Feasibility Analysis of Solar Powered Power plant in Sultanate of Oman

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***Abstract*— Sultanate of Oman is Identified as one among the significant solar energy potential Zone. A preliminary study of options for the expansion of power generation capacity has identified solar energy development as potentially prospective The level of Solar Energy density in Oman is among the highest in the world . In this context , a feasibility analysis for solar powered technologies to be done. Taking into consideration of these facts , in this paper an attempt is done for the Feasibility analysis of Photo Voltaic & Concentrating Solar power(CSP)technologies in different regions of Sultanate of Oman.**

***Keywords*— RETscreen4 , GHG emission , Emission factor , Capacity factor , life cycle costing**

I. INTRODUCTION

The Gulf Cooperation Council (GCC) states i.e. Kuwait, Saudi Arabia, Qatar, Bahrain, United Arab Emirates and Oman are dependent on fossil fuel (the main cause of carbon emissions); and their economies are reliant on the oil, gas and petrochemical based industries. Electricity demand in Oman is increasing with industrialization. In this paper, the economic feasibility of the Solar Photo Voltaic and Concentrating Solar Power Power plant of 5MW capacity is analysed for different locations in Sultanate of Oman. The locations selected are ; Thumrait , Salalah , Sohar and Nizwa.

II. RENEWABLE ENERGY TECHNOLOGIES

A. Requirement of Renewable Energy Technologies

First, As on February 2011, 191 countries in the world have signed and ratified the Kyoto Protocol to the United Nations Framework Convention on Climate change (UNFCC) with the goal of achieving stabilization of greenhouse gas concentrations. Oman, as a member of UNFCC has agreed on January 2005 to contribute to combating global warming along with the rest of the world[1 To meet the future electricity demand, the government has recently announced to invest on upgradation and construction of the conventional diesel, gas and coal based power plants. This action will persist to enhance the emission of Greenhouse Gases (GHG). To diminish the ill effects of climate-sensitivities and to combat global warming problem, reduction of CO_2 and other pollutants is inevitable. For these aspects use of Renewable energy technologies is the best option. The level of solar energy density in Oman is among the highest in the world. There is significant scope for developing both solar PV and Concentrating Solar Power throughout Oman. Solar energy systems can meet the Oman's peak demand requirements and provide some electricity for export. High solar energy density is available in all regions of Oman.

B. Solar Photo Voltaic Power Generation

The solar photovoltaic (PV) technology is a well proven technology for producing Electricity. PV systems are either grid connected (with electricity fed directly into the grid system) or PV systems used in off-grid applications in small power systems in combination with diesel power gen-sets.. The potential for producing electricity using PV systems is highest during the summer which coincides with the period of peak electricity demand in Oman. The most parts of country bear clear sky (except some part of southern Oman) with annual average sunshine duration of 3708 hours per year [4].

C. Concentrating Solar power(CSP)

Suitable land availability and the direct solar radiation are the main essentialities for the CSP based power generation. These 2 factors are abundant in sultanate.CSP based on the troughs or tower concepts can be an option in Oman. Sultanate of Oman is blessed with a higher insolation rate of more than 4.5 to 6.1 kWh/m^2/day for autonomy of 342 days throughout the year.

D. RETSCREEN 4 for feasibility analysis

RETScreen 4 is Canadian software which holds a complete database for any location in the world, optimised for using the best available data at each location from about 20 sources, the main ones being the WRDC and the NASA irradiance data. NASA and WRDC data are available free of cost. RETScreen International is a clean energy awareness, decision-support and capacity building tool.

The core of the tool consists of standardised and integrated clean energy project analysis software that can be used world-wide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of energy efficient and renewable energy technologies (RETs).

In this paper the feasibility analysis of 5MW Photovoltaic & CSP based power Generation in Oman are compared.

III. GEOGRAPHICAL LOCATIONS SELECTED FOR ANALYSIS

For the analysis, 4 selected locations in Sultanate of Oman are (1)Sohar (2) Thumrait (3) Salalah (4) Nizwa

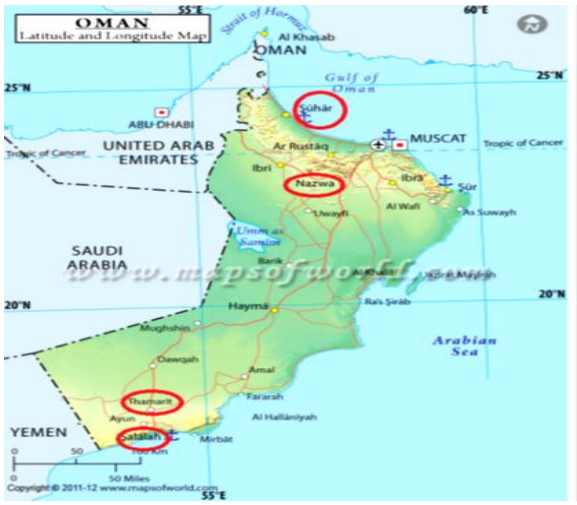

Figure 1:Locations in Sultanate of Oman[11]

1. Sohar

Table 1. Geographical location Parameters ; Sohar

Parameter	Magnitude	Unit
Latitude	24.5	˚N
Longitude	56.6	˚E
Elevation	4	m

2. Thumrait

Table 2. Geographical location Parameters ; Thumrait

Parameter	Magnitude	Unit
Latitude	23.6	˚N
Longitude	58.3	˚E
Elevation	10	m

3. Salalah

Table 3. Geographical location Parameters ; Salalah

Parameter	Magnitude	Unit
Latitude	17.0	˚N
Longitude	54.1	˚E
Elevation	23	m

4. Nizwa

Table 4. Geographical location Parameters ; Nizwa

Parameter	Magnitude	Unit
Latitude	22.9	˚N
Longitude	57.5	˚E
Elevation	383	m

Direct Solar radiation data for all the 4 geographical locations selected are given in Table 5. These data's are projected from the weather database of RETScreen 4.

Table 5: Average Monthly Solar Radiation in KWh/m²/day of different Locations

	Thumrait	Sohar	Salalah	Nizwa
Jan	5.18	3.96	4.60	4.33
Feb	5.76	4.80	4.90	5.12
March	6.40	5.29	5.60	5.71
April	6.99	6.27	5.80	6.70
May	7.43	6.94	6.10	7.29
June	6.73	6.95	5.20	7.09
July	6.23	6.26	3.30	6.55
Aug	6.18	6.23	3.00	6.42
Sept	6.44	5.89	4.60	6.10
Oct	6.08	5.34	5.40	5.48
Nov	5.31	4.37	4.80	4.64
Dec	4.83	3.75	4.40	4.14
Yearly	**6.13**	**5.5**	**4.8**	**5.79**

For further discussions location considered will be Thumrait as it is having the highest average monthly solar radiation. In this paper, 2 case studies of Solar PV and solar thermal technologies power plant of 5MW capacity are considered.. Major conventional power plants in Oman are working with natural gas as fuel. So comparison will be with Natural gas run Gas turbine based power plants. Transmission and Distribution losses are taken as 14 %.The feasibility analysis is done in RETscreen in 3 stages.

Stage -1 Energy Modelling
Stage -2 Emission Analysis
Stage -3 Financial Analysis

IV SOLAR PV GRID CONNECTED POWER PLANT 5MW

Solar PV System is analysed in RETscreen under 2 cases schematic is as shown in Figure 2;

a) PV system without Green House Gas reduction credits

b) PV system with Green House Gas reduction credits

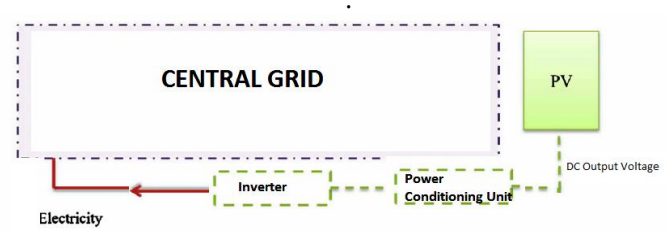

Figure 2: Electrical schematic model for PV Powered powerplant

A. Energy Modeling of PV Powered RO

Table 6: Specifications of Solar PV parameters used in Energy model of RETscreen Analysis

Parameter	Specification/Rating
Capacity of installation	5MW
Type of PV module used	Mono crystalline Si
Manufacturer/model	BP/ Mono-Si – BP5170S
Capacity Factor	20%
No of Modules	29416units
Total MWh to Grid	8761.3
Electricity Export rate	78$/MWh

B. Emission Analysis of PV Powered RO

Conventional power generation in Oman is the natural gas based combined cycle power generation. Annual Greenhouse gas (GHG)emission for the natural gas based power plants are calculated by the RETscreen as 7591Tonnes of carbon dioxide (tCO2) while generating 8761MWh of electricity to grid. Proposed PV based desalination has zero GHG emission and net annual GHG emission reduction is 7591 tCO2 which is equivalent to 17654 barrels of crude oil not consumed. A clear cut policy for the carbon credit scheme is not approved in GCC countries. So we adopted literatures for the carbon credit Mechanisms [10]. A Transmission & Distribution loss for this system is 14% [7].

Table 7: Inputs for the Emission Analysis of PV Powered RO

Base Line System in Oman	Natural gas based Power generation
T&D Losses	14%
GHG Emission factor	0.866 tCO2/MWh
Electricity exported to grid	8761MWh
GHG reduction Calculation Inputs	
GHG reduction credit rate	30 $/ tCO2
GHG Reduction credit duration	15Year
GHG reduction credit escalation rate	2%

Table 8: Calculated GHG Emission reduction for PV Powered RO Systems by RETscreen

GHG Emission	
Base line Case	7591 tCO2
Proposed case	0 tCO2
Gross annual GHG emission reduction	7591 tCO2
Equivalent Crude oil consumed for NET annual GHG emission reduction	17654Barrels of Crude oil

Gross GH Gas emission reduction credit rate is 30$/tCO2 [10] and its credit duration is 15 years. GHG reduction credit escalation rate is 2%. This data will be carried on for the next stage of financial analysis in RETscreen.

C. Financial Analysis of PV Power Plant

Financially, the project will be feasible or not can be observed from its payback period calculation. Inflation rate of Oman is observed to be 4%[11]. The initial cost for the PV installation and its accessories is taken as 2333332.48$/MW[9]. Annual Maintenance cost of the unit is taken 10% of its initial capital cost [12].

Table 9: Inputs for the Financial Analysis of PV Powered RO

Inflation Rate	4%
Project Life	25 years
Initial cost of system	2333332.48$/MW
Operating cost	10% of capital cost annually
Electricity export income	78$/MWh
GHG Reduction income	30 $/ tCO2

Table 9: Results of the Financial Analysis of PV Power Plant

	PV without GHG Credits	PV with GHG Credits
PreTax IRR- Assets	5.9 %	8 %
Equity Payback	14.5 years	11.4 years
Simple Payback	19.9 years	14.2 years

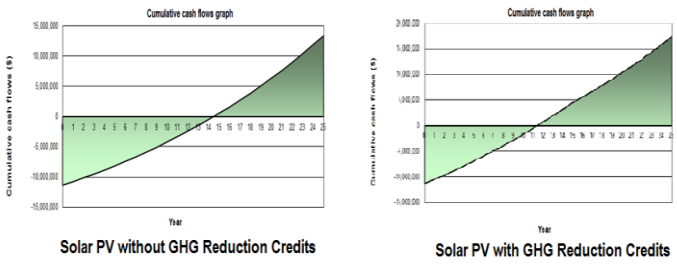

Figure 3: Cumulative Cash flow graphs of case a&b of Solar PV power plant

V. SOLAR THERMAL BASED POWER PLANT(CSP)

Solar Thermal System based power plant is analysed in RETscreen under 3 cases;

(a) Solar CSP system for RO without Energy storage (ES) and Green House Gas reduction credits

(b) Solar CSP system for RO with Energy storage and Without Green House Gas reduction credits

(c) Solar CSP system for RO with Energy storage and Green House Gas reduction credits

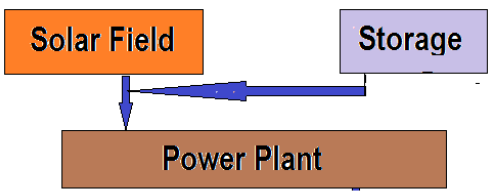

Figure 4: Block diagram model adopted for Solar Thermal Powered power plant

A. Energy Modeling for CSP powered power plant

Table10: Specifications of Solar CSP module used in RET screen Analysis

Parameter	Specification/Rating
Capacity of installation	5MW
Type of Thermal module	CSP
Manufacturer/model	Solargenix Energy/LS2
Capacity Factor	20%
Total MWh to Grid	8760MWh

Since the power generation will be 3 times that of the power generation of CSP without energy storage medium[10], capacity factor for the CSP with energy storage medium was considered 60% in the case b and c.

B. Emission Analysis of CSP powered Power plant

Table 11: Inputs for the Emission Analysis of CSP Powered power plant

Base Line System in Oman	Natural gas based Power generation
T&D Losses	14%
GHG Emission factor	0.866 tCO2/MWh
Electricity exported to grid by CSP without Energy storage	8761MWh
Electricity exported to grid by CSP with Energy storage	26280MWh
GHG reduction Calculation Inputs	
GHG reduction credit rate	30 $/ tCO2
GHG Reduction credit duration	15Year
GHG reduction credit escalation rate	2%

Table 12: Calculated GHG Emission reduction for CSP Powered power plant by RETscreen

GHG Emission	
Base Line system comparing with CSP without storage	7591 tCO2
Base Line system comparing with CSP with storage	22769.8 tCO2
Proposed case CSP with or without energy storage	0 tCO2
Gross annual GHG emission reduction for CSP without energy storage	7591 tCO2
Gross annual GHG emission reduction for CSP with Energy storage	22769.8 tCO2
Equivalent Crude oil consumed for NET annual GHG emission reduction comparing to CSP without storage	17654Barrels of Crude oil
Equivalent Crude oil consumed for NET annual GHG emission reduction comparing to CSP with storage	52953 Barrels of Crude oil

C. Financial Analysis of CSP powered Power plant

When Energy storage facility added to the basic CSP module ,the initial cost as well as the maintenance cost of the system will increase but at the same time the output power is also increasing . Inflation rate of Oman is 4% [11].

Table13 : Inputs for the Financial Analysis of CSP Powered RO

Inflation Rate	4%
Project Life	25 years
Initial cost of CSP system without storage	2588996 $/MW [9]
Initial cost of CSP system with storage	3721683 $/MW [9]
Operating cost	10% of initial cost annually
Electricity export income	78$/MWh
GHG Reduction income	30 $/ tCO2

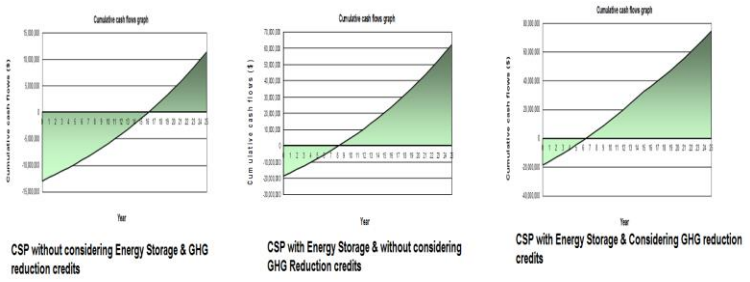

Figure 5: Cumulative Cash flow graphs of case a,b &C of Solar CSP powered Power plant

Table14 : Comparison of pay back periods in 3 cases of CSP Powered Power plant.

	CSP without ES & GHG credits	CSP with ES & without GHG credits	CSP with ES & GHG credits
PreTax IRR- Assets	4.7 %	13.2 %	16.6 %
Equity Payback	16.2 years	8.3 years	6.4 years
Simple Payback	23.1 years	10 years	7.3 years

VI. CONCLUSIONS

Among the solar technologies considered in this RETscreen analysis for Power plants in Oman, Concentrating solar power(CSP) with energy storage systems seems to be a viable option in Thumrait with GHG reduction credits.

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