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Analysis Of Renewable Energy Potential Sources For Kavaratti Island, Lakshadweep

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Abstract: *This study was carried out to analyze the potentials sources of renewable energy in Kavaratti Island using solar, wind and wave energy. This enhances the economy compared to the present scenario over long-term, in a reliable and sustainable manner. In Kavaratti Island, presently the electric supply is done using diesel generatorswhich is a non-green system compared with proposed system. Moreover, the large quantity of diesel used for power generation is transported from main land. The renewable energy production achieves green energy with higher degree of energy sustainability. Due to the consistent wind energy potential in coastal areas, the helical vertical axis wind turbine was considered to analyze the energy efficiency. The analytical calculation is carried out based on the wind speed and rotor characteristics of helical wind turbine to get efficient output.Considering solar energy, the average radiation received over the Kavaratti islands was5.12kWh/m*^{2}*/daywhich shows the high potential of solar.The estimated wave energy potential in the Kavaratti offshore and coastal areas was calculated as 1.5 - 8 kW/m for different seasons using Mike 21 numerical modeling and the theoretical formulas. This study shows the alternate resources for energy potential sources using gridded multi-source power generation. The power generationcapacityof the solar, wind and wave potential vary from season to season.The integration of these three renewable energy resources helps to provide uninterrupted, green energyto the Kavaratti Island.*

Keywords: *Renewable energy potential,solar energy, Wind energy, Wave energy, Kavaratti*

I. Introduction

The renewable and sustainable energy are the clean and inexhaustible sources widely used by different well developed nations[1]. Hence in recent years, the global demand on sustainable energy shows the necessity for research and development on solar, wind and wave energy[2]. Considering the power requirement especially for Islands, cost effectiveness,significant quantity of power production, installation and feasibility in the environment makes it complex to meet out the Island power demand[3]. The Islands of Lakshadweep show high potential of renewable energy sources[4]. Presently, the power is generated by diesel generator in all the islands of Lakshadweep with stand-alone capability[5].The diesel used by the diesel generator is being transported from mainland (Kerala). The utilization of alternative energy sources like solar, wind and wave energy system satisfies the future energy demand by replacing the present mode of power generation by a sustainable approach.All the 12 inhabitedIslands of Lakshadweep are installed with the diesel generator setsand solar photovoltaic (SPV) of the required capacity[6]. The power demand of the Islands is linearly increasing over the years.

Considering theminimum power requirement raise to be at 5% per annum is also crucial and it has to be generated using the renewable energy sources. Hence sustainable renewable energy has to be harnessed without affecting the aesthetics, fauna and flora of the island[7].This paper investigates and analyzes the potential sources of renewable power using wind, wave and solar energy at Kavaratti Island.

II. Study Area

The Lakshadweep Islands were located in Arabian Sea which is one of the major island groups in India. The archipelago of Lakshadweep islands consists of 36 coral islands scattered about 500 kilometers from the west coast of India. Kavaratti is the capitalIsland and is the principal town of Lakshadweep Islands as shown in Fig. 1. This island has a total area of around 3.63 km^2 and the total population of Kavaratti Island is about 11210. The atmospheric temperature of this Island ranges from 22°C to 30°C during winter and 25°C to 33°C during summer season. The Island exhibits very small land cover area which is densely covered by coconut plantation.

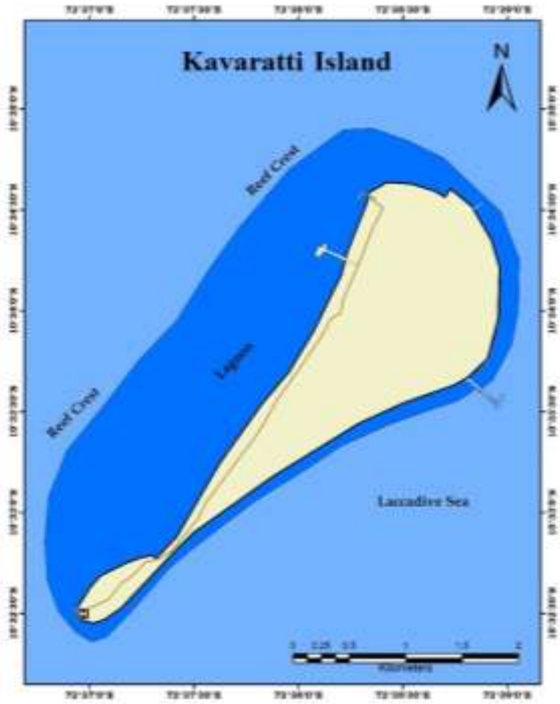

Fig. 1. Kavaratti Island of Lakshadweep Archipelago

The high wind blows during monsoon season and low during the post monsoon season. The coconut plantation around the island protects the buildings and houses within the Island during extreme events such as Cyclone.Highest rainfall of about 1450mm is received a year including southwest monsoon.

III. Methodology

The present study uses field observational datasets and the numerical model such as spectral wave models to compute the solar, wind and wave energy around the Kavaratti Island.The meteorological parameters were collected from theAutomated Weather Station (AWS) instrument installed in the premises of theDepartment of Science & Technology, Kavaratti Island. The meteorological wind speed and direction were obtained in the interval of 2 minutes and averaged to every one-hour interval using moving average method. The long-term wind and solar data were collected from the European Centre for Medium Range Weather Forecast (ECMWF) for the mathematical computations. The physical oceanic parameters like significant wave height, wave period and wave direction were obtained from the wave rider buoy in the 6 hour interval which is deployed by the Indian National Centre for Ocean Information System (INCOIS), Hyderabad.

The mike 21 spectral wave model was used for simulating the wave power around the Kavaratti region. The model bathymetry is extracted from various sources such as Mike C-Map,GEBCO 30”and EOMAP data. The GEBCO data has about 900mhorizontal resolution whereas, Mike C-Map and EOMAP have a horizontal resolution of 90 m and 15 m respectively. The satellite derived bathymetry EOMAP data were extracted using optical algorithm and it has high resolution in coastal regions compared to other data sets. The model bathymetry and wind field of the domain is prepared more accurately usingthese three different sets of data.

IV. Renewable Energy Sources

The renewable and regenerative energy sources such as solar, wind and wave energy are not being depleted by the course of time. The renewable energy system may be high or less efficient in terms of technology and economy depending on the system and environment. The major limitations for the islandto produce 100% electricity through these renewable sources aredue to the following reasons: The sources of energy supply vary significantly in terms of seasons and moments. Hence, the combination of different renewable energy system such as solar, wind and wave provide high reliability in energy production. The diverse sources of power generation shows the significant constant outcome of power supply along with the efficient distribution network.

4.1. Solar Energy

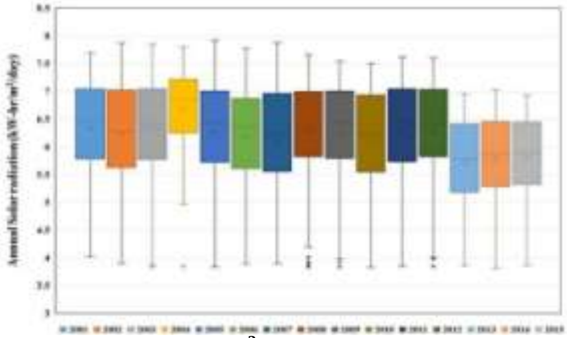

Fig. 2. NASA Annual solar radiation(kW-hr/m^2/day) of Kavaratti Island for 15 years (2001 to 2015)

The solar spatial variations were studied using the 15 years NASA datasets for the Kavaratti Island. The solar energy was calculated using the solar panel area, panel yield, average irradiation(annual) on panels and performance ratio, coefficient for losses. Solar Energy formula is given in Eq. 1.

$$E = A \times r \times H \times PR \qquad \text{--- (1)}$$

where, E is the Energy (kWh), A is the Total solar panel Area (m²), r is the solar panel yield (%), H is the Annual average irradiation & PR is the Performance ratio / coefficient for losses.

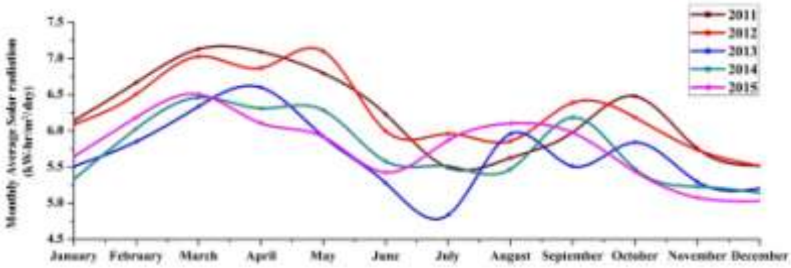

Fig. 3. Monthly average solar radiation(kW-hr/m2/day) for 2011 to 2015

The NASA average solar radiation data were given in Fig. 2.The monthly average solar radiation(kW-hr/m^2/day) were segmented from the NASA dataset for 2011 to 2015 and its shown in fig. 3. The Fig. 3 shows that the pre-monsoon months from February to March shows high solar radiation around 6.5kW-hr/m^2/day compared to the other months. The monsoon season especiallyJune & July shows low value of around 4.8 to 6 compared to other seasons.

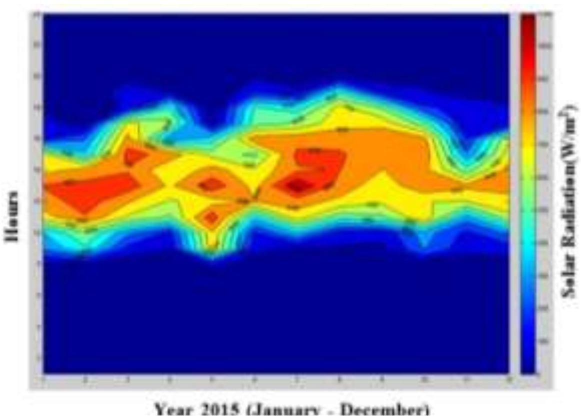

Fig. 4. Hourly solar radiation(W/m2) observed during the years 2015

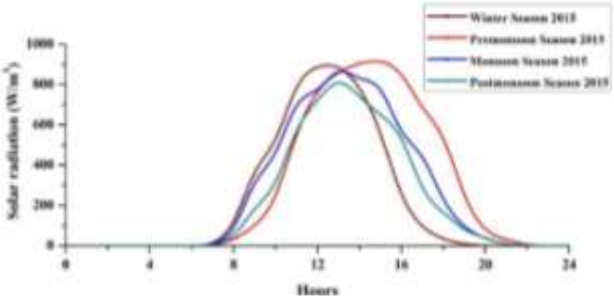

Fig. 5. Hourly averaged solar radiation(W/m2) observed during different seasons of the years 2015

The solar irradiance and the daylight time for the solar radiation were calculated for the year 2015. The hourly solar radiation (W/m^2) observed during the year 2015 is given in Fig. 4. The peak solar irradiance against time varies with seasons and the

maximum daylight occurs during the pre-monsoon season given in Fig. 5.The average solar radiation received during the year 2015 is around 5.312 KWh/m^2/day and hence the Kavaratti Island receives good amount of solar radiation except during the monsoon season showing the ideal chance for solar power as per the U.S. Environmental Protection Agency (EPA). Currently, the Kavaratti Island has grid interactive Solar Photovoltaic plant of 100 KWp. The grid interactive solar power plant is synchronized with diesel generator grid on the island. The SPV grid is operating successfully so that further grid interface can be done for wind and wave power generation. The 100 KWp SPV plant includes PV array for electricity production, Power Conditioning Units (PCUs) and data acquisition system. The solar plant requires large land area for the SPV installation. But the Island has limited area and it is densely covered by coconut trees. Even the roof tops of the houses and major buildings are thickly covered by trees of around 10 – 12 meters. The shadowing of sunlight on SPV arrays thus significantly reduces the solar irradiance. In order to fulfill the present increased demand of electricity in the Islands, a floating SPV plant has to be installed in the east part of the Island.

4.2. Wind Energy

The natural wind power drives the mechanical turbine connected with a generator which produces electricity. The wind source is clean and sustainable but it varies with seasons.The NASA Langley Research Center Atmospheric Science Data Center Surface meteorological wind data were collected for analyzing the wind energy. The NASA’s yearly averaged wind data at 10 meters and 50 meters from 2001 to 2018 are given in fig. 6. The wind speed and direction observed at the Kavaratti Island for the year 2016 during winter, pre-monsoon, monsoon and post monsoon seasons are given in Fig. 7. The highest peak value of about

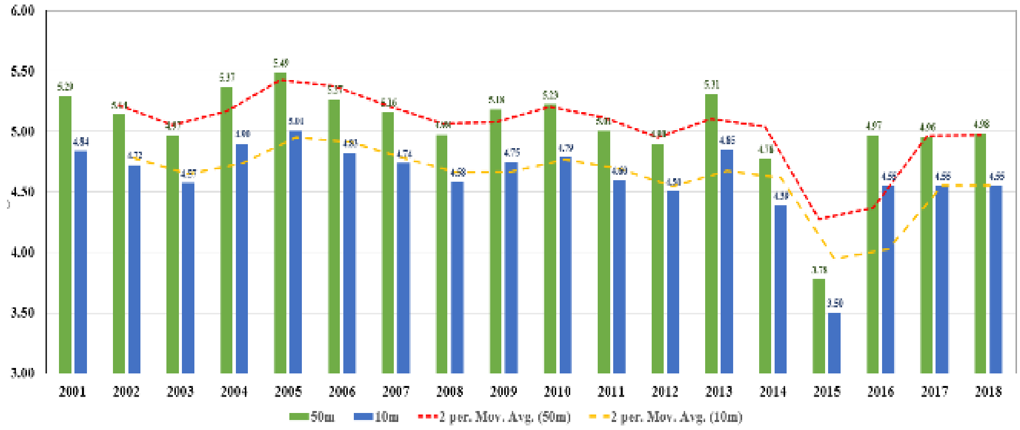

Fig. 6. NASA yearly averaged wind data at 10 meters and 50 meters from 2001 to 2018

11.2 m/s is observed during July and the maximum occurance of wind speed during the monsoon period is inbetween 4.4 to 11.2 m/s.

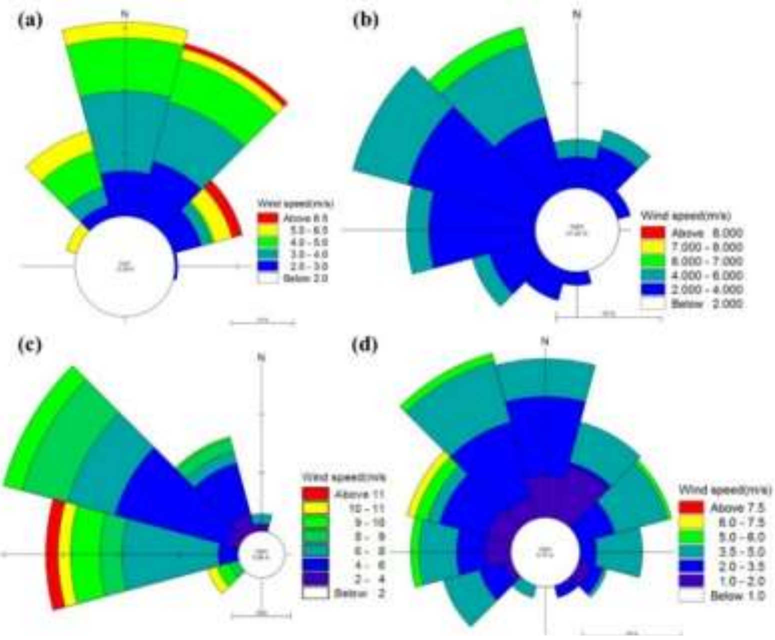

Fig. 7. Wind speed and direction at the Kavaratti Island during (a)winter, (b)pre-monsoon, (c)monsoon and (d)post monsoon seasons of the year 2016

The monthly average wind speeds were analysed for the year 2011 to 2018 as shown in Fig. 8(a), Fig. 8(b). The monsoon month (June, July & August) for the years 2011 to 2018 shows high wind speed in between 5.5m/s to 10.2m/s. The winter, pre-monsoon, monsoon and post monsoon of the year 2016 also analysed with respect to the hours in a day as shown in figure Fig. 8(c). The pre-monsoon and post monsoon shows the average wind speed to be around 3 to 4.2 m/s. Hence, the computation shows that the wind speed during the monsoon season and pre-post monsoon season is sufficient for generating the required quantity of electricity for the Kavartti Island. The solar and wind energy production in this Island complements each other because during monsoon wind energy is high and during pre-post monsoon solar energy is high. Hence the two source of energy is coupled to produce a high degree of electric generation to attain efficient power supply.

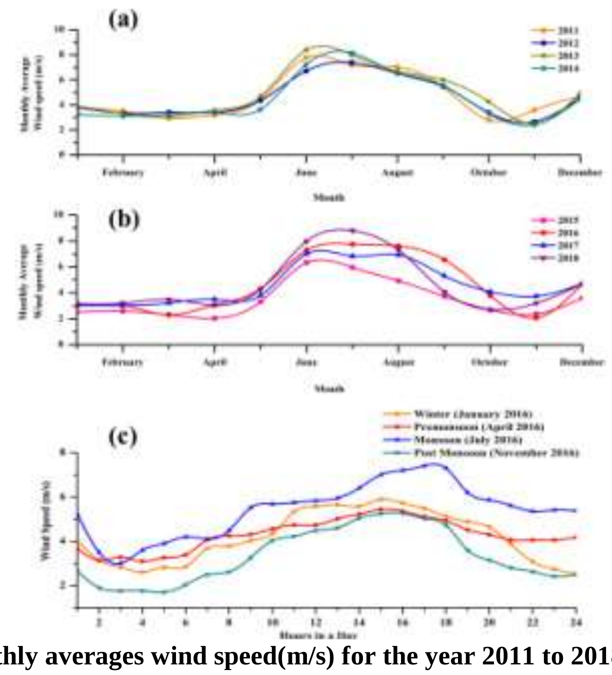

Fig. 8. (a) & (b) The monthly averages wind speed(m/s) for the year 2011 to 2018, (c) Seasonal wind speed for the year 2016 with respect to time(hours)

The helical shaped vertical axis wind turbine can be used in Kavaratti Island which is reliable and can generate power around 1000W. The product of FINEX Company, special helical shape type with the fiber glass material works without noise and such a turbine can be very efficient.Multiple shaped turbines with increased generation capacity are growing in market and research. Such turbines are economically competitive with low production cost and high power generation in Megawatt per hour (MWh) which are more suitable of Islands.

4.3. Wave Energy

The wave energy potential depends on parameters such as wave period (T), gravity (g), wave length (λ) and wave height (H). The wave length and depth of water is directly proportional to wave period and velocity. The energy generated by the ocean waves on a physical system is termed as potential energy. The amount of power generated by ocean wave energy is given in Eq. 2. and 'Pw' is the electrical power(watts) generated by wave energy.

$$Pw = \rho g^2 T H^2 / 32\pi \text{ --- } (2)$$

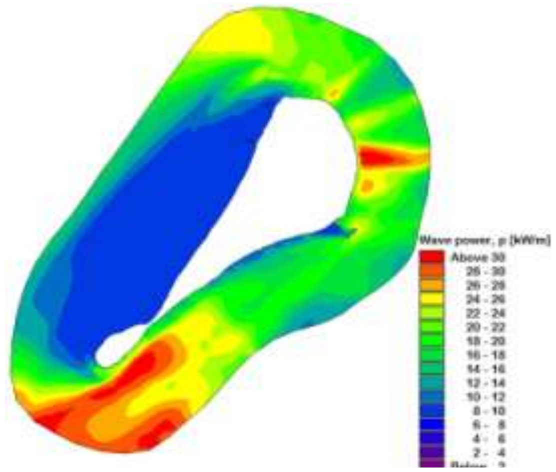

Fig. 9. Mike 21 spectral wave simulation for wave power during monsoon (July 2016)

The intensity of wave energy induced by the ocean surface waves is said as wave power. Here the wave energy moves the turbines which changes the mechanical energy to electrical energy. The depth of the region supports the intensity of wave forcing in generating the wave power. The ocean waves moving in up and down direction perpendicular to sea surface generate the motion in energy turbine.

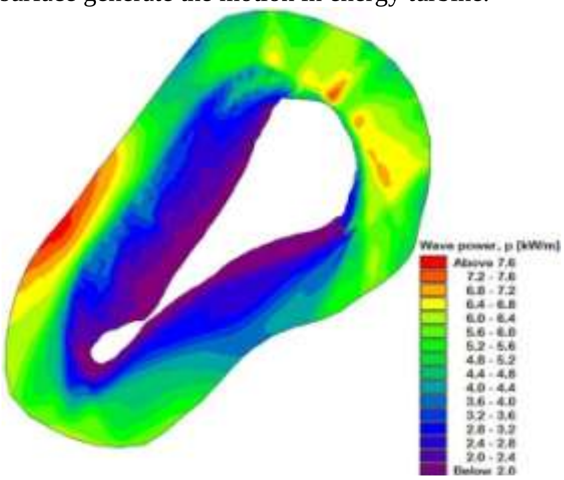

Fig. 10. Mike 21 spectral wave simulation for wave power during post monsoon (November 2016)

The numerical simulation using Mike 21 spectral wave model tool shows the wave energy potential sources during monsoon and post monsoon season around Kavaratti offshore region. The seasonal changes during monsoon makes the wave intensity harmonious with electricity demand. The generation of wave power is predictable and can be extracted continuously without breaks compared to solar energy.The Kavaratti Island exhibits the high potential source for wave power. The Figure 9 and Figure 10 shows the distribution of wave power. During the monsoon season in-between June to September, the wave power is very high in the range 20 kW/m k- 32 kW/m. During the pre-post monsoon season, the wave power is within the range 2 – 8 kW/m.

Considering other renewable energy sources, wave energy shows highest energy density on the eastern part of the Kavaratti Island.

V. Results And Discussion

In Kavaratti Island, the renewable wind energy sources proves to be a good potential for electricity generation. The assessment of potential renewable energy extraction from wind, solar and waves on Island shows in-depth analysis from the observed data during 2015 and 2016. This Island shows opportunities for renewable energy generation using solar, wind and wave energy. Due to the variable climate patterns and availability of multiple energy sources, the demands in electricity throughout the time can be satisfied showing positive correlation in generation and consumption.

The solar power source is available throughout the year except during the monsoon season. The existing solar photovoltaic plant of 100 KWp has to be upgraded and more floating solar PV panels should be installed in the eastern part of the coast which will generate more electricity considerably.The computation and model prediction shows that, the wave and wind power sources is high during monsoon. The wind energy and the wave power at the southern tip region of the Island is maximum compared to other areas. The helical shaped vertical axis wind turbine can generate high electric power even with low wind. The energy production from the sea waves due to the winds and currents shows constraints on the installation of offshore wave energy turbines but it shows low environmental impacts if installed at the eastern seaward side of Kavaratti Island.The result shows the availability of high wave energy potential on the offshore waters due to the high wave intensities relative to deep bathymetry at the Eastern side of the Island. The gridded alternative power sources lead to efficient power management due to decentralized energy production. Such techniques reduce the gaps between energy sources and services providing highly efficient services.The present non-renewable energy system such as diesel generator can be used for provisional purpose and it’s not suitable for long-term production in terms of economy and eco-friendliness.

VI. Conclusion

The Kavaratti Island shows vast renewable energy potentials for solar, wind and wave based on the energy analysis and simulations. The combination ofthese energy resources result in high production of electricity even during extreme events. Hence the existing non-conventional energy sources such as diesel generator can be completely replaced to satisfy the future demand of electricity. The limitations on seasonal variability of energy production should be controlled using the integration of solar, wave and wind energy using the efficient energy distributors. But the environmental considerations are to be focused during the installation of floating solar panels, wind turbines and wave generators due to the presence of highly sensitive coral ecosystem. This paper helps to accomplish detailed characterization of energy sources as ideal solution in coastal and offshore region of Kavaratti Island and to estimate the potentials demand.

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