# Application of Indicator Guided Multi Nomal Regression Analysis (IGMNRA) for Estimation of Location Suitability for a Hybrid Wind-Wave Power

Uma Shankar Pande
School of Hydro-Informatics Engineering
National Institute of Technology
Agartala, India

Ankit Khare
School of Hydro-Informatics Engineering
National Institute of Technology
Agartala, India

Mrinmoy Majumder
School of Hydro-Informatics Engineering
National Institute of Technology
Agartala, India

## ABSTRACT
The progression of the human race and technological advancements has imposed burgeoning levels of energy demand. Also, due to the rapid development of the industrial and agricultural sector added with the lust for the luxury of the human population, pollution has become one of the major reasons for the deterioration in the overall health of human beings. For both of this aspect, the role of renewable sources of energy, as a possible alternative to fossil fuels, was increasingly becoming significant. But due to the uncertainty in availability and cost involved for conversion the popularity of such type of energy is limited. That is why in various places, the potential of hybridizing two different sources of renewable energy was investigated which was found to be impacted by different location dependent factors. It appears that selection of location has become significant in the success of hybridized power plants. Unfortunately, there is a lack of adequate and reliable methods for selection of location objectively without any human influence for hybrid power plants. The present study proposes a new model for estimation of location suitability for a hybrid Wind Wave Power Plant. The results encourage the authors for further application of the new method.

Wind and wave Hybrid renewable energy system is a newly introduced system in the renewable energy field. This system involves the integration of two energy system that will give continuous power supply. In this hybrid system electricity is generated by the system in which wind energy system and wave energy system works simultaneously to compensate for time. When one of them is not available we can use other one and vice versa. Wind energy when combined with any other alternative source of energy it can provide a reliable supply of electricity with minimal impact on the environment. So the efficiency of the plant also depends on the location if the location is not suitable it will affect adversely. Availability of the sources can be different in different locations. This paper deals with the combination of wind and wave hybrid energy system which lead to generate electricity without deleterious the environment .this present study discuss the development of location suitability model with the help of group method data handling which used the decision forest algorithm for modeling.

## Keywords
Group method data handling (GMDH), Decision forest, hybrid energy system;

## 1. INTRODUCTION
After systematic literature review is conducted it was found that the electricity is one of the serious issues for the whole world.in this scenario, the non-conventional energy source is used as the main source of energy but unfortunately, we are running out of the fuel which is required for the conventional source of energy, for example, most of the electricity which is generated by the thermal power plant utilize coal as the working fuel [7, 8]. But in this world coal is in a certain amount so there is a need of some alternative source of energy which can provide us a sufficient and continuous supply of energy to fulfill the requirement of current scenario of energy.in this aspect renewable energy play a significant role to fulfill that requirement and wind and wave energy is one of the fastest growing renewable energy source from last two three decades so there is a need of introducing new technology which can deal with the optimistic problem so hybrid renewable energy system is introduced to overcome this types of problem[1,2, 4].

In neural network model various training algorithm are used to learn the problem but the number of algorithms is in educate and model performance may get enriched with the application of another training algorithm that is why in the present study a non-linear index based polynomial neural network model was applied to develop a multinomial model which estimate the suitability of location as per the value of the input parameter for the specific location [9].

The system is totally automated and the priority of the parameter remain hidden from the user of the system this ensure the model to be impartial and completely free of human bias.

## 2. OBJECTIVE
The present investigation for the following objective- Development of an objective method for identification of optimal location fir hybrid wind wave energy power plant .the model must be

free of human bias

Completely automated

Non-linear and multinomal

The implementation of multinomal regression analysis model will be making the framework, exhaustive and not specific to the data set with which the model will be a trend.

## 3. FEATURE WHICH Affects THE HYBRID WIND AND Waves ENERGY SYSTEM
To convert the low-grade energy into power by the OTEC plant a suitable, optimal and organic working fluid is required and the properties of the working fluid are discussed below[3, 5, 6]-

## 3.1 Wave height

Wave height is the difference between the elevations or crest and trough the molecular weight of the organic working fluid should be high because the suitability of the working fluid increases with higher molecular weight to obtain the higher turbine efficiency.

## 3.2 Wave period

Wave period is the measured of time it takes for the wave cycle to complete. Wave period measured in second. Wave period is directly proportional to wavelength and inversely proportional to speed of the wave and wind

## 3.3 Wavelength

Wavelength is a measure of distance between any two points with the same phase such as the distance between the crest or distance between the trough. Wavelength is inversely proportional to the frequency of the wave. Wave with shorter frequency have higher wavelength and vice-versa

## 3.4 Wind speed

Wind speed is caused by pressure difference usually due to change in temperature. When air flow from high pressure to low pressure then wind blows. Wind speed is the most important parameter for selection of a location for hybrid wind and wave energy system. Wind speed increases the wave frequency and wave height which directly increase the power output the system.

## 3.5 Ambient temperature

Air temperature varies from place to place.at different location it will be different. Some place has higher air temperature and some place at lower air temperature .as the air temperature falls it will increase the chilling effect of any wind and vice versa.

## 3.6 Swept area of turbine

The power output of the wind turbine is directly related to swept area. The larger the diameter of the blades the more power it is capable of extracting energy from the wind.

## 3.7 Natural hazards

Wind and wave power can be related to natural hazards in a different way. Wind turbine disasters run the gamut of possibilities from noise and vibration issues to complete turbine failure, which can result in launching the enormous blades great distances.

## 3.8 Altitude

The tower height is the most important parameter in the design of horizontal axis or vertical axis wind turbine. Wind speed close to the ground usually subsides whereas at higher altitude the wind blows faster rate so wind speed is the dependent factor for the designing of the horizontal axis wind turbine. Wind speed increases with increase the tower height. Doubling the altitude of turbine wind speed expected to increase about 10% and the expected power by 34%.

# 4. GROUP METHOD-DATA HANDLING

Group Method of Data Handling is a polynomial neural network where multiple models are used to select the optimal number of inputs and network topology. In this aspect, a fitness function like Root Mean Square Error or Maximum Absolute Error were used to find the optimal configuration according to the data provided to the model [11, 12].

Various application of GMDH can be seen in the literature like Wang et.al. (2017), Hosseini and Afrakoti (2017), Zjavka. Where the model was utilized to predict the operational efficiency of Small and Medium Scale Enterprise in China, energy spectra unfolding, photovoltaic output power respectively. Much other related application of GMDH can be found where the model was utilized either separately or with another type of algorithm (like Genetic Algorithm or Evolutionary Fuzzy Logic etc.) to map the output and inputs with the level of non-linearity[9, 10].

## 4.1 MODEL GENERATION FLOW CHART

Method for model generation given in below flow chart

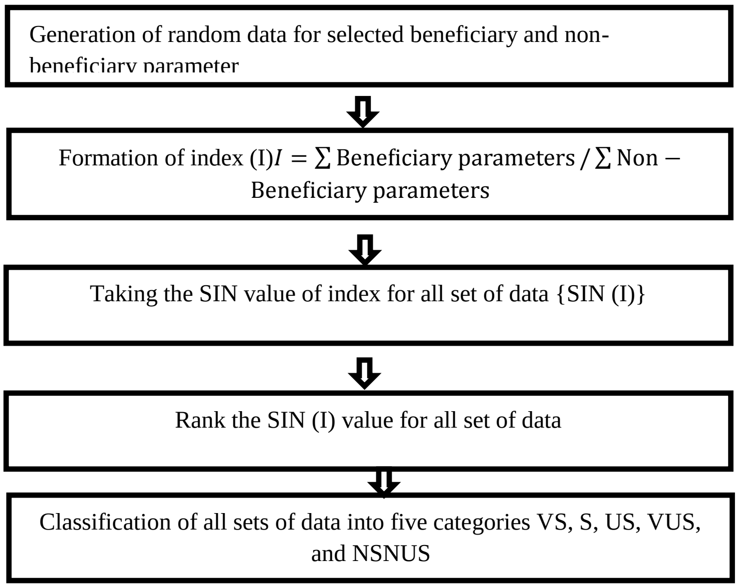


**Figure 1: Model development flow chart**

# 5. POTENTIAL OF WIND AND WAVE IN ANDAMAN AND NICOBAR ISLANDS

Andaman and Nicobar Islands have the great potential of wind and wave hybrid energy system. So in this study, this region has been selected for the validation of the model which is developed in GMDH shell. The locations selection criteria are-

I. Wave height (feet)
II. Wavelength (m)
III. Wave duration (second)
IV. Wind speed (knot)
V. Altitude (m)
VI. Swept area ($m^2$)
VII. Natural hazards probability (%)
VIII. Ambient temperature (°C)

The data source for all the parameter is WWW.BUOYWEATHER.COM and NOAA.

**Table 1: Potential profiles for the plant**

| Lattitude | Longitude | WH | WL | WD | WS | ALTTD | SA | NH | AT |
|---|---|---|---|---|---|---|---|---|---|
| 11.632°N | 92.752°E | 7 | 28 | 14 | 10 | 120 | 1500 | 20 | 27 |
| 11.564°N | 92.733°E | 6.5 | 18 | 15 | 10 | 80 | 3000 | 15 | 26 |
| 11.548°N | 92.733°E | 4 | 25 | 15.5 | 12 | 100 | 3500 | 25 | 27 |
| 13.401°N | 93.068°E | 2.5 | 15 | 14 | 10 | 130 | 2500 | 18 | 25 |
| 13.392°N | 92.089°E | 4 | 20 | 15.5 | 12 | 110 | 3500 | 22 | 25 |
| 13.061°N | 92.793°E | 2.75 | 18 | 14.5 | 11 | 95 | 4500 | 20 | 28 |
| 12.861°N | 92.647°E | 3 | 20 | 15 | 10 | 90 | 4000 | 18 | 26 |
| 12.499°N | 92.702°E | 2.5 | 25 | 14 | 12 | 120 | 3000 | 30 | 27 |
| 11.631°N | 92.752°E | 4 | 18 | 15 | 11 | 110 | 3200 | 26 | 25 |
| 13.246°N | 93.056°E | 3 | 15 | 15 | 10 | 100 | 3500 | 20 | 28 |
| 11.638°N | 92.607°E | 4.5 | 22 | 14.5 | 12 | 120 | 2000 | 25 | 28 |
| 11.531°N | 92.644°E | 3.5 | 20 | 14 | 11 | 95 | 2500 | 22 | 30 |

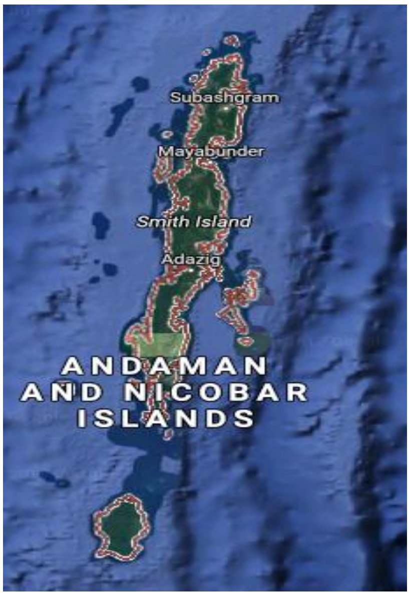


**Figure 2: map of Andaman Nicobar islands**

## 6. VALIDATION OF MODEL

The generated model in the GMDH shell need to be validated and it is validated by input parameter of the selection location which is discussed in the previous section.to validate this model all the parameter of the each location is taken as an input variable and after applying these input a result is found which indicate that which location is suitable or which is unsuitable. Input variable is given in table 2 which is a normalized value of table 1.

| WH | WL | WD | WS | Altitude | SA | NH | AT | Index | SIN(i) |
|---|---|---|---|---|---|---|---|---|---|
| 0.090395 | 0.114754 | 0.079545 | 0.105634 | 0.094488 | 0.040872 | 0.076628 | 0.091837 | 1.639838 | 0.997618 |
| 0.146893 | 0.07377 | 0.085227 | 0.070423 | 0.062992 | 0.081744 | 0.057471 | 0.088435 | 2.192722 | 0.812758 |
| 0.090395 | 0.102459 | 0.088068 | 0.084507 | 0.07874 | 0.095368 | 0.095785 | 0.091837 | 1.729965 | 0.987359 |
| 0.056497 | 0.061475 | 0.079545 | 0.056338 | 0.102362 | 0.06812 | 0.068966 | 0.085034 | 1.255944 | 0.950842 |
| 0.090395 | 0.081967 | 0.088068 | 0.084507 | 0.086614 | 0.095368 | 0.084291 | 0.085034 | 1.720352 | 0.988837 |
| 0.062147 | 0.07377 | 0.082386 | 0.077465 | 0.074803 | 0.122616 | 0.076628 | 0.095238 | 1.696133 | 0.992156 |
| 0.067797 | 0.081967 | 0.085227 | 0.112676 | 0.070866 | 0.108992 | 0.068966 | 0.088435 | 2.000547 | 0.90907 |
| 0.056497 | 0.102459 | 0.079545 | 0.084507 | 0.094488 | 0.081744 | 0.114943 | 0.091837 | 1.343499 | 0.974279 |
| 0.090395 | 0.07377 | 0.085227 | 0.077465 | 0.086614 | 0.087193 | 0.099617 | 0.085034 | 1.526372 | 0.999013 |
| 0.067797 | 0.061475 | 0.085227 | 0.070423 | 0.07874 | 0.095368 | 0.076628 | 0.095238 | 1.517477 | 0.998579 |
| 0.101695 | 0.090164 | 0.082386 | 0.098592 | 0.094488 | 0.054496 | 0.095785 | 0.095238 | 1.496725 | 0.997258 |
| 0.079096 | 0.081967 | 0.079545 | 0.077465 | 0.074803 | 0.06812 | 0.084291 | 0.102041 | 1.478902 | 0.995781 |

**Table 2: Input variables for the GMDH model**

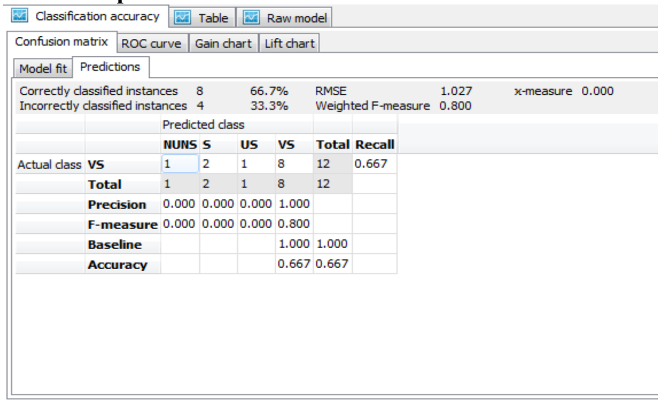


**Figure 3: Model characteristics**

## 7. RESULTS

The result of validation are given in table this shows that location 1, 3, 5, 6, 9, 10, 11, 12 are very suitable and location 4, 8 are suitable and location 7 is neither suitable nor unsuitable and location 2 is unsuitable for installation of wind and wave hybrid renewable energy system. In this way, model has classified all the potential profile

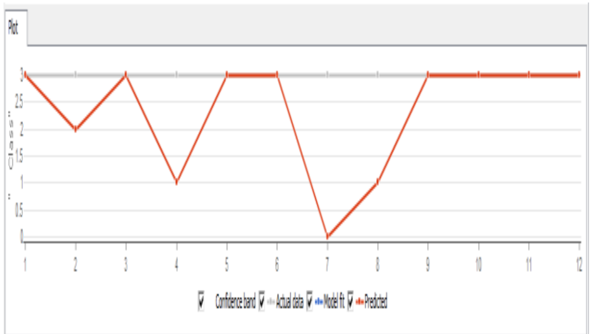

**Figure 4: classification graph**

**Table 3: Classified location**

| ID | Actual | Prediction | Hit/miss |
|---|---|---|---|
| 1 | VS | VS | Hit |
| 2 | VS | US | Miss |
| 3 | VS | VS | Hit |
| 4 | VS | S | Miss |
| 5 | VS | VS | Hit |
| 6 | VS | VS | Hit |
| 7 | VS | NUNS | Miss |
| 8 | VS | S | Miss |
| 9 | VS | VS | Hit |
| 10 | VS | VS | Hit |
| 11 | VS | VS | Hit |
| 12 | VS | VS | Hit |

# 8. CONCLUSION

The present study tries to develop a model which can predict the suitability of the location for the wind and wave hybrid renewable energy system. This model gives the result in the form of categories and the categories are vs., s, nuns, us, vus. Location selection for wind wave hybrid power plant till now not attempted any of the public studies. In most of the hybrid renewable energy system the selection of location was performed based on expert's feedback, utilization of multi-criteria decision-making system and linear or neural network regression model The problem of these approaches are their dependence on human inferences also the location selection problem is a non-linear problem and it cannot be at adjudged be linear method. So this method can be used for the further classification and prediction of the potential profiles.

# 9. REFERENCES

[1] Manwell, J. F., McGowan, J. G., & Rogers, A. L. (2010). Wind energy explained: theory, design, and application. John Wiley & Sons.

[2] MacCarthy, B. L., & Atthirawong, W. (2003). Factors affecting location decisions in international operations–a Delphi study. International Journal of Operations & Production Management, 23(7), 794-818.

[3] Ghosh, S., Chakraborty, T., Saha, S., Majumder, M., & Pal, M. (2016). Development of the location suitability index for wave energy production by ANN and MCDM techniques. Renewable and Sustainable Energy Reviews, 59, 1017-1028.

[4] Yang, H., Zhou, W., Lu, L., & Fang, Z. (2008). Optimal sizing method for stand-alone hybrid solar–wind system with LPSP technology by using genetic algorithm. Solar energy, 82(4), 354-367.

[5] Pérez-Collazo, C., Greaves, D., & Iglesias, G. (2015). A review of combined wave and offshore wind energy. Renewable and Sustainable Energy Reviews, 42, 141-153.

[6] Ackermann, T., & Söder, L. (2000). Wind energy technology and current status: a review. Renewable and sustainable energy reviews, 4(4), 315-374.

[7] Dincer, I. (2000). Renewable energy and sustainable development: a crucial review. Renewable and Sustainable Energy Reviews, 4(2), 157-175.

[8] Kaldellis, J. K., & Zafirakis, D. (2011). The wind energy (r) evolution: A short review of a long history. Renewable Energy, 36(7), 1887-1901.

[9] Wang, R., Ling, B., & Wang, F. (2017). Application of GA-GMDH Prediction Model in Operational Monitoring of SMEs in Chengdu. In Proceedings of the Tenth International Conference on Management Science and Engineering Management (pp. 513-524). Springer Singapore..

[10] Hosseini, S. A., & Afrakoti, I. E. P. (2017). Energy spectra unfolding of fast neutron sources using the group method of data handling and decision tree algorithms. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 851, 5-9.

[11] Ivakhnenko, A. G., & Ivakhnenko, G. A. (1995). The review of problems solvable by algorithms of the group method of data handling (GMDH). Pattern Recognition And Image Analysis C/C Of Raspoznavaniye Obrazov I Analiz Izobrazhenii, 5, 527-535.

[12] Srinivasan, D. (2008). Energy demand prediction using GMDH networks. Neurocomputing, 72(1), 625-629.