Energy harvesting in underwater environment

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1 Abstract

Energy harvesting is becoming increasingly common and really useful for every kind of embedded system, from wearable devices to environment data extraction. Developing a good harvester system is not easy, but it is necessary in order to open new doors in the field of embedded systems. One environment that has not been thoroughly studied yet is the underwater world. Given the increasing interest in this field, I would like to create a module able to provide the energy needed for operation. In this way I will open doors to new opportunities in the sea. I'm also interest in developing it to give an alternative to batteries, usually not environment friendly.

2 Problem statement and objectives

My problem to resolve is to provide a harvesting module suitable for underwater environment. In particular I narrow down the field on the first 3 - 40 meters of the sea. The device that I want to develop is intended to serve as a substitute of a battery in embedded system. So the hardest part is managing the power extract because it has not create peak of power (both high and low level). I identify the following objects and steps to help me develop the module.

- Objective 1 : estimate in the worst case, the mean consume in a embedded system with at least one communication tool, one CNN module, one Microprocessor and two or three sensors.
  - Step 1.1 : find three popular embedded system with these specifications. It will help me to define boundaries.
  - Step 1.2 : find and analyze the datasheets. It will help me to understand the usual electrical behavior of the chosen devices.
  - Step 1.3 : write a final report that can summarizes what I find and my consideration about. It will help me to have a clear vision of the work done.
- Objective 2 : study the current state of art for harvesting tools for underwater that use mechanical energy as source of energy.

  - Step 2.1 : learn a bit about electrical motors, piezo materials, energy converter. it will help me to analyze and understand better future researches.
  - Step 2.2 : find and analyze the common mechanical way to extract energy. It will help me to understand the usual way to get electric energy.
  - Step 2.3 : find and analyze the technology in underwater to get electricity. It will help me to understand the differences compared to generating electricity out of water, and the main difficulties in this environment.
  - Step 2.4 : find and analyze the devices for energy harvesting underwater. It will help me to start with some work already done in order to speed up my project.

- Objective 3 : resume what I studied previously and design multiple projects with different settings and principles.
  - Step 3.1 : divide the material studied (for Objective 2) by operating principle and write brief descriptions of the principles.
  - Step 3.2 : create a summery table with the key characteristics of all the devices.
  - Step 3.3 : identify the best solution of each group.
  - Step 3.4 : improve every concept, if possible, with simple ideas

- Objective 4 : find the best customized project to allow the normal functionality of the system studied previously. If different designs are suitable I will choose the easiest to build.
  - Step 4.1 : eliminate any project that is too large in size, produces too much or not enough energy, is too invasive.
  - Step 4.2 : understand how the device can be built and how difficult it is.
  - Step 4.3 : estimate the cost and availability of the material.
  - Step 4.3 : create at least four sorted lists based on: the estimation cost of the material, the availability of the material, the difficult of assemblage, device's fragility.
  - Step 4.4 : individuate the best tradeoff between the items in the lists and choose the final device.

- Objective 5 : build the module.
  - Step 5.1 : create a checklist of material needed for create the device.
  - Step 5.2 : create a checklist of material useful for the building process.
  - Step 5.3 : check already available material in the company's warehouse.

  - Step 5.4 : verify if it is possible to use that material instead of other specific materials.
  - Step 5.5 : order unchecked material.
  - Step 5.6 : plan a way to assemble the project.
  - Step 5.7 : create the prototype.
  - Step 5.8 : analyze what done and find the fragility in the module.
  - Step 5.9 : resolve the fragility.

- Objective 6 : evaluate and characterize the device outside of water.
  - Step 6.1 : find a solution to emulate the movement that is used to create energy.
  - Step 6.2 : if the emulator is not available build it.
  - Step 6.3 : attach the emulator to the device.
  - Step 6.4 : test the device by applying different settings on the emulator (i.e. speed, frequency, amplitude, forces).
  - Step 6.4 : collect all possible data during the testing phase using an easy board with a Microcontroller, an ADC and memory.
  - Step 6.5 : analyze the data and show it in the form of tables and graphs.
  - Step 6.6 : write a report on the data analyzed. Highlights the best and worst points illustrating it with the data.

- Objective 7 : evaluate and characterize the device in water.
  - Step 7.1 option A : find a location where to install a pool
  - Step 7.1 option B : find a location where to test it in water, such as a small lake or swimming pool.
  - Step 7.2 : find a way to recreate the water movement that is used to create energy.
  - Step 7.3 : install the water mover and build a environment similar to the ideal spot for the device.
  - Step 7.4 : install the device.
  - Step 7.5 : leave the device for at least one day (24 hrs).
  - Step 7.6 : recover the device.
  - Step 7.7 : repeat steps from 6.4 to 6.6.
  - Step 7.8 : repeat from obj 7.3 in a non-ideal environment for the device's operation.

- Objective 8 : if there is a lot of time, repeat with other variants or try to improve the efficiency.

- Objective 9 : merge all test report into a single result and compare to what was studied for Objective 2.
  - Step 9.1 : merge all test reports.
  - Step 9.2 : compare it to the report written in Objective 2.

3 Required topics to review

For the theoretical understanding, I need to complete the read up and document the following topics: energy generation using electromagnetic properties, ocean waves, fluid dynamics and statics. I would like to learn and understand the process from the idea of a device to prototype it, the electric motor as generator, the electricity management under water. Furthermore, I want put in practise all my useful previous knowledge as an electronic engineer.

4 Validation approach

For validation approach I decide to test the functionality of DUT (device under test) attaching to it another board composed by a Micro, an ADC, a memory and some sensor to measure the power of the movement used to extract energy. To simulate a normal device I close the harvester's circuit into a RLC (resistor, inductor, capacitor) circuit, and repeat the testing with different combinations. After the testing phase I want to summarize all the data in tables and graphs. My main idea is to relate the electrical power to the behavior of the movement. I would like to create a map where it is possible to show the characteristics of the mechanical motion and the extracted current or voltage. As final validation I compare my prototype to other underwater energy harvesters and identify the best feature to implement in a new prototype as starting device.

5 Moonshot (optional)

To complete the experience I would like to test my device in offshore environment for more than a day. To achieve this I should follow the following Objective and steps:

- Objective 7.1 : make the inspection of one possible zone
- Objective 7.2 : find a specific location where to install the device
- Objective 7.3 : install the device
- Objective 7.4 : leave the device for at least one day (24 hrs)
- Objective 7.5 : recover the device
- Objective 7.5 : analyze and process all the data as in Objective 6.

These can be the final demonstration of the value of the built device.

6 Your work legacy for the future world out there

As conclusive output, I share all the experience, and the work done into a final report where I want to summarize all my previous reports. I also want to include code used to collect data, the project design, the raw data and conclude with consideration about the developed device. This report will be uploaded to a github project with all the files that I used during the project.

7 Time plan and deliverable

The time plan is:

- 23 January 2023: start
- week 23 - 27 January: theoretical understanding and researching (obj. 1 - 2)
- week 30 January - 3 February: pause for exams.
- weeks 6 - 10 February: resume what done and start the design (obj 3 - 4)
- week 13 - 17 February: finish the design and start to build (obj 4 - 5)
- week 20 - 24 February: complete the build (obj 5)
- 27 March 2023: start lessons so I can not be a full time worker
- week 27 - 3 March : lessons and evaluation outside of the water (obj 6)
- week 6 - 10 March : lessons and evaluation out of the water (obj 6)
- week 13 - 17 March : lessons and evaluation in the water (obj 6)
- week 20 - 24 March : lessons, evaluation in water and final report (obj 7 - 9)
- 24 March: end date (final report submission - 9 obj.)