

Wave energy potential for power generation in the Gulf of Thailand

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Abstract:

Regional wind-wave model is the computational model which is applied from the Wave Model (WAM). The data of regional hindcast, operational WAM model, and wind data are used in the validation and calibration. Then, the Simulating Waves Nearshore (SWAN) wave model is used for the calculation of nearshore wave parameters, spectral time series and statistics. Due to the high cost of full SWAN model, utilization of the offshore WAM model results together with nearshore satellite observations is a cost-effective alternative. In the area of Gulf of Thailand (GOT), it is found from WAM and SWAN that areas of the GoT present a stable wave energy and power. Moreover, the average significant wave height is also used to preliminarily evaluate the wave power. From the previous study, it was found that the station S11 is the station with the highest significant wave height of 2.6 m. It was also found that the highest significant wave height can be found in September. As the result the suggested potential locations for wave energy are stations S7-S14. For the extreme case of typhoon Linda in 1997, the highest significant wave height is 2.71 m at S16. Moreover, the average significant wave height and wave power in September 2011 were studied. The results show a good agreement with the previous study that stations S7-S14 are the stations with high potential. However, the results of stations S11, S13, S14 seem to show the highest potential of power generation amongst all stations.

Keywords: Wave energy; Power generation; Gulf of Thailand; Wave Model (WAM); Simulating Waves Nearshore (SWAN) wave model

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1. Introduction

Currently, the renewable energy of 1.4% of all energy sources can be used as the sources of power generation in Thailand. The main renewable energy sources include biogas, biomass, solar radiation and water. Nowadays, Thailand still imports 5% of electricity from the neighboring countries which costs of more than 12 billion baht (DEDE, 2012). The sustainability of energy in Thailand, then, is affected from the neighboring countries. Therefore, the government of Thailand needs to find the new source of energy to promote and use to support the energy consumption. While, worldwide researchers will have been interesting and improving the renewable energy from ocean wave. In addition, ocean wave energy can be improving the environment by replacing fossil fuel plants and reducing carbon emissions. Pelc and Fujita (2002) studied the characteristics of each renewable energy resource from the ocean. The energy sources were divided into 4 types, which were ocean thermal energy conversion (OTEC), wave energy, tidal, and offshore wind. Any renewable energy technologies were probably to be highly site specific and scale dependent. Ou et al. (2002) Simulating typhoon waves by SWAN wave model in coastal waters of Taiwan for understanding in the characteristic of wave caused by typhoon. Ivanova et al. (2005) simulated Octagonal linear generator for wave energy extraction in deep water at Shannon site near the south-west coast of Ireland. This site has large wave with 5 m height and 11 s period, and high energy equal to 68 kW/m. Akpınar et al. (2012) evaluated the numerical wave model (SWAN) for wave simulation in the Black Sea. The results of this study indicate that agreement between simulated and observed wave parameters. However, it still has lower estimates for the maximum values of wave parameters. These lower estimates are probably due to too low wind speeds in the Applied ECMWF wind fields. The aim of this research is to evaluate the potential of wave energy in the Gulf of Thailand for the power generation by using WAM and SWAN.

2. Mathematic Model

The WAM model is a third-generation spectral wave model, which does not impose any restrictions on the two-dimensional spectral shape. It runs operationally at ECMWF carrying out wave prediction on the global. The equation of WAM model as follows (Herast et al., 1994);

$$\frac{\partial}{\partial t} F = S(F, u) = S_{in} + S_{dis} + S_{nl} \quad (1)$$

where $\frac{\partial}{\partial t} F = S(F, u)$ is the wave spectrum, u is the wind speed and S is the source function which consists of three terms: S , the input term, S_{dis} the dissipation due to white cap-ping and S_{nl} the non-linear wave-wave interactions.

In the SWAN wave model, the solution of the wave spectrum is described by the spectral action balance equation for Cartesian coordinates as follows (Hasselmann et al., 1973);

$$\frac{\partial}{\partial t} N + \frac{\partial}{\partial x} c_x N + \frac{\partial}{\partial y} c_y N + \frac{\partial}{\partial \sigma} c_\sigma N + \frac{\partial}{\partial \theta} c_\theta N = \frac{S}{\sigma} \quad (2)$$

where σ is the relative frequency, θ is the wave direction, N is the wave action density and is equal to the energy density divided by the relative frequency: $N(\sigma, \theta) = E(\sigma, \theta) / \sigma$, and $E(\sigma, \theta)$ is the wave energy density. Eq. (2) is an approximation with simple bottom topography and current distribution. The first term on the left-hand side represents the local rate of change of the action density with time. The second and the third terms represent propagation of the action in geographical space with propagation velocities c_x and c_y in the x- and y-space, respectively. The fourth term represents shifting of the relative frequency due to variations in depths and currents with propagation velocity c_σ in s-space. The fifth term represents depth-induced and current-induced refraction with propagation velocity c_θ in θ -space. The term S on the right-hand side of the action balance equation is the source term in terms of energy density representing the effects of generation, dissipation and nonlinear wave-wave interaction.

3. Methodology

Wave power can be simulated by using the mathematic models are Wave Model (WAM) and Simulating Waves Nearshore (SWAN) wave model. Offshore wave is simulated by using WAM. The input data consists of wind data. The NOGAPS data from USGODAE are used to validate and calibrate with the satellite and buoy data. Nearshore wave is simulated by using the SWAN wave model, the fully direction wave spectra time series from WAM, those used as a boundary conditions in SWAN wave model to calculate the nearshore wave parameter, wave spectral time series and wave statics. Water levels at Hua-Hin and Rayong stations are used in the calibration process. The results of 2 models can be separated into 2 parts; first, normal case which is the observing of the wave height and wave power at each station in study domain by using the simulation period of 2011. Another case, typhoon Linda was used for the investigation the characteristics of wave height in extreme case, the simulation period starts from 20 October to 09 November 1997 in order to cover period of typhoon.

4. Results

4.1 Normal case

The domain of the present study is Gulf of Thailand as shown in Fig. 1. It was found that the station S11 shows the highest significant wave height of 2.6 m in September (Wannawong et al., 2014). The average significant wave height and wave power in September 2011 were in-depth studied. The results show a good agreement with the previous study that stations S7-S14 are the high potential

stations of wave energy. However, the results of stations S11, S13, S14 show the highest average significant wave height and wave power amongst all stations as shown in Fig. 2. It can be concluded that the appropriate locations with the highest potential of power generation can be found at the stations of S11, S13, S14.

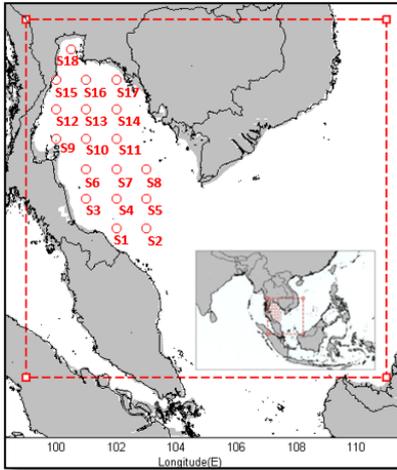
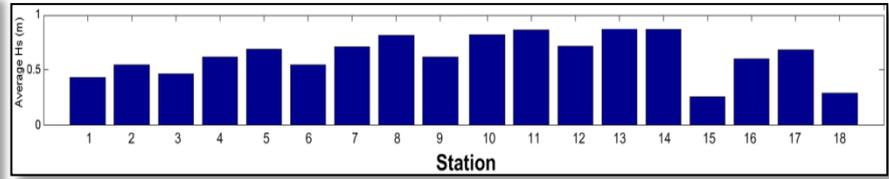
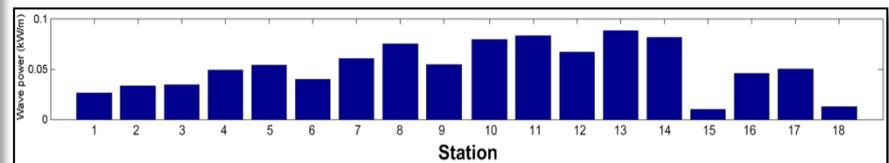


Fig. 1 Study domain by Wannawong et al.(2014).



a) Average significant wave height (m)



b) Average wave power (kW/m)

Fig. 2 Average significant wave height and wave power in September.

4.2 Extreme Case (Typhoon Linda)

The extreme case of typhoon Linda is used to consider for the limitation of highest case. Simulation period covers 20 days of typhoon Linda event, start from 20 October -09 November 1997. The first 2 days of simulation time is used as the initial condition. The average significant wave height of typhoon Linda at Hua-Hin and Rayong stations and the average significant wave height contours (3 November 1997) are distributed along the study domain as shown in Fig. 3 and 4, respectively. The maximum average significant wave height is 2.71m at S16 and 2.37 m at S13.

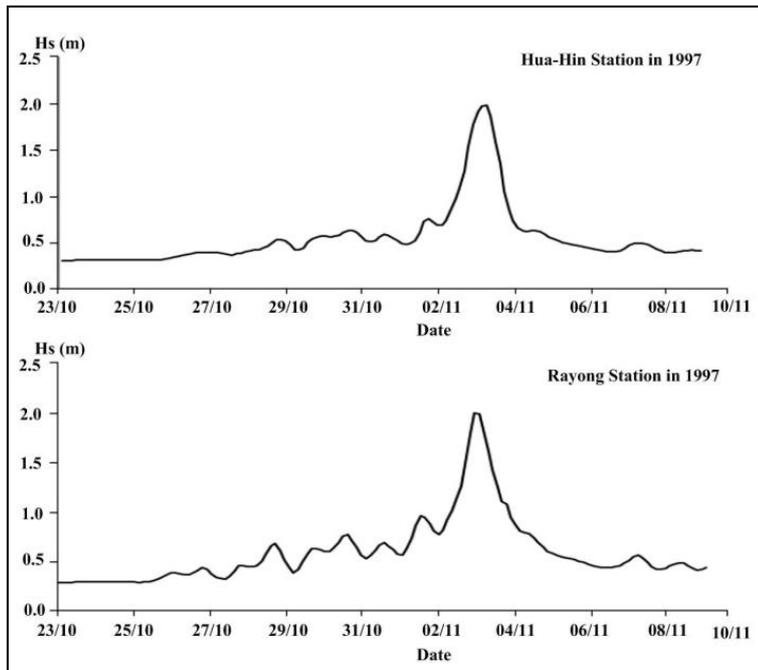


Fig. 3 average significant wave height of typhoon Linda.

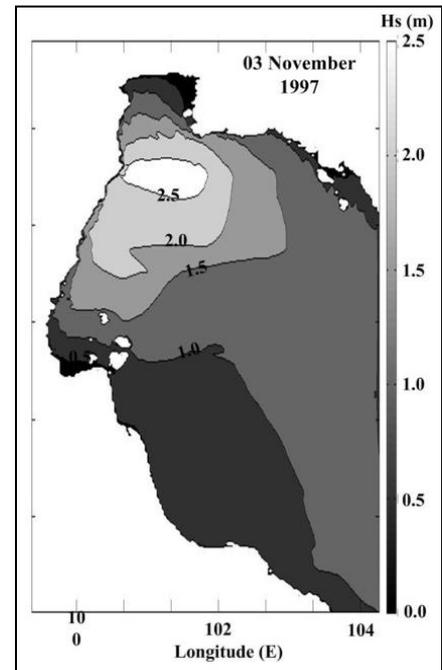


Fig. 4 significant wave height contours.

5. Conclusion

The offshore wave can be simulated by using WAM and the nearshore wave can be simulated by using the SWAN wave model. It is found from WAM and SWAN that areas of the GoT presents a stable wave energy and power. In the present study, the average significant wave height is used to preliminarily evaluate the wave power. It was found that the highest significant wave height can be found in September. The results show a good agreement with the previous study that stations S7-S14 are the stations with high potential. However, the results from the in-depth study of stations S11, S13, S14 show the highest potential of power generation amongst all stations. In the case of typhoon in the GoT it was found the station S16 and S13 are the appropriate locations with the average significant wave height of 2.71 m and 2.31 m respectively.

6. References

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