OPTIMUM METHODOLOGY FOR SITE SELECTION OF WAVE ENERGY CONVERTERS

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ABSTRACT

A critical review on the feasibility of extracting wave energy in the marine environment for the purpose of generating electric power has been carried out using a methodology of resource assessment to analyse the different elements involved in the site selection process and as it relates to the operation and maintenance (O&M) activities for deployment of wave energy converter (WEC) technologies.

Part of the issues affecting the choice of using wave energy as an alternative source for power generation centres on the uncertainty surrounding cost of O&M for these power generation technologies. The resource assessment approach examines the different aspects of the operational process starting from the initial site selection stage, and the cost implications of various O&M practice. The objective is to establish the evidence which clearly illustrates that the selected site does not have too many environmental or technical constraints that could impinge on the development of the project. This approach will help prospective investors and developers of marine renewable technologies in planning the project implementation.

Keywords: Resource Assessment, Wave energy, O&M, Feasibility study

1. INTRODUCTION

The focus of this paper is on the feasibility of deploying ocean wave energy converter (WEC) technologies as an alternative source for power generation. Ocean wave energy is one of the most concentrated and widely available forms of renewable energy in coastal areas. So far, the current installed electric capacity is about 3.5TW ($1TW=10^6$ MW) and estimated installed capacity from wave energy devices increased from 0.75MW in 2005 to 120MW in 2010[1].

Section 2 of this paper presents a review on wave energy extraction technologies. It is observed that the propagation of energy from ocean waves has more prospect considering the size, availability and reliability of the resource[2]; other advantages' of it being environmentally benign has made it more suitable and attractive compared to other sources of marine renewables[3].

Within the context of finding better ways to reduce the uncertainties surrounding the operation and maintenance cost for generating electricity using ocean wave energy technologies section 3 discusses a case study of the resource assessment approach based on the experiences of offshore wind installations. A method of assessing the suitability of a site is analysed; taking into account the wave generation parameters [4] necessary for estimating the wave resource.

There are several device technologies [2,3] developed for extracting energy from the marine environment and most of these experimental or prototype devices have achieved success in the initial testing phases [5]. Apperently, only a few of these technologies have been put into use for electricity generation in the marine environment. This situation makes it difficult to independently assess the economic feasibility of deploying alternative technologies for commercial scale electricity generation in different parts of the world. Section 4 further extends the resource assessment approach by discussing the factors influencing the cost of deploying the WEC.

Section 5 presents the mathematical model to simulate and describe the O&M practice of a typical device installation, in order to analyse the issues surrounding operational cost, based on relevant O&M activities in terms of planned and unplanned maintenance events. Section 6 emphases on the methods of analysing the reliability of the device and risk mitigation approach thus presenting a method for analysing the uncertainty issues that may be encountered in the course of O&M of the device. Some findings of this study are discussed in section 7 to justify the need for investment/capital expenditure on facilitating such projects towards the cost of operating the facility for a period of 20 to 25years life cycle.

2. REVIEW OF WAVE ENERGY TECHNOLOGIES

Energy extraction using WECs can offer a sustainable alternative to conventional sources and a predictable alternative to other renewable energy technologies. Extracting wave energy is very complex. Generally, the wave energy device can be classified by means of the type of displacement and reaction system deployed [4. The energy content of ocean waves is a function of the wave height (H_s) and wave period (T_p); often referred to as the sea state and in real sea conditions many wave height and wave periods occur simultaneously. Assessing the performance of WECs, in real sea conditions depends on accurate measurements and the knowledge of the wave climate.

The initial assessment for the deployment of WEC should be based on the feasibility study, to evaluate the environmental, risk and economic factors of the intended project [5]. to analyse the environmental conditions suitable for ocean wave energy propagation some work was done [6] using the regular (monochromatic) wave model to propagate the representative sample of sea states, considering the significant wave height(H_s), Average mean period direction(T_p) of the sea, including swell components provided by the reanalysis database. It is also necessary to incorporate Wind data (velocity and direction) into the propagation model to improve local wave generation [6]. It is clear that measuring the wave climate is not often an easy task, the reason being that it varies considerable over all its time scale..

Waves generated have the tendency to dissipate very little energy and unless they encounter head-winds, they can travel for a longer time over a considerable distance [7]. This is possibly why [8] acknowledges that deep water surface waves are oscillations of the sea surface layer under gravity so that to a good approximation may consist of the linear superposition of a larger number of simple components.

2.1 Preliminary Considerations for Analysing Site Requirements

Part of the initial considerations for selecting a suitable site for deploying a WEC is the criteria for the resource assessment which could also possibly define the conversion requirements in terms of the most appropriate equipment's and techniques for measuring the instantaneous resource[9]. In an attempt to determine the quantity of energy that may be practically harvested from a wave energy certain assumption which ordinarily provides the basis for the Preliminary Considerations are made, depending on the following criteria [10]:

- Mean power levels
- Wave frontage available
- Number of rows of the wave energy device that can be economically sited in a farm
- Space available, taking into account the environmental designation, sea lines and other competing sea uses.

Investigating the possibility of harvesting the energy of wave in coastal waters in most parts of the world could be very challenging due to the limited engineering and technological experience, and availability of reliable data. Although, measurements are often available in industrialized nations, they can be used to derive useful statistical parameters such as significant wave height, wave period, and wave direction, to describe the behaviour and interaction of the wave energy for preliminary assessments of the wave energy resource.

According to Studies [9], the process of preliminary assessment was summarised into two phases such as:

Phase 1: involving the preliminary assessment of the suitability of the area in terms of undertaking the following activities [9]:

i. Defining the general characteristics or requirement of the entire project.

ii. Requirements for the proposed type of marine renewable energy technology to be installed.

iii. Consideration of overall power output.

iv. Conditions for the restricted sea zones.

v. Analysis of operational depth range.

vi. Modelling the sea bed morphology.

Phase 2: this stage begins when the preliminary assessment shows evidence of the suitability of the site; in the sense that it could be worth spending time and money to plan a project in the area.

2.2 Resource/Site Selection

The extraction of wave energy is considered viable in areas where the potential annual wave power exceeds 30KW/m [11]. For successful application of WECs the knowledge of the ocean wave propagation and characteristic parameters are necessary. The energy resource contained in the marine environment can be divided into five categories [11]:

- **Theoretical resource:** This resource may be determined by modelling the wave energy propagation within that zone. It is the gross energy content of the Ocean Wave within a certain zone.
- **Technical resource**: This resource is based on ocean wave parameters, existing device efficiency and water depth. It is calculated using the same method as theoretical resource, only it is limited by existing technology.
- **Practical resource:** is determined by limiting the technical resource. Some of these limitations include wave exposure, seabed conditions and shipping lanes.
- **Accessible resource:** when conducting the initial site assessment it is necessary to include any possible environmental issues, so that the accessible resource is determined by limiting the practical resource because the limitations are generally environmental in nature.
- **Viable resource:** this includes the commercial constraints and may be determined by limiting the accessible resource.

It is possible to develop a techno-economic model to determine the viable ocean wave energy resource as well as including costing for a particular site.

2.3 Resource Assessment Methodology

Studies [12] have been conducted to evaluate the wave energy resource in coastal waters. Generally, these resource assessment methods include some of the following steps namely:

i. Calibration of deep water wave reanalysis data;
ii. Sea states classification;
iii. Deep to shallow water propagation processes for the most representative sea states;
iv. Propagation processes for the complete series of sea states using an interpolation scheme;
v. Statistical model characterization for the wave energy resources in the objective points.

These steps could be analysed based on wave data obtained from numerical reanalysis of meteorological data. Considering the initial site selection processes, the steps followed for resource assessment in terms of estimating the wave energy resources, is illustrated using the flowchart (figure 1). Following these processes, any kind of wave statistics can be obtained in any point of the propagation mesh So long as we take into account: Metrology/ ocean data; Wave height; Wave period and Kinetic flux etc.

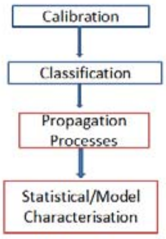

Figure 1: Flow chart of the methodology

3 CASE STUDY

The figure (2) below shows the elements that need to be considered using the resource assessment method to ensure that the site is well suited for the deployment of the WEC or tidal stream array technologies.

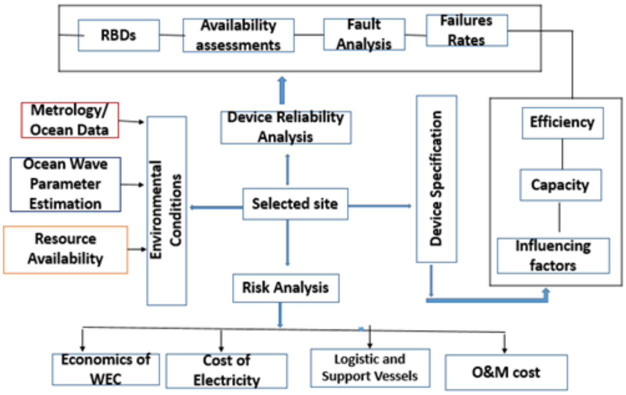

Figure 2: Methodology for considering the Characteristics and parameters for site selection

3.1 Application to Site and Installation of WEC

To achieve maximum profitability with respect to managing O&M activities of offshore wave generating plants, operators are required to understand how different elements of the O&M

interact with each other. The parameters which are necessary to evaluate the environmental condition e.g. Metrology/Ocean data, (tides, wind and wave data) can be systematically analysed with the aid of computer simulation models [13] to also meet other objectives of being able to map wave energy resources in waters of more than 30 m depth.

3.1.0 Environmental Conditions
3.1.1 Metrology/ Ocean Data

Metrology/ ocean data is necessary for wave propagation; these data may be obtained off nautical charts from the Naval Hydrographical Service. Tidal level can also be relevant for wave propagation when waves propagate in shallow waters.

Wave and wind data can be obtained from different sources, example of some useful sources of data may include:

- Nautical charts from the navy hydrographical service
- Wind and wave data from numerical models
- Wave buoy data
- Remote sensed data
- Global telecommunications services (GTS)
- Fluid mechanics laboratory ocean engineering tools

Reported in [6] the results and estimates from these sources could be adapted for use to explicitly represent the behaviour and interaction of wave characteristics.

3.1.2 Ocean Wave Parameter Estimation

A selection of spectral parameters is typically required for characterization of the sea state. Although, different types of measurement principles and numerical wave models are available for the estimation of a wave energy resource. Reviews of these methods have been published [8].

the two basic approaches used to analyze measured ocean wave data are: frequency domain and time domain analysis. Depending on the approach, both methods have their advantages and disadvantages. The principle behind a frequency domain approach is that an irregular signal is the superposition of a series of regular waves which can be decomposed into frequency components as shown in Figure (3)[14]. The time domain analysis is mainly based on the zero crossing method motivated by graphical recordings on paper from when analysis was carried out by hand.

Test conducted using monochromatic waves [14] show that the time series of a WEC may not be perfectly sinusoidal, and they may change in magnitude with time due to suboptimal wave generation or reflections. The Characteristic of ocean wave parameters specifically defined by time series are shown in Figure 3.

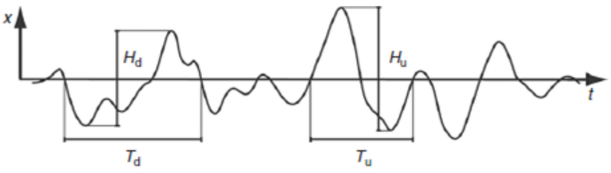

Figure 3. Wave parameters in the time domain

These are the zero up crossing H_u and zero down crossing wave height $H_d$dand the zero up Crossing $T_u$or zero down crossing period T_d

33.1.3 Significant Wave heightH_s and Average Wave period T_z

Investigating the influence of these parameters under the action of regular (monochromatic) waves [14] defined the wave power of linear waves per unit length of wave front in deep water using the expression:

$$Powwer = \frac{\rho g^2 H^2 T}{32\pi}\ (Wm^{-1}) \approx H^2 T (Kwm^{-1}) \quad (1)$$

The power, which is often rated in watts per unit meter of the wave width, can also be expressed for irregular (panchromatic) waves pattern using the formula:

$$Power = \frac{\rho g^2 H_s^2 T_z}{64\pi}\ (Wm^{-1}) \quad (2)$$

The power (W) actually available for a WEC can be indicated by the power per unit length of wave front (Wm−1) multiplied by a characteristic length scale of a device such as the hull width (m) [14].

The basic components being a sinusoidal wave train, with period which appears to travel at a phase velocity often expressed as equation 3 [8]:

$$U = \frac{gT}{2\pi} \quad (3)$$

From this understanding, it implies that the water particles are not travelling: because for a simple sinusoidal wave they oscillate in circles and their amplitude a_d falls off exponentially with depth d ($a_d = aexp(\frac{-2\pi}{L})$).
So that the energy of the wave train per unit is expressed as [8]:

$$E = \rho g H^2 \tag{4}$$

Where: $\rho =$ the ensity of the water and $H =$ the root mean square wave height $\left(H^2 = \frac{a^2}{2}\right)$.

The significant wave height H_s in the time series context is defined as the average of the highest
One-third of the wave heights, estimated from a ship without using instruments. (H_s) is a standard measure in the offshore industry and it is by definition $H_{\frac{1}{3}}$: which implies one 3rd of the total number of waves in a record counted and selected in descending order starting from the highest wave. Hence the mean value = $H_{\frac{1}{3}}$.
This same procedure could be applied for the wave period resulting to $T_{\frac{1}{3}}$: the significant wave period.

3.1.4 Kinetic Energy Flux

The kinetic energy contained within ocean waves can be harnessed using various technologies. The physics is similar to that of wind energy [15], where the power available at any particular site is proportional to the fluid density and the cube of its velocity [16]. The major difference between the two resources (wind and wave) is the density of the working fluid [17]. The density of seawater is much greater than the density of air (approximately 832 times greater). Therefore the power output from a WEC is higher than a wind energy device of similar dimensions assuming similar fluid velocities. Studies have shown the relationship between the significant wave height and the kinetic energy flux [1] these parameters are useful for evaluating the energy available in the wave energy resource. The effect of ocean waves on kinetic energy balance was emphasized [2] because the kinetic energy associated with ocean waves in the air is smaller by the ratio of air to water density compared to the kinetic energy of the water motion; thus suggesting that the kinetic energy budget should be taken into account.

4 DEVICE SPECIFICATION

The type of WEC technology selected may depend on the specific requirement of the site or location of the wave energy resource. When considering the potential for cost reduction in terms of uncertainty and thus the cost of energy associated with deploying an array of WECs, the key design parameters may include an analysis of the overall performance of the WEC [7]. The important considerations for analysing the O&M activities of WEC relevant for a selected site may include parameters such as:

4.1 Efficiency of Device

Efficiency assessment for different WEC types operating in the Portuguese coastal environment have been performed [22]. Efficiency of a device can be defined in several ways; a simple way of defining the efficiency of the device may be to consider ‘’ resource-to-wire’’ efficiency: i.e. the ratio of the energy a device actually captures to the energy that is available to be captured. The efficiency of a WEC can be defined with the capture width (m), which is the absorbed power (W) of a device relative to the wave power per unit length of wave front (Wm−1). It is common to express the efficiency as a relative capture width (–) which is the capture width (m) divided by a characteristic length scale of a device (m), such as the diameter.[14].

4.2 Capacity Factor

In this case, the capacity factor is used to represent the energy produced during a certain period divided by the energy that would have been produced had the device been functioning continuously and at maximum output In order to conduct a proper risk assessment for installation and maintenance activities of ocean energy devices we may need to take into account the following:
- Device Storage requirements
-Failure rates
-Number of device
.

4.3 Factors Influencing Device’s Operation and Maintenance Costs

The capital costs associated with the development of an ocean wave energy farm can be separated into device and site-specific costs. The main site-specific costs associated with the development of these technologies include:

- **Grid connection costs**: the cost of grid connecting a WEC farm is dependent on plant generating capacity, connection voltage, distance of the farm from shore and the number of connections required including transmission lines, switch gear and infrastructure required to connect a WEC to the grid.
- **Permits and permissions costs**: when the suitable sites and technology are selected, permissions and permits are required, being the costs associated for the preparation and the application of the various permits required for the deployment of the WECs.

Figures 4 below is an illustration of a wave energy project at a particular location involving a single wave energy converter. It is observed that a split of CAPEX between different costs Centre's varies considerably by project size and also depends on the particular generation technology and project location. Considering operation and maintenance costs in terms of cost Centre's it is seen that the cost Centre's shown are fairly typical, for planned and unplanned maintenance, licenses to be stationed at the location (often referred to as consents and permits), insurance, and ongoing monitoring activities.

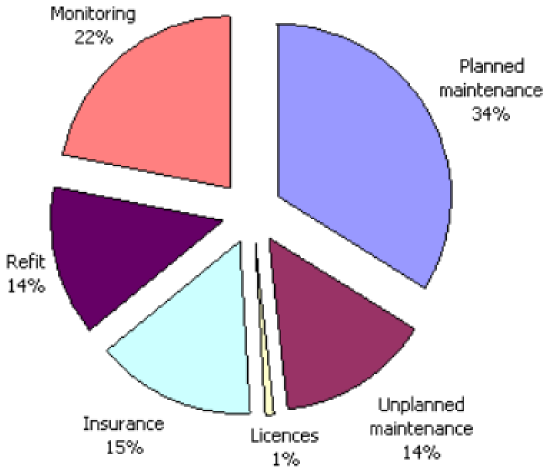

Figure 4. O&M cost breakdown for a particular wave energy device installed as a single unit [10].

For this particular technology, a mid-life refit has been selected as a good compromise between maximizing availability and minimizing costs. It can also be seen that about 1/7th of the total O&M costs are assigned to unplanned maintenance activities, which reflects a degree of uncertainty in the device's design for reliability.

5 RISK ANALYSIS

5.1 Economics of WEC Devices

In assessing the economic viability of marine renewable energy installations, Capital costs has been described in terms of cost centres [18] so as to allow comparisons of cost by category. The reason being that the capital cost of marine renewables devices may consist of several parts: station-keeping, structural, energy conversion components and sub-assemblies, and project costs [5]. Capital and O&M costs are closely related and design decisions affect them both together. Greater CAPEX can lead to either increased or decreased OPEX. Redundancy is a means of compromising costs and performance to reduce cost-of-energy, but may not always be possible.

5.2 Cost of Generating Electricity

The basic method for establishing the cost of generating electricity accounts for the following:

- **Capital costs:** these are once-off costs applicable to the development of a new wave energy farm. Capital cost can be separated into site-specific and device costs. The site-specific costs consist of design and specification costs, grid connection costs, cabling costs, installation costs, permits and permissions costs and commissioning costs. The device costs are made up of the turbine costs, structural costs, electrical machinery costs, control systems costs, foundation or mooring costs, cabling costs, delivery costs and assembly costs.
- **Running costs:** these are the on-going expenses for running the wave energy farm, after the capital cost has been paid off. Running cost is made up of the operation and maintenance (O&M) costs. The annual running costs are made up of servicing, insurance, telecommunications, taxes and administration.
- **Financing**: this is the cost of repaying loans from banks and investors. If the project was financed by an investor, the loan repayments will be required and they may equally demand a return on their investment.

The cost of a WEC could be expressed using three different ways namely:

- The cost per rated power of the device (cost/MW),

- The cost per unit size of the device (cost/unit area), and
- The cost per unit of electricity generated (cost/kWh).

The simplest way to express the cost of a WEC is the cost per rated power. The cost per rated power is obtained by dividing the cost calculated using one of the above methods by the rated power. This is often misleading due to the functions of the WEC design parameters, and since we are often more concerned with the cost of generating a unit of electricity, the cost per kWh is a much better way of economically assessing the cost of a WEC.

The most accurate method of calculating the cost per rated power is life-cycle costing (LCC).The LCC method provides the means of evaluating the economics of energy technologies. In order for the technology to be economically assessed, the LCC method incorporates all the revenues and expenditures over the life-time of the project into a single cost. The equation for calculating the LCC of any particular energy technology is given as [19]:

$$LCC = C_{pv} + M_{pv} + F_{pv} + X_{pv} + S_{pv} \qquad (5)$$

Where:
C_{pv} −Capital cost of the total technology which is considered as a single payment occurring in the initial year of the project, regardless of the finance conditions.
M_{pv} −O&M costs on a yearly basis, including salaries, inspections and insurance.
F_{pv} −Yearly fuel costs.
X_{pv} −External costs which includes damage cost and damage prevention.
S_{pv} −Salvage value of the technology in its final year of lifetime

Another method of calculating the cost per kWh is to calculate the levelised energy cost (LEC). A LEC is basically an economic assessment of the costs associated with generating electricity over a certain time scale. This method expresses the costs that occur at irregular intervals as equivalent equal payments at regular intervals. This method expresses the LCCs as equal annual repayments.

A LEC is calculated as the annual LCCs divided by the annual electricity generation and is simply defined as the cost of energy (unit cost/kWh). A LEC comparison is often used to compare emerging energy technologies against those already in widespread use.

The benefits of using LEC method of cost comparison rather than comparing the capital cost of each technology is that, the method provides a realistic assessment of the LCC of the technology thus allowing a comparison of different energy technologies. Secondly, it makes possible the evaluation of all the costs associated with installing and operating any power plant over its life-time.

5.3 Model Analysis of Risk In Terms Of Planned and Unplanned O&M Cost Activities

The model analysis takes into consideration various aspects of O&M cost and uncertainty issues relating to planned and unplanned events for the operation of WEC. These different aspects may also include the component repair and vessel charter cost.

5.3.1 Logistic support vessels

The main problem encountered in offshore wave plants is the accessibility of the WEC for maintenance purpose. Accessibility may be defined as the number of times an offshore installation can be approached. It is possible that the location of the WEC could be inaccessible by boat or helicopter for a period of one to two months due to harsh weather conditions. Secondly O&M in the offshore environment sometimes requires special and very expensive equipment for lifting actions.
The Planned and unplanned O&M activities can be analysed using the following Parameters schedule:

$$C_{PL} = c_{trans} + C_{lab} + C_{work} + C_{eq} \qquad (6)$$

Where:
C_{PL} − Cost of Planned maintenance (£)
c_{trans} −Cost of Transportation Cost (£)
C_{lab} −– Labour cost (£)
C_{work} − Workshop Cost (£)
C_{eq} −Equipment cost (£)
Assuming C_{trans} is used to represent the attributes of two associated cost namely: hire vessel cost and the new built vessel cost (C_{nb}), this implies that:

$$C_{trans} = C_{nb} \qquad (7)$$

If two maintenance vessels are employed, then the associated vessel cost becomes a combination of vessel 1 hire cost (V_{h1}) and vessel two hire cost(V_{h2}) so that :

$$C_{trans} = C_{Vh1} + C_{Vh2} \qquad (8)$$

Where:
C_{trans} – Transportation Cost (£)
C_{nb} –Capital cost for new built vessel (£)
C_{Vh1} –Vessel 1 hire cost (£)
C_{Vh2} –Vessel 2 hire cost (£)

Following the statements presented in equations 6,7 and 8; it shows that hire cost of vessel 1 could be obtained from the expression:

$$C_{vh1} = t_1 \times R_1 \times (1 + F_{ves}) + \left(\frac{Cf}{2}\right) \quad (9)$$

Where:
C_{vh1} – Vessel 1 hiring cost (£)
t_1 –Time vessel 1 is hired (days)
R_1- Daily rate of vessel 1 (£)
F_{ves}- Vessel contingency factor delays due to weather conditions (%)
C_f – Annual cost of fuel (£)

The time for which vessel 1 is being hired for the maintenance task could also be equal to:

$$t_1 = t_{wp1} + t_{wp2} + t_{wp3} + t_{ins} \quad (10)$$

t_{wp1}-Time taken to reach the offshore wavw location (hours)
t_{wp2}-Time spent in the offshore wave location (hours)
t_{wp3}-Time to detach / attach one OWC device (hours)
t_{ins}-Inspection time per OWC

Furthermore, time taken to reach the offshore wave location could also be equals to:

$$t_{wl1} = \left[2 \times \frac{Dist\ 1}{(Vsp1 \times 1.852)}\right] \times (1 \times F_{ves}) \quad (11)$$

Where:
t_{wl1}-Time taken to reach the offshore wave location (hours)
$Dist\ 1$-Distance to the offshore wave location (Km)
$Vsp1$-Vessel speed to reach the wave location (Knots)
F_{ves}-Vessel contingency factor delays due to weather conditions (%)

Also the time spent in the offshore wave location may be equal to:

$$t_{wl2} = Dist\ 2 + \left[2 \times \frac{Dist\ 1}{(Vsp2 \times 1.852)}\right] \times (1 \times F_{ves}) \quad (12)$$

Where: t_{wl2}-Time taken to reach the offshore wave location (hours)
Dist 2-Distance to the offshore wave location (Km)
Vsp2-Vessel speed within the offshore wave location (Knots)
F_{ves}-Vessel contingency factor delays due to weather conditions (%)

The time taken to detach the old OWC and replace it with the new OWC is calculated as:

$$t_{wL3} = (T_{Rov} + T_{other}) \times (1 + F_{ves}) \quad (13)$$

Where:T_{Rov} -Time taken to mobilise /demobilise the ROV from the vessel (hours)
T_{other} - Time other than time taken to bring ROV on board (hours)

The inspection time (t_{ins}) may vary depending on the initial tine of the examination of the OWC, therefore it could be considered on an hourly basis per devices.To calculate the cost of fuel needed for a single vessel to perform the planned maintenance task we use the expression:

$$Cf = Dfc \times D_{sea} \times Pr_{fuel} \times N_{main} \times Oil_{corr} \quad (14)$$

Where:Dfc – Daily fuel consumption (tons of fuel)
D_{sea} – Number of days at sea
Pr_{fuel} – Price of fuel (£)
N_{main} - Number of main engines (Constant)
Oil_{corr} - Lubrication correction factor set at 1.15(Constant)

It is essential to reduce to a minimum the level of maintenance effort that would be required when installing the WEC offshore. This is because the cost implication of installing a WEC offshore is far greater when compared to the choice of locating the WEC near shore.

6 DEVICE RELIABILITY ANALYSIS

The reliability assessment of WECs is a challenging task and it is a key issue that has to be addressed in order to make them a viable energy option. The idea of considering the reliability of the device is to be able to analyse certain issues that may be encountered in the process of developing realistic assessments of the systems reliability using generic data. It has been observed that the lack of reliability data (failure rate data) leads to rather unfavourable and highly uncertain results. With the aim of optimising availability of WEC at the selected location the tools used for reliability prediction and lifecycle management are described briefly below:

6.1 Reliability Block Diagrams (RBDs)

Figure 6, is the diagrammatical representation of a system's reliability performance. An assessment using the RBDs would have to define the success of the system in terms of the system's ability to produce power. The components that affect the logical behaviour of the WEC are divided into blocks that are statistically independent. Depending on the configuration of WEC each block is associated with a probabilistic failure rate. One of the major limitations of reliability assessments is the lack of comprehensive data on equipment failures and load distributions [20]. It is possible to produce a stochastic representation of the system’s probability of failure in a given period of time when all blocks are linked up into a ‘success path’.

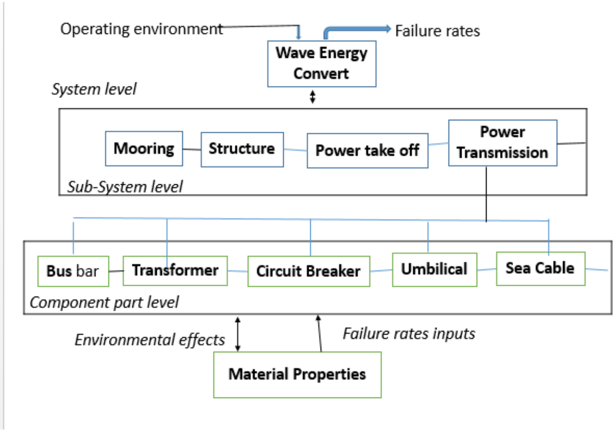

Figure5: Generic Reliability Block Diagrams for wave energy converters

6.2 Availability Assessment

Availability of a WEC may be defined as the proportion of time that the device is ready to generate, irrespective of whether the resource is suitable for generation. Statistical methods based on discrete event simulation [21] could be employed for performance forecasting in order to assess the availability of WEC devices. The major difference between reliability and availability is the O&M strategy adopted for the system. A system could be considered as being very reliable in term s of the frequency of failure being very low, but when no maintenance action or repair is taken after failure; its availability becomes very poor. In this case failure refers to the termination of the ability of a system to perform its required function. The question of maintainability is used to address the issues relating to ease of repair. It is often consider as a quantitative subject and it can be expressed in terms of hours required to complete a maintenance action [22].

The availability assessment may require that each component or sub-system is assigned a probabilistic distribution representing the statistical description of its time to failure, and another distribution for the time to repair, along with the interval between planned maintenance [20].

7 DISCUSSION

Lowering the operational cost over the total life time of the WEC in order to improve the economics of the wave or tidal energy project should be given consideration.

The primary objective for analysing the O&M cost in the initial assessment plan is to ensure the deployment of minimum resources required to ensure that components perform their intended functions properly and also to ensure provisions are made for the system to recover in case of a breakdown.

The necessary long term investments make reliability a key challenge towards developing economically viable wave energy devices.

It is observed that apart from the properties of the device in terms of failure rate and service demands, other external factors can affect the availability levels of the WEC.

It follows that the maintenance activity becomes necessary in order to ensure the system and components continue to perform the functions for which they were designed.

. The main issues identified are related to the use of condition monitoring systems to access the reliability of the generating plant, turbine reliability, and equipment for transfer of personnel, weather conditions, and crane vessels for hoisting of parts etc.

The risk analysis and decision making methodology included in the site selection approach emphasis on the imperative to always minimize the level of risk involved in the handling/installation, operation and maintenance activities in the offshore environment.

The model chooses a value for the time to failure of each component from the distributions and runs the simulation until the first event occurs (either a failure or a planned maintenance), at which time an action is usually required (which could be shut down for maintenance or maintenance on-line depending on the nature of the failure.

The downtime associated with the event is calculated, and the simulation runs to the next event. Once the simulation has been run for the specified lifetime of the system, the total downtime is calculated and a value for the system availability in that time can be produced.

8 CONCLUSION

The paper describes in detail an optimum resource assessment method for selected sites for the deployment of any Wave energy farm project.

The set of principles which can be employed to evaluate a specific site for the deployment of a WEC technology has been established.

The method combines both the theoretical and practical aspect of the resource assessment to form a strategy which can be applied to deal with the problems of uncertainties surrounding the factors such as capital and operating cost associated with the O&M activities for deployments of wave energy converter technologies.

A concise reliability assessment of WECs forms the basis for the commercial case and In order to foster the progress of the marine energy industry, the reliability assessment of devices has been incorporated into the initial site selection requirements so as to encourage demonstration improvement and dissemination of existing failure knowledge and future operational experience.

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