Optimizing a PV/Diesel Hybrid System in Oil and Gas Industry using Metaheuristic Techniques

Mohammad M. EL-Yamany*, Sameh O. Abdellatif**‡, Wagdy R. Anis***, Hani A. Ghali**

*Petroleum Engineering Department, The British University in Egypt (BUE), 11387 Cairo, Egypt.

**Electrical Engineering Department, and FabLab, Centre of Emerging Learning Technologies (CELT), Faculty of Engineering, The British University in Egypt (BUE), 11387 Cairo, Egypt

***Electronics and communication engineering department, Faculty of Engineering, Ain Shams University, 10247 Cairo, Egypt

(Mohammad.Elyamany@bue.edu.eg, Sameh.Osama@bue.edu.eg, wagdy_anis@eng.asu.edu.eg, Hani.Amin@bue.edu.eg)

‡ Corresponding Author; Sameh O. Abdellatif, The British University in Egypt, El-Sherouk City - Misr Ismalia Desert Road, Postal No. 11837 - P.O. Box 43, Tel: +201222194077, Fax: (+202) 26890000, Sameh.Osama@bue.edu.eg

Received: 11.02.2021 Accepted:14.03.2021

Abstract- The purpose of this work is to develop a systematic optimization methodology for utilizing renewable energy resources, specifically Photovoltaic (PV), in Oil & Gas Industry. The study has been applied on sucker rod pump, which is considered as the conventional technique for lifting crude oil (artificial lifting). The pump is operated with integrated solar assisted system and standalone diesel generator. The annual energy requirements using the levelized cost of energy (LCOE) for a sucker rod unit at western desert in Egypt have been evaluated. A metaheuristic optimizer (Water Cycle Optimization Technique WCOT) has been utilized to optimize the PV contribution in the hybrid PV/diesel system proposed. The results have shown that the hybrid system can provide up to 25% reduction in the LCOE with respect to the running diesel generator 24/7 system. Over and above, by considering the annual saving, only two years of payback period will be needed.

Keywords PV/diesel systems; Sucker-rod pumping; LCOE; Techno-economic feasibility; Metaheuristic Optimization.

1. Introduction

Oil and gas fields are usually located away from the developed residential areas where the national electrical grid is not connected [1]. The energy demand of these plants is provided via external electrical generators (mainly diesel generators (DG)). However, it has been reported that integrating the conventional generators with alternative renewable energy sources would result in lowering the cost of energy for the mentioned plants [2-6]. In addition, the difficulties of transporting diesel to the remote, isolated and inaccessible areas have increased the operational costs of providing energy to the oil and gas plants [7].

Sucker rod pumping is considered as the conventional technique for crude oil artificial lifting [8]. In Egypt, oil and gas industrial sector has encountered many problems during the lifting operations especially those problems related to electrical power supplying as described in [1]. Furthermore, the electrical power consumed has been found to be different from one well to another depending on several factors, including but not limited to; flow rate, specific gravity of fluid, fluid level, weight of sucker rod, stroke length and pump speed [9]. As a result, prime mover should be adequately sized to provide sufficient power to lift the production fluid and to overcome friction loss in the rod string and polished rod. Consequently, several researchers have proposed numerous solutions to enhance the power supply reliability and sustainability in remote areas [1, 7, 10-12].

Embedding renewable energy sources either as a replacement for DG or in a hybrid system is considered as one of the booming solutions in this track [3-6]. Five out of the eight major petroleum companies already started the investment in the renewable energy. Bloomberg statics states that both BP and Eni already devoted 200 million USD in the renewable energy sector while Total already spent around 500 million USD. Statoil also devoted 600 million USD, and Shell invested the largest share with 2 Billion USD in the renewable industry. In 2014, Cimino et al [7] have enhanced the efficiency of oil production operation by integrating solar system with diesel fuelled generators. They have reported a configuration able to supply energy to the pumps in order to a steady-state production, reduction of fossil fuels energy intensity of oil and gas production chain and reduce carbon dioxide (CO2) emissions. However, they have not considered the lifetime of the PV modules. In addition, they have not calculated the LCOE of the integrated system and have not compared it with the traditional system. In 2017, Elhousieny et al [10] have discussed the challenges of operating sucker rod wells and the influence of integrating solar assisted systems and diesel generator. They have reported the optimum configuration of the PV/Diesel hybrid system with respect to the load demand. However, they have not considered the economic impact in terms of the LCOE for the hybrid system and standalone diesel generator systems.

Additionally, Kirmani, et al [13] have investigated the optimum configuration for different combination of hybrid energy systems that would fulfill the electrical energy requirement of selected village reliably and economically. They have selected a remote site which is a prospective location for the installation of a hybrid renewable energy system and optimized all configurations to reach optimum alternative. On the other hand, they have not considered the inflation rate for the calculated period. Finally, Diab, et al [12] have utilized the well-known hybrid optimization of multiple electric renewables software to get the optimal configuration of a hybrid renewable energy system, based on the user inputs of loads, components costs, components technical details and solar resources availability. They have explained the cash flow with life time of each component and implemented an optimization process for a configuration to achieve the optimal alternative. On the other hand, they have not mentioned whether the inflation is considered or not in cash flow calculations. Further, they have not considered the LCOE of the new system with respect to the traditional system.

On the other hand, the research mentioned in [14] discussed a real case study and implementation on involving the solar PV system with the DG in a remote oil field in the Egyptian western desert. The system saved over 15000 liters of diesel and reduced the CO2 emissions by 40 tons/yr. (12% reduction). In spite of that, the research did not mention the total system cost, the LCOE or even the economical parameters or terms that has been used in the study. The study that has been presented in [15], focused on the economical factor of the study with sustaining the technical term within the acceptable limits. The system was designed based on the average daily solar radiation and average wind speed. However, the relation between the renewable energy generation cost and the conventional energy generation cost has not been mentioned.

This work demonstrates a techno-economic feasibility for a real case study at the western desert in Egypt. We provides three alternatives for energy generation including standalone diesel generator (as a reference system), PV standalone system with batteries and hybrid PV/diesel generator system with different contribution percentages to reach an optimum configuration with respect to LCOE. The LCOE, as well as other economic parameters, have been studied based on our previous definitions in [16-20].

2. Systems Design

2.1. Sucker-rod pump power calculation

In the western desert of Egypt, a field consists of ten wells has been considered as the case under study for investigating the feasibility of integrating PV system to supply sucker-rod pumps (SRPs), seeking for minimum levelized cost of energy (LCOE). In order to design a sucker-rod pumping system, initial set of parameters should be defined. Targeting optimum design for a specific application, each variable must be evaluated in terms of the particular requirements of that specific system. In order to calculate the energy consumption per pump, the hydraulic horsepower should be investigated. Hydraulic horsepower is the theoretical work required to lift the well fluid from the net depth, which can be calculated by:

$$H_{hydr} = 7.36 \times 10^{-6} \times Q \times Sp.Gr \times L_{dyn} \tag{1}$$

where H_{hydr} is the hydraulic horsepower required for lifting the liquid, Q is the liquid production rate, $Sp.Gr$ is the specific gravity of the produced liquid and L_{dyn} is the dynamic liquid level in the well.

The sources of down-hole energy losses in the sucker-rod pumping system are the pump and the rod string that has been affecting on the stroke length. The equation for calculating friction horsepower losses can be illustrated by:

$$H_f = 6.31 \times 10^{-7} \times Wr \times S \times N \tag{2}$$

where H_f is the friction horsepower to overcome friction losses is, W_r is the weight of sucker rod, S is the stroke length and N is the pump speed.

The prime mover should be properly sized to provide adequate power to lift the production fluid, to overcome friction loss in the pump in the rod string, polished rod, and in the pumping unit. The power required for lifting fluid and to overcome friction losses is called ''Brake horsepower'' Thus, the required prime mover power can be expressed as

$$H_b = F_s\,(H_{hydr} + H_f) \tag{3}$$

where H_b is the brake horsepower of the prime mover and F_s is a safety factor of 1.25–1.50 based on manufacturer decision. In the current study, a safety factor of 1.5 was chosen. For selecting an appropriate prime mover, the nameplate horsepower rating of the engine should be substantially reduced to reach the actual engine capacity. For an electric motor the nameplate rating must be reduced to account for horsepower capacity which is lost because of motor heating resulting from cyclic loading imposed by rod pumping. Consequently, the motor rating can be expressed by:

$$P_M = H_b/(1 - \%\,of reduction\ in\ nameplate\ rating \tag{4}$$

Hence, P_N is the motor rating which is the calculated power that is resulted from required power for the whole system and the losses that can be measured in the system. It is also called the theoretical power of the system or the required power that is needed in the mechanical model of the SRPs.

2.2. Sucker-rod pump actual measured power

The sucker rod load is unsteady due to the distinction of the amperes consumed in the upstroke and that is consumed in the down stroke. During the movement of the pump through upstroke the maximum load will be reached and a maximum ampere is consumed by the motor. On the other hand, a minimum ampere is consumed during the down-stroke. Hence, the actual loads have been calculated using two ranges of amperes (one is considered for the upstroke and one for the down stroke) [10].

The current study will give a specific focus on one well due to its unique desired flow rate leading to the highest current in the upstroke with respect to the other nine wells. However, the proposed study can be expanded to cover the 10 wells with utilizing the same procedure. For the well under test, the desired electric energy system should feed a motor (three phases-AC) of a sucker rod pump with an actual power of 27.45 KW, which has running time of 24 h that is 658.80 kWh/d. Full details related to the sucker-rod pump under test is illustrated in Table (1).

Table 1: Sucker rod pump specifications for the first well

Parameter	Value
Volt (V)	380
Current (I) Rated (Amp)	86
Current (I) Actual (Amp)	30 for down-stroke – 67 for upstroke
Power Factor	0.86
Rated Power (kW)	48.6
Actual Power (kW)	27. 45

3. PV Integration

In the current study, three alternatives are demonstrated to study the feasibility of integrating PV system to supply the pump under test. In the coming sub-sections, a full illustration for the proposed alternatives is introduced.

3.1. Alternative #1: Diesel Generator (Reference system)

For alternative #1, the diesel generator unit has been considered as the main and only source of electrical energy. This alternative can be considered as the conventional case in most of petroleum companies in Egypt. Herein, we consider this alternative as a reference (system 1), where the other two alternatives will be evaluated with respect to alternative #1. The proposed system is based on a 120 kW diesel generator which consumes 370 L/d of fuel. The diesel price is taken to be 10 EGP/L and the renting cost of the diesel generator is 1,155 EGP/d, including the maintenance.

3.2. Alternative #2: PV with Batteries (Standalone system)

For alternative #2, PV with batteries as storage system has been considered as the only source of electrical energy where solar PV array has been sized to meet the required energy demand as mentioned in a section 2.2 (system 8). The technical specifications for the components of the proposed system that meet the required energy demand have been composed of 340 W polycrystalline PV module, with open circuit voltage of 46.2 V and short circuit current of 9.4 A. It has been integrated with a battery of 12 V and 150 Ah. In an attempt to match the requirement of the three phase sucker rod pump, a 27 kW (DC/AC) inverter of 3-phases output has been used, with maximum input current of 47.7 A and AC output current of 40.9 A/39.1 A.

3.3. Alternative #3: PV/Diesel (hybrid system)

For alternative #3, six different systems (systems 2 to 7) have been considered, in order to achieve an optimum alternative with respect to LCOE, these alternatives are varying in the percentage of contributions between PV and diesel generator as represented in Table (2). It is worth to highlight that for systems 2 to 6, PV system with DG is operating while no need for storage bank. In those systems, the percentage of PV contribution is limited to sunlight working hours, where night loads are totally covered by DG. On the other hand, system #7 is the only hybrid system where a storage bank is obligatory. Additionally, a smooth starter is attached to all systems under investigation to ensure smooth start up.

Table 2: Various hybrid PV/Diesel systems

System	PV contribution (%)	Diesel contribution (%)
2	21	79
3	29	71
4	38	63
5	46	54
6	54	46
7	63	37

4. Results and Discussions

4.1. Load Profile

Following the sucker-rod pump calculated and measured power presented in section 2.1 and 2.2 respectively, the power for the well under test has been found to be 27.45 KW (actual power) and 26.73 KW (calculated power, see equation 4). Accordingly, the actual power is considered as the targeted load in this study, where the calculated power has shown approximately 97.3% matching with the measured one.

Consequently, the power supply for a sucker-rod pump has been divided into two main divisions, which are the power of upstroke (maximum power) and the power of down stroke (minimum power). Furthermore, the time required for this process is 1:1 shares with a 6.3 stroke/min. In both strokes a 3-phase voltage 380 V is needed while the consumed current are 67 A and 30 A for up and down stroke, respectively. The total consumed power in both upstroke and down stroke are 37.9 kW and 16.9 kW, respectively. Accordingly, the required energy per day is 658.80 kWh/d, leading to an overall demand of 240,462 kWh/y. As mentioned earlier, herein the maximum load corresponding to the worst case demand is always considered.

4.2. System Optimization

Following the previously defined system, herein we introduce water cycle optimization technique (WCOT) to optimize the system performance [21]. Our proposed fitness function is defined by:

$$\zeta_{LCOE} = \sqrt[3]{(LCOE^{E}_{PV})^{(\beta_1)} \times (LCOE^{E}_{DG})^{(\beta_2)} \times (LCOE^{E}_{B-DC})^{(\beta_3)}} \qquad (5)$$

$$\sum_{i=1}^{3} \beta_i = 3 \qquad (6)$$

where β is the weighting factor of the corresponding elements. Herein, a geometric average for these three parameters is introduced to optimize the proposed system. The three parameters are the levelized cost of energy for PV system, DG system and the added battery if needed. LCOE (EGP/kWh) is calculated over 20 years and can be described by:

$$LCOE = \frac{ATLCC}{E_L} \qquad 6)$$

where (ATLCC) is the Annual Total Life Cycle Cost for the system under test and EL is the total energy produced by the system. To calculate the ATLCC of any system, the inflation and interest rates of the project location must be counted. Based on [22, 23], the average inflation rate for Egypt from 1984 till 2021 is 11.45% while the interest rate in 2019 is 5% for the renewable energy projects based on the Central Bank of Egypt (CBE). The inflation rate has been taken as an average for the 40 years as it will affect the income of the project. Meanwhile, the interest is using the rate of 2019 only as it is the year of the project loan.

Based on the outputs listed in Table (3) and figure 1, the optimal configuration is 89.2 kW PV array with 262 panels, four (27 kW DC/AC) inverters and 120 kW diesel generator with diesel consumption of 61,898 litre/year. Following this optimal system, the total capital cost is 871,117 EGP, the total fuel cost is 618,980 EGP/year and the levelized cost of energy is 5.35 EGP/kWh as shown in figure 1. The recorded optimal LCOE has illustrated an overall reduction of around 24.2% with respect to the reference system (alternative #1).

The importance of different scenarios appears in excluding all infeasible scenarios and arranges or ranks all possible scenarios. The sixth scenario has been reported as the optimal system that used 54% of PV and 46% of diesel. If the batteries have included to the seventh scenario, the system has added several PV arrays to meet the load demand with more capital cost equal to 1,407,974 EGP. The eighth scenario has showed that if the PV is only used to meet the pump load, then this is the most expensive cost as the system will add several PV arrays and batteries with a total capital cost equal to 3,650.579 EGP. The second, third, fourth and fifth scenarios have showed that if the PV system is used at the defined percentage of each scenario, it will be infeasible compared to the sixth scenario. The first scenario is considered as a reference scenario.

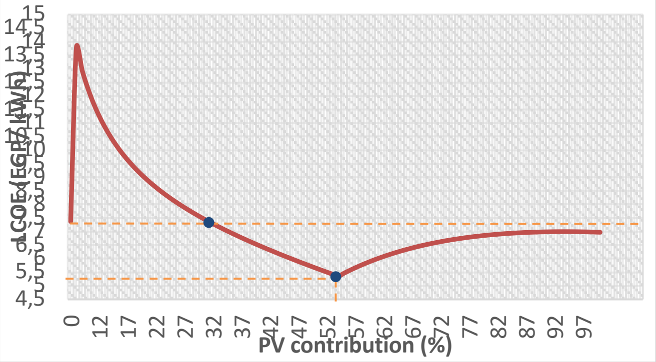

Fig. 1. LCOE minimization using WCOT model against PV contribution variation in PV/DG hybrid system under test

4.3. Optimized System Outputs

Based on the outputs, the optimal configuration is the sixth scenario i.e. 89.2 kWp PV array with 262 number of panels, four (27 kW DC/AC) inverters and 120 kW diesel generator with diesel consumption of 61,898 liter/year. In other words, 54% sharing of PV and 46 % diesel generator is the best configuration. All the system configurations with LCOE values are shown in figure 2, which clearly shows alternative 6 as the optimal one. Following this optimal system, the total capital cost is 871,117 EGP, the total fuel cost is 618,980 EGP/year and the levelized cost of energy is 5.35 EGP/kWh.

The recorded optimal LCOE has illustrated an overall reduction of around 24.2% with respect to the reference system (alternative #1). When the payback period of various system alternatives is considered, it may have some impact on the optimized system which means the final optimized scenario could be changed. In order to understand the full cost-efficiency of various configurations, payback period is also considered for all the configurations. The payback period for all systems, with finite payback period within the lifetime of the project, is also presented in Fig. 3. Fortunately, a minimum payback period of 2 years has been also recorded to the optimal system (System 6).

Beyond this specific PV and diesel contributions, the system has added several PV arrays to meet the load demand with more capital cost added to the system making and thus making it infeasible. Similarly, if the PV is only used to meet the pump load (the eighth scenario discussed in this study), then it will be a most expensive cost as the system will add several PV arrays and batteries with a total capital cost added to the system making it infeasible as compared to sixth scenario. Therefore, based on this discussion, it can be easily concluded that the optimal system is the one with 54% of PV contribution and 46 % of diesel generator contribution to meet the pump load demand.

Table 3 Techno-economic Results for Proposed Alternatives

Configuration	PV energy share (%) / Diesel energy share (%)							
	(0/100)	(21/79)	(29/71)	(38/63)	(46/54)	(54/46)	(63/37)	(100/0)
Solar PV (kWp)	-	34.3	48	61.8	75.5	89.2	102.9	165
Diesel Generator (kW)	120	120	120	120	120	120	120	-
Batteries (Unit)	-	-	-	-	-	-	90	539
PV panels (Unit)	-	101	141	182	222	262	303	485
Area (m^2)	-	345	480	618	755	895	1029	1650
DC/AC inverters (27 kW) (Unit)	-	2	2	3	3	4	4	6
Total Capital Cost (EGP)	-	402877	501752	637027	735902	871177	1407974	3650579
Diesel consumption (L/y)	135050	106915	95660	84406	73152	61898	50644	-
Generator renting cost (EGP/y)	421575	421575	421575	421575	421575	421575	421575	-
Total Fuel Cost (EGP/y)	1350500	1069150	956600	844060	731520	618980	506440	-
Total Electrical Production (kWh/y)	240462	253026	258034	263041	268049	273057	278064	300607
ATLCC (EGP/y)	1772205	1954956	1728921	1572621	1416321	1286471	1589454	1719303
LCOE (EGP/kWh)	7.37	8.13	7.4	6.54	5.89	5.35	6.61	7.15

Figure 4 and 5 preview the cash flow of the optimal system listed by component and cost type. It is worth to mention that the cash flow has been demonstrated assuming a five years renewing contracts, this attributes the observed peaks at years 5, 10, and so on. Additionally, a weighted average calculated inflation rate of 11.4% is used to compensate currency fluctuations across the project life time.

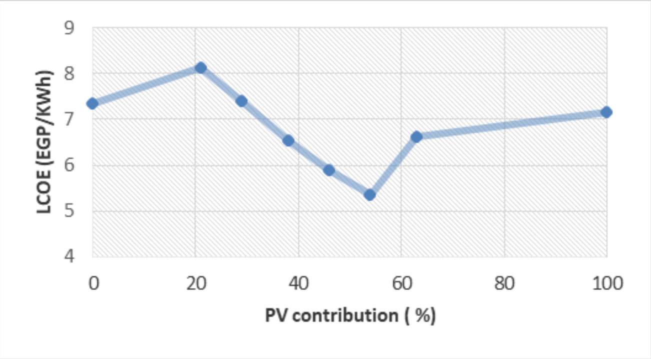

Fig. 2. LCOE Based on the Energy Shared in the System from the PV

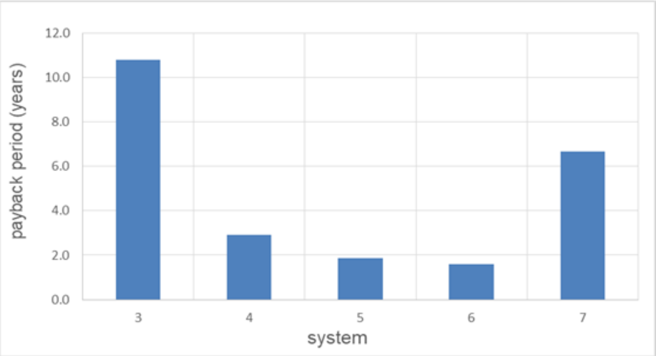

Fig. 3. Payback period estimation for various hybrid systems

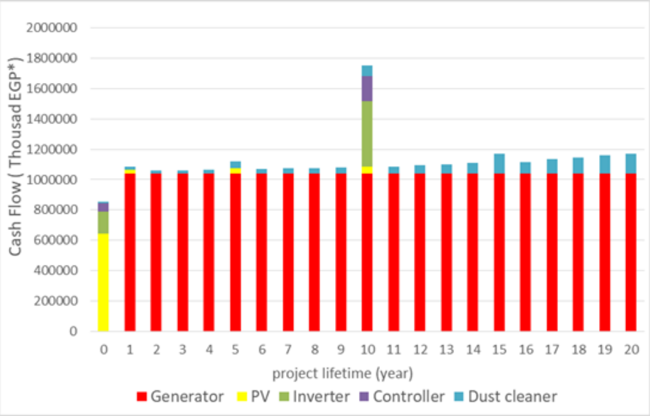

Fig. 4. The Cash Flow of the Optimum System Listed by Component

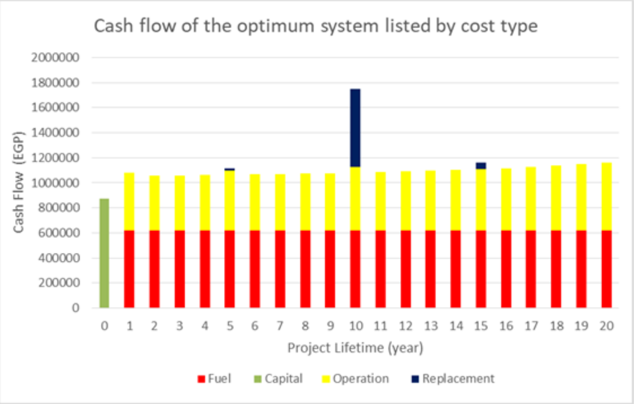

Fig. 5. The Cash Flow of the Optimum System Listed by Cost Type

5. Conclusion

The vast growth of energy demands has resulted in increasing the costs of sourcing and delivering fossil fuels. In addition, due to the fact that fossil fuels reserves are diminishing, the replacement of fossil fuels with alternative sustainable, indigenous and inexhaustible energy rFesources is essential. Solar Photovoltaic (PV) systems have been considered as an efficient electric energy source that could reduce the dependence on fossil fuels. Further, the falling prices of PV during the last years have triggered a global reliance on PV systems. Explicitly, the PV systems are considered as ideal solution for the lack of electricity and energy in rural and remote areas that are far-off the electrical national grids. The location of oil and gas plants is usually existed in rural areas that are not connected to the grid power connections. Hence, electricity is mainly provided using decentralized diesel generators. However, the inaccessible conditions of the plants usually create problems for transporting and delivering enough fossil fuels for the plants.

This study has demonstrated a techno-economic feasibility to address the utility of integrating PV system in the oil and gas industry. Namely, sucker road pumps driven by diesel generators have been targeted for better sustainability and reduced levelized cost of energy. All technical as well as economic parameters for various 8 systems have been investigated in this paper to demonstrate various alternatives including the integration of storage systems and variation in hybrid configuration by varying percentage of contribution of each source. A 54% PV system hybrid with 46% of DG unit is reached in this study to show optimal performance reaching an overall reduction of 25% with respect to the reference running case.

References

[1] M. A. Khatita, T. S. Ahmed, F. H. Ashour, and I. M. Ismail, "Power generation using waste heat recovery by organic Rankine cycle in oil and gas sector in Egypt: A case study," Energy, vol. 64, pp. 462-472, 2014.

[2] A. Ramadhas, S. Jayaraj, and C. Muraleedharan, "Use of vegetable oils as IC engine fuels—a review," Renewable energy, vol. 29, pp. 727-742, 2004.

[3] K. E. Okedu, H. A. Nadabi, and A. Aziz, "Prospects of Solar Energy in Oman: case of oil and gas industries," International Journal of Smart Grid, vol. 3, pp. 138-151, 2019.

[4] Y. Choi, C. Lee, and J. Song, "Review of renewable energy technologies utilized in the oil and gas industry," International Journal of Renewable Energy Research, vol. 7, pp. 592-598, 2017.

[5] M. A. Halabi, A. Al-Qattan, and A. Al-Otaibi, "Application of solar energy in the oil industry—Current status and future prospects," Renewable and Sustainable Energy Reviews, vol. 43, pp. 296-314, 2015.

[6] H. Hajjar, F. Dubaikel, and I. Ballard, "Bifacial photovoltaic technology for the oil and gas industry," in 2015 Saudi Arabia Smart Grid (SASG), 2015, pp. 1-4.

[7] F. Castaldo, V. Brocco, R. Cimino, G. De Ghetto, and S. Rossini, "Development of Innovative Solar-Fossil Hybrid Plant in a Remote O&G Area," in Offshore Mediterranean Conference and Exhibition. Offshore Mediterranean Conference, 2015.

[8] E. K. Mantey and B. B. Wolodko, "Method and apparatus for controlling downhole rotary pump used in production of oil wells," ed: Google Patents, 1998.

[9] G. Takacs, Sucker-rod pumping handbook: production engineering fundamentals and long-stroke rod pumping: Gulf Professional Publishing, 2015.

[10] M. Elhousieny and A. Khalil, "Photovoltaic/Gen-Set Hybrid System at Egyptian Western Desert," in Offshore Mediterranean Conference and Exhibition, 2017.

[11] M. Said, M. El-Shimy, and M. Abdelraheem, "Photovoltaics energy: Improved modeling and analysis of the levelized cost of energy (LCOE) and grid parity–Egypt case study," Sustainable Energy Technologies and Assessments, vol. 9, pp. 37-48, 2015.

[12] F. Diab, H. Lan, and S. Ali, "Novel comparison study between the hybrid renewable energy systems on land

and on ship," Renewable and sustainable energy reviews, vol. 63, pp. 452-463, 2016.

[13] M. Jamil, S. Kirmani, and H. Chatterjee, "Techno-economic viability of three different energy-supplying options for remote area electrification in India," International Journal of Sustainable Energy, vol. 33, pp. 470-482, 2014.

[14] R. CIMINO, V. BROCCO, F. CASTALDO, G. De GHETTO, M. FAVARETTO, and T. J. J. o. t. J. I. o. E. AKMAL, "Deploying a Solar Hybrid Technology in a Remote Oil and Gas Production Site," vol. 94, pp. 1163-1168, 2015.

[15] C. A. Osaretin, T. Iqbal, S. J. A. E. Butt, and E. Engineering, "Optimal sizing and techno-economic analysis of a renewable power system for a remote oil well," vol. 4, p. 132, 2020.

[16] M. M. Zarie, P. Makeen, S. O. Abdellatif, I. M. Mahmoud, and T. S. Abdel-Salam, "Techno-economic Feasibility of Photovoltaic System for an Educational Building in Egypt : (Case Study)," in 2019 International Conference on Innovative Trends in Computer Engineering (ITCE), 2019, pp. 521-525.

[17] N. M. Elsayed, R. A. Swief, S. O. Abdellatif, and T. S. Abdel-Salam, "Photovoltaic Applications for Lighting Load Energy Saving: Case Studies, Educational Building," in 2019 International Conference on Innovative Trends in Computer Engineering (ITCE), 2019, pp. 564-569.

[18] M. A. Khafagy, M. M. Eshak, P. Makeen, S. O. Abdellatif, and H. A. Ghali, "Investigating the Utility of Perturbation and Observation, Incremental Conductance and Grey-Wolf MPPT Techniques for ON-Grid PV System Under Fluctuated Environmental Conditions," in 2020 IEEE International Conference on Power and Energy (PECon), 2020, pp. 338-343.

[19] M. M. Eshak, M. A. Khafagy, P. Makeen, and S. O. Abdellatif, "Optimizing the performance of a stand-alone PV system under non-uniform irradiance using Gray-Wolf and hybrid neural network AI-MPPT algorithms," in 2020 2nd Novel Intelligent and Leading Emerging Sciences Conference (NILES), 2020, pp. 600-605.

[20] A. K. M. MOHAMED O. AHMED, PETER MAKEEN, SHEHAB EDIN I. BETELMAL,, M. M. A. MINATALLAH M. HASSAN, AHMED AYMAN, MOHAMAD H. EL-ADLY,, and A. N. A. S. O. ABDULLATIF, "Optimizing the Artificial Lighting in a Smart and Green Glass Building-integrated Semi-Transparent Photovoltaics: A Multifaceted Case Study in Egypt " WSEAS Transactions on Environment and Development, vol. 17, pp. 118-127, 2021.

[21] M. Elkasrawy, P. Makeen, S. O. Abdellatif, and H. A. Ghali, "Optimizing electric vehicles station performance using AI-based decision maker algorithm," in Emerging Topics in Artificial Intelligence 2020, 2020, p. 114691W.

[22] T. ECONOMICS, "Egypt: Inflation rate from 1984 to 2021."

[23] M. o. E. a. R. Energy, "Interset Rate 5% for the renewable energy projects," 2018.