A MULTICRITERIA APPROACH TO EVALUATE OFFSHORE WIND FARMS IN TAMILNADU COASTAL REGION

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ABSTRACT

Wind energy offers significant potential for greenhouse gas emissions reductions. Most applications have been developed onshore but the planning and sitting conflicts with other land uses have created considerable interest and motivated research to offshore wind energy establishments. As per Lawrence Berkeley National Laboratory & WISE (World Institute of Science &Environment) reports, the offshore potential in India is estimated more than 100 GW. The coastal regions along Tamil Nadu is having very high potential in wind energy with net Capacity Utilization factor (CUF) of over 40%and wind power density of over 700 w/m^{2}at many locations. In this study, a systematic process is carried out in order to investigate the most feasible region among 21 islands in Gulf of mannar for implementing the offshore wind farms. This can be achieved, by considering 4 criteria's like wind velocity, distance from shore, ship route distance and depth of the sea by using relative importance method.

Keywords: Capacity Utilization Factor, World Institute of Sustainable Energy

I.INTRODUCTION

Worldwide, wind energy is accepted as one of the most developed, cost-effective and proven renewable energy to meet increasing electricity demands in a sustainable manner. While onshore wind energy technologies have reached to a stage of mass deployment and have become competitive with fossil fuel based electricity generation with supportive policy regimes across the world, exploitation of offshore wind energy is yet to reach a comparable scale

About 5 GW offshore wind capacity has already been installed around the world and approximately an equal capacity is under construction. There are a large number of offshore wind farms in Belgium, Denmark, Finland, Germany, Ireland, Netherlands, Norway, Sweden, and United Kingdom. The European Union has established aggressive targets to install 40 GW of offshore wind by 2020 and 150 GW by 2030.It is estimated that by 2030, the installed capacity could reach 191 GW globally. Developing countries have more than 1/3rd global wind power capacity. In India - onshore wind energy deployment has crossed 19600MW - attracted $16.5 billion of investment in 2012, created179, 000 'green collar' jobs in manufacturing, project development, installation,

operation, maintenance, consulting etc., saving 131 million tons CO_2/year. Centre for Wind Energy Technology (CWET) has reassessed India's onshore wind power potential as 102,778 MW (at 80 meters height and 2% land availability).

Technology for offshore turbines same as that of onshore turbines and their operational life also same (~ 20 years).The rated capacity of turbines higher than that of onshore - in range of 3 MW-5 MW .Off shore wind farms in water depths from 0.8 to 220m with monopole, jacket, tripod and floating technologies. At different depths, turbine installations require different type of bases for stability .Mono pile base is used for water up to 30 m depth, whereas turbines installed on tripod or steel jacket base for 20-80 m depths.

II.GLOBAL SCENARIO OF OFFSHORE WIND TURBINES

2.1 Introduction on Offshore and Onshore Structures

2.1.1 Offshore structure: The structures and facilities installed in a marine environment for the production and transmission of electricity, oil, gas& other resources

2.1.2 Offshore wind turbine: Refers to the construction of wind farm in bodies of water to generate electricity from wind. Better wind speeds are available in offshore compared to on shore, so offshore wind power's contribution in terms of electricity supplied is higher.

2.1.3. Onshore structure: The structure & facilities install from the sea towards the land.

2.1.4. Onshore wind turbine: It refers to wind turbines located on land to generate electricity.

2.1.5. Advantages of offshore wind farm over onshore wind farm:

- Wind velocity in offshore is more than 20m/s and can reach as much as 50m/s where as in onshore limited (11 to 15m/s).
- Availability of free area for the installation of wind farm.
- Offshore wind velocity is higher & steadier in deep waters.
- Continuous availability of wind in offshore and extraction of energy is more efficient.
- Low Noise Pollution and Visual Intrusion.
- Most of the potential onshore sites already utilized.

2. 1.6. Evolution of offshore wind projects:

First Offshore Wind Turbine – Sweden (1990)

- 220 kW – Single, 250m from the coast@ 7m Water Depth Supported on Tripod

First Offshore Wind Farm – Denmark (1991)

- 450 kW – 11 Turbines, 1.5 – 3 km from coast@ 2-6 m Water Depth Gravity Foundation.
- Global Installed Capacity - 5.5 GW
- India is blessed with coastline of about 7600 Km. There are 3 zones located in Indian coastal lines. They are EEZ, pollution prevention zone, continuous zone & territorial zone. The EEZ lies 200 nautical miles from the base line of the shore, territorial zone lies 12 nautical miles from the base line of the shore and continuous zone lies 12 nautical miles from the base line of the territorial zone.
- "United Nations Convention on Law of the Sea" gives India a exclusive rights over its Exclusive Economic Zone (200 nautical miles from baseline) to develop offshore wind energy.

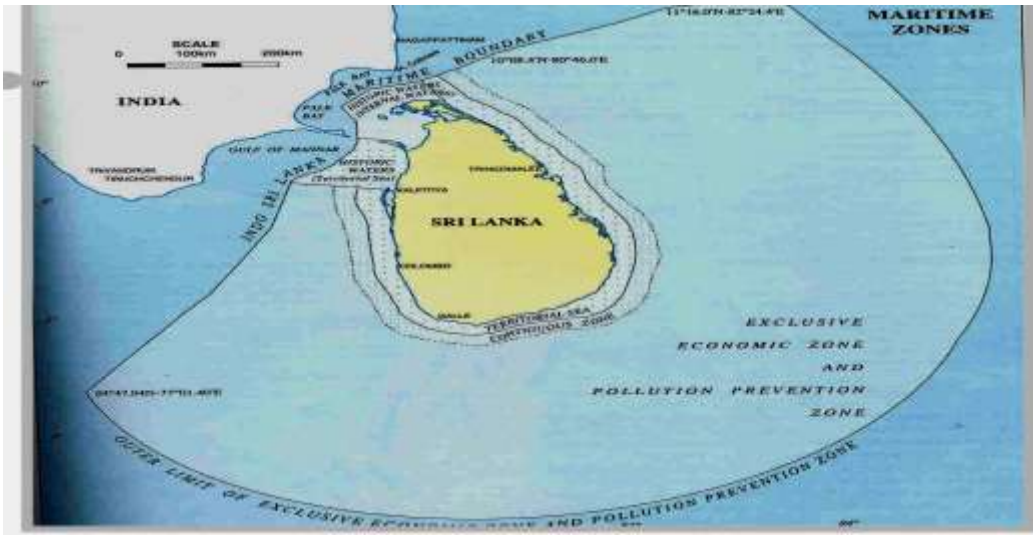


Fig.1 Indo-Sri lanka boundary line and Exclusive Economic Zone boundary line.

Source: United Nations Convention on the Law of the Sea (UNCLOS)

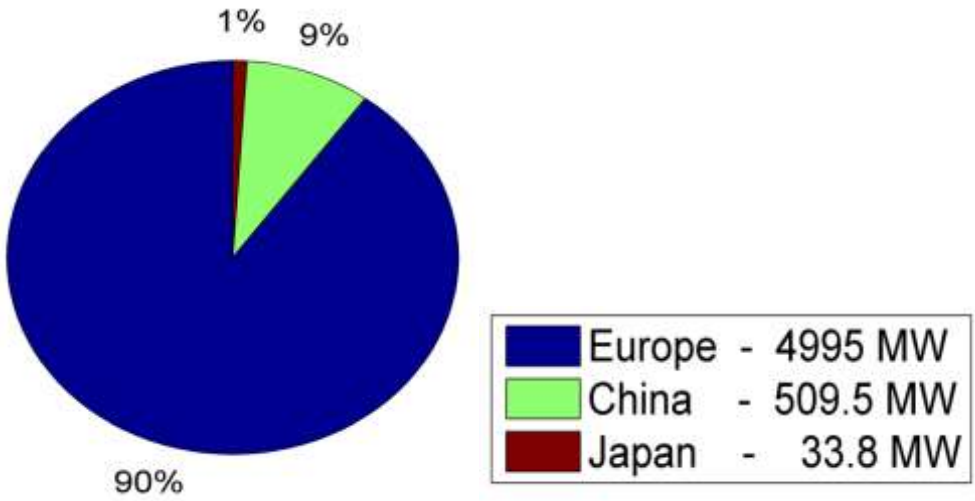


Fig.2.Global Scenario

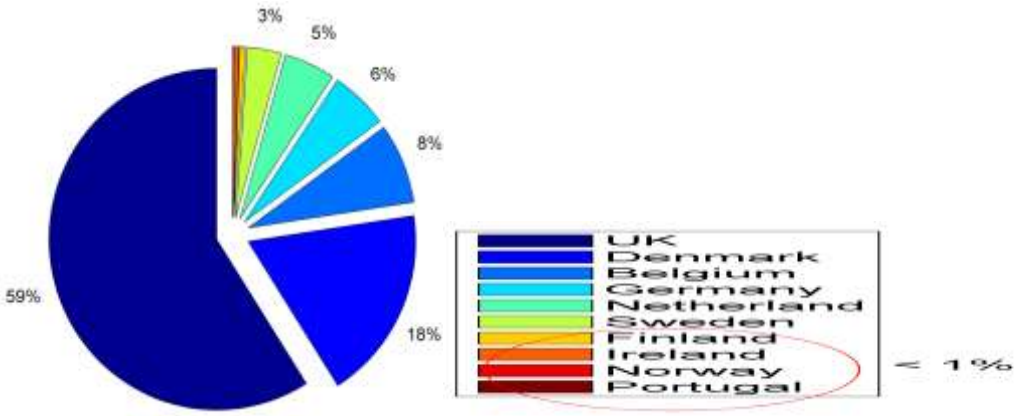


Fig.3.Installed Capacity in European countries

III.EXPERIMENTAL WORK

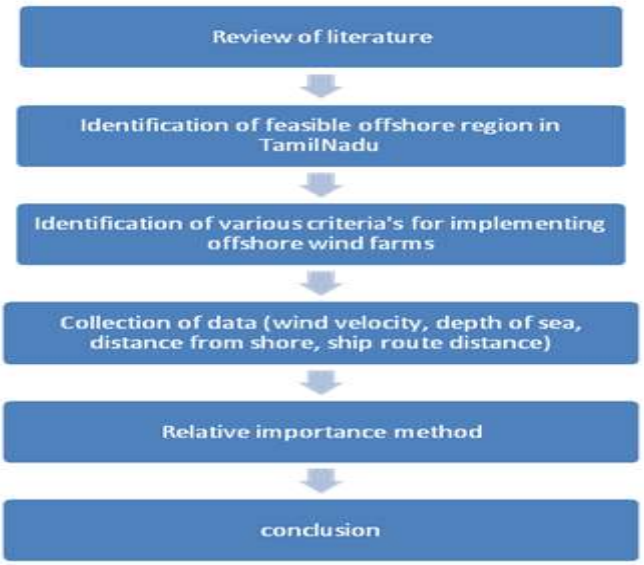


Fig.4.Methodology

The 4 criteria's are consider for implementing the offshore wind farm are studied from the review of literature, the criteria's as follows.

Table.1. Four Criteria Selection

Criteria's	Types	Description
Average wind velocity (m/s)	Quantitative	Average wind velocity
Depth of sea (m)	Quantitative	Average depth
Distance from shore(km)	Quantitative	Average islands distance from the shore
Distance to ship route (km)	Qualitative	Average distance of the ship route from the shore

IV IDENTIFICATION OF FEASIBLE OFFSHORE REGION IN TAMIL NADU

The Gulf of Mannar is the region among the Tamil Nadu coastal regions and is chosen for feasibility study implementation of offshore wind farm.

The Gulf of Mannar lies between India and Sri Lanka. It encompasses the territorial waters of the southeast coast of India, from Dhanushkodi in the north to Kanyakumari in the south . It has a chain of 21 islands, with each island having an area of 0.5 ha minimum and 129 ha maximum.

Islands are located 2 to 10 km from the mainland along the 140 km stretch between Tuticorin and Rameswaram (Lat8°55'-9°15'N and Long 78°0'-79°16'E). The Gulf of Mannar Marine Biosphere Reserve came in to existence on 18th February 1989 by a joint declaration of Government of India and Government of Tamil Nadu.. The purpose of the marine park is to create awareness on Conservation and management of the marine resources in a scientific manner so that there will be proper socioeconomic development in the region.

The aim of the park is to promote judicious and optimal utilization of the resources for research, education and recreational purposes following appropriate ecological principles. The depth of the Gulf of Mannar beyond the island chain ranges from 3.5 to 15 m with a sudden fall after that giving oceanic condition. There are 21 islands located in Gulf of Mannar region that fall under 4 groups (mandapam group, vember group, keezhakari group and tuticorin group).

Fig.4. Location of Gulf of Mannar Region in Indian Map

Fig.5. Islands in Gulf of Mannar

V IDENTIFICATION OF VARIOUS CRITERIAS FOR IMPLEMENTING OFFSHORE WIND FARMS:

5.1 Wind Velocity

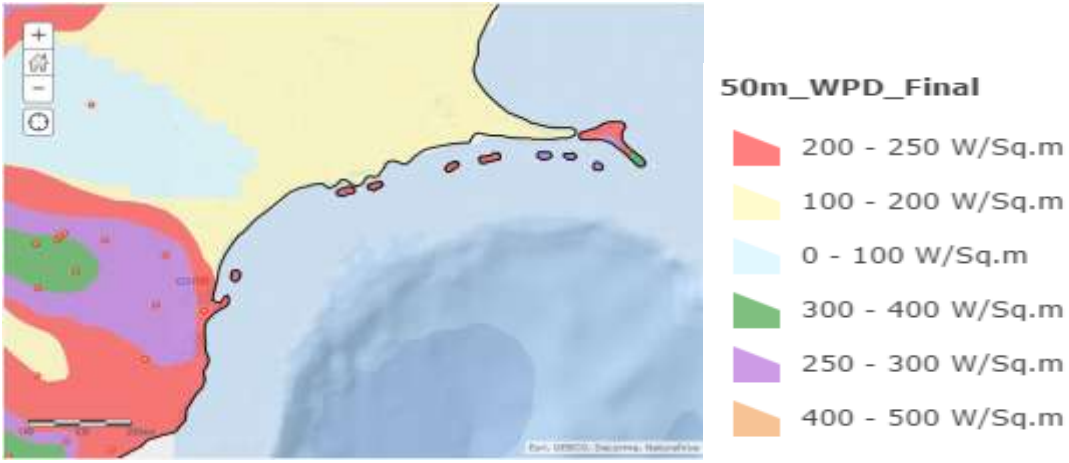


Fig 6.Wind velocity on 30.9.14

Source: National Institute of Wind Energy

The wind power density (WPD) is represented in different color pattern in Tamil Nadu southern coastal map. The highest wind power density is found both in onshore and offshore. The onshore wind power generation reached the enormous growth rate in power generation and hence the wind source found in the offshore are not utilized for power generation despite of initial high cost but output efficiency will be comparatively more when compared to onshore wind power generation. From the fig.3.4 highest offshore wind energy range 250-300 W/sq.m is generated in mandapam group region among four groups.

5.2 Ship route: There is no ship passage in-between the 21 islands; hence the region is having shallow depth (3.5m-15m).

5.3. Distance of island from shore

TABLE.2.Distance from shore

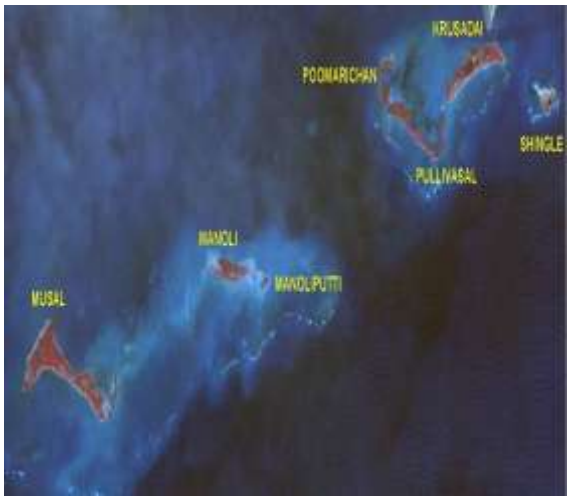
Island	area(ha)	Distance from shore(km)
Mandapam group island		
1. Shingle	12.69	4
2. Krusadai	65.80	3.5
3. Pullivasal	9.95	3
4. Poomarichan	16.58	3

5. Manoli	25.90	5
6. Manoliputti	02.34	5
7. Musal	129.04	7
Keezhakarai Group island		
8. Mulli	10.20	10
9. Valai	10.15	9
10. Talairi	75.15	9
11. Appa	28.63	8
12. Poovarasanpatti	0.25	8
13. Valimunai	6.72	8
14. Anaipar	11.00	9
Vembar Group island		
15. Nallathanni	110.0	10
16. Pulivinichalli	6.12	8
17. Upputhanni	29.94	8
Tuticorin group Island		
18.Karaichalli	16.46	15
19.- Vilanguchalli	0.95	15
20. Kasuwar	9.50	7
21. Van	6.0	6

The islands in Gulf of Mannar regions are kept as reference point for the study of implementing offshore wind farm. so the distance of the islands are measured from shore. From the above data it has been observed that the mandapam group islands is having shortest distance from the shore when compared with other groups.

5.4 Depth of Gulf of mannar regions(From shore to Island)

The depths of Gulf of Mannar regions are measured from the shore to the islands. The depth of the 4 groups of islands is shown in fig as below.



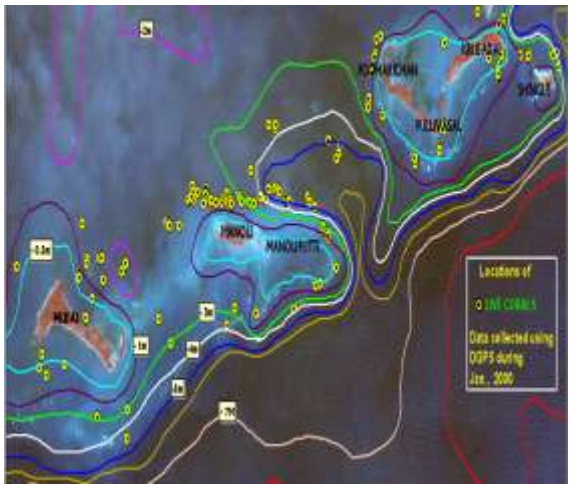
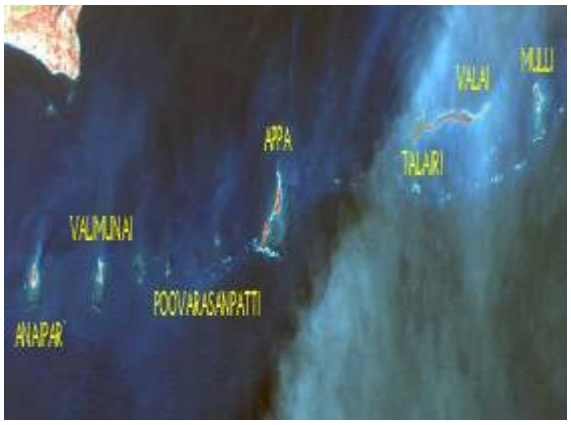


Fig.7.Islands in mandapam group **Fig.8.contour map indicating the depth of mandapam group islands**

Source: *I*ntegrated Coastal and Marine Area Management *(ICMAM)*



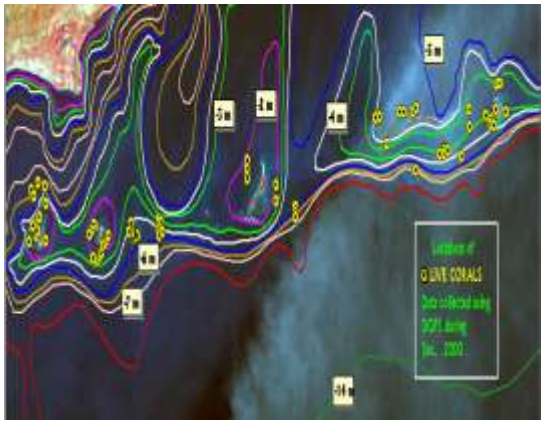


Fig.9.keezhakarai group islands **Fig.10. contour map indicating the depth of keezhakarai group islands.**

Source: *I*ntegrated Coastal and Marine Area Management (ICMAM)

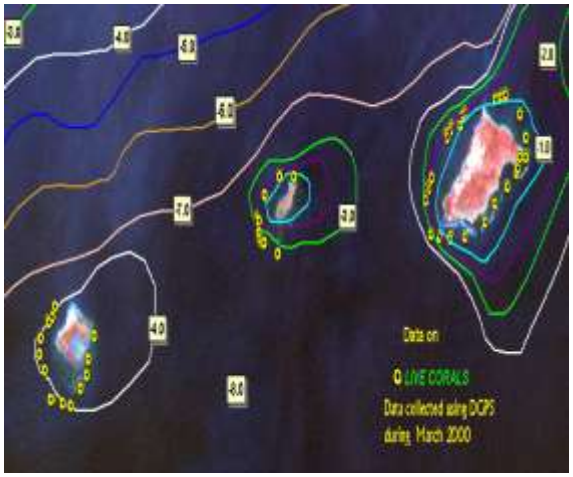


Fig.11.Vember Group Islands. **Fig.12. Contour Map Indicating The Depth Of Vember Group Islands.**

Source: *I*ntegrated Coastal and Marine Area Management (ICMAM)

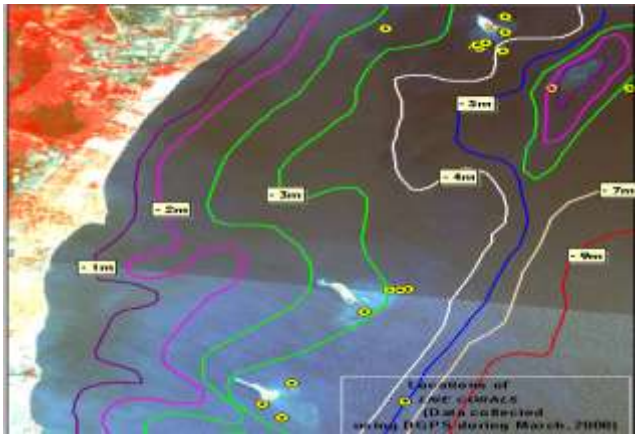


Fig.13.Tuticorin Group Islands Fig.14. Contour Map Indicating the Depth of Tuticorin Group Islands.

Source: Integrated Coastal and Marine Area Management (ICMAM)

VI MULTI CRITERIA RELATIVE IMPORTANCE METHOD:

TABLE.3.Comparison method for 4 groups by considering 4 criteria's

Island group	Average wind power density (WPD)	Average distance from shore(KM)	Average depth (m)	Ship route
Mandapam group	**250-300**	**04.35**	**3.21**	**No**
Keezhakari group	200-250	08.71	5.85	No
Vember group	200-250	08.66	4.30	No
Tuticorin group	200-250	10.75	4.42	No

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VII CONCLUSION

- The data's of factors were collected and analyzed using comparative method
- The factors influencing on implementation of wind farms in the Gulf of mannar region were identified.
- The mandapam group satisfies all the criteria's (**max wind power density, shortest shore distance, average depth and no ship route)** when compared with other 3 groups and it results in the best region for implementing the offshore wind farm.

- The 7 mandapam group islands are having highest wind power density than the other groups of islands in Gulf of Mannar regions. The average depth of mandapam group regions (3.21m) lesser than the other group

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