Identification of Park Effect Probability in Wave Energy Conversion System using Multi Criteria Decision Making Method (AHP) and Neural Network Model (GMDH Shell)

Satyabrata Saha, Mrinmoy Majumder, Manish Pal

Abstract: The present research work demonstrates the trend of Park Effect to the Wave Energy Conversion system or in wave energy converter. The Park Effect occurred due to various reasons in a real field application of Wave Energy Conversion. Park Effect occurred in wind energy as well as wave energy. All possible factors are considered to find out the Park Effect. To analyze the Park Effect probability, Analytical Hierarchy Process (AHP) is used, from the result a model is generated through Neural Network software named GMDH Shell. There are significant uncertainties arising in particular from the lack of field tested result to calculate the Park Effect proximity on the devices. However, applying various hypotheses for design and physical parameters, it was found that the benefits of Park Effect influenced factors are all non-beneficiary to Park Effect trend. After all the calculations it can predict the proximity of the Park Effect in a Wave Energy Conversion system.

Keywords: AHP; Group Method of Data Handling (GMDH); Multi Criteria Decision Making; Park Effect; Wave Energy; Wave Energy Converter.

I. INTRODUCTION:

The term "Park Effect" refers to a renewable energy sector where a multiple number of renewable energy converter is present for power generation [1]. The park effect is mainly found in the wind turbine in a wind farm, in the turbine of a tidal power plant and also in a Wave Energy Converter (WEC) in wave power generation hubs [1, 2]. Every energy conversion device absorbs some quantity of energy from the source; therefore, input sources are slightly reduced to the adjacent converter, and then the converter resides close to the previous converter. This total phenomenon is termed as Park Effect. It has a significant amount of loss of input resources energy when the multiple number of wave energy converters are need to establish in a suitable location in where high potential of wave power availability is present. For a wave power industry, the park effect is to be calculated to design an array of WECs.

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II. SIGNIFICANCE OF PARK EFFECT IN WAVE ENERGY CONVERSION:

Wave power a perfect energy sources for efficiently providing renewable energy to densely inhabited coastal areas. In various research it has been found that the park effect has a tendency in decreasing the distance between the WECs increasing. For discussing the park effect in arrays of ocean wave energy converters, it is compulsory to know the practical approach of a wave energy conversion device interacts and absorbs energy from the adjacent incident wave and direct ocean wave [1, 3]. An incident wave is a wave propagating due to its natural phenomena, mainly in one direction, where a diffracted or radiated wave propagates in every direction from the source or from the origin purpose (due to self-created by the WEC). WEC isn't solely a wave absorbent material however additionally a power take off (PTO) mechanism is also affected by the motion of each WEC is also experiencing from the ocean waves created by is adjacent WECs once they are on the subject of every alternative. The general wave field is disturbed almost to all places around the body, but not effected at some distance [1].

WECs appear to be placed in various geometrical shape of arrays of devices. In an array of WECs, the interaction between equipment, structure, incident wave, diffracted wave, radiated wave can impact the overall efficiency of the array and the production. While discussing on the wave interaction designing of the array is so important, such as space between the converters draws more concentration. A metaheuristic approach to the array design such multi criteria decision making strategy is good one to decide it [1, 4]. The result of the interactions between arrays on the power production is described as the ratio between the output powers from an array to the same no of times the output power from a single isolated system. If the ratio is less than 1, it means the average energy production of every system within the array is below the energy production of the single system. Hence, the wave interference has a decreasing result on the output power of the wave farm. Reversely, if the ratio value greater than 1, the result is take positively and the array is effective [1].

III. FACTORS WHICH IMPACTS ON THE PARK EFFECT REGARDING POSITION OF THE WEC:

A wave farm contains a number of ocean wave energy converters (OWECs) installed within an area or region. The management department sets a goal for a wave farm increasing energy or power generation. Accurate energy output for the approachable connection to a grid, minimizing hardware losses, and maintaining the safe working conditions of the devices, etc. most of the devices inside a wave farm are actually because of nearby to one another due to several problems, like distance limit, wire and cable preparation, electricity generation and regular maintenance. Hence, each WEC isn't a wave absorptive material. The position of the WECs suggests the activity of each WEC is tormented by the passive waves generated by adjacent waves. This phenomenon make complexity in every modeling and so the management of the wave farm. In order to in socio-economic scenario, the machine price of the total setup unit is usually refractory for real time operations [5].

There are few factors are responsible for park effect in a Wave Energy Power hub, each of those factors are no beneficiary to the power generation i.e. these all factors can increase or decrease the park effect.

A. Distances between two Converters:

The lateral and longitudinal distance between two converters is inversely proportional to the park effect [1, 6]. Close array WECs are greatly affected by the park effect. Incident wave interaction with any converter then the diffracted wave or radiated wave created by the WECs will spread to the WECs nearby. This will cause loss of some amount of input energy sources. If the other converter resided sufficient amount of distance from the previous one then, diffracted wave will not cause any affect to that WECs. Such as for Oscillating Water Column (OWC) has to be established a few meters of distances [6]. The motion of every devices created the radiated wave in such a pattern those are a unit of a bigger operation of the management and decision making policies to be utilized on each and every device, that creates the best usage of devices via inter devices communication, coordinates in between their motion to the mutual benefits of all devices at intervals of the wave farm. This is associates with the best farm power generation which is the objective [9].

B. No of converters and types of array:

Management sets a goal for a wave farm for increasing the efficiency in the power generation, dealt successfully the power output for a connection to a grid, reducing equipment cost, and keep maintaining the safe functioning of the devices. The no of converters, especially array in the wave farm is expounded to park effect. Thus smaller array has an effect of less park effect. Not only has a smaller array had a chance to produce park effect to each other, if they are not placed properly in the grid. Such as an offshore array of WEC is not placed like a proper geometrically, radiated waves can affect the other WECs nearby. In case of a larger array it has the most chance to produce the park effect, because multiple WECs are placed closed to each other than

diffracted wave can cause park effect. The ratio factor described earlier permits the analysis of the absorption performance for isolated device, and it provides a helpful metric for the comparison of the performance of various array configurations [9].

C. Position of WEC Regarding Incoming Wave:

For offshore location of the sea, the Wave Power Conversion device such as Buoys, uses the vertical hydraulic forces of waves. For Near shore location of the sea, the Wave Energy Conversion device (Example: bottom hinged flaps) uses horizontal force components by the piston cylinder mechanism moving through the waves [8]. For offshore the incident waves are strikes at the first WEC, if in that array the converter are not placed properly like one after another then diffracted waves can cause park effect, on the other hand onshore it has less effect on the WECs with respect to the incoming waves. For an example of Over topping device Wave Dragon placed in offshore and it is interacting with wave, so there the incident waves over flowed inside the storage reservoir then some portion of the available energy absorbed here. The rest of the structure of the device creates some diffracted waves around it. So this kind of converter absorbing some amount of available hydraulic energy from the incident waves in that location. [1, 9].

D. Types of Converter:

In a wave farm wave energy arrays contain large equipment may be submerged of fully merged. The equipment are compactly established. It forms a unit production house. Each unit contains larger construction. Few examples of larger devices that contain a unit such as Pelamis [10, 13], Oyster [13] and Power buoy, and closely packed arrays of WECs like Wavestar, Fred Olsen Lifesaver [8], Manchester cork [11] and spear technologies [9]. From research it was found that circular arrays are more efficient than other geometrical shape of a array [13]. In various results of research and field works it is observed that Comparing to Oscillating Water Column (OWC) has a better result against park effect. It has a partially submerged concrete structure and vessel and one side open as a passage and other side resides below the water surface. Air is trapped into the chamber or vessel and compressed by the incoming wave, and the air flow through a bidirectional turbine that drives an electrical generator [14]. For an OWC has a smaller chance of park effect if it's established on the coastal region with sufficient distance to avoid the radiated wave. Geometrically small size converter has a less chance to produce park effect to each other comparison to large converter.

E. Types of Wave interaction with the WECs:

In the open ocean, waves are variety in regular and irregular manner. In a regular incident waves interacting with WECs have a chance of creating the park effect.

In regular wave, the wave interaction dependent on wave frequency and wave period, the effective radiative wave has an equal chances to produce it will remain a long distance, then the corresponding park effect will be there. For an irregular wave, the wave interaction is smaller because of constructing and the destructive turbulent wave effect will compensate between them [11, 14]. But in case of regular waves have an effective effort on power generation, so the park effect is needed to avoid for better production. On the other hand, the irregular waves have a tendency to minimize the diffracted waves by its own order of flow, so the array designing in a smaller area is possible without more disturbances of park effect.

F. Other Wave Parameters are also having some roles in Park Effect like Wavelength, Wave Frequency Water Depth:

For an ocean wave, these are the main parameters regarding wave energy production, these parameters also affect the park effect, like if wavelength is very long then it has a little tendency to produce the park effect, because for a long wave length the earlier declared ratio value has an tendency to be more [9], so the chances of park effect weak. With respect to shorter wave length the ratio factor is very low because of the destructive interference between the incident wave and diffracted wave. So the park effect can be generated within the WECs converter array.

For wave frequency and wave periods are related to park effect in regular waves, as well as affecting the above ratio factor, if wave frequency or wave period is less, then it has tendency to give the ratio factor less, the result cannot be constructive, i.e. park effect can occur. In case of irregular wave, the wave frequency or wave period don't have much role on it [13].

IV. LOCATIONS OF THE WAVE ENERGY CONVERTER

In the definition of Wave Energy Converter, (WEC) is a device which utilize the hydraulic force of ocean waves and covert it in to electrical energy. In the ocean wave energy conversion plant establishment there are mainly three types of suitable locations are considered, Offshore, Near shore and Onshore.

Wave energy converters are updated day by day in last ten to fifteen years. It is mainly classified in location based and power generation capacity. In modern day the technology has grown in wave hydraulic forces. The primary source of power in WECs are considered in the coastal region or shoreline. The next generation WECs are after coastal region which is near shore, most of the WECs are submerged and converters are attaching it by cable or rope to the shore or to an anchor. Apart from these two types of converter third generation converter are those which located at offshore in the ocean. In offshore the condition are more difficult than the previous two locations. In the offshore location installation and operational function too harsher [12]. The factors which might cause the choice of one of the three locations are specific to the budget accessibility and so the requirements or restrictions set by Management.

V. METHODOLOGY

Methodology of this study is described in the flowchart of Fig 1. Initially, the problems related to the Park Effect of WECs are considered because of better performance or improved output of huge investment regarding Wave Energy Conversion process. Major factors that influenced Park Effects are considered from the mechanical operation. Those parameters are placed properly by using Multi Criteria Decision Making methods [17]. The types of Converters are considered as criteria such that Offshore, Nearshore and Onshore and the Park Effect influenced six parameters are considered as alternatives in the process of identifying the weights of parameters by using AHP [7]. AHP scale value 1 to 9 were applied for comparison matrices with respect to alternative versus alternative and criteria versus criteria, After comparison matrices the weights are found, then the ANN software GMDH was trained by those weights and the model was generated to predict the Index value of Park Effect probabilities [16].
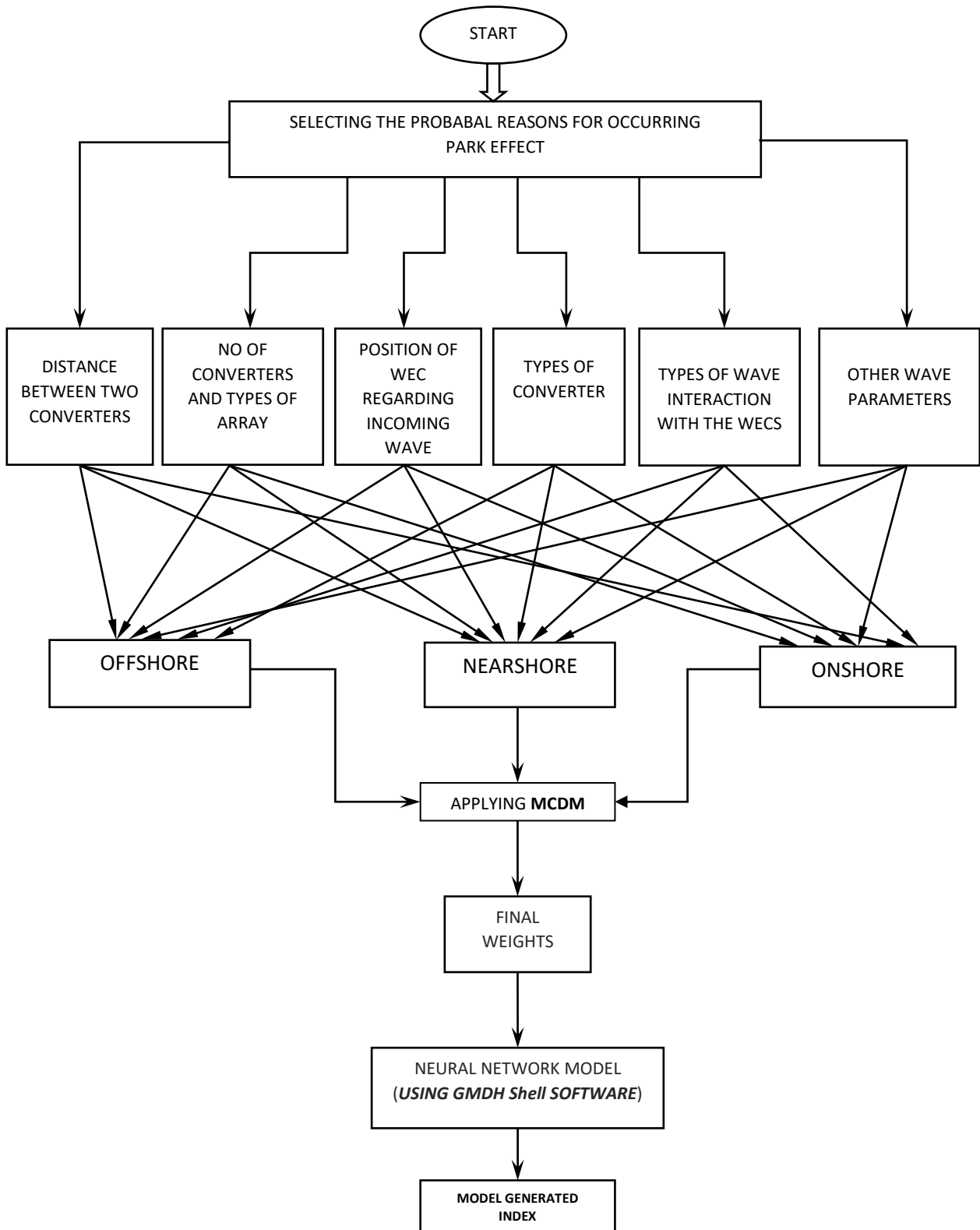
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Fig 1 Flowchart of the total process

VI.   RESULTS AND DISCUSSIONS

Multi Criteria Decision Making method was used to ranking the six Park Effect influenced parameters as per their weightage value, with respect to the locations of the converter (offshore, near shore and onshore). AHP was used to detect the relative importance of the alternative with respect to the criteria for unbiased and objective decision making [7, 17].

A. MCDM Result:

Table I: Final Weights of Park Effect Parameters by AHP methods

PARK EFFECT INFLUENCED FACTORS IN WECS	OFFSHORE	NEARSHORE	ONSHORE	CRITERIA WEIGHTS	FINAL WEIGHTS
DISTANCE BETWEEN TWO CONVERTERS	0.3011	0.3001	0.1572	0.5041	0.2782
NO OF CONVERTERS AND TYPES OF ARRAY	0.1577	0.2423	0.0882	0.3491	0.1793
POSITION OF WEC REGARDING INCOMING WAVE	0.2313	0.1587	0.2647	0.1437	0.2137
TYPES OF CONVERTER	0.1015	0.0667	0.1765		0.0989
TYPES OF WAVE INTERACTION WITH THE WECS	0.0657	0.1343	0.2059		0.1116
OTHER WAVE PARAMETERS	0.1343	0.1052	0.1174		0.1282

B. PNN Software predicted algorithm:

$$F_I = N_C + \sum_{n=1}^{n}(w_n x_n)\ldots\ldots\ldots (i)\ [16]$$

P_I = Park Effect Index, N_C = Neural Network Model Constant = 372137×10^{-13} [Obtained by GMDH Software]

W_n = Weight of the parameter, X_n = Parameter data (Scale to 1)

Generated by GMDH Shell 3.6.6 (Software)

Y_1 = 1.55849e-14 + P_1×0.276291 + P_2×0.181212 + P_3×0.214006 + P_4×0.0980197 + P_5×0.112374 + P_6×0.129218
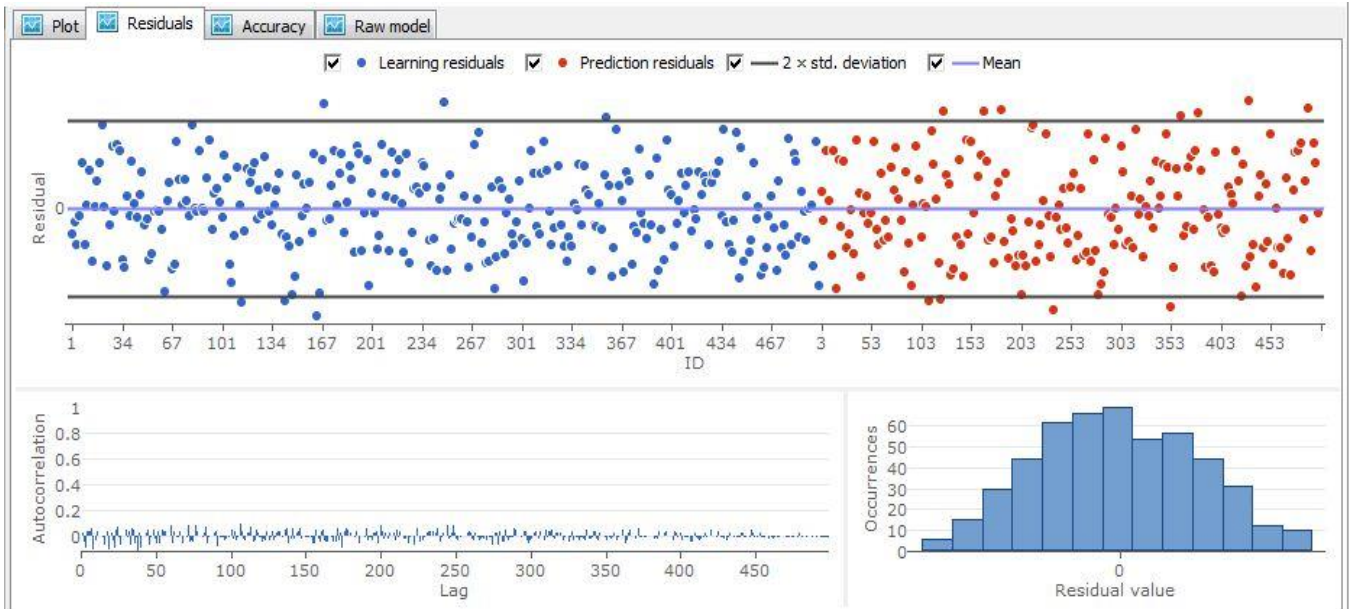
Model   Criterion value
Y_1 3.72137e-08

P_1 = *Distance between Two Converters*
P_2 = *No of Converters and Types of Array*
P_3 = *Position of WEC Regarding Incoming Wave*
P_4 = *Types of Converter*
P_5 = *Types of Wave Interaction with the WECs*
P_6 = *Other Wave Parameters*

All the input parameters were uploaded in Excel file and trained in GMDH Shell. After initialization GMDH shows the output results for datasets. Fig 3 blue colored portions are input parameters and red colored points are predicted results.
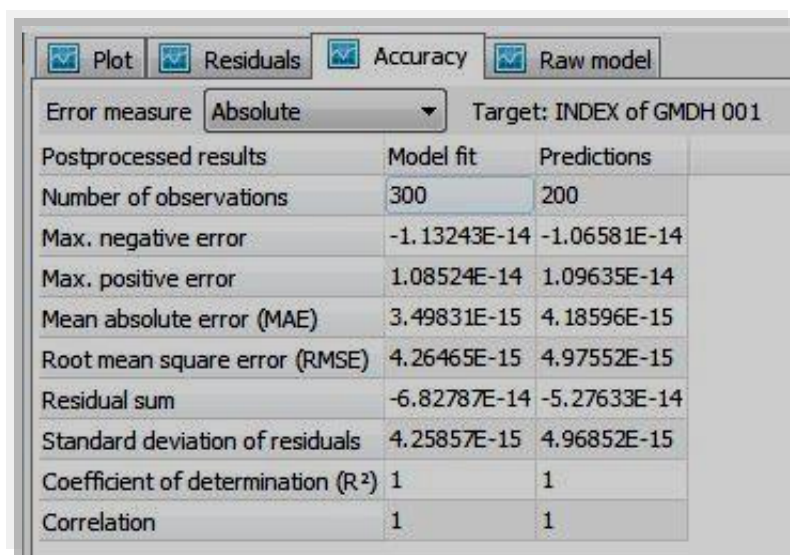
Fig 2 Analysis of Accuracy of the Model developed by GMDH software

Fig. 3 Distribution of Residual, Autocorrelation and Occurrence of Residual Values

B. Application of Neural Network:

The present investigation is to observe and estimate the correlation between the variables as input and also the output as model index. Thus, the chosen parameters are used as inputs and the feasibleness index (model index) was considered as the output.

Table: II Sample Model Data generated from GMDH Software

SL NO	DISTANCE BETWEEN TWO CONVERTERS	NO OF CONVERTERS AND TYPES OF ARRAY	POSITION OF WEC REGARDING INCOMING WAVE	TYPES OF CONVERTER	TYPES OF WAVE INTERACTION WITH THE WECS	OTHER WAVE PARAMETERS	INDEX	PREDICTED.INDEX
1	0.9578	0.9296	0.0351	0.5290	0.1176	0.0657	0.5139	0.5140
2	0.6019	0.5617	0.7937	0.4800	0.4539	0.2334	0.5623	0.5623
3	0.1739	0.7433	0.7653	0.4066	0.0917	0.5354	0.4591	0.5548
4	0.7216	0.6081	0.0767	0.4820	0.8792	0.7033	0.5547	0.5093
5	0.7167	0.6918	0.2191	0.4567	0.8079	0.0672	0.5129	0.3892
6	0.3443	0.1701	0.8938	0.0018	0.8379	0.8281	0.5093	0.6429

From the Table: 2 third reading has a more tendency of fatigue failure, whereas the fifth one has a lower chance of fatigue failure on WEC.

VII. CONCLUSION

The present study tries to estimate the chance of Park effect in the wave energy device with the assistance of an index by implementation Multi Criteria decision making methodology, AHP and group method of data Handling, a new adaptation of Neural Network technique..

According to the results Distance between two converters was found to be most significant among the selected factors and have the highest priority value as determined by the AHP method. However, position of converter regarding the incoming wave was identified as the second and no of converters and types of array was as the third most important parameter in the estimation of the index which represents the park effect probability of a Wave Energy Conversion system. The GMDH model was used to map the selected input factor and the index and to develop an automatic framework for the estimation of the chance of Park Effect. In this aspect the model performance was satisfactory and its accuracy level was approximately near

about the input variables. However the lack of application in the real time scenario may raise question about the reliability and the practical feasibility of the index. But this can be dealt in further studies so that a simple, cost-effective and automatic system can be used widely.

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