Under Water Energy White Paper Rough Draft

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Contents

Abstract

This should be the document.

1 Managerial

1.1 Introduction

This project aims to design an electric energy harvesting system for dead oil platforms in offshore locations using water currents as a source. These oil platforms are typically xx kilometers away from the coast, where the water depth is xx meters. The power requirement for the basic functions of a dead oil platform is in the order of 100 kW. At present there are xx oil platforms located in offshore locations. Of these platforms, xx have ceased functioning. However, the cost of dismantling them is so high that it is preferable to leave them at their locations. Therefore, the necessary energy to sustain basic functions, such as lighting, must be provided by refueling them every xx months. Removing this requirement by enabling these platforms to be energetically self-sufficient will reduce the cost associated with their maintenance. The first requirement for the proposed system is to deliver the necessary power for the basic functions of the oil platform. As part of this requirement, issues concerning variable supply or demand of energy must be addressed by creating some form of energy storage that will accumulate energy during excess periods and supply it when needed. The second requirement is to minimize the cost of the energy generated. The cost will be considered to include manufacturing, delivery to the site, start up, maintenance over its lifetime, shut down, retrieval and disposal. This requirement might set up conflicting requirements such as manufacturing simplicity versus operational reliability. The third requirement is an environmentally friendly system.

1.2 Motivation

Having to refuel offshore sites requires deep sea travel. Such travels are expensive and dangerous. Self-powered oil platforms allow for remote monitoring while maintaining essential functions. Thus, travel becomes necessary only in the case of an emergency or at scheduled maintenance intervals. This greatly reduces the cost associated with dead oil platforms. The field of electric power generation keeps gaining importance as more regions around the world obtain their electric power from renewable sources. However, the field of energy harvesting from water sources, other than dams, is relatively new. There are a few companies that have designed and deployed turbine-based systems to harvest water flow energy. As of the writing of this document, only one design attempts to harvest energy at an offshore location, and this particular design requires large startup cost in order to fix the generator on the seafloor. The design of a cost effective, easy to deploy, water current generator will have a strong impact in the field. The energy present in the movement of sea water around an oil platform is larger than the energy required to maintain the essential functions of the oil platform. [Public image, Political reasons, Environmental benefits, Importance of fundamental research, Education benefits, Advancement of fields, Possible future applications]

1.3 Deliverables

The deliverables of this project consist of the definition of the necessary requirements to achieve the projects goal. Those issues and variables which affect the requirements will be identified. Competing harvesting technologies will be analyzed based on the requirements. The family of systems capable of fulfilling these requirements will be specified. A particular novel system will be proposed which exceeds the requirements. Detail design regarding said system will be included, including the design of a mechanical system capable of turning fluid motion into mechanical motion, an electromechanical transducer which will convert mechanical into electrical energy, and an energy storage system which store the excess energy and deliver it when the source does not provide enough power.

1.4 Extension of research

JOMM wrote: An effective current flow energy harvester can be adapted to power microsensors attached to marine wildlife, enabling longer lifespan and greater range of these sensors. The amount of energy harvested can be increased in order to produce fuels such hydrogen, oxygen and liquid nitrogen. A novel method of capturing the flow can be reversed to create a new type of water propulsion system. JLM wrote: Unused oil platforms powered by renewable energy are an excellent resource for marine scientists and engineers. Boat time is perhaps the mostly costly component of ocean research expeditions. In cases where scientists or engineers need a ship to travel to and stay at one spot for an extended period of time it may save a lot of money to instead use the ship only for traveling to and from an oil platform. Then the scientists or engineers can do their research while living on the platform. For example, in researching ocean power technologies a group of engineers could install several different technologies on and around the platform and then assess and maintain the devices as needed as they live on site for a period of time.

Ocean power technologies developed for obsolete oil platforms could also be implemented on a working platform, decreasing the platforms energy costs and environmental effects. Moreover, beyond powering platforms, the research conducted will greatly contribute to the field of renewable energy technology. Technologies developed for this application will be valuable prototypes for larger-scale ocean power generation projects. In a future where renewable energy may be the primary method for addressing the worlds energy needs, developing ocean power technologies now is an important and necessary step.

ED wrote: Capturing energy from the motion of the ocean segues to areas of research that demonstrate the scalability of the technology we intend to develop. Opposite the macro, megawatts scale of harvesting energy is the venture of developing devices to capture energy in the micro-scale regime of milliwatts from movements of the oceans inhabitants.

One such idea is the concept of harnessing the energy of an animal as it swims through the waterin essence turning the animal into a power plant to power monitoring tags and other devices currently used by scientist to study pelagic animals. Provided the animal is sufficiently large and provides a critical minimum amount of convertible mechanical energyfrom either flow around the body or body movement this seems plausible. Such a power supply could replace the batteries found in current acoustic, satellite or pop-off archival transponder tags relied upon to study aquatic life absent from our gaze. Used in concert with existing methods, such a tool could expand the range and depth of understanding by gathering more and new types of data for longer periods of time.

There are several animals large and powerful enough for this method to work quite well e.g., certain species of shark and tuna known as obligatory ram ventilators must always be swimming at some minimum speed so to pass a sufficient amount of water through their gills. However, it seems reasonable that with specialization this method could be used to provide power for monitoring marine life of a variety of shapes and sizes. Such developments could offer advances in the field of remote ocean sensors. They could also have military applications.

2 Technical

2.1 System diagram, definitions, metrics

JOMM wrote:

Figure 1 shows a system diagram of the proposed system. It describes an autonomous device capable of capturing the energy from an underwater flow of current and converting this energy into regulated electricity for use in an oil platform. Throughout this project, different designs and technologies will be analyzed and compared. The usual metrics used to qualify the performance of these devices are the power or energy density, which measures the power or energy per volume for a given device, and/or specific power or energy, which measures the power or energy per mass. Another common metric in energy systems is the efficiency defined as the amount of energy obtained from a particular device versus the amount of power sent into the

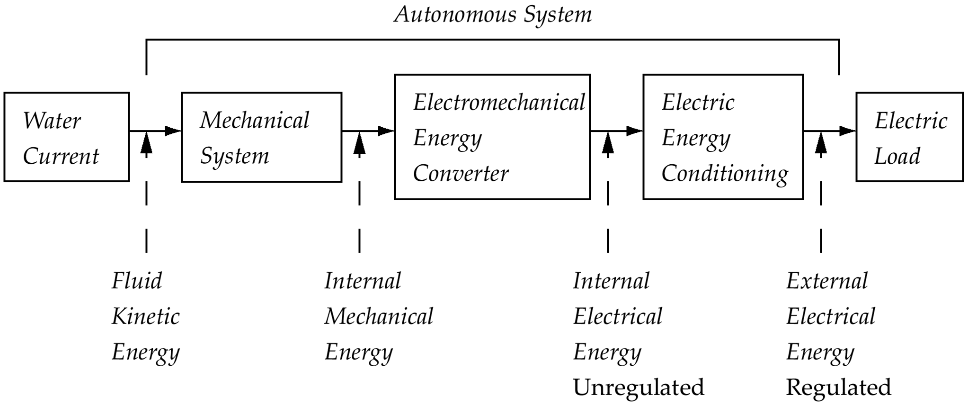

Figure 1: **add caption here**

device. TTT wrote: This section will outline a diagram of the system, definitions of the different terms used throughout the paper (nomenclature), and the main metrics we are considering. I think that having the nomenclature spelled out at the beginning is one of the easiest ways to include the terms precisely and succinctly, but some people don't like the idea so we should discuss it. For the purpose of a white paper it may be a bit of an overkill and more applicable to a full on proposal.

Nomenclature

η = Capacity factor = $\frac{powerobtained}{possiblepowerobtained}$

η = Effeciency $\eta = \frac{Totalpowerobtained}{Totalpoweravailable}$

a = Amplitude (m)

λ = Wavelength (m)

f = Frequency (Hz)

ρ = Water Density (kg/m^3)

ω = Angular frequency

T = Period

k = Wave Number

C_p = Phase Velocity

C_g Group Velocity

KE = Kinetic Energy

PE = Potential Energy

Λ = Energy Flux

P = Power

FIGURE OF THE TRANSFER OF ENERGY to come later ($Source- > Mechanical + Losses- > Mechanical + losses- > Electrical + Losses- > Storage- > Useableenergy$)
Caption:Here I will put in a diagram of how the energy could be extracted.

A device is placed in water or air that is forced into an oscillation of some sort. Possible methods of oscillation are rotation (i.e. turbine), up and down motion (i.e. wave sensitive device, flapping foil, etc.). The oscillation converts incoming energy from the waves, wind, water currents, etc. into mechanical energy. The mechanical energy can then be converted into electrical energy, which will charge batteries and store the energy as needed. It is also possible that the energy from the waves, water, wind, etc will be stored first as in the case of a tapered channel or oscillating water chamber (OWC).

In order to know the optimal design to harvest power for an oil rig some essential components of the environment must be understood. The available power must be calculated. This is done by studying the capacity factor, which is equal to the total possible power being input through the system divided by the possible power that can be obtained. For solar energy this means the total power that could be obtained (i.e. assume no clouds etc.) and the possible power obtained (i.e. exclude nighttime, cloudy days, etc). This is then combined with the mechanical efficiency and electrical efficiency to determine the overall efficiency of the system. From this one can determine whether the proposed system would power the needs of the plant. The environment will also dictate which systems are more beneficial. If the currents are constant in direction and speed for most of the year then the system may be more efficient if a turbine is used than say a flapping foil. This study would look at such issues to determine the most suitable technology to power a station like this one.

2.2 Means / Opportunity

JOMM wrote:

1. Natural energy sources; theoretical calculation of available energy
2. Theoretical approach to reality: back-of-the-envelope (zeroth-order) analysis shows order of magnitude numbers; fluid to mechanical, mechanical to fluid storage, mechanical to electrical, electrical storage, other storage
3. Experimental approach to reality: existing technology, development trends (foreshadow or quote background to be presented in next section)

4. Both approaches converge to the goal requirements

TTT wrote: Since the team of scientists specialize in theoretical and experimental approaches to solving energy needs like this one, the team can combine the resources of both to ensure that the solution is well studied and understood. Theoretical models include both analytical and numerical approaches and can be used to determine the feasibility of prototype and initial design phases. As the work moves into specific applications of various technologies the theoretical models can model specific features and produce feedback about how to maximize electric output. Once proven, these models can then optimize the system output by being implemented into real time feedback loops to ensure maximum electrical productivity.

Experimental procedures tend to illuminate subjects that are not easily modeled by theoretical predictions. Systems like the one proposed here will require some experimentation to overcome problems quickly and accurately that are not readily solved by the theoretical models. MIT in conjunction with the other facilities mentioned is well adapted to performing the necessary experiments, which may include a variety of things from complex fluid flow analysis in the MIT water tunnel facility, to corrosion testing in WHOI's pressure chamber. Experimental approaches to problems also utilize information that is already available to scientists from previous work. The existing technologies presented in the background section have collected data and analyzed performance previously. Studying this analysis can help facilitate cutting edge research and help develop existing technologies into specific energy solutions for off-shore structures.

A viable system for electrical self sustainment of off-shore structures should be analyzed by combining theoretical predictions with current cutting edge technologies and studying the two with key experiments as needed.

2.3 Background

Scientists and engineers, especially in Europe, have been exploring ways to exploit the enormous amount of energy in ocean tides, currents, and waves since the 1960s. In the 1970s as a result of oil shortages research into ocean power technologies picked up significantly. Numerous patents were granted as many universities and companies began to develop prototypes of renewable energy systems to harvest power from the ocean. Unfortunately, the majority of these systems soon proved unrealistic and unprofitable. Wave energy systems were often hindered by the shear size required of the device to produce reasonable amounts of energy. Meanwhile the development of marine current energy systems was halted by the logistics of installing and maintaining systems in areas of high current flow, in addition to transmitting the power from remote locations. Recently, advances in power transmission, energy conversion efficiencies, and advanced materials development, in combination with higher fuel and electricity prices has caused the reemergence of research in ocean power technologies. Again European countries have taken the lead in the development of these technologies, and for the most part research has been focused on feasibility studies, prototype design, and device assessment.

Tidal power technologies generally rely on the use of marine turbines to capture power from water flow. One of the first and largest tidal power systems is the La Rance Tidal Power Plant, in Brittany, France. Built between 1961 and 1967 the power plant uses a damn at the head of a tidal bay to capture high tides, which are then focused and drained through turbines. To this day La Rance still powers around 200,000 homes. Unfortunately maintenance costs have plagued the system since the beginning, which is probably why this technology has not been exploited throughout the world. However, several companies such as Blue Energy (Canada), Tidal Hydraulic Generators Ltd (UK), and Woodshed Technologies (Australia) are currently working on creating low maintenance advanced turbine systems, which are easier to service, in an effort to make tidal power a more promising renewable energy option.

Other companies are developing turbines/propellers to harness the energy in marine currents. Though it is possible, it is a very difficult task to focus marine currents in order to create high enough flow-rates for traditional turbines. Therefore, companies such as Marine Current Power (UK), Verdant Power (US), and SMD Hydrovision (UK) have focused their research on designing special turbines/propellers optimized for low-speed conditions. Another company, The Engineering Business Ltd (UK) has taken a different approach and designed a device called the Stingray, consisting of a hydroplane that connected to a fixed structure through a hydraulic joint. The hydroplane oscillates as the water flows past it powering a generator. After four years of work the company recently stopped research on this project due to its projected unprofitability. Unfortunately, due the remoteness of many high-velocity marine current sites, all of these technologies still struggle with efficient power transmission and low-cost machinery maintenance.

There are many different ways to extract wave power from the ocean. The first of these involves focusing waves with a tapered channel. The focused waves rise higher than the surrounding waves and can crash over a fixed barrier. The water behind the barrier is therefore at a higher potential than the ocean and can be drained through a low-head turbine for energy generation. Companies in both Norway (TAPCHAN) and Java, have explored this technology in locations where natural features provide the majority of the tapered channel structure.

Another way to harvest wave power is by using an oscillating water column (OWC). An OWC is composed of a chamber placed halfway within the water. The bottom of the chamber is open to the ocean and the top is composed of one or more turbines. As the waves cause the water level to rise and fall within the chamber the air is forced through the turbines, generating power. A system of valves can be used to ensure that the turbine spins in only one direction. Alternatively, a pair of counter-rotating turbines can be used. Both fixed and floating OWC devices have been developed. Daedalus (Greece) and Wavegen (UK) have both built and implemented fixed OWCs. Wavegen, probably the leading OWC developer, is now working on a large-scale project to install an enormous fixed OWC within a coastal cliff on Faroes Island. This project will entail digging out part of the cliff to create the water/air chamber. Other companies such as ORECon (UK), in addition to the Japanese Agency for Marine Earth Science and Technology (JAMSTEC) have developed floating OWCs. JAMSTECs Mighty Whale is not only used for generating power by eating waves, but also for providing a serene, wave-free environment downstream of the device that is ideal for water sports.

A third method for extracting wave energy is by using a series of hydraulically connected floating rafts. As the rafts move relative to one another the hydraulic fluid is pumped back and forth and this forced motion can be used to generate power. This method of power extraction was first envisioned by Sir Richard Cockerell in the 1970s. However, significant advances in materials and hydraulic control systems have only recently made this technology a realistic prospect. Ocean Power Delivery Ltd. has spent the last five years developing Pelamis, a 150m long device that looks like a sea snake. Its three joints connecting its four discrete sections derive power from the roll and pitch of the device as it follows the waves. The Pelamis has been thoroughly tested in the North Sea and recently the company earned its first contract, from the Portuguese government.

A final significant method for wave power extraction is through use of a linear generator. Usually, these devices consist of two structures, a fixed internal unit and a floating hood. The fixed unit is tied to the seafloor and contains a large permanent magnet. The floating hood is free to heave and consists of a wire coil wrapped around the circumference of the hood. As the hood bobs up and down with the waves over the magnet an electrical current is produced in the coil. If the natural frequency of the system is tuned to the average wave frequency resonance can be achieved. Two companies have been working on this technology: Wave Power Technologies (US) and Archimedes WaveSwing (Netherlands).

(Sorry, I still need to throw in pictures and references. I found/computed of power statistics for many of these technologies how many/what kind would be good for this paper? JLM)

2.4 Scope

Many of the ideas pertinent to extracting energy from the movements of the ocean have existed for years. However, not until recently has it started to emerge as an enterprise with a clear future and place in the worlds energy market. Our intended research will not only aim to provide power to oil rigs, but will offer a medium for developing ocean energy technologies that will have a greater utility and range of application.

The solutions for powering ocean platforms from sources in the local ocean and atmosphere will be focused on honing existing technologies and developing new engineering solutions. In contrast to other means of energy procurement, the processes and systems for extracting energy from the ocean are nascent. While larger scale efforts have begun on these and related efforts in Europe such as the Seaflow project conducted off the coast of the Britain by the UK and German governments, there exists to date only a modicum of industrial and government funding in the United States for such efforts.

Many of the present limitations, inefficiencies and problems subsumed in the process of extracting energy from the ocean are a result of its seminal stage. Naturally, as more research is directed toward solving the current problems afflicting these technologies, the overall progress, efficiency, and lucrative nature of these endeavors will increase.

The engineering tasks we plan to focus on, beyond their immediate application of supplying power to oil platforms, will join the body of technology and science that have coalesced around the problem of extracting clean energy from the environment. While these solutions and benefits will be directly applicable and suited to your needs, they will also lend benefit to increasing the efficiency of other ocean energy systems.

Guided by the particulars problems posed by your application, you will benefit from a specified and considered heuristic process geared for your use and benefit. Although our aim is to conduct academic and engineering research, it will be guyed by the applications and promise of providing power to platforms from local ocean and atmospheric sources. With the ultimate goal of producing sound engineering solutions to be integrated with your platforms, this variety of research offers a unique boon to your companys benefit.

Our focus, aside from goals of innovation and improvement, will be shored by an acute awareness of how our work contributes to the larger and critical issues of yield, efficiency, reliability, required maintenance, associated costs and their pluralities. We will work under the maxim that a good engineering solution is also a fiscally viable one that assumes feasible manufacturing, installation and maintenance costs. Ameliorations will be made by exploring the arena of known and unknown failure modes, focusing on new materials and conceptual design to extend life-time and reduce costs. We will also aim to address current reliability issues centered about the common ocean structure failures of brittleness and fatigue, scour, dynamic and static loading, erosion, fretting, corrosion and bio-fouling. Our strong and variegated background will ensure competence and completeness in these enterprises.

Concomitant with our aim of maximizing the efficiency of existing mechanisms and developing new energy harvesting methods will be our concentration in optimizing the overall energy harvesting process. Critical properties of ocean energy sources like waves and currents vary over time. By focusing on the development of systems that sense and adapt in real-time to the inherent fluctuation of an energy source by continually tuning its mechanical and electrical properties to its environment to optimize efficiency we can increase the overall efficiency of such a system and thus increase energy capture. While this research in optimization will be developed for applications appropriate to ocean platforms, these advances will be an article of value to future technologies of similar application and scope.

3 Logistical

3.1 Qualifications / Means (How are we doing this? What makes us qualified?)

Woods Hole Oceanographic Institute is the largest independent oceanographic institute in the world. It has three large research vessels allowing access to the open seas, full testing facilities including a twenty-thousand psi pressure test chamber, complete machine, welding and metal fabrication shops and over 130 full-time scientists and engineers. It is located directly on the ocean providing the unique ability to easily essay objects in an marine environment.

The team working on this project includes Alexandra Techet, Professor of Ocean and Mechanical Engineering at the Massachusetts Institute of Technology in Cambridge, MA, Jose Oscar Mur-Miranda, Visiting Assistant Professor of Electrical and Computer Engineering at the Franklin W. Olin School of Engineering in Needham, MA, and Rich ¡title¿. Graduate (?) students working on this project include Tadd Truscott (MIT), Erik Dawe (WHOI) and Johanna L. Mathieu (MIT). Extra undergraduate students will be hired from both MITs and Olins undergraduate population.

The facilities at the disposal of the team include Prof. Techets laboratory and computing facilities at MIT, as well as assorted machine shops with various capabilities at MIT and Olin. Extensive maritime equipment can be obtained at WHOI. The Maine Maritime Academy has test locations suitable for testing the designs.

3.2 Timeline (Gantt chart)

- Background and state-of-the-art research
- Feasibility studies
- System design
- Prototyping and testing

3.3 Budget

4 Conclusion