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Development of a Solar-ESP Based Wellhead System for Remote Wellhead Operations in Marginal Oilfields

Francis Enejo Idachaba, Covenant University Ota; Esther Wokoma, Shell Petroleum Development Company

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Abstract

Marginal Oilfield status is the terminal point of all mature producing oilfields before they are finally abandoned. At this point, it becomes uneconomical for most operators to continue producing the field due to the very low oil production from the fields coupled with the increasing water cut and sand production from the wells. In spite of the low production from these fields, records show that the field still contains up to 40% of its reserves. The field at this point is either abandoned or sold out to marginal operators who manage the fields with minimal OPEX to maintain profitability. The strategies to be deployed to ensure profitability of the field must guarantee very minimal or zero OPEX both for the production and the operation of the field. Artificial lift is a technique used for increasing the flow from low producing oil wells and the Electric Submersible Pump is a tool used in facilitating the increase of the well flow especially when the crude oil production has decreased. This work presents the development of solar power driven Electric Submersible Pump (ESP) for increasing the flow from oil wells. The system operation is managed by a controller which manages the operation of the ESP. It also utilizes the ESP and the choke to control well pressure while a sand trap is inserted between the wellhead and the choke to separate the sand from the oil. The utilization of solar power for the ESP eliminates the need for other sources of power supply which require increasing OPEX costs and integration of the electronic choke enables remote operation and control of the wellhead, thus minimizing operator visits. This system will enable marginal field operators produce from remote wells with minimal OPEX. It will also enable major operators extend the production from their oil fields especially in this era of low oil prices where new explorations are too expensive to consider.

Introduction

A definition of marginal fields is dependent on a mixture of specific conditions which include hydrocarbon resources, oil price, technical feasibility, operating company portfolio, commercial frame work and regulatory issues. Marginal fields can be broadly defined as oil and gas fields which are uneconomic to develop due to reserve size, complexity, fiscal and market conditions, or distance from nearby infrastructure. They could also be low volume producing fields near the end of their economic life where revenue is below operating expenditure.

Marginal fields are mainly located in areas that are very far from existing production facilities. Investors find it difficult to develop this type of field because of its nature which when tied to economics, lack attractiveness [2].A marginal field as defined in the Nigerian Oil and Gas nomenclature is a field located within an area covered by an existing Oil Mining Lease (OML) held by one or more companies. Such a field is characterized by the following features:

1. It has oil and gas reserves booked and reported annually to the Department of Petroleum Resources (DPR)
2. It has remained unproduced for 10 years; and
3. It has been declared to be a marginal field by the President.

Marginal fields may also have some, or all, of the following features: [1]

1. Oil reserves with unconventional crude oil characteristics (such as very high viscosity and low API gravity);
2. High gas and low oil reserves;
3. They may have been abandoned by the OML holder for upwards of three years.
4. Lack of nearby existing production facilities to put on stream,
5. Unfavorable market and fiscal situations,

Figure 1 shows the map of marginal oil fields in Nigeria

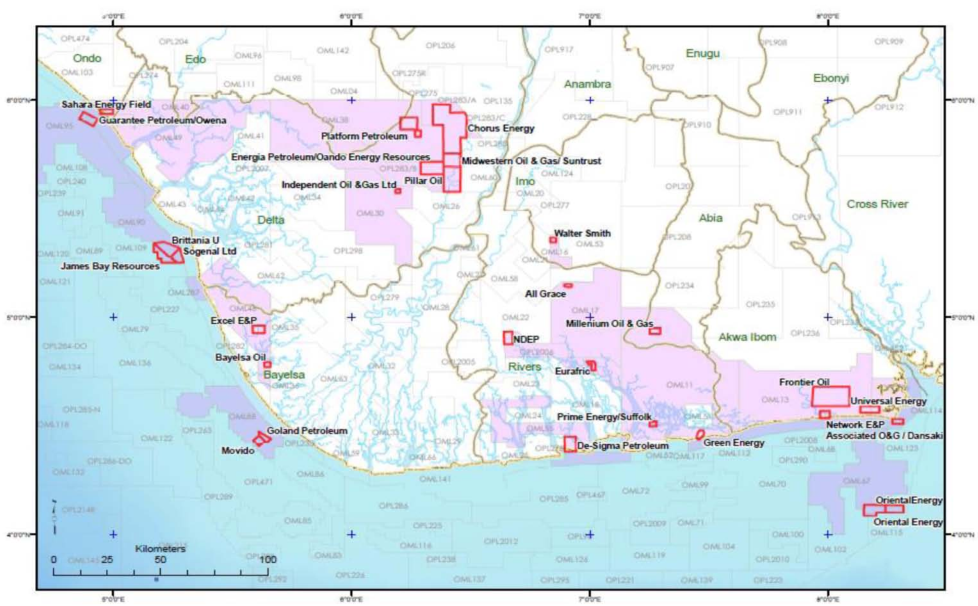

Figure 1—Map of Marginal oil fields in Nigeria

A Marginal Oil Field can also be defined as an oil field that does not produce enough net income to make it worth developing at a given time. [3][5] Other characteristics of the marginal oilfields includes a field with few or one well undeveloped for about 10 years by the multinational oil company (MOC), a field that may still have reserve but uneconomical for development by the MOC.

From the map shown in figure 1, the following justifications were provided by the federal government in Nigeria for introducing the marginal field regime.

The justifications were:

1. *Increasing oil and gas reserves*:

2. *Increasing indigenous participation in the oil and gas industry:*
3. *Employment generation*:
4. *Increasing production*:

Marginal oil wells are also known to have very minimal flowrate and those with flowrates of less than 10 barrels per day (B/D) are also referred to as stripper wells. Table 1 shows the marginal oil production in the USA for 2012.

Table 1—2012 List showing Marginal crude oil production in the US

States	Number of Marginal Oil Wells	Marginal Share of total production %	Average daily production per well (Bbls)
Texas	142,726	19.3	2.2
California	34,682	21.5	3.4
Oklahoma	31,460	18.1	1.4
Ohio	28,204	78.1	0.4
Illinois	27,479	100	1
Kentucky	26,424	84.6	0.3
Pennsylvania	22,430	87.5	0.3
Kansas	20,565	38	2.2
Louisiana	16,679	13.9	1.6
New Mexico	15,914	18.7	2.7
Colorado	10,245	18.9	2.5
Arkansas	4,387	47.8	2
West Virginia	4,386	32	0.5
Wyoming	4,244	7.6	2.8
Indiana	3,399	80	1.5
New York	3,386	98.8	0.3
Montana	2,843	8.2	2.1
Michigan	2,375	41.8	3.6
Utah	2,347	11.6	4.1
North Dakota	1,656	1	4.1
Nebraska	1,553	61.5	2.7
Mississippi	1,000	5.7	3.7
Alabama	701	9.4	3.5
Missouri	425	100	1.1
Nevada	36	15.8	4.4
South Dakota	28	2.6	4.4
Arizona	16	35.8	3.2
Virginia	3	1.6	0.1
Maryland	0	0	0

From Table 1 and Figure 2, the production from the Marginal oil fields constituted the totality of the oil and gas production from Illinois in 2012 while Nevada and South Dakota had the highest average daily production from marginal oil wells. The production profile from these marginal oil wells ranged from 0.1 barrels to 4.4 barrels of oil per day. The state of Texas which produced 37% of the total crude oil in the US was the largest producer from the marginal oilfields as it contributed 47% of the oil produced from Marginal wells. As at 2012, the US had a total of 266,867 Marginal oil wells and over 50% of the wells (142,726) were located in Texas. [4]

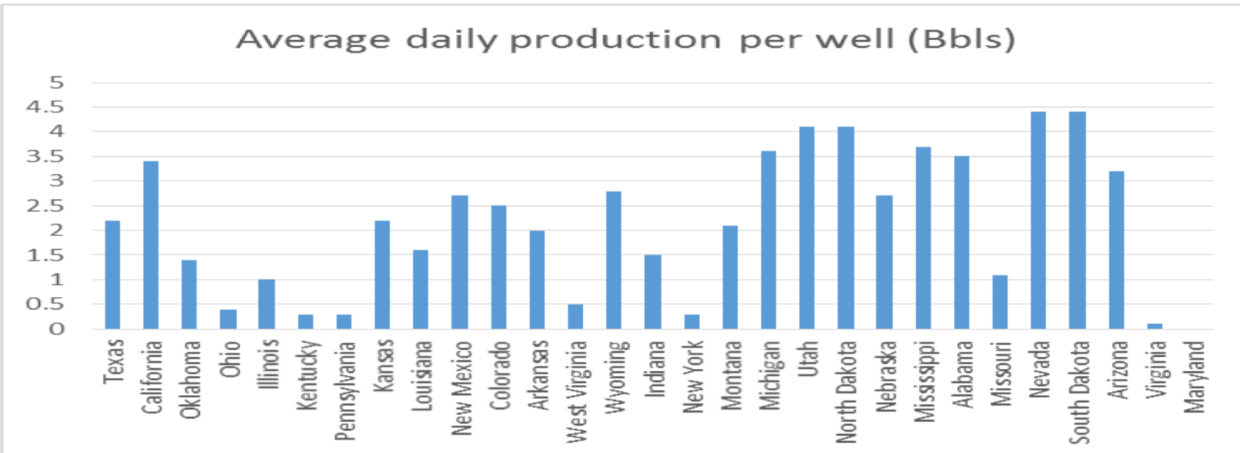

Figure 2—Average daily crude oil production from Marginal oil wells in the US

Electric Submersible Pump

The electric submersible pump, also known as an ESP, is a pump which is used in artificial lift deployments for providing lift to the reservoir fluids. It is a reliable artificial-lift method for lifting moderate to high volumes of fluids from wellbores. The main components of the ESP system include: a multistage centrifugal pump, a three-phase induction motor, a seal-chamber section, a power cable, and surface controls. The ESPs have a number of advantages over other artificial lift systems and these advantages range from being highly adaptable to highly deviated wells; up to horizontal, but the ESP must be installed in a straight section. It is safe and sanitary for operations in environmentally sensitive areas such as offshore locations and it allows for the placement of wells on production even when drilling and work over activities are taking place on nearby wells. Key disadvantages of the ESPs include the fact that they can only tolerate a minimal percentage of solids (sand) production. Special pumps with hardened surfaces and bearings have however been developed to minimize wear and increase run life. Operations below 400 B/D, results in a sharp drop in power efficiency for many of the ESPs. These coupled with the costly pulling operations and production loss which occurs when correcting downhole failures, account for the key disadvantages of the ESP system.

ESP Installation and Design

There are various manufacturers of ESP and each of these systems come in various selections ranging from low voltage/high amperage to high voltage/low amperage. Voltages range from 440 to 4,000+V, and amperages typically range from 15 to 150+ amps. The relationship of the HP, voltage, and amperage is

$$HP_{output} = (V \times I \times 1.73 \times \text{power factor (PF)} \times \eta_m)/746.$$

Where HP is the power output of the motor.

Power costs are the most significant part of the required OPEX for running an ESP system. The diagram in figure 3 shows the typical installation of an ESP system.

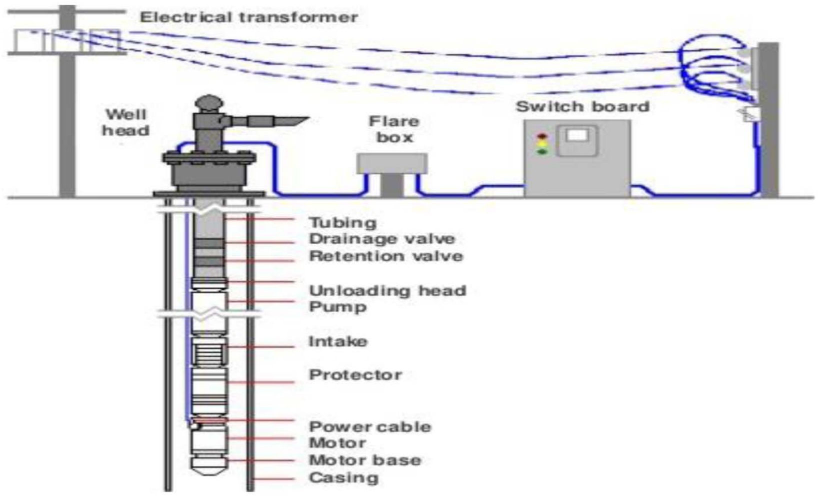

Figure 3—Installation diagram for an ESP system

From the diagram in Figure 3, the typical power installation requirements for an ESP installation includes:

1. Infrastructure requirement for public utility power supply extension to the wellhead. This includes the power cables, the Electric poles and Right of Way
2. The Three Phase transformer for Electric Motor
3. The cost of the power consumed.

The utilization of public utility has its advantages especially in locations close to the public utility supply systems. This will minimize the infrastructure requirement for extending the public utility to the wellhead. It will however not eliminate the need for the transformer or the cost of the power consumed. The cost of energy and the associated equipment are a major contributors to the ESP costs. The cost associated with the use of public utility is especially high for installations in remote wellhead locations and swamp locations. This coupled with the ease of removal of the power cables makes the use of public utility for remote wellheads an uneconomical approach at supplying power to the ESP system. This paper presents a renewable energy system where the ESP is powered from standalone solar power systems located at the wellheads. This system comprise of the solar panels, the charge controller, battery bank and the inverter systems as shown in figure 4.

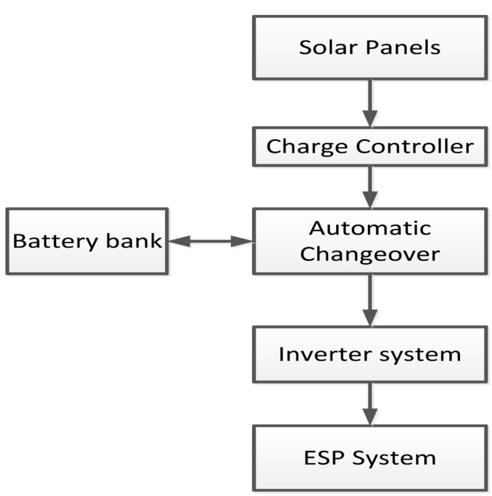

Figure 4—Proposed power supply architecture for the ESP system

Figure 4 shows the components of the proposed renewable energy based power supply system for the ESP system. The current utilization of AC power for the motors has necessitated the use of an inverter system to convert the DC power from the panels and the battery bank to AC. In the event of the availability of DC motors for the ESP system, the Inverters system will not be needed, thus further simplifying the design of the power supply system.

Proposed System Architecture

The architecture for the proposed system is shown in figure 5

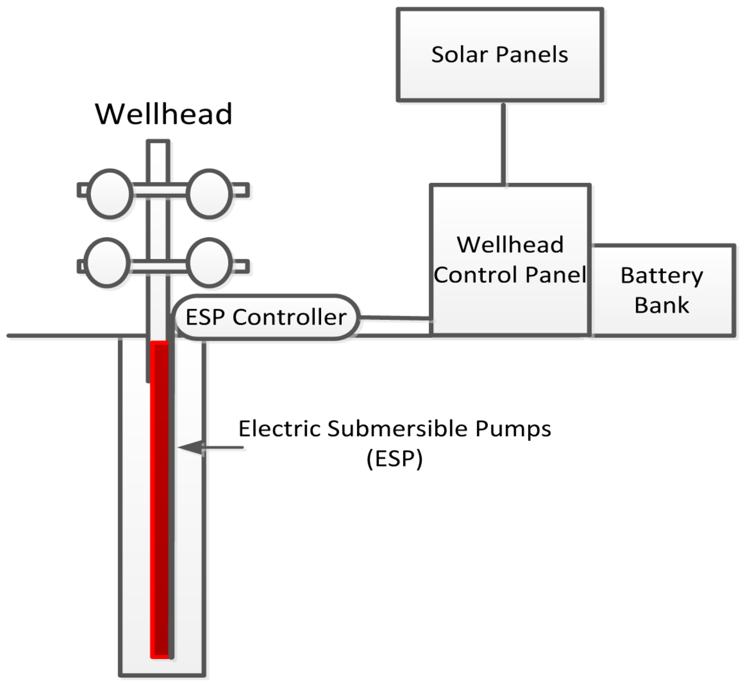

Figure 5—System architecture diagram

The system architecture shown in figure 5 comprise of a wellhead control panel which contains the metering systems and other associated controllers. The inverter and the charge controller are also installed in the control panel. The battery bank is installed in a special enclosure suitable for the zone classification of the wellhead area and installed outside the control panel.

Discussion

The current range of ESPs available in the market are designed to support higher flowrates than the current flowrate from marginal fields as shown in Table 1. The Marginal fields have a typical average daily flowrate of 0.1 B/D for Virginia, 0.3 B/D for New York and a Maximum of 4.4 B/D for Nevada. From these data, the existing ESP systems will be uneconomical when deployed in those wells. There is therefore a need to develop low power ESP systems that will be able to work effectively at the extra low flowrate. In order to ensure profitability from the wells, there has to be a special type of ESP with a low OPEX and CAPEX cost to allow operators, especially those in remote locations where public utility is absent and unrealistic to deploy, produce from these wells profitably using the available renewable power supply in those areas.

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