A FIRST VERSION OF STAKEHOLDERS'REQUIREMENTS FOR WAVE ENERGY CONVERTERS PLANTS

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INTRODUCTION

Wave energy converter (WEC) technology development as a whole has to date not yet delivered the desired commercial maturity nor, and more importantly, the techno-economic performance. Both commercial readiness and economic viability are required for successful entry into and survival in the market.

The ways in which WEC technology have been and are being developed have been analyzed in [1] and [2]. The key deficiencies with these approaches have been recognized and the fundamental requirements for successful WEC technology development have been identified.

- Technology development progress, technology value and technology funding have largely been measured, associated with and driven by technology readiness, measured in Technology Readiness Levels (TRLs). Originating primarily from the Space and Defense industries, the TRLs focus on procedural implementation of technology developments of large and complex engineering challenges where cost is neither mission critical nor a key design driver. In order to compensate for this deficiency, Technology Performance Levels (TPLs) have been introduced in [1] and further detailed in [2] as a techno-economic performance assessment metric for WEC technology. Possible further refinement of the TPL assessment methodology is the subject of another paper presented at this conference [3].
- WEC technology concept innovation has predominantly been driven by intuitive methods and expressed with respect to overall system concept ideas. In 2014, NREL and SNL started a project that will apply Innovation Techniques from System Engineering to innovate novel WEC technology solutions aiming to identify WEC technologies with high commercial potential. In this aim, it is essential to develop a **c**omprehensive specification of WEC functional requirements. This paper describes first results of this work.

To our knowledge, this work is the first attempt to formulate functional requirements for WECs at the wave energy plant level. In [4], functional requirements were formulated in the wave energy conversion context, but only for the mooring system. Even in a more mature industry such as wind energy, only one reference was found dealing only with technical requirements for grid connection of wind energy plants [5].

MISSION STATEMENTS FOR A WAVE ENERGY PLANT

First activity in functional analysis is to state the mission of the product, i.e the wave energy plant in our case [6]. Note that it is the wave energy plant that should be considered, not the wave energy converter unit, because most of the end-user will use wave energy plants possibly composed of many WEC units rather than a single isolated one.

According to [6], the mission statement describes the service that the product provides to the end-user by acting on the state of something. In the case of a wave energy plant, the “something” is obviously ocean waves. For the end-user, it can be a utility of course, but it can also be a fresh water supplier. Indeed, it has been proposed to produce fresh water from sea water and wave energy through desalination (see [7] for example). A third alternative end-user is a not-grid connected user (for example, an O&G offshore platform, an isolated science station of equipment). According to [8], wave-powered navigation buoys were commercialized in Japan as early as 1965. More recently, wave power is being used commercially for propulsion of an ocean sensor [9].

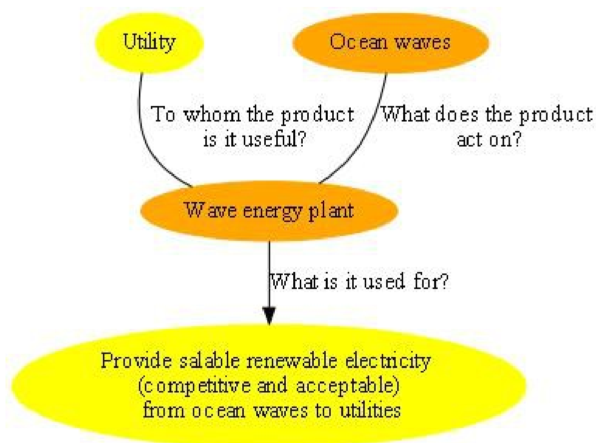

FIGURE 1. MISSION STATEMENT FOR A WAVE ENERGY PLANT IF USER IS A UTILITY

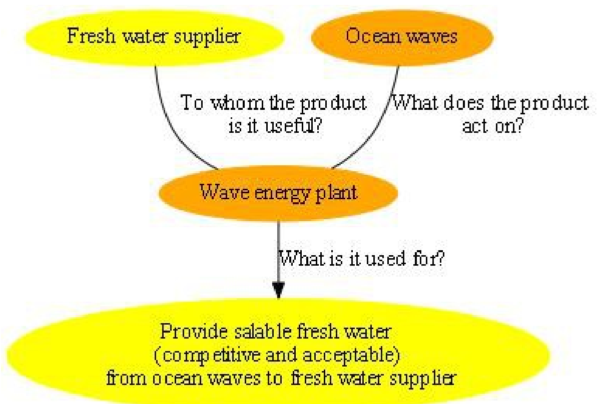

FIGURE 2. MISSION STATEMENT FOR A WAVE ENERGY PLANT IF END-USER IS A FRESH WATER SUPPLIER

The mission statements are different for the different end-users. They are shown in Figure 1 to Figure 3 for each case of end-user.

If the targeted end-user is a utility (Figure 1), the mission of the wave energy plant is to provide salable renewable electricity to utilities by converting ocean wave energy. Salable means two things: the produced electricity should be competitive with other renewable energy sources and it must be acceptable for all stakeholders. The first of these two things highlights the fact that wave energy technologies does not only compete against each others but also against other renewable energy technologies. It is believed that it is important to take this into account when developing a wave energy converter. Indeed, to become commercial, a wave energy plant that has the cheapest cost of energy of all wave energy plants still needs to be competitive with respect to other renewable energy solutions (i.e wind turbines, solar PV) at least in certain sites. Of course, local authorities may put in place financing schemes (e.g Feed-in tarriff) for wave energy plants for political reasons (creation of local jobs for example), but it remains crucial to minimize the difference in the cost of energy with other energy sources.

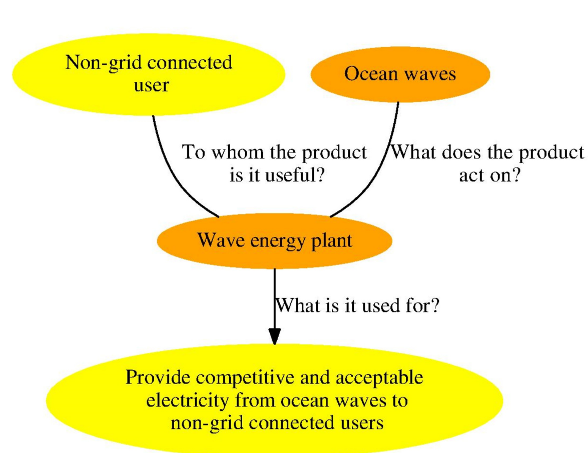

FIGURE 3. MISSION STATEMENT FOR A WAVE ENERGY PLANT IF END-USER IS A NON-GRID CONNECTED USER

The targeted end-user may be a fresh water supplier (Figure 2). In this case, the mission is to provide salable fresh water to the fresh water supplier. As in the case where the end-user is a utility, competing technologies that provides the same service must be taken into account. Note that in this case competing technologies should include the ones using non-renewable energy sources because, to our knowledge, there is no market distinction (support schemes, feed-in tariffs, subsidies, …) between fresh water production using renewable and non renewable energy sources.

If the targeted end-user is a not-grid connected user (Figure 3), the mission is to provide competitive and acceptable electricity. In this case acceptability is expected to be much less constraining than in the case of a utility scale wave energy plant. As for the case of fresh water production, competing technologies may include non-renewable energy sources. because renewable or non-renewable may not make any difference from the user perspective. However, other users or communities may choose renewable energy sources even if the cost of energy is higher than non-renewable sources.

LIFECYCLE OF A WAVE ENERGY PLANT

Functional requirements shall be specified at each stage of the lifecycle. Thus, a necessary step is to identify all these stages. Result of this work is shown in Figure 4. Phases of the lifecycle are described in the following.

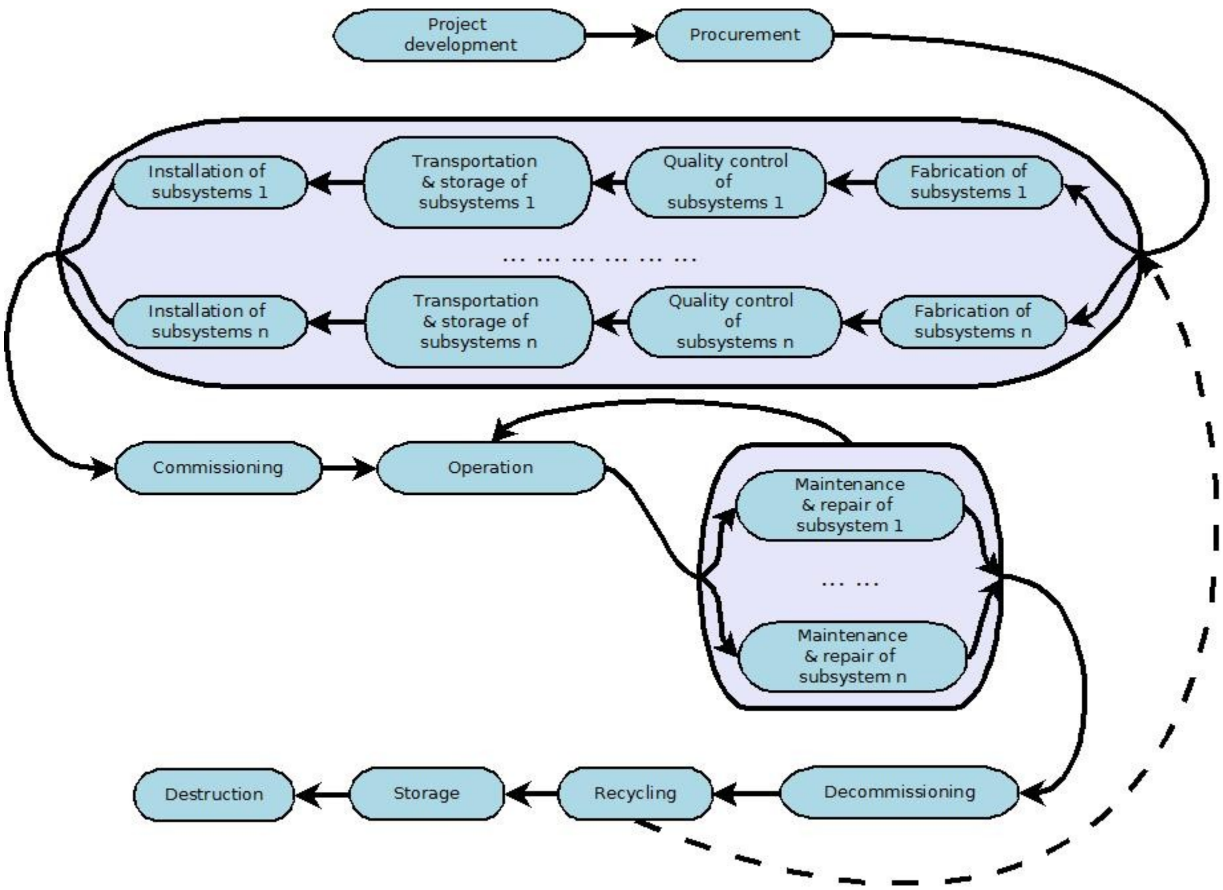

FIGURE 4. LIFECYCLE OF A WAVE ENERGY PLANT

Lifecycle of a wave energy plant starts with project development. In this phase, the most important activity is to find sites where the wave energy plant will be profitable for the investor. At the end of this phase, it is important to realize that technical specifications, budget and schedule are defined. Thus, in all activities carried out in the following phases of the lifecycle, a fundamental requirement is that cost & delays are kept on budget and schedule as defined in the project development phase.

Once technical specifications, budget and schedule are defined, the project enters into the procurement phase. In this phase, the activity is to find suppliers for all subsystems of the wave energy plant. Here, the wave energy plant is splitted into subsystems because it is unlikely that one supplier will provide and install the whole energy plant. Typical subsystems that may be provided or installed by different suppliers are the wave energy converter units, station keeping systems, electrical cables and the electrical substation. In this phase, it is critical for the project developer to make sure that the suppliers will be able to deliver according to specifications. At the end of this phase, suppliers have been contracted for all subsystems and activities that will be carried out at least until commissioning.

The next phase is the fabrication of the subsystems. In this phase, the supplier builds the subsystem according to the technical specifications. For the supplier, it is critical to keep costs & delays under budget & schedule agreed with the project developer in the procurement phase. At the end of this phase, the subsystems are finished and ready for inspection.

Thus, the next phase is quality control. In this phase, the project developer verifies that the subsystem that is provided complies with the technical specifications. In the end of this phase, the subsystem can be shipped to where it will be stored during the time waiting installation.

electricity meets the target that was set in the business model in the project development phase. This phase can end with a maintenance or failure of a subsystem.

The next phase is maintenance and repair. In this phase, the faulty subsystem is maintained or repaired. It is critical that costs and delays of these operations are kept on budget & schedule. In the end of this phase, the wave energy plant is back to fully operational.

At the end of the wave energy plant lifetime, it enters into the decommissioning phase. At the end

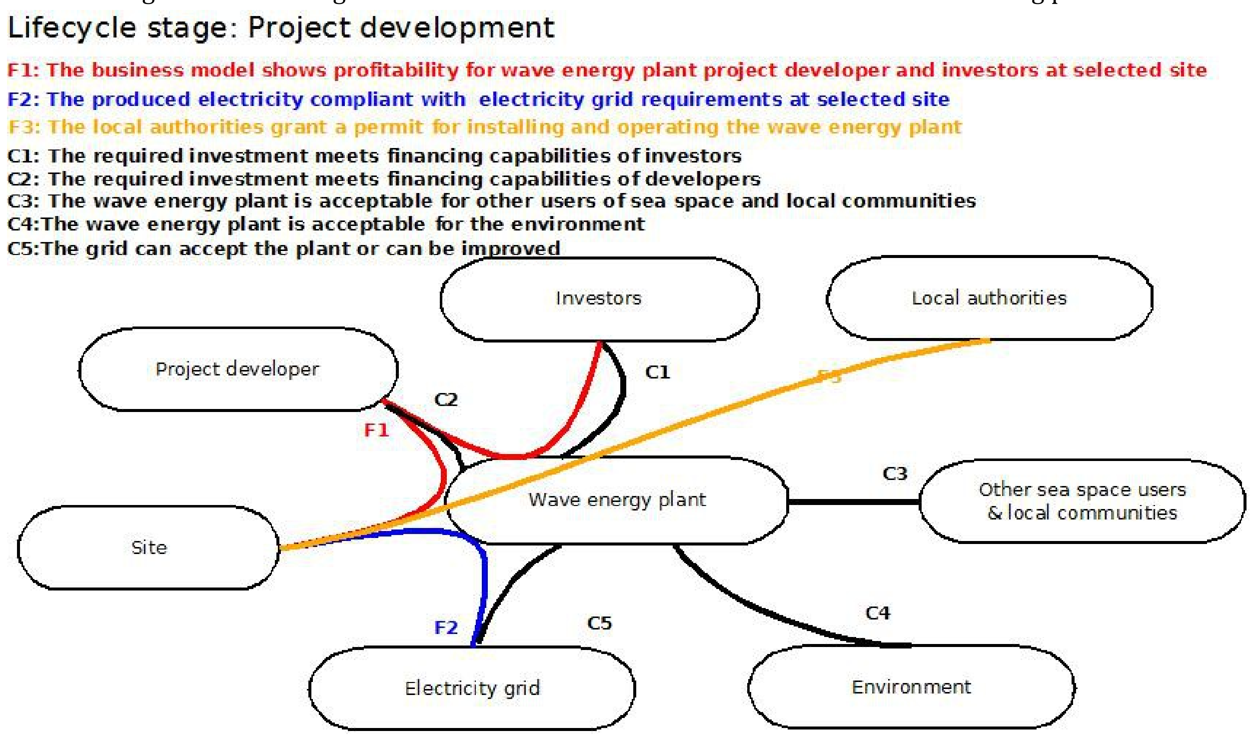

FIGURE 5. STAKEHOLDERS' REQUIREMENTS AT PROJECT DEVELOPMENT STAGE

The next phase is transportation & storage. In this phase, the subsystem is transported from the fabrication facility to the storage facility. In the end of this phase, the subsystem is stored in the storage facility, ready to be installed.

The next phase is installation. In this phase, the subsystem is installed. For the installation contractor, it is critical in this phase to keep costs & delays on budget and schedule. When all the subsytems are installed, the wave energy plant is ready for commissioning.

The next phase is commissioning. In the end of this phase, the wave energy plant can start operating.

The next phase is operation. In this phase, the wave energy plant is delivering electricity at the point of sale. As it corresponds to the income of the project, it is critical that the amount of

of this phase, the wave energy plant is recycled (some parts of it may be used in the fabrication of a new wave energy plant), the remaining parts are stored and then destroyed.

STAKEHOLDERS REQUIREMENT

The mission statement and the lifecycle decomposition having been defined, the next step is to list all stakeholders that interact with the wave energy plant, and then the functions by which they interact with it. The functions have been developed with the objective of identifying all the requirements that a good technical solution should meet. In other words, for each function that the technical solution must fulfill, the thinking is "The technical solution is a good solution if …" .

An example of the results of this analysis is shown in Figure 5 for the project development stage of the lifecycle. Eight stakeholders have been identified. First of all, there are the project developer of course, the investors that will finance the project, and the technical conditions at the selected site (wave resource, bathymetry, soil conditions, wind and current conditions). For these stakeholders, the requirement is that the business model of the wave energy plant shows profitability (at the selected site, for both the project developer and the investors). The local electricity grid is another stakeholder, for which the requirement is that the produced electricity is compliant with the grid requirements at the point-of-sale. The local grid must also be able to absorb the produced power, or its capacity must be increased. The local authorities are another stakeholder because they will grant the permit for installing and operating the wave energy plant at the site. Other sea space users, local communities and the environment (marine life) puts requirement in terms of acceptability of the plant.

Same types of graphs have been developed for the other stages of the lifecycle. They will be shown at the conference. Overall, 29 different stakeholders have been identified, a number that well illustrates the high level of complexity of any wave energy project.

CONCLUSIONS

Functional analysis has been applied to a wave energy plant. Proposal for the formulation of mission statements for wave energy plants, lifecycle decomposition and stakeholders' requirement have been made. It is hoped that these first steps will prove to be useful in the next steps of development of functional requirements' specification for wave energy converters and wave energy plants.

ACKNOWLEDGEMENTS

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