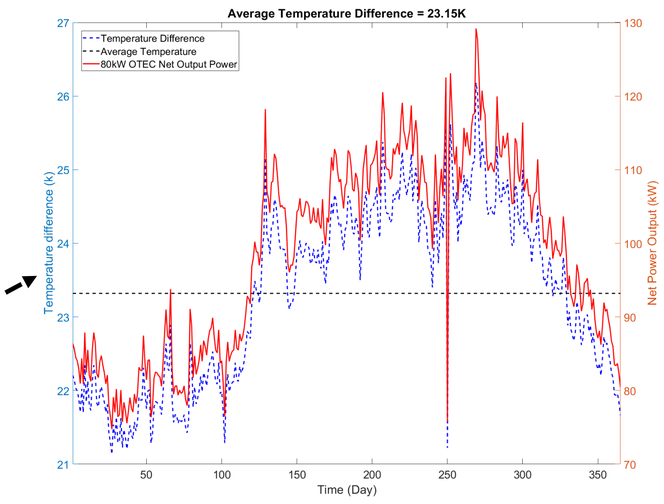

Figure 3. Daily temperature difference for the selected location (yellow star in Figure 2:$20°02.4'\ N, 81°33.6'\ W$*) and corresponding OTEC output power*

Table 2. Optimal results for different scenarios

Scenario	OTEC (kW)	Battery (kAh)	DG (kW)	RI (%)	CI (%)	LCOE ($/kWh)
Diesel Generator alone	0	0	305	100%	0	3.40
Small-scale fish farm	80kW	52	31	100%	95%	6.89
Large-scale fish farm	750kW	559	425	100%	85%	3.28

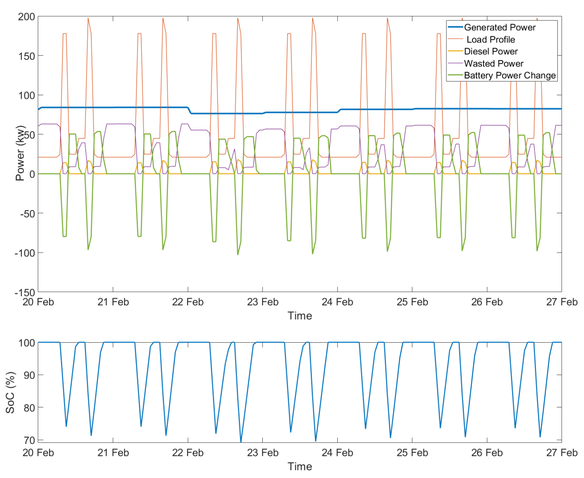

*Figure 4. Load demand and power contributions from OTEC, Diesel Generator , battery energy storage in a week in **winter***

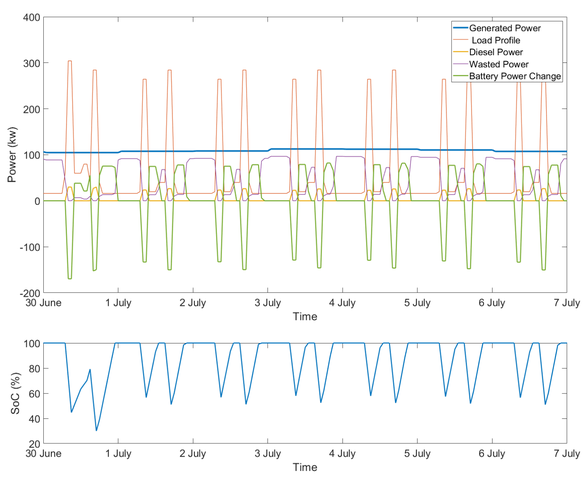

*Figure 5. Load demand and power contributions from OTEC, Diesel Generator , battery energy storage in a week in **summer***

Conclusion

- Investigating different scenarios underscore the effectiveness of the proposed system to meet the energy demands of fish farms while minimizing the levelized cost of energy, especially for larger scale fish farms.
- The non-linear relationship between OTEC capacity and its capital cost means that small changes in OTEC capacity can result in rapid and substantial changes in capital costs, making economic feasibility crucial for smaller-scale implementations.
- The considerable increase in the curtailment index when integrating OTEC and BES can be linked to a significant peak demand of 200kW compared to a lesser baseload of 11kW, resulting in system oversizing.
- The results demonstrate that scaling up the hybrid system not only reduced the LCOE but also reduced the energy wastage, making it a more economically viable solution for large-scale fish farming operations.
- One key benefit of employing renewable energy sources is the mitigation of carbon emissions. Hence, in prospective research, it may be beneficial to take into account the social cost of carbon.

CONTACT

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