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INVESTIGATION AND FEASIBILITY STUDY OF EXTRACTING WAVE POWER IN NORTHERN AND SOUTHERN SEA WATERS OF IRAN

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Introduction

Nowadays replacement of new sources of energy is considered as the best alternative for fossil fuel energy consumption. Among all those energy sources, sea waves are from the most important sources since their energy is convertible to the forms of energy necessary for various uses. This paper presents our study on whether it is feasible to integrate the wave energy into the current Iranian energy program.
Using wave's simulated data, average wave power in Northern and Southern seas of Iran is estimated and feasible convertors applicable in these regions are introduces considering water depth and wave length and height. In addition, to verify the results, the conformity of calculated amount of wave power for South of Iran is compared with its amount announced by international sources. Furthermore, a comparison between average annual wave power calculated for all Iran's seas with that of Turkey's sees, while Turkey is surrounded by seas from three sides, is done as a witness to feasibility and justifiability of extracting energy from Iranian sea waters.

Sea Waves

Waves are formed due to effect of wind over the sea surface, so are subsequently considered as a form of solar energy. One of the main benefits of wave power over solar and wind power is higher density of the energy over the unit area. For example, at a latitude of 15 N (Northeast trades), the solar insulation is 0.17 kW/m2. However the average wind generated by this solar radiation is about 20 knots (10 m/s), giving a power intensity of 0.58 kW/m2 which, in turn, has the capability to generate waves with a power intensity of 8.42 kW/m2 [1].
Total amount of wave energy over the world is estimated to be about 1 to 10 TW which is almost equal to total world energy consumption [2]. Since Iran has sea borders expanded over North and South of the country, benefiting from this source of energy could be justifiable to be considered in future energy program.

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Extractable Sea Wave Power

Wave power "P" is delivered energy by waves, which in fact is an indicator of available energy of waves. This amount usually is shown by kW per a meter of wave crest and calculated using the below equation [3]:

$$p = EC_g = \frac{1}{8}\rho g H_s^2 C_g \qquad \left[\frac{w}{m}\right] \qquad (۱)$$

In this equation E indicates wave energy per unit area, ρ is used for water density while H_s presents significant wave height (the average of the highest one third of the waves). Also Cg represents wave group velocity (m/s).

Wave Power Equations Based On Water Depth Categories [4]

To calculate wave power, first we have to study the water condition in the selected areas. To do this, Le Mehaute chart [5] and also table of d/l for d/l_0 (from .0001 to 1) [6],[7] are employed.

Equations number 2, 3 and 4 shows power of shallow water (d is water depth), intermediate water (l is wave length and T is wave period) and deep water [8].

$$P_{shallowwater} = \frac{1}{8}\rho g^{3/2} d^{1/2} H_s \qquad \left[\frac{w}{m}\right] \qquad (۲)$$

$$P_{intermediatewater} = \frac{1}{8}\rho g n H_s^2 \frac{l}{T} \qquad \left[\frac{w}{m}\right] \qquad (۳)$$

$$P_{Deepwater} = \frac{1}{32\pi}\rho g^2 H_s^2 T \qquad \left[\frac{w}{m}\right] \qquad (۴)$$

Wave Energy to Electricity Convertors

Among all convertors made since 18th century up to now and have been tested in different scales, only AWS,Oceanlinx, PowerBuoy, Pelamis, Limpet and Pico owc are fabricated and tested successfully and are used in different countries. [9]

Oceanlinx, Limpet and Pico owc are working based on oscillating water column method which is an underwater structure in which the air upon the water surface is trapped and entering waves cause the water column to oscillate and to move the turbine [10]. AWS and Power Buoy are from point absorber group of convertors and Pelamis is an attenuator device.

Conclution

In this study the results of numeric simulation by SW module of Mike 21 are used to estimate the extractable wave power in 7 harbors in the south and 3 harbors in the north of Iran [11],[12]. The average of waves' extractable power at unit area of the coast (annual wave power) for waters in north of Iran is about 6.2 kW/m and for waters in south is about 14.5 kW/m. As it is shown in figure 1, the recent amount has conformity with the figure presented in "approximate global distribution of wave power levels" [13]. Consequently, Iran's annual wave power estimated to be 20 kW/m, while the annual wave power of the neighbor country, Turkey, which is surrounded from three sides with the seas and predicted to benefit the most utilization possible from wave potentials is at maximum 17 kW/m[14].

Considering the situation in Caspian Sea which is almost deep with average waves AWS ، Pelamis ،Oceanlinx and Power Buoy convertors are recommended while for Persian Gulf which is a shallow sea with smaller wave amplitude, compared to Caspian sea, Limpet, Pico owc, and Oceanlinx convertors are proposed. Also south harbors and ports of Iran are introduced as the best sites for wave energy conversion.

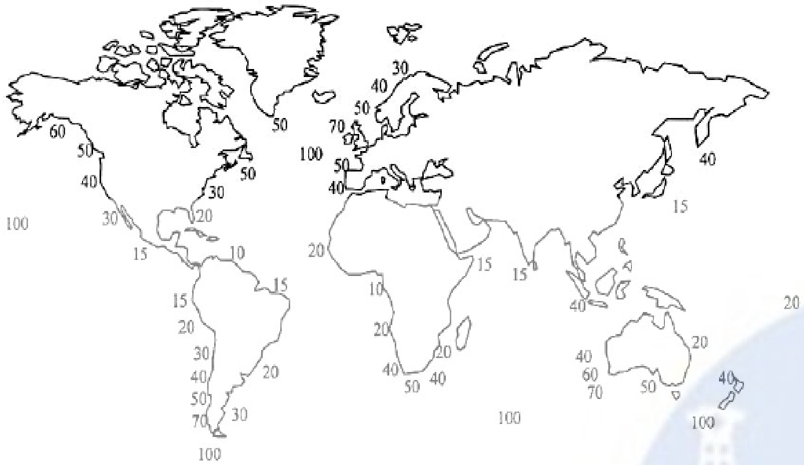

Figure. 1) Approximate global distribution of wave power levels (kW/m of wave front)

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