Journal of Energy & Environment

Journal homepage: journal.uniten.edu.my/jee

ISSN: 1985-7462

A Review on Risk Management of Wave Energy Converter by Using Method of Risk Identification of The Project Life Cycle and Method of Failure Modes and Effects Analysis

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Keywords

Renewable energy
Wave energy converter
Risk management
Project life cycle
Failure modes and effects analysis

Abstract

The utilization of wave energy is considered a new renewable energy technology in Malaysia and is exposed to a lot of risks. This study emphasis on a Wave Energy Converter (WEC) that harvest energy from waves and convert it into electricity. The objectives of this research are to study the method of risk identification on WEC by using two different approaches and identify whether the method is suitable to be used. The first method is risk identification on WEC's Project Life Cycle (PLC). It focused on the identification of risks, separates them by every stage of the PLC, and determines the origin, impact and risk level. The second method is Failure Modes and Effects Analysis (FMEA). It concentrates on diagnosing crucial failure modes of WEC and the priorities of risks are determined through Risk Priority Number (RPN) and provide recommended solutions via discussions. It has been recognized that both of these methods are deemed suitable to be implemented on this WEC project because they comprise all aspects of the project's risks as a whole and as an individual component.

1. INTRODUCTION

Ocean energy (wave and tidal) can become like a clean energy source and is capable to supply more than 50 percent of the world's electricity demand. Wave energy and tidal energy resources are approximated to accessible as 1 and 1.5 times of the world's utilization [1]. Technology for harvesting energy from this source is still new and the industry has finite practice and experience and there would be a huge amount of ambiguities associated with technology, performance, and cost [2]. It is an industry dependent on investment demanding projects, proposed for a long period and usage. These ambiguities threaten the assurance of the shareholders hence procrastinating the progress of the industry.

Since the industry is relatively new, there will be a lot of uncertainties about the technology thus created a lot of risks. Risk can be described as vulnerable to loss/gain or the possibility of an incident of loss/gain amplified by its various sizes [3]. It is important to manage the risk and it is described as all parts and actions implemented to manage risk [4].

A sufficient risk assessment takes extensive risk identification but there are limitations like time, resources, or data [5]. The project's risk identification needs to be studied to appraise them corresponding to the risk criteria and establish the proper feedbacks. PLC of WEC is selected as risk identification because it covers the overall process of the project and the risk can be recognized early and preventive actions can be taken.

Failure Modes and Effects Analysis (FMEA) is selected as a method for appraising the effects of possible failure modes for WEC. FMEA has the competence to cover failure rates for each failure mode to conclude a possibility analysis [6]. Also, FMEA is a mechanism for tabulating the analysis and giving the recommended design changes.

This study will be implemented for a construction project of WEC and a battery house. WEC is a platform that will harvest energy from ocean surface waves which are wind energy that comes from the waves that coming through the platform and converts it into electrical energy through the rotation of the turbine that is located inside of the turbine. The platform is scheduled to be planted at Mantanani Island in Sabah prefecture. There are three small islands which are Mantanani Besar, Mantanani Kecil, and Lungisan which are called the main island. The WEC platform will be placed at Mantanani Besar. A battery house will also be constructed in this project. The battery house will be used as a storage to batteries that store the harvested energy from WEC and also storage to the inverter, Ac/Ac rectifier, and Ac/Dc converter.

2. METHODOLOGY

A. Risk Identification on Project Life Cycle (PLC) of WEC

Risk identification is concentrated on common risks of the project based on the literature survey and analysis of the stipulated work. Risks registration is guided on the qualitative risk analysis from every stage of PLC of WEC and the level of the risks can be determined according to their priority. PLC is used as a mechanism to enhance the operation of the project. Scope of PLC varies from each industry and uses a diverse term with different phases used depending on their respective sectors. However, several terms are often used within one particular sector even though several phases can vary [7].

Taken examples from Emanuel Martins, he claims that PLC for WEC is composed of four phases, starting from construction, installation, operation and maintenance (O&M) phase and finally the decommissioning phase [5].

B. Construction Phase

The construction phase relates to the idea of advancement, design, and creation of the WEC platform. There are diverse theories of WEC that consist of the components, design, and fabricate. Some segments are similar in these devices, they are the platform of the WEC that in contact with the wave, the power take-off, and the mooring system that acts as an anchor to fix the location of the WEC. These WEC platforms need to be constructed in consideration of these aspects, which are survivability, reliability, and affordability [2].

C. Installation Phase

Carbon Trust gives out guidelines on the installation of WEC. They stated that the installation phase is complicated work because it requires transportations, assemblies, underwater operations, and other recommended actions to fix the WEC platform to their desired location. The WEC platform needs to be well maintained and safe all the time. Every action needs to be prepared and carried out to conform to safe practices [8].

The design of a WEC platform will affect the process of installation specifically to these aspects, which is, the size of the WEC platform because a bigger size of the device will affect the complexity of the installation. The placement of the device also affects the installation process because it poses a different confrontation. Lastly is the portability of the device. It is because the bigger the magnitude of portability of the device, the simple and quick the installation of it.

This WEC platform will be installed at the nearshore of the island and need to be moored and fixed to the seabed. A battery house that acts as a substation will be constructed on the island and a cable will be installed that connecting from the WEC platform to the battery house.

D. Operation and Maintenance Phase

The O&M phase correlates to the routine operation of the WEC platform. All of the maintenance tasks will be carried out throughout the installation phase until the decommissioning phase. This phase will also correlate to the platform's serviceable life.

During the operation stage, the WEC platform must be required to do continuous supervision. Probable actions for the supervision are on-site routine monitoring, distance monitoring, data record, and monitoring of fundamental guidelines and a record of significant events all through the life cycle of the device [8].

E. Decommissioning Phase

The decommissioning phase subsists of the discharge from working off the WEC platform and the termination of the project. this phase might be planned or unplanned. The potential actions of this phase are the relocation of the WEC platform from the site, elimination of the mooring system, and the eradication of the submarine cables. The elimination probably is limited because some of the equipment might stay at the site, be neglected, or re-used for other reasons. Disintegrated tools and equipment are probably recycled and reused as part of the phase [8].

The advantage of using this method is that the risks will be easily detected because this method breaks the risks according to their phase in the life cycle. Based on the severity of the damage the method shows the likelihood to happen, impact, origin cause, type of risk, category, and level of risks which can give some gateway to handle the damages. However, this method requires thorough inspection throughout the PLC phase and needs to be done by the experts. This method also did not show the ranking priorities of which risk need to be solved first as it's only shown the level of the risk.

The risks are determined from each phase of its PLC and some of them are presented in the PLC Risk Register in Table 1 as mentioned by Emanuel Martins [5]. The majority of risks that have been identified are connected with the Installation Phase and O&M Phase.

Table 1. PLC risk register [5]

Event	PLC Phase	Origin Cause	Category	Type of Risk	Impact	Likelihood	Level of Risk
Conflicting uses on project area	Construction	Selection of project area	Environment	Negative	Moderate	Rare	Low
Reduction of the project cost	Construction; Installation; O&M; Decommissioning	Economies	Dimension	Positive	Outstanding	Likely	High
Insufficient weather window	Installation; O&M; Decommissioning;	Condition of the sea	Environment	Negative	Moderate	Likely	Medium
Damage of asset	Installation; O&M; Decommissioning	Collisions, Mix up	Quality	Negative	Catastrophic	Rare	medium
Misuse consent of short term	Fitting	Regulation	Legal	Negative	Catastrophic	Unlikely	Medium
Unplanned maintenance	O&M	Damage needed instant action	Quality	Negative	Moderate	Possible	Medium

3. FAILURE MODES AND EFFECT ANALYSIS (FMEA) PROCESS

Failure Modes and Effect Analysis (FMEA) is a mechanism for assessing the effects of capable failure modes of the assemblies, components, and subsystems. It is a dependability mechanism to find failure modes that can negatively influence the total system reliability [6]. The objective of the modes is to identify and then limit or avoid all potential failure modes and their associated mechanisms [9]. FMEA is commonly implemented by a team consisting of designer team and maintenance personnel and their experience and opinions will be included in the factors to be weighed in the analysis and then they will provide a functional summary of all capable modes of failure with their level of apparent risk.

FMEA is selected because of its advantages which is, it is simple to understand and performed, rather inexpensive to execute, and yet it provides relevant results, provides accuracy for directing the analysis, and yields a reliable prediction of the item that is analyzed [6]. However, FMEA also has its restriction which is, it is concentrated on single failure modes types instead of the merger of the failure mode, it is not laid out to identify hazards irrelevant to failure modes and it demands proficiency on the product or process that is under analysis [6]. Based on their judgment, the advantages of FMEA can apply to the WEC project in Sabah.

Automotive Industry Action Group (AIAG) says that FMEA design is more competent when it is practiced before the model of the product is issued [10]. There are three fundamental variables were used in FMEA. They are severity(S), occurrence(O) and detection(D and rated based on a 10 point scale system [10].

Severity is a rating that correlates to the significance of the effect on potential failure and a rating of severity as 1 means it is not creating harm and 10 means as most harmful [11]. Occurrence is a rating that correlates to the probability rate in which a source and its failure will happen and a rating of occurrence as 1 means that the failure is improbable to happen and a rating as 10 means it is probable to happen [11] Lastly, detection correlates to the possibility that it will detect the potential failure before it happens and a rating of detection as 1 indicates that it will detect the failure, and a rating as 10 indicates that it is certain it will not detect the failure [11].

Multiplication of (S), (O), and (D) will give the Risk Priority Number (RPN). It is a risk ranking index for reliability and effective in diagnosing the crucial segments corresponding to the order of the Risk [11]. A review of the FMEA report of the WEC is presented in Table 2 as taken from Chandrasekaran.

Ranking of severity (S), occurrence (O), and detection (D) is concluded to their criteria and condition and there are guidelines to determine the ranking of (S), (O), and (D) [12]. These guidelines are contributed by Bala Ramanan and are stated in Tables 3, 4, and 5 below.

4. DISCUSSION

Both methods above are suitable and can be applied to the WEC project in Mantanani Island in Sabah. Risk identification on the PLC of WEC shows the identification and registration of risks according to their respective phases. The benefits of this method are that the source of the risks can be located easily as it is monitored throughout the process of the WEC project. The FMEA shows the potential failure modes of WEC subsystems, assemblies, components, or functions. The benefits of this method are the risks will be identified and then limit or avoid all potential failure modes and a functional summary consists of the effects of damages, the root of failure, risk priority number, and recommended action will be concluded in the analysis report.

For the selection of which method is suitable for the WEC project, we will discuss the actual risks that we had been facing. First is the choosing of a suitable place that meets the requirements of the project. Before Mantanani Island being selected, the first selected place is located at Mandi Darah

Table 2. FMEA of WEC [11]

Component	Function	Failure Mode	Effects	(S)	(O)	Root of Failure	Controls	(D)	RPN	Recommended Action
Buoy	Give movement in heave motion	Does not give anticipated movement & force	Power at low voltage or no power being regenerated	4	3	Defective of design or weak wave energy	Inspect the design of the buoy and wave energy accurately	7	84	A rigid trial in the laboratory before placing buoy
Lever arm	Changes displacement into oscillatory movement	Jammed throughout oscillation or pivot pin fracture	Low or no power output	4	3	Rust or high magnitude of the wave	Galvanizing the arm and balancing it with a counterweight	6	72	Schedule maintenance and testing to find a counterweight
Uni-directional gearbox	Bi-directional spin into a uni-directional spin	Shattered of gearbox tooth	No power output	3	3	Wavering or fabrication defects	Inspect design and lubricate appropriately	6	54	Routine maintenance
Step-up gearbox	Increase the speed of the spin	Shattered of gearbox tooth	No power output	2	3	Wavering or fabrication defects	Inspect design and lubricate appropriately	6	36	Routine maintenance
Bearings	Helps in moving the device efficiently	Damage of ball bearings	Effectiveness reduced	3	2	Fabrication defects	Inspect design appropriately	6	36	Routine maintenance

Table 3. Guidelines for Severity [12]

Effect	Severity of Effect	Ranking
Catastrophic	Resource not available / problem unknown	10
Extreme	Resource not available / problem known and cannot be controlled	9
Very high	Resource not available / problem known and can be control	8
High	Resource available/major violation of policies	7
Moderate	Resource available/major violation of the process	6
Low	Resource available/major violation of procedures	5
Very low	Resource available/minor violation of policies	4
Minor	Resource available/minor violations of process	3
Very minor	Resource available/minor violations of procedures	2
None	No effect	1

Table 4. Guidelines for Occurrence [12]

Probability of Failure	Failure Probability	Ranking
Very high: Failure is almost inevitable	>1 in 2	10
	1 in 3	9
High: Repeated failures	>1 in 8	8
	1 in 20	7
Moderate: Occasional failures	1 in 80	6
	1 in 400	5
	1 in 2,000	4
Low: Relatively few failures	1 in 15,000	3
	1 in 150,000	2
Remote: Failure is unlikely	<1 in 1,500,000	1

island in Sabah. We choose the latter because the waves at Mandi Darah island did not meet the minimum requirement for the operation of WEC as the island is covered by 2 islands while Mantanani Island is not covered by anything and it is clear and open towards the south china sea. This situation is suitable by using the first method which is risk identification on the WEC PLC because the risk can be perceived in the early stages of the WEC project and know the level of the risk.

Another risk that the WEC project has been facing is the finalization design for the WEC model. WEC has a variety of design options such as Wave Activated Bodies, Overtopping devices, Point absorbers, and Oscillating Water Columns. The finalized design for the WEC project is by using Floating Oscillating Water Columns because the design is more suitable to the geography of the chosen place and the design can generate more power output of electricity. This situation is suitable by using the second method which is FMEA because the analysis covers the overall individual components of WEC and the risks can be managed accordingly alongside the failure mode, effects, root of failure, and the recommended action. This method also provides a Risk Priority Number (RPN) to identify which risks are more dangerous that can cause harm to the project if not treated first.

Based on the risks discussed above, both methods are suitable and can be applied for the WEC project. However, the usage of the method is different as both methods cover different aspects of risks. The first method is more suitable for the overall general aspects of the project as it is focused on the phases of the PLC while the second method is more suitable for the individual aspects of the project

Table 5. Guidelines for Detection[12]

Effect	Severity of Effect	Ranking
Uncertainty	Control **cannot** prevent/detect potential cause/mechanism and subsequent failure mode	10
Very Remote	**Very remote** chance that the control will prevent/detect potential cause/mechanism and subsequent failure mode	9
Remote	**Remote** chance that the control will prevent/detect potential cause/mechanism and subsequent failure mode	8
Very Low	The **very low** chance that the control will prevent/detect potential cause/mechanism and subsequent failure mode	7
Low	The **low** chance that the control will prevent/detect potential cause/mechanism and subsequent failure mode	6
Moderate	The **moderate** chance that the control will prevent/detect potential cause/mechanism and subsequent failure mode	5
Moderately High	The **moderately high** chance that the control will prevent/detect potential cause/mechanism and subsequent failure mode	4
High	The **high** chance that the control will prevent/detect potential cause/mechanism and subsequent failure mode	3
Very High	The **very high** chance that the control will prevent/detect potential cause/mechanism and subsequent failure mode	2
Almost Certain	Control **will** prevent/detect potential cause/mechanism and subsequent failure mode	1

like mechanical parts as it is focused on each component of WEC.

5. CONCLUSION

Risk is a factor that is sure to happen and it is usually recognized as a negative term. That is why risk identification is important and needed to be done through their overall PLC. From the risk identification of PLC for WEC above, it has been recognized that the event of reduction of project cost and poor job performance gives up an outstanding impact on the project and has a high level of risk. For the FMEA method, it shows that the floating buoy component is determined as the weakest part with the highest value of RPN of 84. The recommended action that needs to be taken is to do rigid testing in the lab before placing the buoy in the sea. The objective of this study can be achieved because both methods are suitable in handling the risks in the WEC project because they cover the different approaches of risks thus it enables to covers all aspects of the project as a whole as generally and individually.

ACKNOWLEDGMENTS

This paper is a part of the multidisciplinary research project of "Development of Optical Heave Buoy Wave Energy Converter (WEC)" and is supported by the Ministry of Water, Land, and Natural Resources under grant H0001 – UPNM/2018/AAIBE-KETTHA/TK/1/P6. The authors would like to thank everyone that involves directly or indirectly who assisted in the making of this paper.

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