Design of an Integrated Offshore Farm with Renewable Energy Technologies

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Abstract: - Deep sea fish farming or mariculture becomes very prospective business for countries surrounded by the sea. In the nearest future mariculture will grow to billion industry that can provide half of all seafood consumed in the world. Certain marine species and fish can be successfully farmed, so producing valuable items for local or international markets. The waste from the sustainable offshore mariculture will be drifted by the ocean currents and will not affect the local ecosystem and will not cause buildup or pollution, as what usually happens with inshore aquaculture. Since the farm will be located offshore in deep waters it is required that the farm to be operated without human interaction and be able to internally generate required amount of energy to remain self-sustaining for a considerable period of time. As the development stages for this project, first the feasibility study of the design of self-sustainable oilrig platform was performed. Then, a conceptual 3D design of the offshore fish farm was created. The oilrig platform will be integrated with the tidal, ocean, wind and solar energy generation systems. Structural integrity of the farm design considering the influence of ocean currents and waves was also studied.

Key-Words: - Mariculture; Ocean energy; Offshore; Renewable Energy; Solar energy; Sustainable; Wind energy

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1. Introduction

Demand for seafood is always at its peak. The offshore fish farming is a game changer for fish production industry, as shown in Fig. 1 [1-2]. The process of these fish from ocean to farm and then to the table is one of an innovative process that could be studied more. Fish farming have been growing with large pace around the world. As per the research between 1998 to 2019 offshore fish farming have increased by 527% [3]. Off-shore fish farming have always been as one of the riskiest occupations. There are so many challenges faced by the people who works in this industry, the materials need to build the system in open sea, climate change, non-stop analysis of fish breeding and separation process.

Maintaining the whole system of fish farming is always a challenging work for those spend their time in this industry. The design of the fish cage is cylindrical making it more reliable in all direction, as shown in Fig. 2. Firstly, the fish are moved into cage and the farm consist of different sectors asper the size of fish and for analysing process. At the beginning all the type of fish will be in a single cage, later the fishes will be separated on behalf of their size and breeding style. Farmers uses a specific technique called image processing technique which helps them to scan and understand the size, biomass, and number of dead fishes in the cages using artificial technology including cameras and sensors and water temperature sensor [4-5].

Some of the challenges faced by this industry is hygiene, separation of fishes, balancing the pH contained in the water. When it comes to the food, the Fish feed depends on the type of the fish they farm, fish like salmon needs to consume a large amount of fish oil and fish meal. And when it comes to the normal fish feed, they use wild fish. For the past twenty years they have been using wild fish since it need only 15-20 % ingredients. The waste management is also a topic that must be discussed. Asper the research, a new solution has been disclosed a complete recycling process i.e., using the fish waste as renewable source. The new method proves that the uneaten fish food is falls into base and creating different elements including nutrients resulting in formation of Algae and mussels. These raw algae and mussel then can be collected, dried and, processed to fish feed.

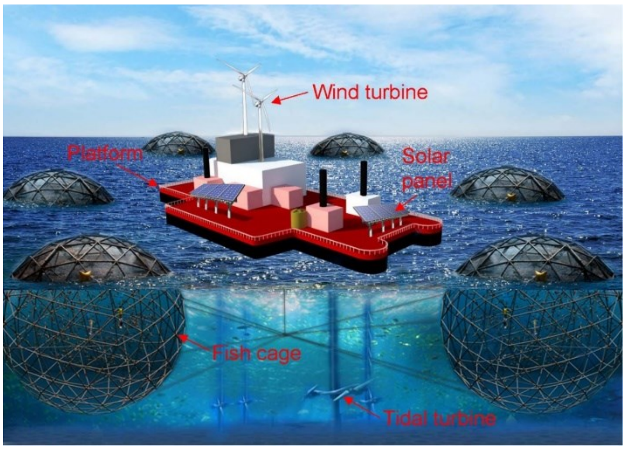


Figure 1. Integrated systems of renewable energy technologies for large offshore mariculture on decommissioned oil and gas platform

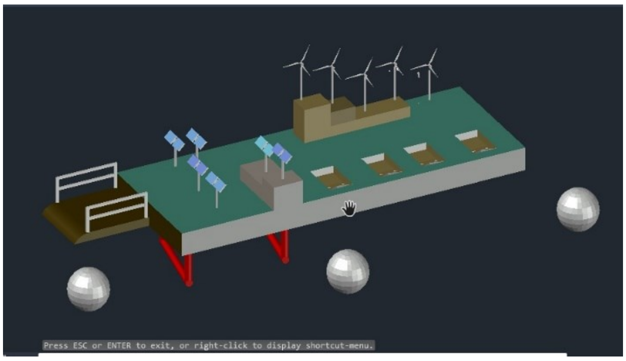


Figure 2. Design of Sustainable Farm With Cylindrical Fish Cage

The main objective of the project is to create a sustainable Fish farm that uses renewable energy and has automations in the process of fish feeding while being feasible, low cost, safe and have maximum functionality. Additionally, we are asked to reduce the use of transportation to and from the fish farm along with the reduce in use of fossil fuel.

2. Design Process

Function Decomposition Analysis (FDA)

In order to design the most efficient and desirable fish farm the technique of Function Decomposition Analysis is really helpful. As described in the below FDA flow chart (Fig. 3) we can easily identify the key components that are required to design a fish farm. As one if the design constrains regarding the fish farm is to make it as simple, low cost and maximum functionality the design of the fish farm was decided to be with a floating structure, with energy sources form solar, wind, and ocean current energy along with the transportation will be mainly driven on renewable energy in the form of solar energy [6-7]. Described below are all the selection criteria for the above discussed final decision.

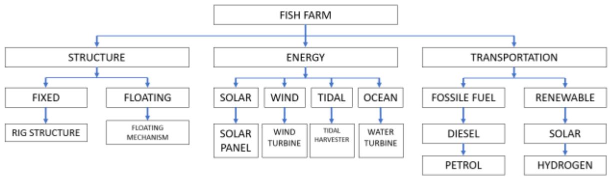


Figure 3. FDA

	Structure		Energy				Transportation	
	FIXED	FLOATING	SOLAR	WIND	TIDAL	OCEAN	FOSSILE FUEL	RENEWABLE
Functionality	4	5	5	4	3	4	5	5
Cost	2	4	5	4	3	3	5	4
Safety	4	4	5	3	5	5	3	5
Total	10	13	15	11	11	12	13	14

Figure 4. Feasibility Table

To summarize the above feasibility chart (Fig. 4), the final design will be based on a floating platform using solar, wind and ocean energy and the transportation will be based on renewable energy.

Energy Sources

As per research we have found that the most efficient forms of renewable energy in the ocean can be in the form of solar energy, wind energy, tidal energy, and ocean current energy [8-9]. As most of the energy from the sun, in the form of sunlight is abundantly and freely available in the ocean, solar energy is one of the best sources to extract energy from and produce usable energy in the form of electricity.

Alongside solar energy comes wind energy wish is also an abundant and untapped source of energy in the ocean. The average wind speed over the surface of the sea is greater than the average wind speed on land due to reduced friction and relatively less obstructions. The energy from the ocean's currents can also be one of the most ideal and clean sources of energy when the setting of the farm is situated deep into the sea [10].

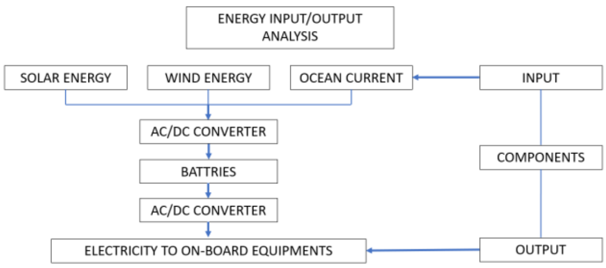


Figure 5. Input Output Analysis

As described in the above Input/Output analysis flow chart (Fig. 5), the energy sources that will be used for the fish farm will be mainly solar, wind and ocean current energy. All of these sources produce AC current which then needs to be converted into DC current which can be stored in the onboard batteries. As not all components in the fish farm will require DC current a second AC to DC converter is used to match the needs of all the equipment onboard such as sensors, lights, and onboard GPS system [11-12].

Final Design

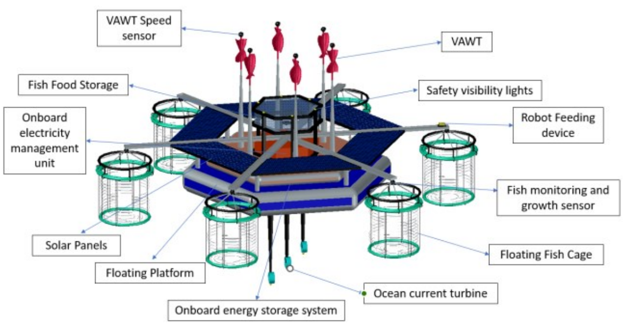


Figure 6. Final 3-D Design

The above and below images (Fig. 6-8) describe and showcase the design of the fish cage incorporating 6 320-watt 72 cell solar panels each and 6 vertical axis wind turbines for better stability and energy production in at times of absence of sunlight, 3 ocean current turbines along with a battery pack and electricity management unit that contains a generator, controller, AC/DC converters, sensor controllers and onboard GPS tracking unit. For the feeding system to be automated the design of a robotic feeding device was incorporated that is designed to take collect food from the central food storage unit to the specific cages at specific times.

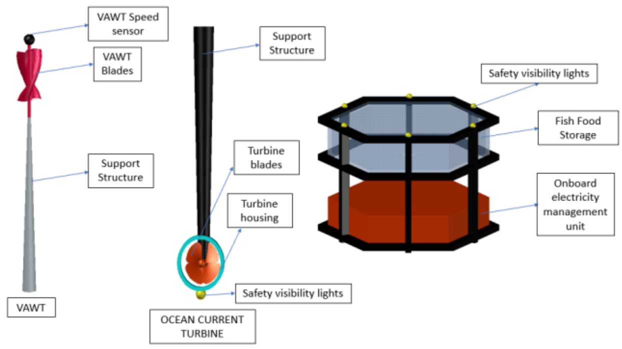


Figure 7. Turbines

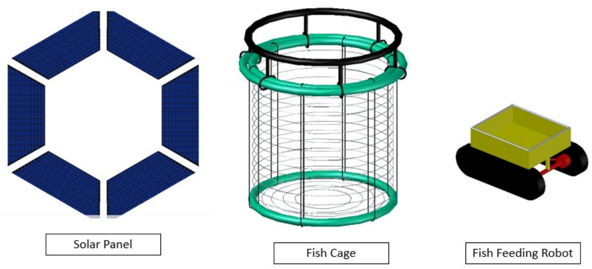


Figure 8. Feeding System

The fish monitoring system (Fig. 9) mounted at the top of each cage allows the users to monitor the fish growth in real time without the need to physically visiting the fish farm. This system uses the technology of infrared scanning to calculate the average size of each fish along with an estimated number of fishes in the system. This system also enables the user to have a look at the conditions of the cage and arrange maintenance schedules accordingly [13-14].

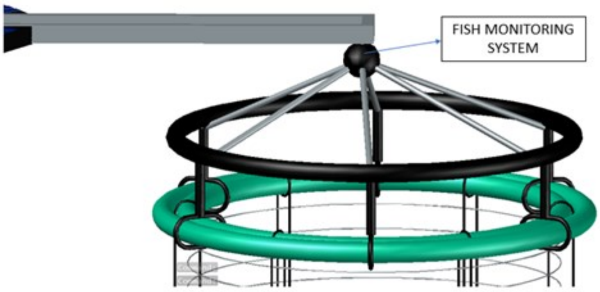
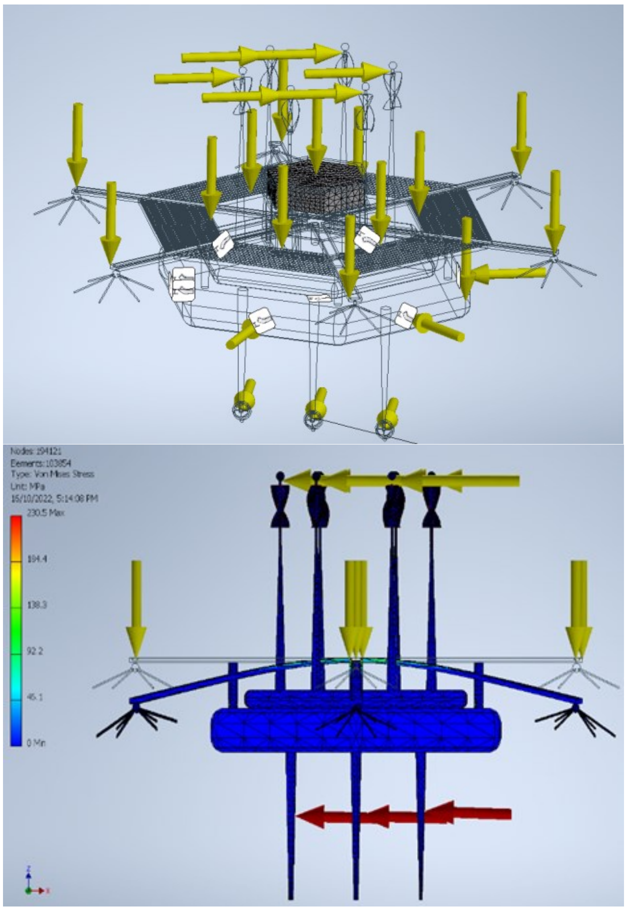


Figure 9. Fish Monitoring System

3. Design Simulation

The below images (Fig. 10] are visual representation of the simulation and safety analysis of the fish farm platform. The simulation was performed keeping in mind the various conditions that could be faces by the fish farm during the events of storms and huge waves.



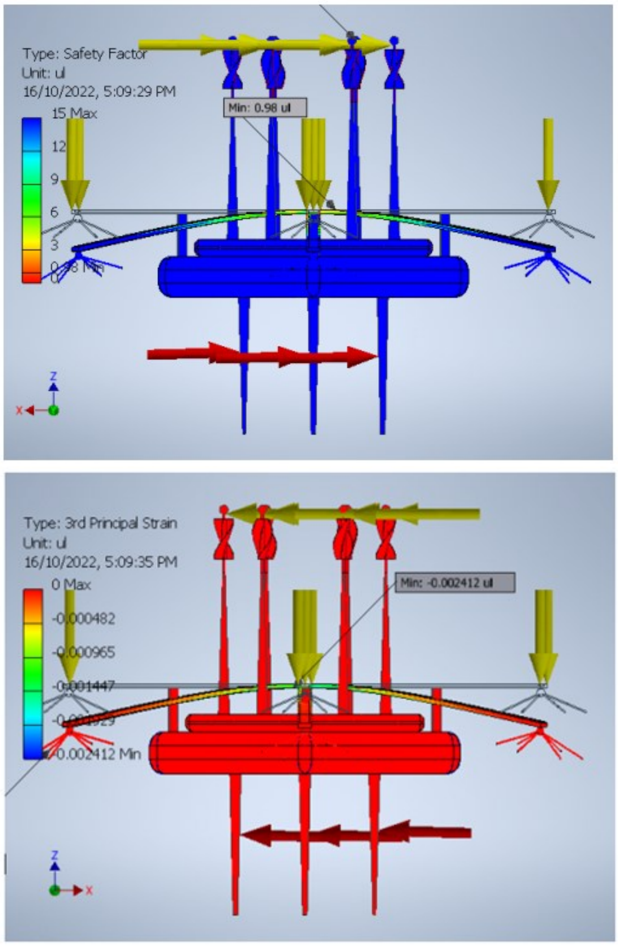


Figure 10. Simulation and Safety Analysis of the Fish Farm Platform

The safety factor for the entire system was found to be 2.87. This is a good value keeping in-mind that the system is designed to be floating which subjects it to multiple dynamic motions and movements throughout the system. The system is restricted to move or displace from its original position in the sea by anchoring the system to the seabed. With we are able to achieve a relatively fixed location without the need to build a physical structure to the seabed.

Another advantage of the floating system besides being cheap and easier to setup, it can be relocated without much of a hassle. This allows us to setup the fish farm in various regions depending on the season and environmental conditions, therefore allowing to have a better yield of the fish farm process [15-16].

The automation of the feeding system using a robotic device that collects the food from the main food storage to the respective food tank makes it much easier to monitor and control the fish growth. The automatic feeding system combined with fish growth monitoring system mounted on each fish cage allows the users to yield the best quality and quantity of fish and also send hazard signals in the case of cage net damage or potential external threat.

4. Energy Analysis

Solar Energy

The solar panels used in the fish farm design are designed to produce an average power output of around 320 watts under ideal conditions. These solar panels are arranged in a configuration to a hexagon for maximum power output (Table 1).

Table 1. Solar Energy Data

Rated Power Output	Size	Weight	Quantity	Total Power Output
320 watts	39X77 inch	25 kg	166 Units	53.34 kW

Wind Energy

The use of wind energy can be harvested during night or stormy conditions under which the solar energy is not available. The design of the vertical axis wind turbine allows it to capture air for all directions from a fixed location while being relatively safe as the axis of rotation is vertical and does not incorporate the use of blades while also being relatively stable, light, and cheap to design. The use of VAWT speed sensor allows the power output from the VAWT to be regulated or totally cut-off during stormy conditions as overspinning of the blades can cause structural damage as well as over voltage in the system (Table 2).

Table 2. Wind Energy Data

Rated Power Output	Blade Size	Weight	Quantity	Total Power Output
8 kW	3.5 meter	250 kg	6 Units	48 kW

Ocean Current

The energy generation from the source of ocean currents is one of the most innovative and untapped sources of energy [17-18]. The energy from the current or flow of water under the sea level or deep in the ocean can be harvested and can be one of the most reliable and clean sources of energy. This system can be used as a back-up energy source (Table 3).

Table 3. Ocean Energy Data

Rated Power Output	Turbine Size	Weight	Quantity	Total Power Output
3-5 kW	3 meters [D]	250 kg	3 Units	9-15 kW

Energy Analysis Summary

The onboard battier pack is rated to store up to 100 kW worth of energy. The electrical system is controlled and monitored by onboard controllers and sensors.

An average household consumes around 30 kW worth of energy in a day, therefore by taking this as a baseline value we can assume that the energy produced by the system is sufficient enough to provide power to the fish farm to operate as per desire (Table 4).

Table 4. Ocean Energy Data

Energy Type	Solar Energy	Wind Energy	Current Energy	Total Power Output
	53 kW	48 kW	9-15 kW	68-62 kW [Day] 57-55kW[Night]

5. Alternative Transport Solution and Fish Farm Layout

As per the problem statement and design constrain, it is necessary to reduce the use of fossil fuels and transportation in general. The onboard bulk food storage (1 ton storage capacity) provision and use of sensors for fish growth and fish cage monitoring system for maintenance is a way to reduce the need of transportation.

As to reduce the use of fossil fuel a solar powered boat is designed, equipped with GPS and autopilot system to reduce the need of human interference. The boat is designed to carry cargo to and from the fish farm to transport things like fish food and the grown fish as well (Fig. 11).

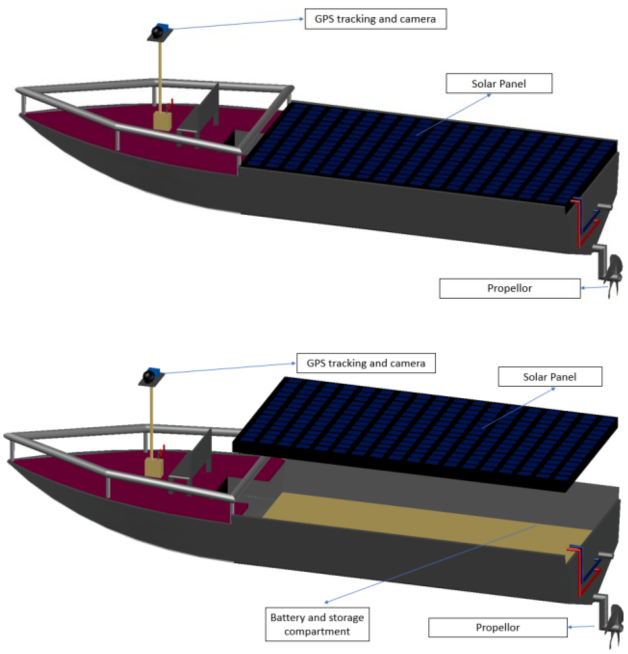
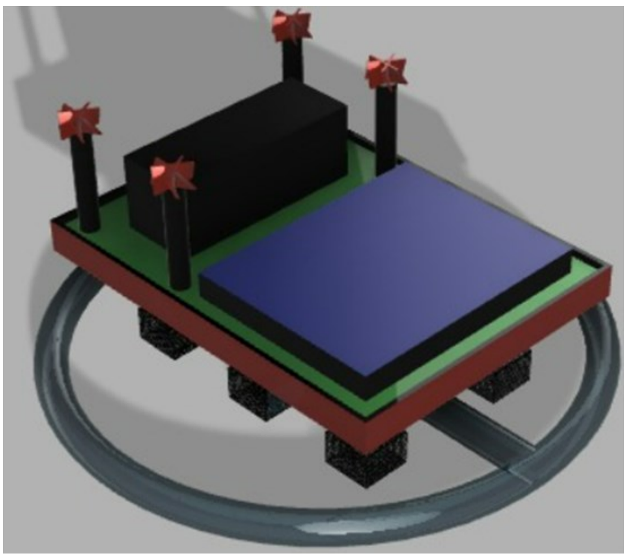


Figure 11. Solar-powered Boat

This is an alternative design (Fig. 12) of the fish farm with similar concepts and energy sources [except for ocean current energy]. This design incorporates a distinctive feature of having a under-water glass tunnel that allows visitors to explore the fish farm procedure and the growth of various fishes with an under-water experience. This way we can also make the fish farm as a tourist destination from which money can be generated to run the farm itself.



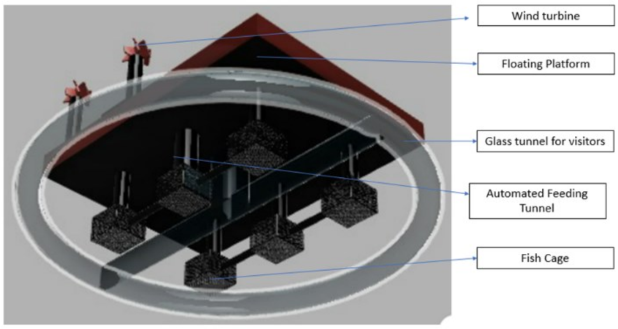


Figure 12. Alternative Fish Farm Design

6. Conclusion

- The sustainable offshore mariculture seeks to minimize transportation costs and fossil fuel use.
- Complete fish farm system integrated with the alternative energy generation system (tidal, ocean, wind, solar, etc.) was designed.
- Mini power stations and generators will be installed on the platform to convert tidal, ocean, wind and/or solar energy into electricity.
- Detailed design of system components (fish cages, automatic feeding system, energy storage system, fixation mechanism, etc.) was provided.
- Farming fish will require regular feeding. The farm will be equipped with the new technology for the long-term storage of feed. The combination of the remote sensing and automated fish feeding system will make the offshore farms both more feasible and economical.
- Structural analysis of the farm design considering the influence of ocean currents and waves was conducted.
- Detailed engineering analysis of the system with optimization in terms of Factor of Safety, Cost, Functionality and Simplicity was provided.

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