SPE-211150-MS

Using a Hybrid Off-Grid Semi-Fixed Solar System to Power a Water Pump in a Water Supply Well in Remote Areas

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This paper was prepared for presentation at the ADIPEC held in Abu Dhabi, UAE, 31 October – 3 November 2022.

Abstract

ARA Petroleum Exploration and Production Company has successfully installed a hybrid off-grid semi-fixed solar system to power an Electrical Submersible Pump (ESP) for a water supply well in Oman's remote area (Oil North Field). The system is designed to provide the power output of a 40 KW water ESP pump. The pump usually runs for 10 hrs/day. The well is used for supplying water for drilling activities and other operational requirements with an actual power of 30 KW.

The uniqueness of this system is its ability to power the ESP well directly without an over-headline (OHL) with a synchronizing system and an automated switchover to a diesel generator when required. Moreover, a real-time operation system that can be downloaded on a mobile application. In addition, a CCTV camera, and solar lighting are available in the location to control and monitor the performance of the solar system.

Utilizing solar systems in this project provides a cost saving on diesel consumption and reduces its associated CO2/GHG emissions. The system runs in the daytime on solar for 6 hours. The rest of the 4 hours is compensated with diesel. The anticipated cost saving on diesel consumption and CO2 emission reduction is around 60%. The success of this project will allow the technology to be replicated in many locations in remote areas.

In order, to support the ICV and develop SME companies, the project was awarded to a local SME company, and the learning from this installation was shared between the vendor and ARA E & P, as this system was the first of its kind implemented in Oman.

Introduction

Due to their low capital costs, diesel generators are the most widely used as small electrical power generating units in off-grid locations around the world. However, diesel engines release many hazardous air contaminants and greenhouse gases (GHG), including particulate matter (diesel soot and aerosols), carbon monoxide, carbon dioxide, and oxides of nitrogen.

ARA's water supply wells were powered by diesel generators. The water supply well that was selected for this project is located remotely from the nearest operating field. The well was powered by a diesel generator to supply and transfer water to the operation area through a flowline. Furthermore, the system was operated manually, in which the operator attended the well daily to start/stop the pump and fill up the diesel volume in the DG tank. Figure 1 describes the previous layout of the water supply well operated by a diesel generator.

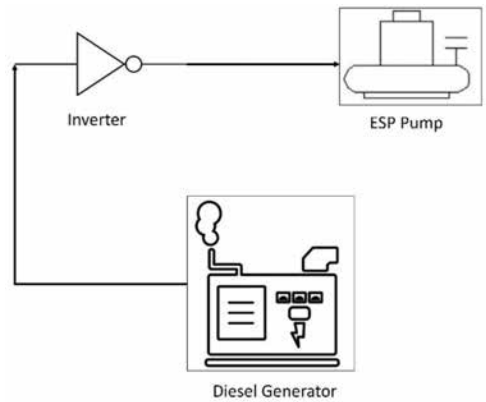

Figure 1—The previous layout of water supply well operated only by diesel

The problems with the existing system can be summarized in the following points

- High CO2e and GHG emissions.
- Noise and dirt-related issues
- Diesel fuel costs a lot of money.
- Short life cycle
- High maintenance with numerous upsets.
- Frequent visits to the location to address operational or maintenance issues

ARA's team introduced a hybrid off-grid semi-fixed solar system to power an Electrical Submersible Pump (ESP) for a water supply well in Oman's remote area (Oil North Field). The system provides the power output of a 40-KW water ESP pump with a synchronizing system and an automated switchover to a diesel generator when required.

The system consists of PV solar panels, DC cable, hybrid inverter, connection box for AC cable, encombi box, distribution box, generator, and three-phase motor. Moreover, a real-time operating system that can be downloaded on a mobile application. Furthermore, a CCTV camera, and solar lighting is available in the location to control and monitor the performance of the solar system.

The uniqueness of this system is that it is a hybrid off-grid solar system that provides power to an electrical submersible pump (ESP) in a water well to supply water to oil drilling activities in a remote area. In addition, a solar system is used to power a submersible pump directly in a water supply well, which is controlled remotely and automatically. Furthermore, the concept of real-time data which can be streamed and accessed via a mobile application

Description and application

There are 3 types of solar systems: on-grid, off-grid, and hybrid. An on-grid solar power system is connected to the required unit and to the traditional electric utility grid. There are no storage batteries in this type of solar power system. An off-grid solar power system, as the name suggests, is a completely independent solar power system with energy storage that is not connected to the main utility grid. A hybrid off-grid solar power system is a solar power system with energy storage that is similar to an on-grid solar power system but includes energy storage in the form of a battery backup. However, this system is more expensive due to the multiple electrical source connections. Therefore, ARA designed a new solar system that combines the features of hybrid and off-grid systems. ARA's solar system consists of hybrid monocrystalline PV modules that are synchronized with a diesel generator without connection to the main utility grid or other energy sources. The power of each panel is 385 watts, and its efficiency is around 85%, but it reaches 95% at STC conditions. The system is designed to provide energy to the ESP pump for water supply in a remote area. The ESP pump normally depends on diesel to run 10 hours per day, based on the activity plan, to supply water as per request. However, using the new proposed system minimizes diesel consumption by having the ESP run for 6 hours on solar power and the remaining 4 hours compensated with diesel. The system is semi-fixed for ease of mobilization to a different location.

Full specification

Off-grid hybrid solar system connected to the diesel generator and semi-fixed for ease of mobilization to a different location.

Design Summary

Table 1—PV solar system design summary

Capacity	**43.5 KW**
Individual Panel Capacity	435 Wp
Total No. Panels	112
No of arrays	6
Operating Temperature	5 -55 degree

System Descriptions

The major Components of the systems:

- Solar PV Module Array
- Solar Inverter
- EC Cube
- Module Mounting Structure
- Concrete Foundation
- Cables
- Monitoring System
- Electrical Distribution Board /isolator/Controller

Solar PV Modules / Array

Solar cells produce direct current from light, which can be used to power equipment or to recharge a battery. Cells require protection from the environment and are usually packaged tightly behind a glass sheet. When more power is required, cells are electrically connected together to form photovoltaic modules. A photovoltaic module is a packaged, interconnected assembly of photovoltaic cells that converts sunlight into electrical power. The cells are hermitically sealed between the glass and the back cover (toddler) to protect them from harsh environments.

Module Mounting Structures

The module mounting structure is designed to hold a suitable number of modules in series or parallel. The frames and leg assemblies of the module mounting structures are made of mild steel powder coated with suitable sections of angle, channel, tubes or any other section. All hardware considered for fastening modules with this structure is of very good quality of Galvanized Iron (GI) or powder coated MS. The module mounting structure is designed in such a way that it will occupy the minimum space without sacrificing the output from SPV panels. At the same time, it will withstand severe wind speeds up to a maximum of 160 KMPH.

Technical Specification – Module Mounting Structures Material Steel GI Coated, 23 Degree Tilt angle

DC Cables

The size of the cables between array interconnections, such as array to junction boxes, junction boxes to isolators, etc., is selected to keep the voltage drop and losses to a minimum.

Technical Specification:

Cables Type PV Insulated, sheath & UV resistance Material Copper Voltage Max. 1100V, Test Voltage 650V/1.1KV

Temperature 10 – 70 °C

Inverter

Inverter: 36 KW, Make: SMA /Satcon /Growatt

Figure 3 shows the top view of the civil construction of the new system. The purpose of this drawing is to depict the layout of the system and show the locations of all the main equipment. The outer circumference is the fencing foundation, where the distance between each fence is 3 m. The inside area describes the panel structure where the horizontal distance between each panel structure is 2 m and the vertical distance is 1.5 m. The distance between PV modules is 1 m and the angle is 19° to avoid the shadow.

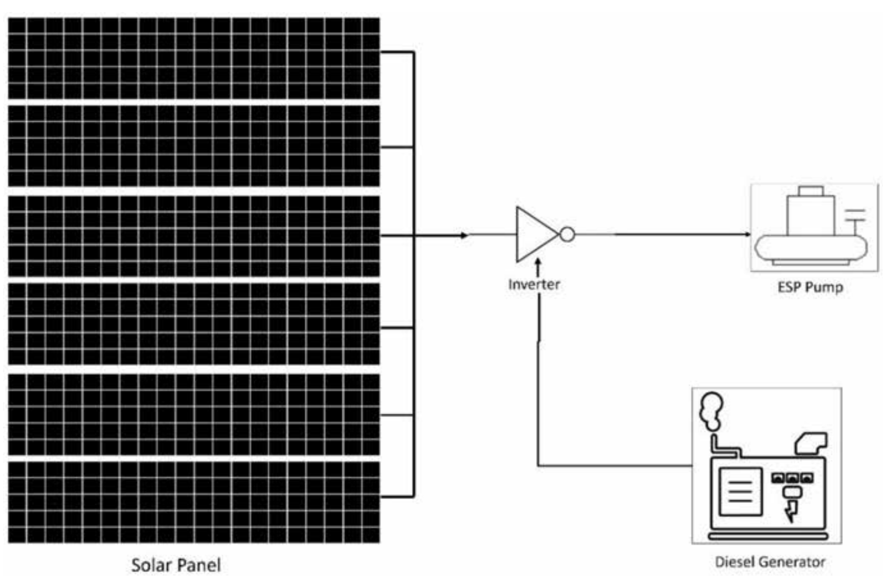

Figure 2—New process of using off-grid PV solar system to generate electricity for ESP pump which used to supply water to the well in remote area

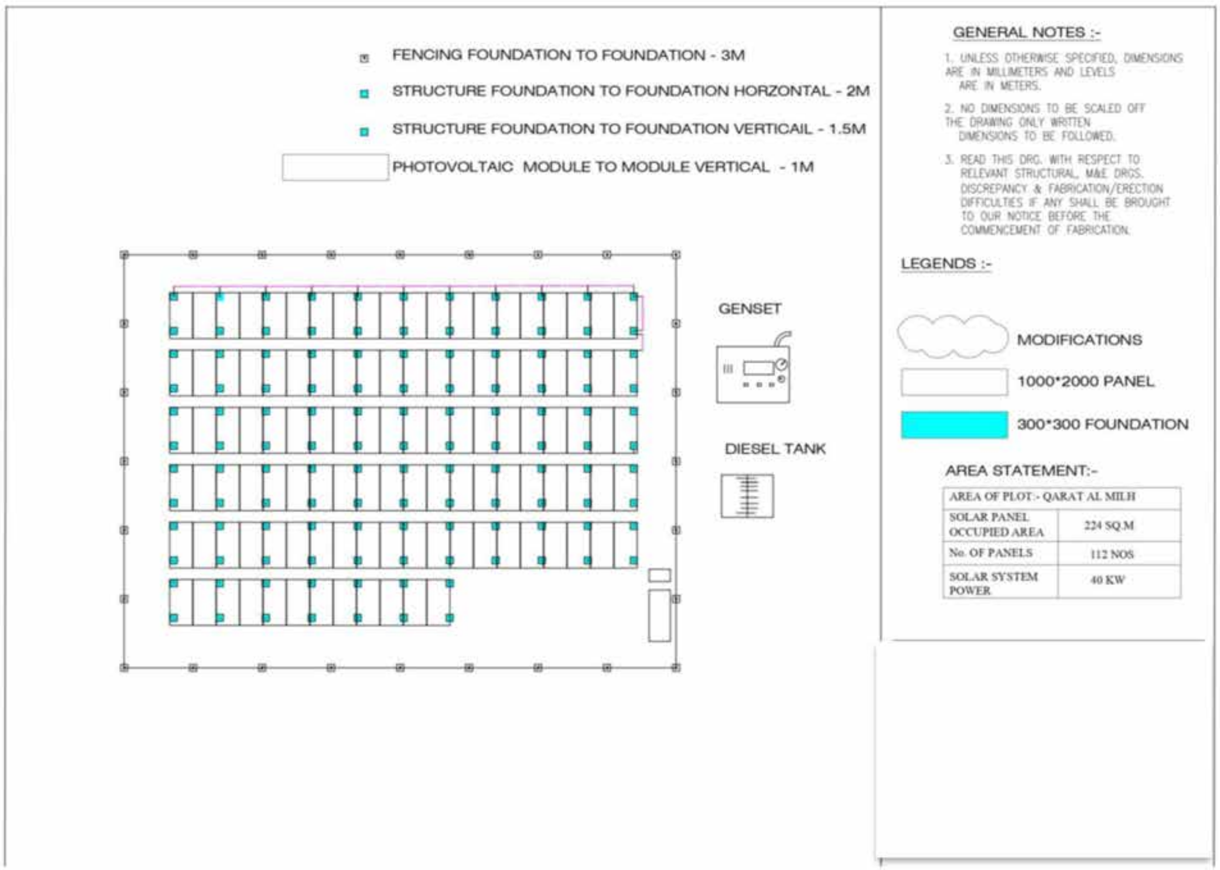

Figure 3—Top view of the civil drawing

Figure 4 shows the single line diagram (SLD) for the system. The purpose of a single line diagram is to show sources of power, electrical equipment, electrical drives, system details, and fault levels. As discussed above, when the PV planner is exposed to light, photons are absorbed, and free electrons are released, producing DC. A hybrid inverter is used to convert DC current into AC current to be able to turn on the motor. The AC current then goes to the DB panel to build a loop connection from the solar system with the diesel generator as two sources, and then connected to the motor.

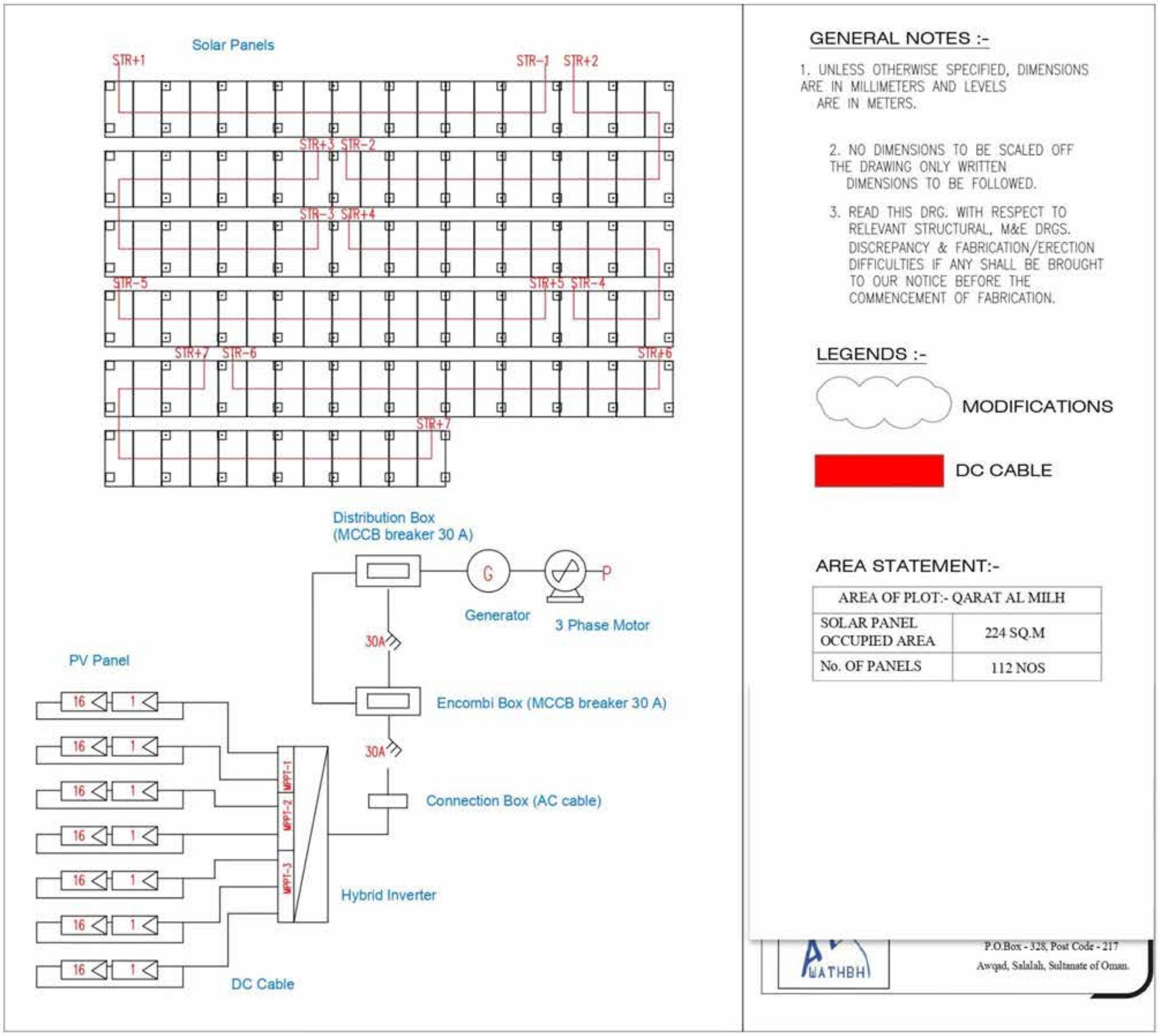

Figure 4—single line diagram (SLD) for the system

Figure 5 is a type of technical drawing that provides a visual representation of an electrical system. Black wires are "hot" wires, which means they carry a live current from the electrical panel to the destination.

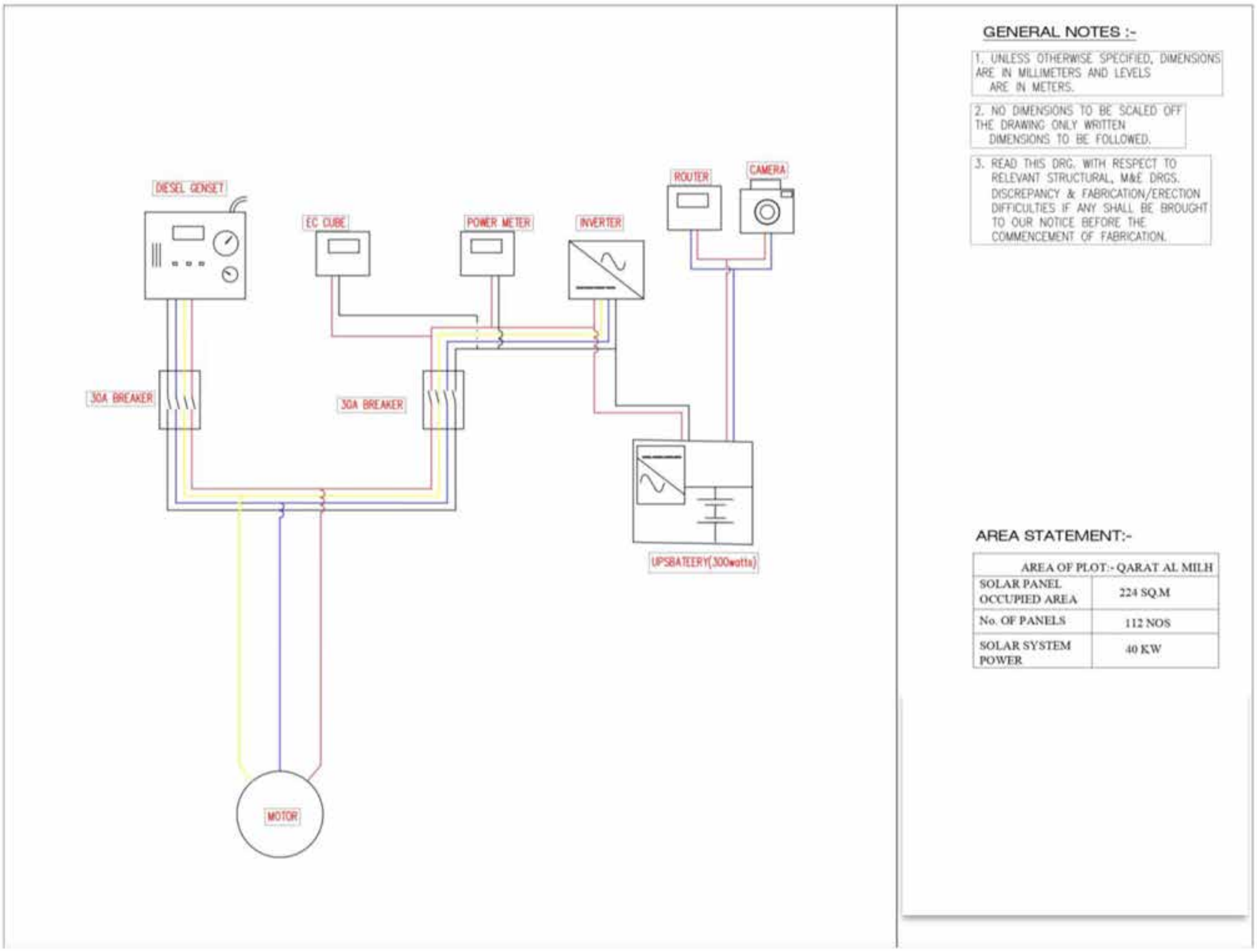

Figure 5—ELECTRICAL Drawing system

Red wires are used as secondary hot wires. Blue and yellow electrical wires are often used as "traveler wires" for transferring power between three-or four-way switches.

Photovoltaics (PV) is a technology that converts solar energy directly into electricity. They operate on the basis of the photovoltaic effect. When certain materials are exposed to light, photons are absorbed, and free electrons are released. The photoelectric effect is the name given to this occurrence. The photovoltaic effect is a way of creating direct current power that is based on the photoelectric effect theory. This direct current will pass through the solar inverter, a device that transforms direct current (DC) from the solar panels to alternating current (AC). It is one of the most important components of a solar power system since it turns solar energy into usable energy and is sometimes referred to as the brain of a solar system. Solar inverters are an essential component of a solar system since solar energy cannot be directly utilized to power electrical equipment; in this case, it is used to power the ESP pump. The inverter is also linked to the diesel generator in order to synchronize electricity in the event of a night operation or the absence of sunshine. An ESP pump is used to supply water for drilling wells.

Performance and Results

The solar unit was installed in a remote area where the nearest service area is about 30 km away. It has been installed to generate the electrical power needed to operate the water supply well via ESP (Electrical Submersible Pump). The main purpose of the water supply is to provide the water for oil drilling operations. Previously, diesel fuel has been used to generate electrical power via DG diesel generator units, where it burns a lot of fuel and produces carbon dioxide emissions continuously. Figure 6 shows the solar panels installed at the location and operated in parallel with the DG diesel generator. The operating philosophy has been defined to select the solar system during the daytime while the diesel generator operates in the evening. The well does not operate continuously for 24 hours/7 days, but it operates whenever required based on the amount of required water for drilling operations. Hence, both the solar system and the diesel generator should be available and active during the operating period. The diesel generator will be on duty at the beginning of the day, in the morning, and then gradually decreases to zero after 3 hours when the sun's radiation increases. Solar energy will be compensated by diesel consumption once the radiation decreases at sunset. This system is a synchronous system as it requires both solar and diesel to run during operation, but the percentage of energy consumed by each varies depending on the time of day and the availability of sunlight on the panels.

Figure 6—The hybrid off-grid semi-fixed solar system, as installed in the water supply well

The performance of the system is remotely monitored through a real-time operation program where the operation team can witness, monitor, extract the performance data and have a fast intervention accordingly whenever required. Initially, the performance of the unit went through many optimizations to ensure the optimal and safe operating conditions that could provide the optimum performance. As per figure 6, an average of 152kwh is generated and that is within a period of 10 hours during the daytime. The system is generating power gradually, coinciding with the intensity of sun radiation where the early morning starts slowly, then reaches its peak, which lasts for almost 6 consecutive hours from 9 am to 3 pm. Figure 7 indicates that the solar system is operating at 50% of its capacity due to the actual operating rate of the pump requiring only 20 kwh. Figure 8 shows the real-time operation dashboard for monitoring the power generated through the solar system and diesel generator.

Figure 7—A Day performance of solar panels

Figure 8—Real Time Operation for Monitoring the Performance through a Dashboard

Looking at Figure 8 that shows the amount of PV energy produced and utilized by the solar system for a period of 6 months (Dec.21 to May 22), it is found that the production of PV energy depends on the amount of energy needed to operate the well based on the amount of water required for operation.

Hence, the performance of solar power varies per month between a range of 1000–5000 kwh. For example, the solar system produced approximately 5,000 kwh in January, which means the solar system was running throughout the whole month at a rate of 150 kwh per day. However, it was reduced based on the demand during the months of May and April to less than 2000 kwh.

The second graph in Figure 9 indicates the percentage of solar energy produced compared to its design capacity. The solar system generated around 60% of its design capacity in December and January and decreased in other months to reach 20% in April and May. The solar system has been designed to cover the pump design rate. However, the actual solar system generates the power required based on the pump operation rate, in which case 40 % can still be utilized to run the pump at a higher rate whenever required.

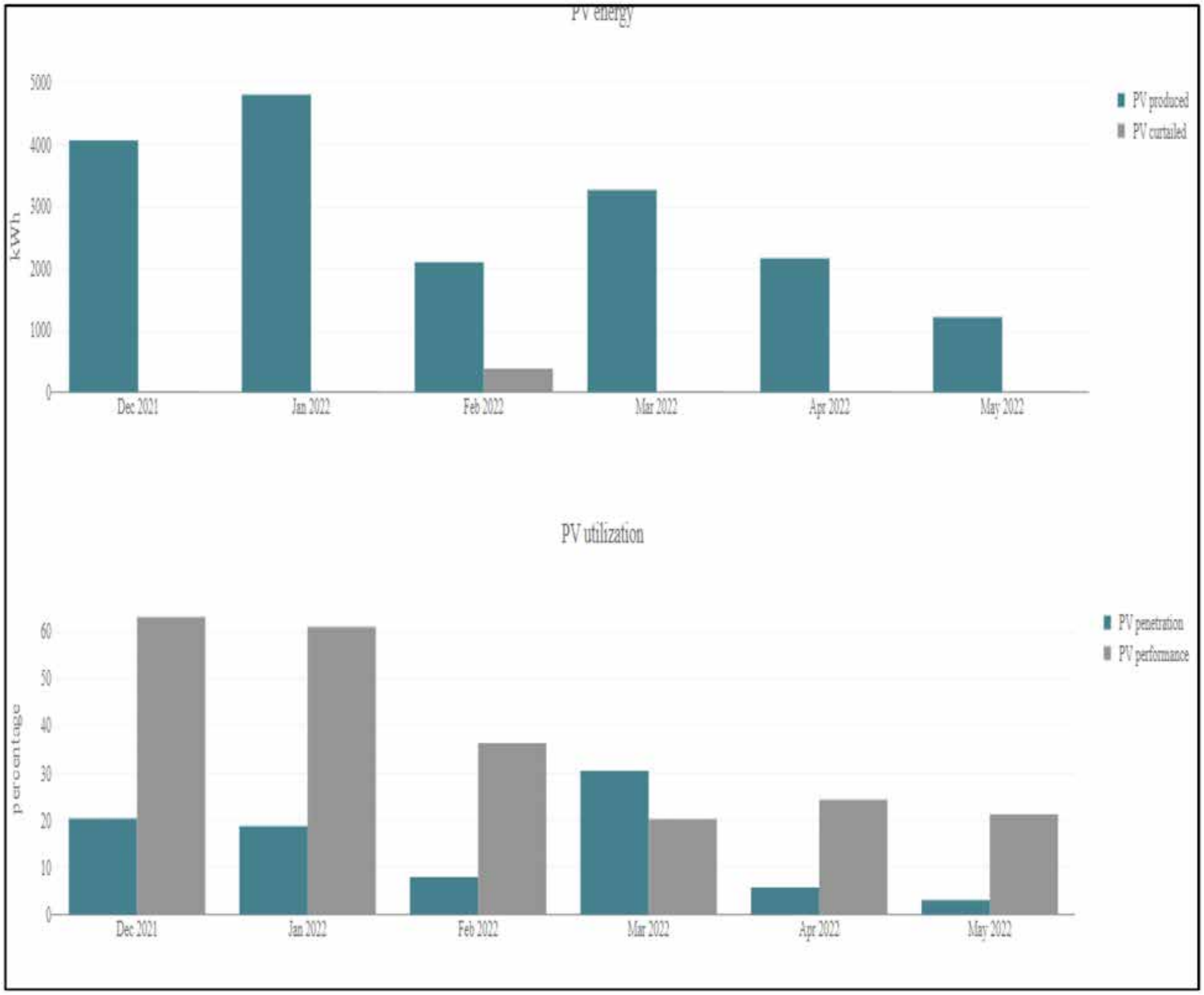

Figure 9—PV energy produced and utilized by solar system from Dec.21 to May 22.

The real-time operation provides the amount of diesel and CO_2 emissions saved during the operating solar system. The largest amount of diesel is saved once the solar system has been in operation for a longer period of time and carbon dioxide emissions are projected based on burning diesel fuel. The highest diesel savings occurred during January, while the lowest was in May. In the event of that, CO_2 emissions have been calculated to show the amount of savings per month. Jan. 22: The most CO_2 emissions were saved because the solar system was used for a longer period of time than in other months.

The solar system is operated during the day for only 10 hours, which means that the total solar energy that can be produced, if we assume that the well is operating all day, is 150 kWh, and the total is 27000 kWh for 6 months. On the other hand, the solar system can provide an 80% diesel fuel saving if the well is operating full time during the day.

Conclusion

ARA Petroleum Exploration and Production Company has implemented a hybrid off-grid semi-fixed solar system to power an electrical submersible pump (ESP) for a water supply. The system is designed to provide the power output of a 40 KW water ESP pump. The pump usually operates for 10 hours a day. The well is used to supply required water for drilling activities and other operational requirements with an actual power of 20–30 kwh. The installation of this system has improved the business while lowering the cost of diesel and reducing GHG emissions. In addition, the operator's well visits are being reduced as the system is operated remotely. The system has been running as per the design with even better performance than expected since it was commissioned in Q4 2021, with an actual operation of 60% of its design. Diesel savings were immediately recognized, and CO2 emissions were reduced as expected and were calculated at 40%–60% with the potential to increase to 80% if the well is operating during the day only. The next plan is to deploy and extend the trail to other wells to further reduce GHG and reduce operating costs. More than 20 wells have been identified at ARA Petroleum E&P. The same system can be replicated in other oil and gas companies.

References

Abdullah Al Aydrous 2020, *AL Wathbah Technical and engineering report*.