Improving aquaculture environmental footprint utilizing offshore renewable energy

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Abstract

The main environmental impacts of aquaculture include eutrophication, chemical pollution and harm to sensitive marine ecosystems. At the same time, the required energy leads to high emissions of greenhouse gases. Offshore wind turbines are a sector of renewable energy that grows rapidly. Offshore wind turbines can be combined with aquaculture units to meet their energy needs, saving fuel and reducing their carbon footprint. However, there are many difficulties in installing aquaculture units in existing offshore wind parks (e.g. small water depth). A new paradigm is to deploy floating wind turbines and aquaculture at open sea. Open sea aquaculture is more environmentally friendly, but has not been developed due to increased supply chain cost and harsh sea state conditions. The aim of this study is to propose a renewable energy system that can cover the energy needs of an open sea aquaculture unit. The system consists of a multiuse floating structure that accommodates wind turbine, photovoltaic panels, batteries, energy management system, fish monitoring devices and automatic feeding system. In this way the frequency and cost of in-situ visits, will be reduced. The above combination makes open sea aquaculture development more attractive and at the same time improves its environmental footprint.

Keywords: open sea aquaculture, product environmental footprint, floating windturbine, offshore renewable energy

1. Introduction

Open sea offers several advantages for both renewable energy and aquaculture (Duarte et al 2009, FAO 2011). The breeding environment is better as currents are stronger, therefore oxygen level remains high and water is cleaner. Stronger currents and deeper water reduce also eutrophication effects, fish excreta are quickly dispersed over a larger area. Therefore, benthic ecosystems are not affected and lack of oxygen on the seabed is avoided. Offshore areas have also higher wind resource, as there are much smaller disturbances in wind flow compared to land. There, wind is more stable and wind velocity is higher. As a result, the available wind energy at sea is much more than in the land (WindEurope 2017). Electricity produced from windturbines and photovoltaics is much cheaper than electricity from diesel generators. Further on, transporting diesel oil barrels to feeding barges constitutes an environmental hazard. On the other hand when operating further offshore all operations become more difficult and costly and in some cases the fish cages will not be able to withstand the waves.

2. Methods

Life cycle assessment and eco labeling becomes an important issue (Henriksson et al 2012, Madin et al 2015). In order to derive a sustainable proposition the possible combinations of renewable energy solutions were examined. Investigating state of the art in open sea aquaculture together with renewable energy, in the Maribe EU project combinations of aquaculture together with wave energy, wind energy, solar energy have been evaluated (Maribe, 2016c). Also, Ydriada, semi-submersible floating platform, has been evaluated as a multiuse platform in the above project. The design and operational characteristics of Ydriada make it suitable for combining open sea aquaculture with renewable energy. On this floating platform a wind turbine, a photovoltaic system and battery storage together with a desalination unit form a three phase microgrid. The main advantages of this autonomous microgrid include: (a) local renewable energy production with low carbon footprint and low overall environmental impact, (b) independence from fossil fuel. (c) possibility of cost sharing by integrating more offshore activities, (d) easy towing of the unit to installation location, (f) anchoring offshore to avoid any disturbances (Dagkinis et al., 2014).The main technical issues that have been addressed are (1) stable operation of the platform, and minimization of movements from wind and wave loads, (4) appropriate modifications of offshore wind turbine components for autonomous operation, (5) appropriate design of the electrical interconnection, control and teleoperation system (Lilas et al, 2007). The above characteristics make this multiuse plaform suitable to be integrated with an opensea aquaculture (Stuiver et al, 2016). The operation of this renewable energy system has been simulated with Homer software in order to derive the economy in the fuel of the generator that can be achieved.

3. Results

The components of the energy system have been modeled in the simulation software (figure 1). The offshore wind turbine (32 kW) in the central floater of the structure is the major power component and runs at varying rotational speed. The power curve is kept constant above 13m/sec wind speed via an active rectifier and inverter. In addition, pitch control does not allow the offshore turbine to over speed at high wind speeds. This configuration enables cold startup, which requires only minimal power for the control electronics and pitch adjustment (Lilas et al, (2007). The output voltage of photovoltaic panel (10 kW) is DC and becomes 3-phase 380 VAC through an inverter. The use of two or more RES smooths productivity and decreases the effect of intermittency (Stefanakou et al., 2016).

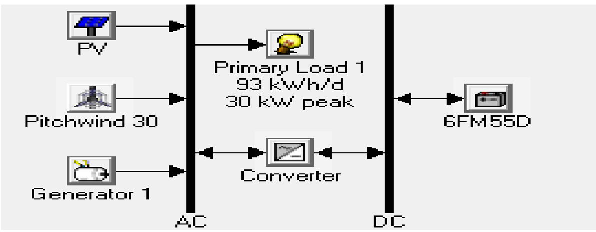

Figure 1. Electrical diagram in simulator

Through simulation of alternative operation modes and assuming an average wind speed of 7m/sec and PV production of 4.69 kWh per kWp per day, it has been shown that the renewable energy system can reduce oil consumption by 41 tons per year and cover 95% of energy requirements. The following figures show the performance of the system and the economy in fuel oil in the generator. Further on, when doubling the battery capacity to 100kWh then almost 100% of the energy needs are covered by renewable energy. Figure 2 describes the unmet electricity load not covered from renewables each month and figure 3 the excess electricity from renewables.

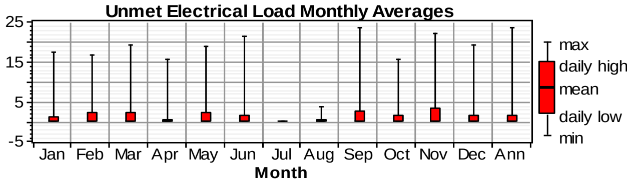

Figure 2. Unmet electricity load

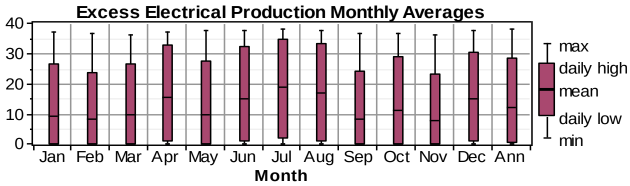

Figure 3. Excess electricity from renewables

4. Conclusions

A suitable combination of open sea fish cages together with a multiuse floating structure that accommodates wind turbine, photovoltaic panels, batteries, energy management system, fish monitoring devices and automatic feeding system can provide and environmentally friendly solution. Autonomous operation is very important in cases of prolonged bad weather conditions that do not allow transporting of fuel and feedstock. In this way, the advantages of open sea aquaculture can be explored without increasing operational cost, since the frequency of in-situ visits will be reduced and energy will come from renewable sources. The simulation showed that renewable operation is possible eliminating diesel oil transportation and consumption and at the same time improving product environmental footprint.

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