# Solar Powered Pump for a Remote Oil Well in Nigeria

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***Abstract-*** **Most times, stripper oil wells, i.e. well with a production rate below 15 barrels of oil per day, are dumped by the oil production company because the cost of production and maintenance does not tally with the production rate. This low production from these oil wells is primarily due to oil spillage. Oloibiri oil well in Nigeria is an example of such failure; due to the diminishing production rate in 1960, the oil well became abandoned with an initial oil production rate of 5,100 barrels per day. Eighteen drilled wells are in the Oloibiri oil site, and oil well 17 is only the well that can be described as a stripper well. Due to the high solar irradiance and solar insolation in Nigeria, the PV system is implemented into the methodology and a design of a solar-powered pump that should lift the oil from the depth of 3800m with a flow rate of 15 barrels of oil per day. The system design will be calculated, compared with the PVsyst and HOMER sizing, and the pump performance will be evaluated**

***Keywords: Photovoltaic, Remote Oil Well, Oil Pumping, PVsyst, HOMERPro, Solar Energy***

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## I. Introduction

Over 3.2 million abandoned oil and gas wells in the United States are obsolete for one reason or another. Environmental issues can occasionally result from another sort of "stripper well," the last of the reserves from a depleting oilfield. Oil wells that produce fewer than 15 barrels per day are known as stripper wells. The Energy Information Administration, EIA, estimates that around 380,000 in the United States are in terrible shape and are harming the environment [1]. Spill hazards can lead to problems for more than just the local natural wildlife. Agriculture is affected, which, in turn, may affect the health of humans. Several abandoned oil wells continue aggressively polluting freshwater aquifers, rivers, lakes, and even the air we breathe. Methane is around 100 times more effective than $CO_2$ in trapping heat in the atmosphere for greenhouse gases; abandoned wells in the US have released 281 kilotons of methane into the atmosphere [2,3].

## II. Literature Review

In Aztec Willson K property, five wells were drilled and equipped [4]. However, there were two difficulties, first off, there was no power on site due to the isolated rural setting, and each well was projected to generate five barrels per day; thus, the expenses of the project needed to be reduced to a reasonable level to ensure a satisfactory return. The second factor was the cost of establishing electricity lines. The installation of LORENTZ submersible progressive cavity pumps was chosen. The choice is in consideration of the pumps' usage of low-power; DC brushless motor is selected because it enables the use of solar power, and it is less expensive to install and maintain than a conventional pump jack. The construction of the systems is in complete remote management capabilities because of the remote location and low operational cost assumptions. between the pump and the pumpMANAGER application, which is cloud-based. Through a web browser interface, pumpMANAGER enables the monitoring and managing of all pumps from any internet-connected device. A liquid level sensor is included in determining each well's fluid level, recording it, and sending the information to the pumpMANAGER programme through the cellular network.

## III. *Site Characteristics – Oloibiri Oil Field*

Oloibiri oilfield is approximately 45 miles east of Port Harcourt in the Niger Delta in Oloibiri, Ogbia LGA, Bayelsa State, Nigeria. Oloibiri field is in a marsh within Oil Mining License, OML 29 and is 13.75$km^2$ in size. On August 3, 1955, the discovery well Oloibiri 1 was spudded and drilled vertically to 108ft [5]. For the first year, the field produced 5,100 barrels of oil on average per day. After then, there was an increase in production, as new wells were completed and placed into service, reaching a high in 1964. There were eighteen producing wells drilled in the site. The field produces heavy oil with an API rating of 20.6. For its 20-year lifespan, the oilfield produced more than 20 million barrels of oil. Finally, oil production ceased in 1978, and the field was closed the following year. Without any enhanced recovery to extract the remnant still present in the site, the Oloibiri oilfield was abandoned [5].

### A. *The Oil Well Development*

The first appraisal well, Oloibiri-2, was drilled vertically to a total depth of 2,932m, and after a declining production rate, the Oloibiri-17 appraisal well was drilled to a measured depth of 12,520 ft, but the outcome was not promising. Oloibiri-17 has been plugged in. The field's production has decreased from its peak level. At the time, the oil well 17 field was nearly empty and regarded as a stripper well with a production rate below 15 barrels per day [5].Figures 1 and 2 below show the current state of the area's oil well and oil spillage.

*Figure 1; Oil Well 17 Current State [6]*

*Figure 2; Oil well spillage and effect on the community.*

This paper will design and analyze a solar power pump for oil well no 17 since that is regarded as a stripper well with a production rate of less than 15 barrel of oil per day.

### *B. Solar Energy in Nigeria*

Nigeria's geographic position (in the equatorial area) is one of the country's most significant advantages in the distribution of solar energy. In Nigeria, solar energy is well distributed, with the north receiving a more considerable proportion. With an average of 6 hours of sunshine daily, the nation has a solar radiation value of roughly 19.8 MJ/$m^2$. The sunshine varies by location, from 9 hours in the far north to 3.5 hours towards the coast [7,8]. On average, Nigeria receives around 7.0kWh/$m^2$, that is about 25.2MJ/$m^2$ per day of solar radiation. It may be inferred from the solar radiation map of Nigeria shown in figure 3, that the country has a solar capacity of between 3.5 and 7.0 kW/m2/day and an average of 4 to 7 hours of sunshine each day [7].

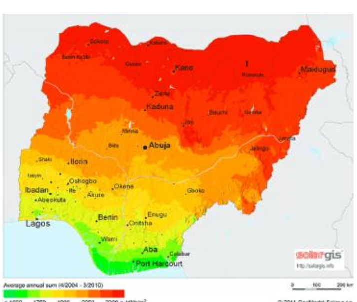


*Figure 3: The geographical Solar irradiance range in Nigeria [8]*

## IV. System Design Calculation

### A. Site Description

Pumps type selection depends on the head and flow rate. The well depth is 3816m with a total dynamic head of about 3820m, static water level to the ground of 3710m, pump level selected to be on a depth of 3800 m, to avoid pump damage from any sands , stones and sediments from the crude oil.

The production rate for this site is 15 barrels of oil per day which is equivalent to 2.4$m^3/day$ . The solar insolation for the location is typically 5 hours per day. Flow rate per second = $\frac{2.4}{5\times60\times60}$ = 0.00013$m^3/s$ (0.5 $m^3/h$ ).

TDH = 3816 m (vertical) + [(0.9 x 1 elbows) + 5 m] x 0.2 = 3817m.The total dynamic head will be estimated at 3820m.

### B. Solar Irradiance of the Site.

Nigeria has a high intensity of solar irradiance and longer hours of solar insolation; integrating solar energy will be the best fit for this renewable energy technology. Homer software was used to estimate the site's solar irradiance of solar energy.

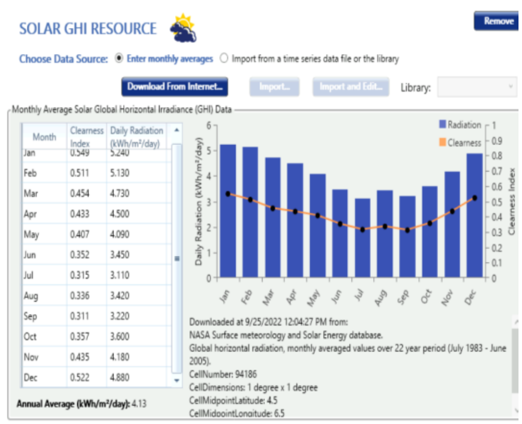


*Figure 4; Solar Global Horizontal Irradiance for Oloibiri, Nigeria (HOMER)*

January has the highest monthly average solar irradiation, while July has the lowest. The annual average solar irradiation in Oloibiri, Nigeria, is 4.13kWh/$m^2$/day shown in figure 4. The minimum and maximum sunshine duration varied between 5 to 9 hours, showing the solar a day.

### C. Pump Sizing

The pump size is essential for the system sizing.

Hydraulic power = $\rho\times g\times H\times Q$

Shaft power = hydraulic power/ efficiency

$\rho$, the heavy crude oil density (925kg/$m^3$), But due to the depth of the well and high pressure at the bottom line, the density is almost equivalent to that of water (1000kg/$m^3$). The oil's viscosity is low since the oil will be hot at that depth

P is shaft power (kW), and $\eta$ is pump efficiency (30%) will be used for the simple calculation . The total head includes the distance from the pump level to the tank, the fraction of elbows, and friction from the bolts and junctions in the delivery pipe. With the total head dynamic of 3820m and a maximum flow rate of 0.00013 $m^3$/s, the calculated hydraulic is 4.5kW, and the shaft power of 15kW can deliver the required amount of oil based on the simple calculation if the system is 30% efficient. Above calculation gave some idea of the required system, the detailed system is done using solar energy software.

## V. Solar Pump Design by PVsyst

For proper sizing of the solar pump to fit the system required for the site characteristics, PVsyst software is used since it includes specific parameters like the pump level, drawdown, static level, borehole diameter, and lower dynamic level (software limitation). Due to the well's depth, the oil's density is assumed to equivalent to that of water. The following oil well specification is needed for the system design in figure 5, with the customized delivery pipe material as medium-pressure seamless steel material with an inner diameter of 200mm and 217mm outer diameters

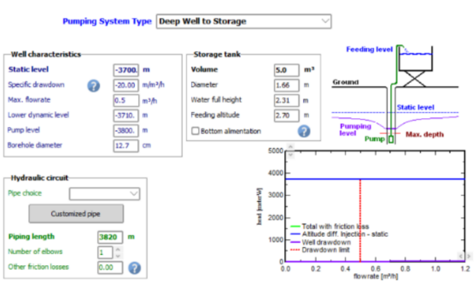

*Figure 5; Input parameter for the system in PVsyst*

*Figure 6; PVsyst system sizing Suggestion*

The PVsyst recommended an 18.2kW pump power, a minimum head of 3702.7 meters of oil and a maximum head of 3712.7meters shown in figure 6.

## VI. PV Sizing by HOMERPro Software

Since the sizing recommended by PVsyst is about 18.2kW, 1.8kW is added to make room for miscellaneous energy needed, such as lighting system and control (there was no such option in PVsyst) shown in figure 7. To accurately find the suitable PV rating to accommodate all the needed electrical load for the entire system for a running time of 5 hours a day. HOMERPro software is used to determine the best-optimized system.

*Figure 7; Load profile*

The running time of this system is between 11am - 4pm, the region with the highest solar irradiance.

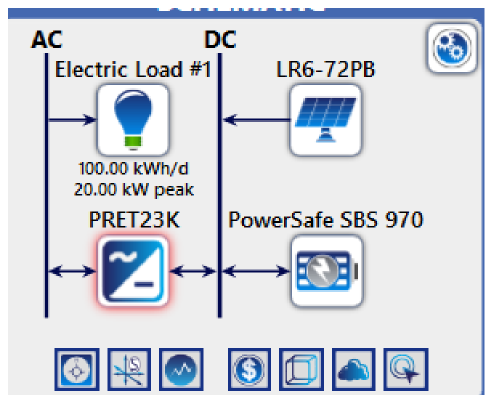


*Figure 8; System Sizing Architecture*

50kW of 370W, 24V LONGi Solar panel, 40 (970Ah, 12V) lead-acid batteries of PowerSafe SBS and a 22.3kW converter of PRETTL REFsol23k for the system design. DC bus voltage is 240V with 20 batteries in one string shown in figure 8 . Figure 9 shows the renewable fraction of 100%, excess electricity of 33.9%, 0.08% unmet electric load and 0.09% capacity shortage. This system is highly feasible to meet the requirement of the site.

*Figure 9; Simulation result details*

## VII. Battery and PV panel performance

The PV panel shows that the penetration level met all requirements for the load by 100% shown in figure 10, while the battery's internal system characteristics indicate that from August, the state of charge has depleted tremendously. This depletion ended in September shown in figure 11.

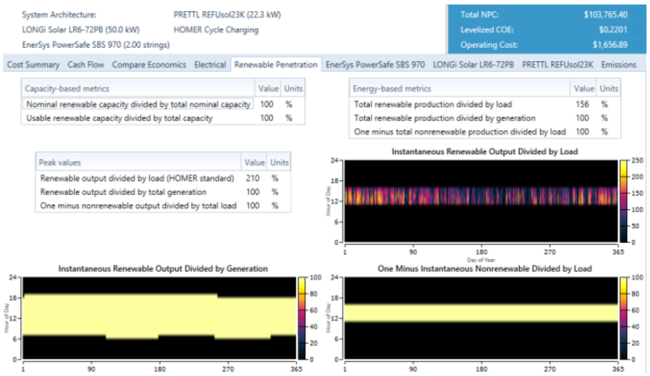


*Figure 10; Renewable penetration details*


*Figure 11; Battery performance details*

## VIII. Pump Performance and System Evaluation by PVsyst

The depth of the oil is vast for the pump dynamics to be evaluated in PVsyst. Therefore, the maximum head is placed at 100m, and the static head and dynamic level are placed at the same level position as the site characteristics. This way, one can fully mimic the system's performance; every result obtained will be multiplied by 38.2 to give an accurate precision if performed with a head of 3820m. The pump is defined according to the needs of the static head and the pump power. In figure 12, The suggested pump power is 422W by PVsyst, 1.4kW Grundfos Solflex DC pump with brushless DC motor with a maximal power 1400 W, 120 V and 3.8 A is the best fit used for the system evaluation. The main result shows that the pump performance efficiency is 37.9%, and the entire system efficiency is 11.4%.

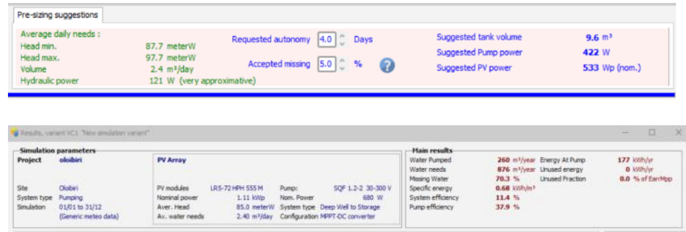

*Figure 12; pre-sizing parameter, simulation parameters and results*

Figure 12 shows a system design for 100m depth with the flow rate when the system runs for 5 hours.

Pump power; 422 x 38.2 = 16.12kW

PV power; 533 x 38.2 = 20.36kWp with many system losses not included

## Conclusion

The side effects of abandoned well that are still depleting in production rate to the environment are catastrophic. Since the cost of production is inherently expensive for oil-producing companies to curb the effect by pumping the leftovers, alternative and cost-effective technology like the solar-powered pump is a convenient option to solve this problem. This paper proposed an intensive system sizing suitable for Olobiri oil well 17. First, the sizing of the pump was suggested by PVsyst, and the performance was evaluated by mimicking an oil depth to fit the site characteristics in the PVsyst software. The software indicated that the system efficiency and pump efficiencies are 11.4 % and 37.9%. Lastly, the overall load of the entire power system was considered to size the PV set up in HOMERpro correctly. With the system running time of 5 hours daily, the software suggested a PV unit of 50kW.

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