CHALLENGES, SOLUTIONS AND OPPORTUNITIES: OFF-GRID SOLAR PHOTOVOLTAIC POWER FOR OFFSHORE OIL & GAS FACILITIES

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Abstract – This paper presents a case study for a recent Company approved offshore oil and gas development project aims to install 19 platforms with off-grid photovoltaic (PV) and battery systems for economic and decarbonization purposes. The study explains the current practice and assesses challenges, of existing off-grid PV installations at similar platforms. The paper addresses identified challenges by analyzing and optimizing the electrical load profiles, adopting alternative technology solutions, introducing new engineering standards requirements, and establishing third party services for operation and maintenance. Furthermore, this paper evaluates the economic feasibility to compare off-grid photovoltaic and battery systems with conventional grid power supply utilizing subsea cables. At the end, the study recommends future opportunities for offshore and onshore applications and highlights potential area of improvements, paving the way for future design enhancements and sustainable energy deployment.

Index Terms — Off-Grid Photovoltaic and Battery Storage Systems, Solar Power, Offshore Oil and Gas Facilities, Renewable Energy, Energy Sustainability, Submarine Cables, Renewables Economics, Challenges, Solutions, Opportunities.

I. INTRODUCTION

The company's earliest offshore oil & gas development was in the 1950s. Yet, company took nearly a decade to produce oil from Safaniyah, its first offshore discovery. Offshore development is unique and comes with many challenges due to offshore environment. Such development includes oil and gas producing wells, water injection wells, tie-in platforms, gas oil separation plants (GOSPs), subsea pipelines, power networks and cabling etc. Installing power infrastructure in offshore environment incurs tenfold higher costs compared to onshore, and is also highly dependent on water depth. Offshore platforms can be classified into two types based on their power demand.

A. Offshore Platforms with High Power Demand:

These offshore platforms are characterized by their high-power demand that exceeds 10 kW which varies based on the function of each facility. Some platforms are for production, named production platforms, that are equipped with electrical submersible pumps (ESPs) as an artificial lift to extract oil from the reservoir to the surface. Other platforms are for local crude oil processing after collecting crude oil from production platforms. The processing platforms includes GOSP and shipment to onshore central oil processing facilities where crude is treated to meet the specifications for export as well as needed for local refineries. Additionally, there are auxiliary and support platforms for utilities, infrastructure and accommodation for operational and basic maintenance purpose.

These offshore platforms require high, reliable and continuous power demand. The power requirements are secured either from local generation units operating in an islanding mode or from onshore utility power source. The selection of the power source largely depends on proximity to onshore power source and is evaluated based on technical feasibility and economic considerations. Meeting high power continuously for these platforms with off-grid PV is not feasible. Due to high power requirements and intermittency of PV power, large number of PV panels and energy storage systems will be required for which bigger with massive structured platforms will be needed.

B. Offshore Platforms with Low Power Demand:

These offshore platforms are characterized by their low power demand typically below 10 kW that varies based on the various functions of these facilities. These include production platforms for gas wells, and oil wells serving reservoirs with high pressure as their pressure functions as a natural gas lift to extract oil from the reservoir to the surface, obviating the need for ESPs. Some platforms are dedicated to wells for injecting water along the periphery of the reservoir to boost reservoir pressure to sustain its production. Other platforms, named as tie-in platforms, gather the oil and gas from multiple production platforms and send them through trunk lines to offshore or onshore oil processing facilities. Moreover, there are other platforms for observing wells, named well observation platforms, that continuously collect well and reservoir data to validate production conditions and accordingly adjust production and take necessary corrective measures.

The power source to these platforms is secured either from off-grid PV or extended from a nearby conventional grid source coming from other platforms or directly from onshore. The power source option is selected based on an extensive evaluation of the technical and operational feasibility, economic considerations and maintenance (O&M) challenges.

II. CURRENT PRACTICE FOR PLATFORMS WITH LOW POWER DEMAND

A. Demand Profile Analysis:

These platforms have very few critical loads that require very small amounts of continuous reliable power. The critical loads include Process Distributed High Integrity

Management System (PDHMS), Flow Meters (FMs), Remote Terminal Units (RTUs) and Communication Systems (CSs), Emergency Safety Devices (ESDs), Motorized Operating Valves (MOVs), Hydraulic Control Valves (HCVs), and security loads. PDHMS, FM, RTU, CS, and security loads are the loads that require continuous power supply. While ESD utilizes a hydraulic power unit that needs to be operated by electrical power to initiate the safe shutdown and isolation of the entire process during any rare emergency conditions. Additionally, MOVs and HCVs are the valves to control the production rate and are operated on a weekly or monthly basis to adjust the overall production. Moreover, PDHMS, RTU continuously logs the process conditions and flow measurements and then transmits the data through fiber or through wireless communication by Very High Frequency (VHF) and Ultra-High Frequency (UHF). Fiber optic connectivity provides continuous data transmission and this is feasible only if the platforms are powered by composite submarine cables which includes both power and fiber optic cables. Alternately, wireless communication is acceptable because any momentary communication disruption in the system will not have immediate impact to the production.

There are non-critical loads that do not require continuous power, but need power only during operation and maintenance services. These loads include platform lighting, utilities, and O&M equipment such as cranes etc. Table I lists all the different loads for typical platforms.

TABLE I
LOAD LIST OF A TYPICAL PLATFORM

Equipment	Criticality	Duty	Power (kW)
RTU & Inst.*	Critical	Continuous	0.1
MOVs & ESD	Critical	Intermittent	2.4
Lighting	Non-critical	Night time	20
Pumps/Cranes	Non-critical	Intermittent	75
Welding sockets	Non-Critical	Intermittent	40

* Inst. includes PDHMS, FM and CS

B. Conventional Grid Supply Option

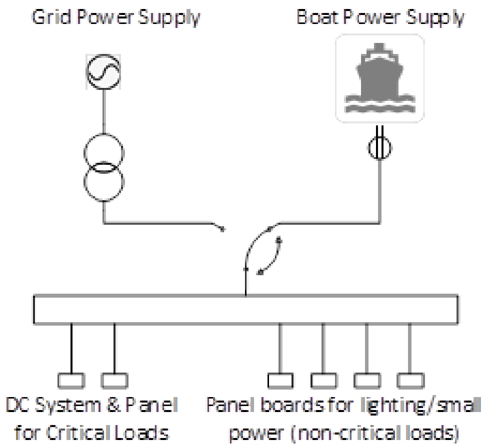

Figure 1: Typical Grid Supply option

The aggregated demand of the typical platform demand in the Table I is 125 kW which is typically supplied by convention source since PV power supply for such capacity would prohibitively expensive, given the offshore space footprint limitation. The conventional grid power supply is established by extending the nearby offshore or onshore power network at medium voltage level (typically 13.8 kV). The power is reduced to lower voltage level and distributed through outdoor switch-rack and panel board units as shown in Figure 1 below. The critical loads are supplied through a DC system with batteries to provide eight hours back-up power during potential power outages.

C. Off-Grid Photovoltaic (PV) and Battery System Option

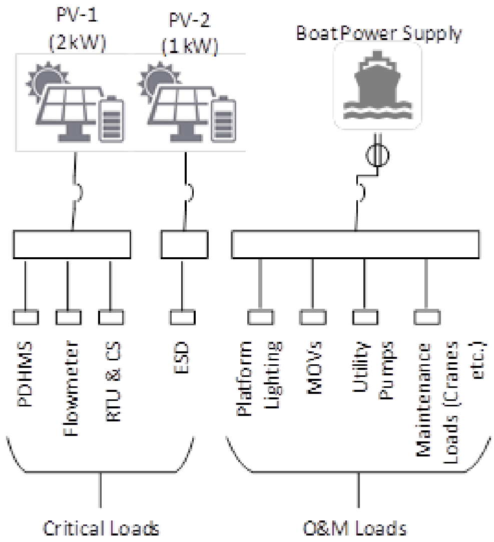

Figure 2: Typical PV Supply option

In this configuration, the loads are segregated into critical loads and non-critical loads as depicted in Figure 2. The power demand for the critical loads will be met by off-grid photovoltaic PV and battery systems. The non-critical loads required during O&M activities, will be powered by onboard generators of the respective boats and barges which are mobilized during O&M activities. With this approach providing convention grid supply with expensive submarine cabling and extension work can be avoided for the platforms especially which have critical loads with low power demand.

Table II provides the details of typical PV system for critical loads at existing platforms. PV systems are segregated based on the load category i.e. continuous and intermittent.

TABLE II
TYPICAL PV SOLAR SYSTEM CONFIGURATION

Equipment	PV-1	PV-2
Duty	Continuous	Intermittent*
Critical Loads	RTU & Inst.	MOVs & ESD
Voltage	24V	24V
Daily Energy	2.4 kWh	1.2 kWh
Daily Ah	100 Ah	50 Ah
Battery size @ C72	420 Ah	210 Ah
PV Panels	6 nos.	4 nos.

* Intermittent loads assumed for 30 min operation per day.

Typically, the bases for sizing are as indicated below:

- Battery capacity - Autonomy for three days, 10% for temperature and 25% for ageing
- PV panel quantity - 85 watts, 5 hour peak sun.

III. CHALLENGES: OFF-GRID PV AND BATTERY STORAGE SYSTEMS

Although standalone PV and battery power supply is a highly cost-effective option for power supply to remote location, but it is associated with certain challenges. These challenges were captured from lessons learned from existing platforms and also based on additional and new operational requirements:

A. Design Challenges:

1) *Off-Grid PV and Battery Standards*: There were no Company standards developed due to limited deployment rate primarily. Standalone PV and battery system requirements were captured under the UPS DC system standard with the simplified off-grid system sizing and deployment scheme.

2) *Sizing of PV & Battery Systems*: Due to lower deployment rate in the past, the reduction of power output from solar panels due to soiling and high fog condition combined with dusty environment was not adequately factored. Moreover, only three autonomy days were considered for battery sizing that lead to inadequate battery back-up due to low sun weather conditions and cloudy seasons during the winter. As a result, monitoring and communication systems at several platforms experienced loss of power after sunset and thereby loosing communication to SCADA systems at central platform.

3) *Redundancy and Lack of Segregation*: Simplified design scheme did not had redundancy for the critical components such as charge controllers and converters. Additionally, the PV and battery systems were not fully segregated for various load types, instead common system was provided based on the duty cycle. For instance, one system was provided for all constant load type such as RTU and PDHMS etc. and another system for intermittent loads such as MOVs and ESD.

B. Latest Standard Requirements Challenges

The latest Company standards mandate specific requirements for installing Off-grid PV to overcome some of the mentioned design challenges. Key considerations in the newly updated standards including additional design factors listed below, and accordingly, will result in larger PV and battery system:

1) Solar Panel Sizing: Requirement of available sun hours is changed from 5 to 4.5 hours to account for radiation data in the northern east of Saudi Arabia. This was in lieu of conducting site specific solar radiation assessment for each site. The 4.5 hours will be sufficient to simulate the low radiation months in Dec/Jan. The PV panel tilt is recommended at 45 degrees to decrease soiling factor and increase solar panel production during winter season. This was selected among a number of simulations between 35~45 degrees which shows the optimum tilt angle to be 45 degrees. The sizing considers factors for 20% deration due to soiling/dust, 10% for system aging and 10% for anticipated future loads and design margin. In addition, since some PV power will feed the load in day, but most will be for charging the batteries, we will approximate this by addition 15% as a battery inefficiency factor for charging.

2) Battery Sizing: Back-up time has been increased from five to seven days for offshore critical loads, and with an extra day totaling eight days for emergency safety systems. This is due to the fact that operation experience with five days in not sufficient especially during cloudy seasons and rough weather conditions. In addition, the recharge time after deep discharges was reduced to 15 days instead of 30 days for special offshore applications. In addition, the recharge time after deep discharges was reduced to 15 days instead of 30 days for special offshore applications. The sizing also considers additional factors including 10% for temperature, 20% for system aging and 10% for future loads.

3) Charge Controllers: Both MPPT and PWM charge controller were evaluated and the PWM charge controller was preferred due to harsh weather condition where MPPT charge controllers would require shelters that cannot be accommodated in an offshore platform.

C. New Load Requirements Challenges

1) *Process:* Process design introduced several enhancements to monitor and automate the operations that resulted in several new process loads. These loads include additional MOVs, Instrumentation, enhanced RTU and instruments. Moreover, due to the lack of actual load profiling the current practice imposes the need to consider conservative duty factors i.e. 30 minutes of operation for intermittent loads such as MOVs. This results in significantly higher power demand.

2) Security: The new design practice for site security requires CCTV on each platform that will require cameras. Moreover, to support continuous video streaming, fiber optic cable installation will be needed. The cost of installing fiber optic cable is significantly high, in the range of composite cable cost, that integrates power with fiber optic into a single cable. In this case, installing composite cable will serve a dual purpose for power and data transfer and hence will be more attractive than PV and battery storage in addition to fiber optics cable. This obviates the need for a PV and battery storage system.

3) Helideck and Staircase lighting: As per Company latest Standards helideck is required for all new platforms for O&M purpose. The safety standards stipulate staircase and helideck lighting to be fed from reliable power supply.

As a result of the above of the additional loads the overall daily power and energy required will be 12.5kW and 43 kWh respectively. In addition, after considering all the factors as per new design / standards requirements the overall daily power and energy will further increase and that will require large number of PV panels and huge battery when compared to previous installations. Moreover, additional PV and battery systems may not be accommodated in currently sized platforms.

Refer to Table III for the summary of the PV and battery capacity ratings to meet the critical loads power demand established as per the latest design requirements and new loads. Th overall daily energy will be 43 kWh that will indeed need larger platform.

TABLE III
LATEST LOADS AND POWER DEMAND

Type	Details	Power (kW)	Daily Energy (kWh)
Process	RTU. & Inst.*	1	12
Process	ESD**	1.5	0.5
Process	MOVs**	5	2.5
Safety & Security	Cameras & Lighting	2	24
		9.5	**43**

* Inst. includes PDHMS, FM and CS
** Intermittent loads with 30 min operation per day.

D. Operational Challenges:

1) *O&M:* The capability to maintain offshore platforms is limited by two offshore platforms per day, mainly due to the substantial time and logistics required to travel by boat to perform O&M activities. Adverse weather conditions can interruption these activities significantly for up to 15 days beyond the planned date. In addition, limited qualified personnel delays these activities further as the available technicians are assigned not only to maintain the PV and battery system, but also other equipment maintenance activities on the platform.

Figure 3: Existing soiled PV solar panels

2) *Operating Environment Conditions:* Excessive soiling of PV panels occurs during sandstorm seasons. Moreover, due to high humidity condition when dust transforms into a very hardened mud like substance on the PV module surface. Furthermore, the soiling of PV cells due to bird droppings is prevalent mainly during bird migration season. The efficiency of battery charging is impacted by dust accumulation and bird droppings resulting in insufficient charging. Having PV systems in numerous offshore platforms located far away from each-other represents a logistical challenge for the frequent cleaning and maintenance. Presently, cleaning activities are performed by the O&M team manually as part of the periodic preventive maintenance activities. The manual cleaning cycle varies between four to six months which is insufficient to maintain optimal system performance.

3) *Inadequate Monitoring*: Existing systems utilize local monitoring and controls along with limited remote annunciations which provides inadequate data points to detect potential failures early and, therefore cannot ensure reliable power supply.

4) *Quality Assurance and Control*: Current off-grid PV is an integrated system with components from several manufacturers. The integration process imposes a high risk related to damage of individual components, poor workmanship and wiring issues. The effective way to mitigate these risks is through comprehensive commissioning tests. However, dedicated commissioning tests were not developed due to low deployment rate.

IV. SOLUTIONS: CASE STUDY

A case study is presented in this section for a project involving the installation of 19 new offshore platforms with low power demand as described in Section 1.B. The size of the PV and battery system is designed to meet the loads while addressing the challenges described in section III.

A. Segregation of PV Systems

The critical loads are organized into four categories based on their functionalities, and each category receives its power from a captive standalone PV and battery systems as shown in Figure 4 below. This will increase system availability and maintainability instead of one system feeding all loads. ESD loads being the most critical are segregated from other loads and are provided with dedicated PV and batteries.

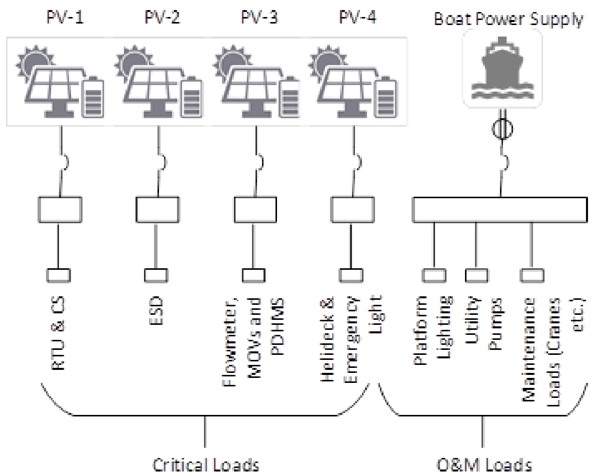

Figure 4: Configuration of PV Supply

B. Load Profile Analysis and Optimization

Analyzing the actual characteristics and operating conditions modes of different loads will facilitate establishing accurate load profile to determine precise overall power demand. Additionally, this analysis will facilitate load shifting and shedding strategies essential for

TABLE IV
LOAD PROFILE OF RTUs & COMMUNICATION SYSTEM – CONTINUOUS LOADS FOR PV-1

Load Description	Load Power(W)	Load Current(A)	Opr. Duration (Hour/Day)	Equipment Quantity	Total Daily AmpHour (Ah)	Total Daily Energy(kWh)
RTU	279	11.625	24	1	279	6.696
Communication	40	0.166	24	1	40	0.96
				Total	**319**	**7.656**

TABLE V
LOAD PROFILE OF HYDRAULIC ESDs – INTERMITTENT LOADS FOR PV-2

Load Description	Load Power(W)	Load Current(A)	Opr. Duration (Hour / 8 Days)	Equipment Quantity	Total Daily AmpHour (Ah)	Total Daily Energy(kWh)
Hyd. Pumps (Running)	768	32	2 x 0.23333*	2	3.75	0.09
Hyd. Pumps (Starting)	4608	192	2 x 0.00277**	2	0.26	0.0064
Control Relays – Type 1	30	1.25	2 x 0.23333	2	0.15	0.007
Control Relay – Type 2	34.8	1.45	2 x 0.23333	2	0.16	0.004
Control Panel	5	0.2083	24 hour	1	5	0.12
				Total	**9.32**	**0.224 kWh**

* Running (10 sec) **Starting (14 min)

TABLE VI
LOAD PROFILE OF MOVs, HCVs, PDHMS – INTERMITTENT LOADS FOR PV-3

Load Description	Load Power(W)	Load Current(A)	Opr. Duration (Hour/Day)	Equipment Quantity	Total Daily AmpHour (Ah)	Total Daily Energy(kWh)
MOV (Running)	192	8	0.00833*	13	0.87	0.02
MOV (Starting)	1152	48	0.00083**	13	0.52	0.0125
HCV (Running)	240	10	0.00833	10	0.83	0.02
HCV (Starting)	1440	60	0.00083	10	0.5	0.012
PDHMS	38	1.583	24	1	38	0.912
Flow Meter	120	5	24	1	120	2.88
Control Panel	4	0.166	24	1	4	0.096
				Total	**165**	**3.95 kWh**

* Running (12 min) **Starting (1.2 min)

TABLE VII
LOAD PROFILE OF HELIDECK & EMERGENCY LIGHTING – CONTINUOUS LOADS FOR PV-4

Load Description	Load Power(W)	Load Current(A)	Opr. Duration (Hour/ 7 Days)	Equipment Quantity	Total Daily AmpHour (Ah)	Total Daily Energy(kWh)
Helideck L	318	13.25	12	1	22.714	0.545
Emergency L.	200	8.333	12	1	14.285	0.342
Control Panel	4	0.166	168	1	4	0.096
				Total	**41**	**0.984 kWh**

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sizing and optimizing the off-grid PV for remote facilities. The above has been applied to all the critical loads which were explained earlier in sections and as listed below for the case study platforms.

1) Continuous Loads of RTU and CS Loads*:* The RTU and CS require a continuous power supply. The duty cycle for these loads is constant at12A at 24V DC power over seven day period as shown in Table IV.

2) Intermittent Loads *of ESD* (HPU) System: Table V shows ESD (HPU) System load over eight days i.e. the battery autonomy period due to criticality of the ESD. HPU pump motor operates for 90 minutes and twice. Pump starting and running demand and time periods are determined to be 4608 Watts at 10 sec and 768 Watts for 14 mins operating twice every eight days. The HPU master panel, control relays operate when the pump motor operates with a power demand 60 Watts and 35 Watts. The pump motor control panel is a continuous load with five Watts power demand.

3) MOV, HCV, PDHMS and FM System Load Profile: MOV and HCV are classified at intermittent load which operates certain times whereas PDHMS and FM are classified as continuous loads. The analysis of the operation of the loads will result in the power demand profile as shown in Table VI and as explained below.

a) *Motor-Operated Valves (MOVs):* There are 13 MOVs divided into four categories based on their torque capacity. The first group of consecutive 13 MOVs' starting and running sequentially power and time periods are 1152 Watts for 39sec and 192 Watts for 6.5 min respectively.

b) *Hydraulic Control Valves (HCVs):* The first group of 10 HCVs starting and running sequentially power and time periods are 1440 Watts for 30 sec and 240 Watts for 5 min respectively.

c) *Process Distributed High Integrity Management System (PDHMS) & Flow Meters (FM):* PDHMS and Flow meters operates as a continuous load with 38 Watts and 120 Watts respectively.

d) *Charge regulator & MOV/HCV control*: Power Charge regulator sleep mode power loss and MOV / HCV control power consumptions are considered as 4 & 5 Watts accordingly.

4) Helideck & Stair Lights: Table VII shows Emergency and Helideck Lighting System load profile 12 hour duty cycles over seven day period which are equivalent to daily 1.72 hour duty cycles with 318 Watts helideck lighting and 200 Watts for emergency lighting power demand as shown in figure 9. Helideck lighting loads require 0.5 day battery autonomy, due to use for emergency cases.

C. Usage of Long-Range Detection Surveillance Cameras of Adjacent Platforms

Data transfer from CCTV to central control room will require fiber optic due to high bandwidth requirement. Alternately, Long Range Detection Assessment System (LRDAS) is adopted as an innovative security solution which can be placed on another existing offshore tie-in or production platform, within a vicinity of 5-10km and already connected with composite submarine power cable due to high power demand by ESPs. This system will extend security coverage of the platforms with low power demand, obviating the need for CCTV. This approach will no longer require any fiber optic cables.

D. Introduction of Off-grid PV System Enhanced Monitoring and Annunciation

Off-grid PV has been specified with additional local diagnostic for monitoring and local/remote annunciation system. All the signals were transmitted to central control room via the RTU. This will provide adequate time for operations to plan any maintenance or attend to any concerns.

Following are the signals included for PV/battery monitoring and annunciation system.

a) Input /output voltage of charge controllers
b) Battery low voltage alarm
c) Battery high voltage alarm
d) Low load voltage
e) High load voltage
f) Battery low voltage disconnect
g) Earth fault
h) 4-20mA solar array current
i) 4-20mA solar array voltage
j) 4-20mA load power demand
k) 4-20mA load current
l) 4-20mA battery current
m) 4-20mA battery voltage
n) 4-20mA pilot cell temperature
o) Common Trouble

E. Introduction of New O&M Approach

This company has initiated the establishment of a Service Level Agreement (SLA) to ensure the seamless operation and maintenance of off-grid PV systems on the offshore platforms. This SLA confirms the Company's commitment to provide essential technical support, operation, and maintenance services. These services include critical activities such as PV panels cleaning and battery maintenance. This contract will also guarantee the continuity and reliability of the solar power systems.

F. Introduction of Ultrasonic Bird Repellent Device

To avoid excessive soiling within offshore environment, ultrasonic bird repellent device is added to be included on the platforms. These devices will distract birds from the PV panels and thereby avoid the bird droppings. These devices can have a standalone dedicated PV panel sized for its operations or alternately, the device power demand can be added to the PV system associated to with the helideck and stair case lighting. These devices will operate operate only during birds season.

V. CASE STUDY: OPTIMIZED PV SYSTEM

Based on the adopting solutions and approach to optimize the final load requirements calculated as per section IV, the estimated size of PV and battery system is tabulated in Table VIII. Refer to Section III.C.1 & III.C.2 for the respective factors that were applied for sizing.

TABLE VIII
SUMMARY OF OPTIMIZED PV AND BATTERY SYSTEMS

PV SYSTEMS	Daily Energy (kWH)	Battery size (Ah @ C168)	PV Panels (335 W)
PV-1	7.65	3242	12
PV-2	0.224	108	1
PV-3	3.95	1155	7
PV-4	0.98	416	2
Total	**12.8**	**4921**	**22**

Accordingly, the optimized daily energy demand reduces from 43 kWh (Table III) to 12.8 kWh and as a result reduces the required number PV panels and battery capacity by more than three times. This will not entail any need of extensions or strengthening of current standard platforms.

VI. ECONOMIC FEASIBILITY

The economic feasibility evaluated two options which include conventional grid supply options and the PV and battery system.

A. Conventional Grid Supply Option

Refer to Figure 5 for the utility power option that is available at three tie-in platforms. It is proposed to extended power to nearest platforms and then subsequently loop to adjacent platforms depending on the distance. The looping configuration will ensure alternate power supply to avoid power outages in the event of any one cable failure.

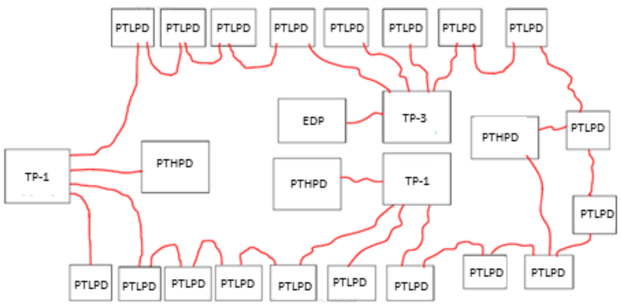

Figure 5: Conventional Grid Supply Option

One of the advantages of this option is that there will be fiber optic connectivity to all the platforms that will ensure continuous data transmission and also can facilitate installation of CCTVs which is better than LRDAS.

B. Economic Comparison

The submarine cables and installation cost itself will be significant cost, which makes the Grid option less attractive when compared to the PV option.

Table IV list the major equipment for both options for 19 platforms.

TABLE IV
EQUIPMENT LIST

Equipment	Grid Option	Off-grid PV Option
Total submarine cables	160 km	-
Total 13.8kV Switchgear	8	-
PV Systems (Panels, Charge controllers etc.)	-	19 x 13
Battery for back-up (Ah)	19 x 1500	19 x 5000
DC System	19 x 38	Integrated
Electrical Distribution at each platform (13.8kV Switchgear, Transformer, Switchrack, LV panels)	19 sets	19 sets

VII. OPPORTUNITIES

A. Offshore Applications

Presently, there are lots of opportunities for off-grid PV. This includes off-shore platforms with light loads and without stringent IT requirements for a fiber optic cable connection. The enhanced solution applied to 19 platforms under this project. As a result of the positive lessons learned, the solutions were applied to other projects with similar offshore platforms, thereby eliminating the need for some 350 km of submarine cables.

B. Onshore Solutions

Utilizing a power supply from off-grid PV for remote onshore locations dates back to the 1980s. A number of the systems and applications powered by renewables back then are still operational today, supporting the reliability and efficiency of this solution. There are still more potential opportunities for small scale off-grid PV for onshore facilities. In line with this, the company has embedded a forward-looking assessment of renewable opportunities — not only to support its net-zero ambition, but also to optimize project performance and capital efficiencies.

C. Standards Development

The company also introduced back in 2018 an engineering standard that addresses the design and specifications of off-grid solar systems that covers both on-shore as well as off-shore applications. The ", Off-grid Solar Photovoltaic (PV) System with Battery Storage" standard addresses the latest technologies and methodologies in system components such as PV panels, charge controllers, batteries, inverters, and solar lighting application.

The engineering standard covers the overall system design as well as system sizing. This standard will ensure that all design offices and contractors utilize a similar approach in the design and construction of these systems to standardize maintenance and operational practices. In addition, the batteries system specifications were updated to include the appropriate requirement for these systems and two engineering best practices were developed to cover PV panels and solar inverters qualifications. Below is the summary of the new standards and best practices to enhance overall design and overcome challenges:

1) Design Redundancy: Redundant charge controller to provide maximum load requirements including Maximum Power Point Tracking (MPPT) charge controllers besides PWM (Pulse Width Modulation) type, with a design margin for safety.

2) Cost Optimization: Exploring vertical PV installation while reducing cost and soiling by eliminating mounting systems and installing a bird repellent device.

3) Energy Efficiency and Design Optimization: Selecting or upgrading energy efficient equipment combined with performing design optimization such as avoiding unnecessary voltage transformation.

4) Hybrid Solution: Utilizing off-grid solar PV system along with fuel cells, vertical wind turbines or other alternative power sources are addressed in the standards to increase reliability and availability, as well as reducing platform footprint.

5) Alternate Battery: Testing and consideration of more efficient and high energy density battery technologies to improve existing off-grid PV. Such technologies are Lithium Iron Phosphate (LFP) battery, Vanadium Redox Flow battery, Iron-Vanadium Flow battery and Lithium-Titanite (LTO) battery.

6) Portable Off-grid PV Solutions: Testing and evaluation of portable off-grid PV to speed up deployment time while optimizing foot-print.

7) Advance PV Monitoring Systems: Development of inhouse advance PV monitoring system with energy prediction utilizing machine learning (ML) and statistical methodologies.

8) Cleaning technologies: Adopting automated O&M activities based on remote monitoring systems and by using a waterless robotic cleaning system.

9) PV technologies: Testing and evaluating new Photovoltaic (PV) technologies specifically the hetero junction.

D. Company Decarbonization

Lastly, the greenhouse gases emissions abatement associated with this off-grid solution can be factored in the economics of this renewable installation, which is the current practice. Utilize off-grid PV targets for reducing Company Scope-2 CO2 emissions. This will support the Company's strategic theme and align with both Saudi Arabia's Vision 2030 and UN Sustainable Development Goals directly or indirectly. The International Energy Agency (IEA) predicts that by 2040, 30% of global power generation will come from renewables.

VIII. CONCLUSION

This paper has demonstrated the technoeconomic feasibility of installing off-grid PV and battery Systems adequately sized for offshore water injection platforms. A novel approach to system sizing, load profile analysis, and optimization has been introduced to ensure not only the operational efficiency but also the economic feasibility of the PV and battery system over conventional grid supply. By enhancing the Solar PV design and adopting to the latest standards and newer technologies of PV and batteries, the reliability can be enhanced significantly. Additionally, introducing a new O&M approach and deploying ultrasonic bird repellent devices further enhances system reliability.

The proposed solutions and opportunities of installing PV and battery storage aligns with the Global and Saudi Arabia Climate Action Plan will facilitate deployment of Solar PV in both offshore and onshore facilities, reducing Scope-2 greenhouse gas emissions and adding economic advantages.

NOMENCLATURE

RTU	Remote Terminal Unit
PV	Photovoltaic
HPU	Hydraulic Power Unit
MOV	Motorized Operating Valve
HCV	Hydraulic Control Valve
ESD	Emergency Shutdown Device
PDHMS	Process Distributed High Integrity Management System
FM	Flow meters
CCTV	Closed Circuit TV
WIP	Water Injection Platform
PP	Production Platform
ESD	Electrical Submersible Pump
UPS	Uninterrupted Power Supply
LFP	Lithium Iron Phosphate
LTO	Lithium Titanate
MPPT	Maximum Power Point Tracking
PWM	Pulse Width Modulation
IEA	International Energy Agency

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