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The Feasibility of Wind and Solar Energy Application for Oil and Gas Offshore Platform

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Abstract. Renewable energy is an energy which is freely available in nature such as winds and solar energy. It plays a critical role in greening the energy sector as these sources of energy produce little or no pollution to environment. This paper will focus on capability of renewable energy (wind and solar) in generating power for offshore application. Data of wind speeds and solar irradiation that are available around SHELL Sabah Water Platform for every 10 minutes, 24 hours a day, for a period of one year are provided by SHELL Sarawak Sdn. Bhd. The suitable wind turbine and photovoltaic panel that are able to give a high output and higher reliability during operation period are selected by using the tabulated data. The highest power output generated using single wind energy application is equal to 492 kW while for solar energy application is equal to 20 kW. Using the calculated data, the feasibility of renewable energy is then determined based on the platform energy demand.

1. Introduction
Nowadays, most of the offshore platforms are operated by burning of fossil fuels to generate electricity. The gas turbines and diesel generators on most platforms are used to drive pumps and compressors on board, powered up by combustion of conventional fuels. Continuous burning of these conventional fuels will generate about 80% of the total CO_2 and NOx emissions from offshore installations [1]. Thus, offshore platform are facing difficulties in term of operating their activities in an environmentally manner.

Currently, great efforts have been taken in greening the energy sector by shifting the usage of fossil fuels to renewable energy in order to minimize current rate of fossil fuel usage and their ensuing effects of climatic changes. Renewable energy such as wind energy, solar energy and ocean energy are highly focused in the feasibility test of replacing conventional fuels to operate an offshore oil and gas platform. Some of the offshore platform has already started to exploit a renewable energy sources to generate power supply to lessen consumption of fuels. For example, a new offshore platform in the Southern North Sea as shown in figure 1 is operated by using their own energy generated through solar panels and wind turbines [2].

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Figure 1. Wind turbines and solar panels on offshore platform [2]

Wind and solar seems like ideal alternative sources of energy as it can provide an infinite amount of clean energy for offshore application. This paper will focus on the capability of renewable energy available around the offshore platform in order to determine the possibility of such utilization to meet the demand needed for these platform activities. Out of all renewable energies available these days, wind energy and solar energy are highly focused in this feasibility test since data collected predicted a rather promising result. Electrical power consumption of a platform is within the range from 10 MW to 50 MW, while the power consumption for smaller unmanned varies from 6 MW to 7 MW [1]. The targeted platform for this study is carried out at SHELL Malaysia Oil and Gas Sabah Water Platform, with the rated power consumption is approximately 10 MW. Based on the data collected from the targeted platform, the rated power output are determined in order to meet the demand of power consumption of this platform.

2. Literature review

2.1. Wind energy
In this feasibility study, SIEMENS SWT-4.0-120 is selected due to its suitable cut-in speed as low as 2.9 m/s. The wind turbine selected is a direct drive horizontal axis wind turbine, with the latest patented Quantum Blade technology used by Siemens, and able to generate rated power output as high as 4 MW with rated wind speed of 13 m/s [3].

In order to determine the rated power output, P_{rated} for specific month, equation (1) is used. Where, A_r is the swept area of the rotor; PD is the power density by the wind; η is the efficiency of the selected wind turbine stated by the manufacturer [4].

$$P_{rated} = A_r \times PD \times \eta \qquad (1)$$

The swept area, A_r by the rotor of wind turbine can be determined by using equation (2) where, D is the diameter of the rotor for the selected wind turbine.

$$A_r = \pi \times \left(\frac{D}{2}\right)^2 \qquad (2)$$

The power density, PD of the wind is determined by the equation (3) where, ρ_{air} is the air density at 50 m above sea level and v is the wind speed.

$$PD = \frac{1}{2} \times \rho_{air} \times \left(\frac{v^3}{1000}\right) \qquad (3)$$

For Siemens SWT-4.0-120, the efficiency for the selected wind turbine is 32%, giving the value of η is equal to 0.32 [3].

2.2. Solar energy
For the solar energy, the selected photovoltaic panel used for this feasibility test is LG290 N1C-G3 MonoX, with the panel area of 1.64 m^2 and peak power output of 290 W [5]. The power output for photovoltaic panel can be determined via the equation (4):

$$P = A_p \times r \times H \times PR \qquad (4)$$

where, A_p = area of solar panel in m^2, r = solar panel yield (%), H = average solar radiation on panels (W/m^2) and PR = Performance ratio.

Previous studies suggested that the performance ratio is set as 0.75 as default when solar panel is tilted at 45° of the direction of irradiation [6]. This value varies depending on the shadings present around the solar panel, as well as the cleanliness of the solar panel itself which is referring to the dust accumulation on solar panel.

Solar panel yield, r can be determined by the equation (5) where, PE is the electrical power of solar module selected; A_p is the area of the solar module.

$$Solar\ Panel\ Yield, r\ (\%) = \frac{PE}{10A_p} \qquad (5)$$

3. Data

3.1. Wind energy
In this research, wind speed data surrounding the SHELL Sabah Water Platform is provided by Sarawak SHELL Bhd. With the tabulated data, the average monthly wind speed hitting around the platform 50 m above sea level are plotted as in figure 2.

Based on figure 2, the wind speeds around the SHELL Sabah Water Platform are within a range of 3.22 m/s to 6.07 m/s. A sample calculation to determine the rated power output is shown using the average wind speed on January (6.07 m/s). The wind turbine specification and wind parameter are listed in table 1.

The power output for January is calculated using the equations discussed before. The swept area by the rotor of wind turbine is given by equation (2):

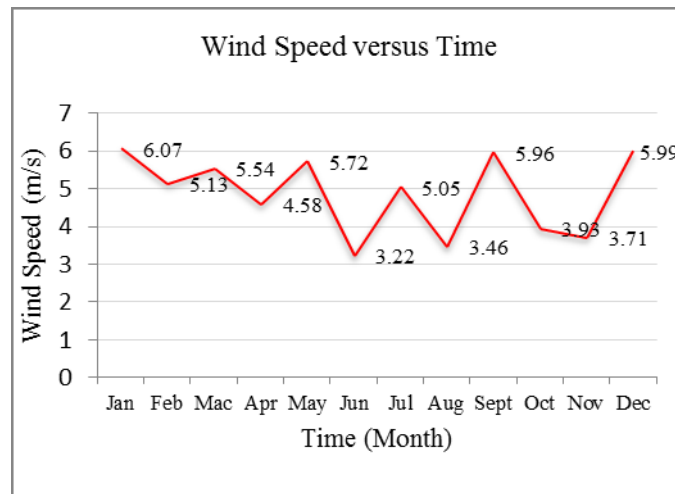$$A_r = \pi \times \left(\frac{D}{2}\right)^2 = \pi \times \left(\frac{120}{2}\right)^2 = 11310\ m^2$$

Figure 2. Average Wind Speed collected on SHELL Sabah Water Platform in 2008

Table 1. Wind turbine and wind parameters

Wind Turbines (SIEMENS SWT-4.0-120)	
Rotor diameter, D [m]	120
Blade length, L [m]	58.5
Efficiency, η [%]	32
Wind	
Air density, ρ_{air} [kg/m³]	1.225 at 50 m above sea level

The power density, PD by the wind onto the wind turbine is determined by the equation (3):

$$PD = \frac{1}{2} \times \rho \times v^3 = 0.5 \times 1.225 \times 6.07^3 = 137 \text{ kg/s}^3$$

Then, the power output for specific wind turbine for January can be determined via the equation (1):

$$P_{rated} = A_r \times PD \times \eta = 11310 \times 137 \times 0.32 = 495830 \text{ W} = 495 \text{ kW}$$

3.2. Solar energy
The solar irradiation available in the surrounding of SHELL Sabah Water Platform is provided by Sarawak SHELL Bhd. With the tabulated data, the average monthly solar irradiation hitting around the platform are plotted as in figure 3.
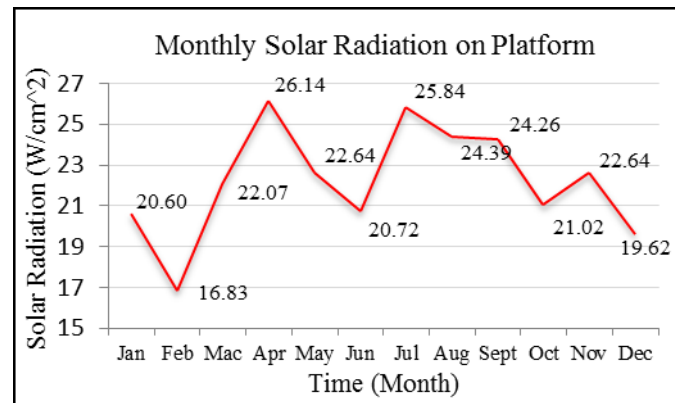
Figure 3. Average monthly solar radiation on SHELL Sabah water platform in 2008.

However, as the energy based on solar is dependent on the availability of the sun, additional graph is plotted based on daily solar irradiation to determine the peak hour of solar irradiation. With the collected data, the average daily solar irradiations hitting around the platform on are plotted as in figure 4.
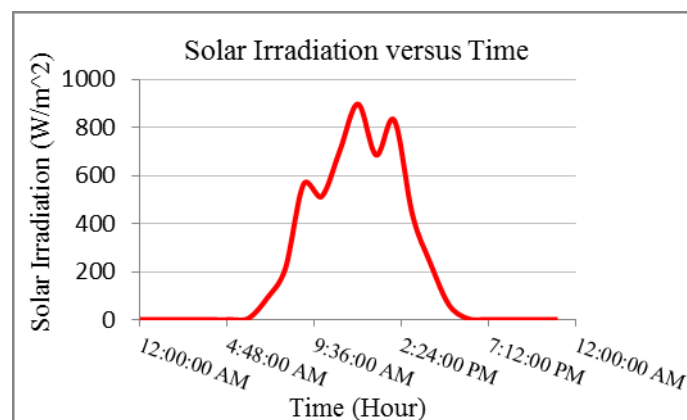
Figure 4. Daily solar irradiation peak hour on SHELL Sabah water platform.

Based on figure 3 and 4, the solar irradiation on the SHELL Sabah water platform varies within a range of 16.83 W/cm^2 to 26.14 W/cm^2 with the peak hour starting from 6 am to 6 pm. A sample calculation to determine the rated power output is shown using the average solar irradiation collected on April (26.14 W/cm^2). The selected photovoltaic panel used for this feasibility test is LG290 N1C-G3 MonoX, with the panel area of 1.6 $4m^2$ and peak power output of 290 W [5]. While its performance ratio is set as default which is 0.75 based on the previous study [6]. The power output for April is calculated using the equations discussed before. Solar panel yield, r can be calculated using equation (5):

$$r\ (\%) = \frac{PE}{10A_p} = \frac{290}{10(1.64)} = 17.68\ \%$$

The average solar irradiation collected in April is converted from 26.14 W/cm^2 to 94.10 kWh/m^2. Then, the power output for photovoltaic panel can be calculated via the equation (4):

$$P_{rated} = A_p \times r \times H \times \text{PR}$$
$$= 1.64 \times 0.1768 \times 94.1 \times 0.75 = 20 \text{ kWh}$$

4. Result and discussion

The rated power output calculated for each month based on selected wind turbine for wind energy application are plotted as shown in Figure 5.
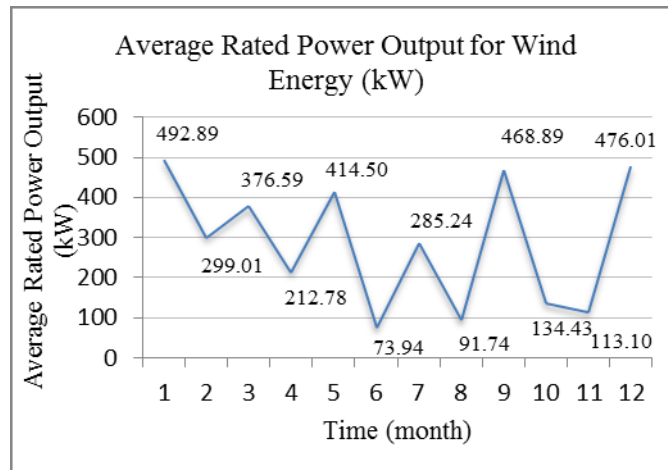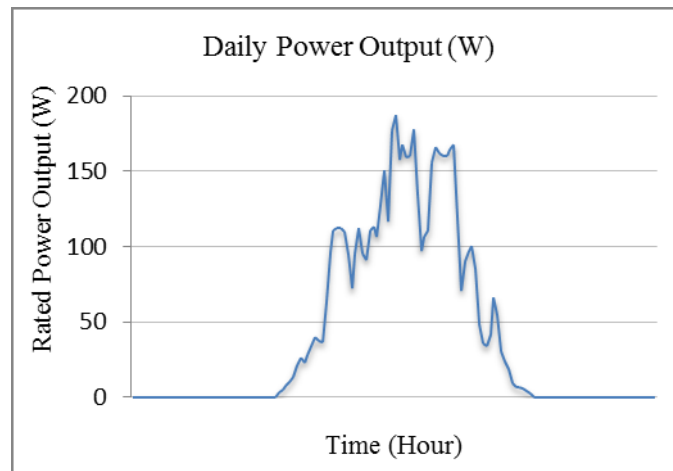

Figure 5. Monthly average rated power output for SIEMENS SWT4.0-120

Based on the figure 5, the monthly average rated power output generated by selected wind turbine SIEMENS SWT4.0-120 varies between the ranges of 73.94 kW to 492.89 kW. The highest power output was generated in January while the lowest month of power generated by this turbine was in Jun.
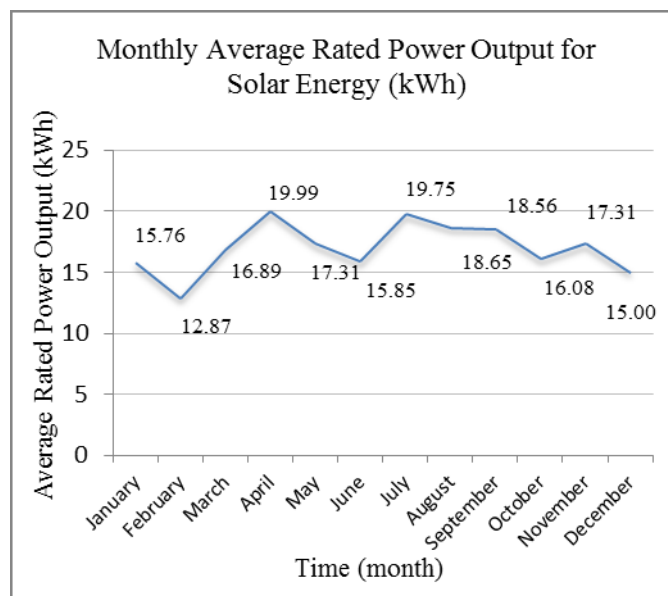
Figure 6. Monthly average rated power output for LG290 NIC-G3 MonoX

Figure 7. Daily average rated power output for LG290 NIC-G3 Monox

Based on the figure 6, the monthly average rated power output generated by solar panel LG290 NIC-G3 MonoX varies between the ranges of 12.87 kWh to 19.99 kWh. The poorest month of solar irradiation falls on February with the power output generated 12.87 kWh while the highest month of solar irradiation falls in April with the power output generated 19.99 kWh.

Based on daily power output in figure 7, at time between 12:00 a.m. and 6:00 a.m. as well as between 6:00 p.m. up till the next morning, the solar irradiation recorded is zero, indicating that the system has its downtime during this period of time. This is due to the availability of the sun [7]. The peak hour of daily solar irradiation falls at time between 11 a.m. to 3 p.m.

Based on the results discussed before, these wind turbine and solar panel can be installed in multiple units to form an array system in order to provide sufficient power supply to the selected offshore platform (figure 8). In order to accommodate the rated power output of 10 MW, the solar irradiation investigated should be from the poorest out of all months and days of all data collected to form an array. Moreover, an integrated system should be considered using both of these wind turbine and solar panel applications [9]. This is due to the complementary power output generated by these two forms of energy under seasonal variant in weather conditions. The solar panel plays a major role in generate highest power output in the summer months when the output from the wind turbine is at the lowest and vice versa during the monsoon season.

Figure 8. Multiple units of wind turbines and solar panels installed on offshore platform (conceptual design from [8])

5. Conclusion

The solar and wind energy application in generating energy is a viable solution of the current energy extraction problem for offshore application. In this paper, it showed that the highest power output generated for wind energy application is equal to 492 kW while for solar energy application power generated is equal to 20 kW. As a single unit of solar or wind turbine system is insufficient in order to provide power supply to offshore platform application, these applications can be installed in multiple units in order to generate sufficient power supply. Both of these systems can also be integrated to each other due to their different capabilities in generated power output based on weathers and climates condition.

Nomenclature

P_{rated}	Rated Power Output, W
P	Peak Power Output, W
PD	Power Density, W/m^2
D	Diameter of Rotor, m
L	Blade length of Rotor, m
r	Solar Panel Yield, %
H	Average Solar Radiation on Panel, kWh/m^2
PR	Performance Ratio
PE	Electrical Power of Solar Module, W
η	Efficiency, %
A_r	Swept Area of Rotor, m^2
A_p	Area of Solar Panel, m^2
v	Wind Velocity, m/s
ρ_{air}	Density of air above sea level, kg/ m^3

I.

Acknowledgement

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