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# Design Procedure of Resident House Grid Connected PV System in Saudi Arabia

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**Abstract**

In recent years, the Kingdom of Saudi Arabia (KSA) has shown interest in adopting renewable technologies on a larger scale. The residential sector consumes around 50% of the country's total electricity generation. Therefore, the introduction of photovoltaic technology in the residential sector can help the country cope with its rapidly growing electricity demand and carbon emissions. It is estimated that electricity tariffs would have to increase by at least 750% or 350% (with a 50% capital investment incentive provided by the government) for GCPV to be cost-effective. The Saudi government is maximizing the use of renewable energy to generate electricity. Investing in solar power in Saudi Arabia is important as the country's load demand is growing rapidly.

This research aims at defining the procedure of designing a resident house grid-connected PV system in Saudi Arabia.

**Keywords:** Design Procedure, Renewable energy, Grid Connected PV.

## * Introduction

Renewable energy It has experienced significant growth in recent years and is becoming an increasingly important type of energy source for power generation in both developed and developing countries. Among these technologies, solar energy is considered an optimistic form of energy because of its faster development. It uses solar energy to generate clean electricity and is considered a stable and efficient energy technology. Due to the increase in power demand in recent years, it has become necessary to reduce power consumption. Solar energy will become an economical method in the next few years because of its better technology in terms of application and cost. Also, the sun is free and considered an unlimited source of energy. The main advantage of solar energy over other conventional generators is the direct conversion of sunlight into solar energy with the help of solar photovoltaic systems. Currently, the Kingdom of Saudi Arabia has published Vision 2030 through the National Transformation Program (NTP). It clearly outlines renewable energy goals under the King Salman Renewable Energy Initiative.

In fact, Saudi Arabia will install 9.5 GW of renewable energy capacity by 2023[1]. Several papers regarding the integration of renewable energy resources in power system by long term energy planning have been done during the past years. Khadiza, et, has studied the design of a grid-connected solar photovoltaic for a residential hall in BUET. They calculate the load roof area for system sizing and analyze the system to reduce dependence on grid power. Their project considers guidelines on how to construct such a possible solar photovoltaic system [2].

Ahmed Alnoosani, et al, A paper presents the design and simulation of a 100 MW capacity grid-connected solar photovoltaic power generation system at Umm Al-Qura University (UQU). It also represents the technical, economic potential and annual production of solar photovoltaic systems. Validate and simulate designs using PVSYST software to determine optimal size, grid-connected PV system size and power generation. The solar photovoltaic system generates 100 megawatts of electricity. The payment could be used to reduce the burden on the Saudi Electricity Company (SEC) and help minimize Umm Al-Qura University's (UQU) annual electricity bill. The study provides a concise financial assessment of photovoltaic systems and operating and maintenance costs. The results of the project should encourage Umm Al-Qura University's decision to install a solar photovoltaic system to reduce load shedding and minimize the cost of powering its facilities. In addition, solar power plants help to save oil and reduce environmental pollution. Such a project could also serve as a guide for possible solar systems at other institutions [3]. Reference [4] Provides guidelines for installing photovoltaic systems, describing the design and installation plan that should be established to achieve the best results with the correct photovoltaic system. Amir A. Imam, et [5], The study shows that the modeling software System Advisor for renewable energy modeling was used to perform a techno-economic feasibility analysis of a proposed grid-connected residential solar photovoltaic (PV) system for a typical house in Saudi Arabia. Sensitivity analyzes examining the impact of different techno-economic parameters on system performance and feasibility are also discussed. The PV system size for a typical Saudi Arabian apartment is estimated at 12.25 kW. The results show that the proposed system can meet 87% of the household's electricity needs. Engineering analysis shows that the capacity factor and power ratio are 22% and 78%, respectively.

The investigations indicate that residential PV installations are option for energy management in the country. Christopher R Lashway, et al. The design and installation of grid-connected photovoltaic systems are analyzed in terms of maximum performance, size and cost. This interactive system is controlled according to available solar radiation and demand. Sizing is based on the expected load of the home, the properties of the PV modules selected and the weather data for the area. In this grid-tied configuration, the system can support most of the peak load for small households while being able to use the utility's net metering capabilities to deliver energy back to the grid under certain conditions [6].

Ali, A., Hussain, M., Al-Sulaiman et al , has studied the impact of grid-connected photovoltaic systems on six major urban sites in Saudi Arabia, including Dhahran, Jeddah, Riyadh, Guriyat, Nyom, and Khamis Mushayt, was studied. As part of the study, they selected a building for 14 families and performed a techno-economic analysis. A small city in northwestern Saudi Arabia called Neom was also included in the study for the first time. They found the technique to be highly efficient and economically viable. For example, the highest net present cost (NPC) was observed for Neom at $80,199, which is an indicator of a project's financial return over its lifetime. This clearly shows that even newly developed places can be a reliable source of solar energy that can meet the energy needs of household consumers[7]. Omar A. Al-Ghamdi et. al, in their paper study the economic feasibility of installing small-scale PV solar systems at a medium-sized house in Saudi Arabia's Eastern Region as a case study. The research provides a clear view of whether the construction of a net metering solar PV system is worth the investment for a single end user. For this feasibility study, different economic metrics are used, including net present value, payback period, internal rate of return, and investment return. In particular, the study examines various regulatory strategies to analyze how desirable the current WERA regulations are for high end-user participation and whether incentives should be proposed [8].

*** Objectives**

The research will concentrate on the following objectives:-

1- Definitions of Selection Criterion of Components Needed of Grid Connected PV System with Taking Saudi Arabia as An Example.

2- Achieving Balance Between the Supplier and Load Demand.

3- Defining the Procedure of Designing a Resident House Grid Connected PV System in Saudi Arabia for Different Case Studies.

4- Evaluated Economic Feasibility for The System When Add Storge.

*** Modelling and Results**

**Modelling Overview:** The number of unknown parameters rises as the chosen model's equivalent circuit gets more practical and less close to its ideal form. However, most of manufacturers' data sheets don't include enough details regarding the characteristics (irradiance and temperature) that depend on the weather. Therefore, to create a mathematical model of the PV cell and the PV module, in addition to using the information provided by the constructors, additional assumptions about the physical nature of the cell behavior are required. This paper's goal is to provide relevant work to individuals who want to concentrate their attention on the PV module or array as a single component of a complicated "electro-energetic system." The objective is to always achieve the highest power while simultaneously being the most precise and, as a result, the value that is closest to the experimental value.

**Simulations Software Models:** In this study we used simulations for performing the needed analysis in the research papers, we used to develop some results and curves from MATLAB, and used to clean the collected load profile, hourly irradiation, and calculations of required areas for each case from Microsoft Excel to compere the result.

**Solar Irradiation Data and Production per Hour:** We Collected the solar radiation data as shown in Fig. 1 and Production per Hour as shown in Fig. 2, so we Fixed the production at 8 kWh to build a solar system and selected Riyadh as sample, and we calculated the number of panels and area required for the system to match our Scenario.

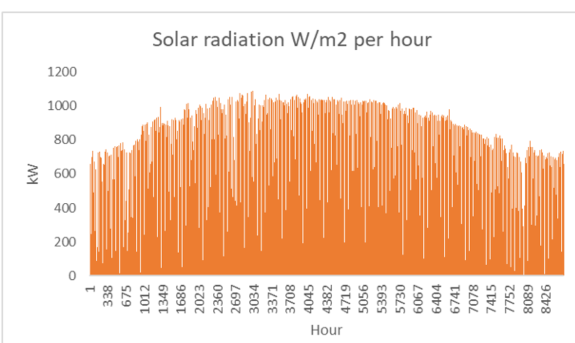


**Fig. 1 Solar radiation W/m2 each hour**

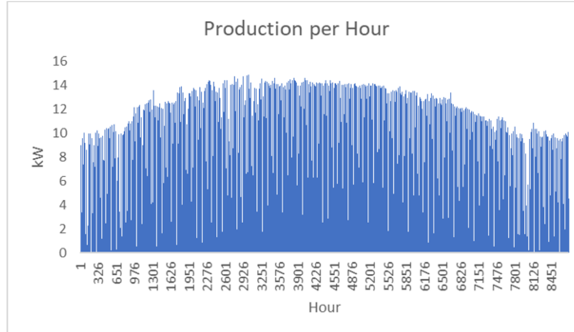


**Fig. 2 Production per Hour.**

**Technical and Economic Data:** Technical data aspect shall be considered also to make our feasibility study more realistic and accurate, so depends on cost of installation panels and inverter within their lifecycle. As for the economic inputs, they are very important factors that contribute to building accurate and more realistic study outputs. as shown in following Table. 1, Table. 2 & Table. 3.

**Table. 1 Technical Parameters**

| Item | Value | Unit |
|---|---|---|
| PV module Lifetime | 25 | Years |
| Power production | 555 | w/h |
| Width | 1.96 | m |
| Length | 2.384 | m |
| PV module efficiency | 21.2 | % |
| Panel Slope to facing south | 24.78 | % |
| Inverter lifetime | 15 | Years |
| Inverter efficiency | 97 | % |

**Table. 2 Economic Data**

| Item | Value | Unit |
|---|---|---|
| Price of panel 555 w | 682 | SAR |
| Inverter for 8 kw | 7000 | SAR |
| Steel structure | 412 | SAR/kW |
| Cable | 70 | SAR/kW |
| Ac panel | 2000 | SAR |
| Sec fees | 4000 | SAR |
| Installation | 380 | SAR/kW |
| Annual cost kWh & Maintenance 20%) | 4450 | SAR/kW |

**Table. 3 Price tariffs**

| Selling to the grid | Buying from the grid | Category Consumption |
|---|---|---|
| 0.07 SAR/kWh | 0.18 SAR/kWh | Residential < 6000 (kWh/monthly |
| | 0.3 SAR/kWh | Residential > 6000 (kWh/monthly) |

**Scenario consumption:** We have a solar system which deal with various type of consumption, so we build a system as fixed production at 8 kWh to these stages of the consumption, we made the study with four scenarios as low consumption, Average consumption, and high consumption, also added the battery in case of low consumption. And we calculated the cost to Building PV system Including all equipment's do by local suppliers by 4450 SAR for each 1 kWh include annual Maintenance.

## * Results and Discussion

### 1- Results

In this Chapter, we summarize the results and performance from all the cases. Moreover, there is several changing factors affecting the economic feasibility of installing solar PV systems such as electricity tariff, selling price, capital cost and consumption amount.

### A- Total consumption for each scenario

In this part we made analyze the consumptions of the selected scenarios as shown in Fig. 3: Fig. 4, & Fig. 5:-

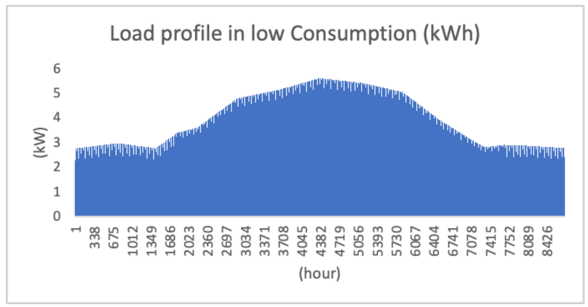


**Fig. 3 Load profile in low Consumption (kWh)**

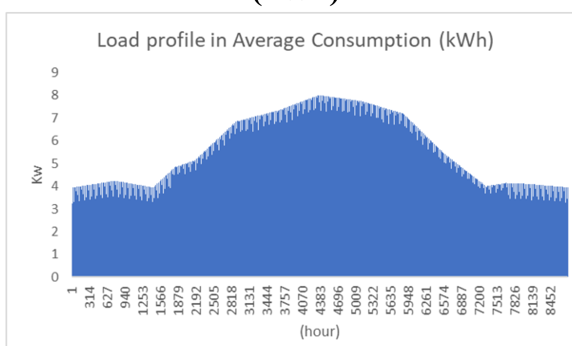


**Fig. 4 Load profile in Average Consumption (kWh).**

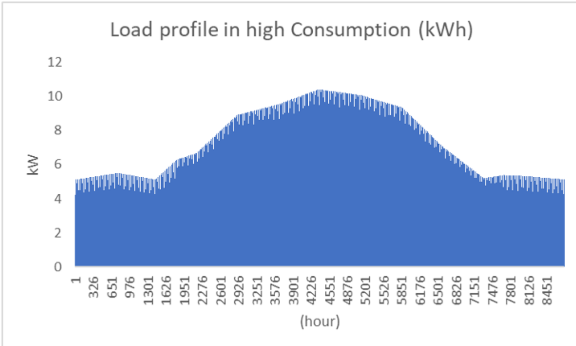


**Fig. 5 Load profile in high Consumption (kWh)**

We notice in the graphs above that the consumption value increases in the summer months and decreases in the winter months, as we conclude that according to the devices used in the summer, which are the air conditioning devices, which are considered one of the highest consumption devices. And we got the average month consumption, total annual consumption and peak electric demand is shown in Table 4:-

**Table. 4 Consumption analysis**

| | Low Consumption (kWh) | Average Consumption (kWh) | high Consumption (kWh) |
|---|---|---|---|
| Average month consumption | 2570 | 3671 | 4772 |
| Total annual consumption | 30834 | 44049 | 57264 |
| Peak electric demand | 5.6 | 8.1 | 10.4 |

### 1.1.1 Total output from the system for each scenario

In this part, we will explain the total solar system output for each scenario as shown in Fig. 6: Fig. 7, Fig.8 & Fig.9:-

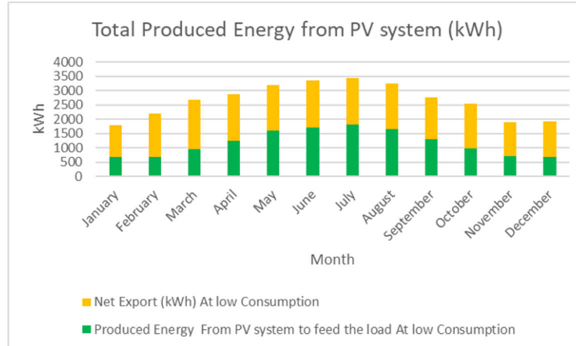


**Fig. 6 Technical and Economic Evaluation at low consumption**

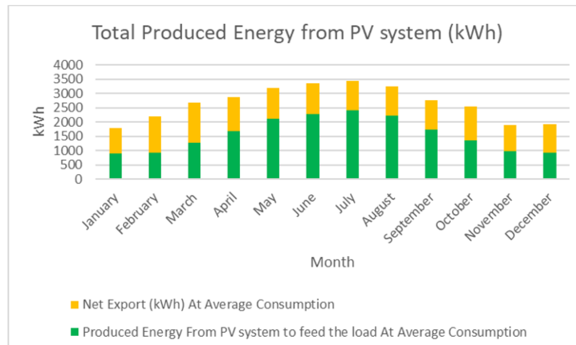


**Fig. 7 Total Produced Energy from PV system (kWh) at Average consumption**

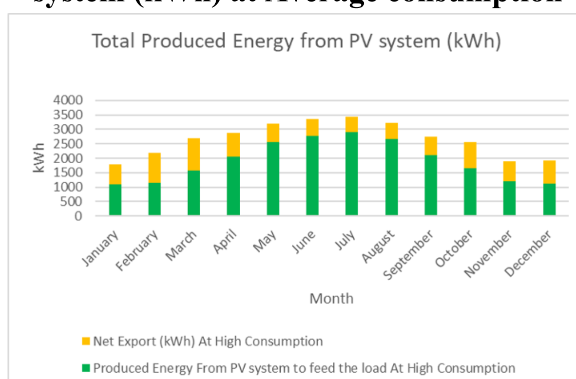


**Fig. 8Total Produced Energy from PV system (kWh) at high consumption**

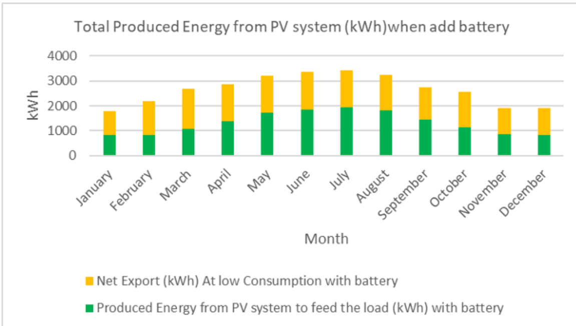


**Fig. 9 Total Produced Energy from PV system (kWh) at low consumption when add battery**

As we can see in the above graphs of the total solar energy production for each scenario, also here we added the graph of the total solar energy production with the addition of the battery through low consumption to benefit from the energy and avoid to export it to the grid, we also note that in the case of high consumption, we obtained the least export, and this means that it is the best appropriate comparison of these scenarios in which was used most energy produced.

Also, in the case of low consumption, we compared the system with adding the battery and without adding the battery to see how we can take advantage of excess capacity storage and reduce export energy to grid, Therefore, the battery that was chosen has a capacity of 5 kWh, and this means that it is fully charged and discharged only once every day, and from here we can benefit from the amount of 5 kWh per day and used it , and mathematically during the month we can benefit from 150 kWh and also during the year we benefited Approximately 1800 kW, as shown in Table. 5:

**Table. 5 Compare Net Export**

| | Net Export (kWh) At low Consumption | Net Export (kWh) At low Consumption with battery |
|---|---|---|
| Annual Total | 17999.8 | 16199.8 |

## * Results Summary

In this part, we obtained the most important results through which we can choose the most appropriate scenario for this system, as we were able to obtain several important values, and from here we can compare these scenarios as shown in Table. 6

**Table. 6 Compare Results**

| | Low consumption | Low consumption with battery | Average Consumption | high consumption |
|---|---|---|---|---|
| **System Size (kW)** | 8 | 8 | 8 | 8 |
| **Total Produced Energy from PV system (kWh)** | 31922 | 31922 | 31922 | 31922 |
| **Estimated Cost (SAR)** | 35600 | 64600 ↑ | 35600 | 35600 |
| Annual Consumption (kWh) | 308345 | 308345 | 44049 | 57264 |
| Annual Energy Drawn from Utility Network (kWh) | 16912 | 15112 | 25279 | 34378 |
| Annual Produced Energy from PV system to feed the load (kWh) | 13922 | 15722 | 18769 | 22886 |
| Total Savings in The First Year (SAR) | 3766 | 3964 | 4299 | 4752 |
| Annual Exports (kWh) | 17999 | 16199 | 13152 | 9035 |
| Annual Exports (SAR) | 1260 | 1133 | 919 | 632 |
| Simple Payback Period | 9.45 | 16.2 | 8.2 | 7.49 |
| Return On Investment (%) | 10.57 | 6.1 | 12.1 | 13.3 |

When we note in the above table there is some important factors and values through which we can take the most appropriate and economically feasible decision such as (Return On Investment and Payback Period), and since the system's output is fixed at 8 kWh, therefor the total cost is fixed in all scenarios except for the scenario in which the battery has been added because the cost of the battery will add to total cost on that scenario(Low consumption with battery) by 29,000 SAR, and also this cost reduced the return on investment and increase payback period,

Finally, from these results, we can select the best scenario for this system by focusing on the lowest value on payback period and the highest value on return on investment.

*** Discussion**

Based on the last summary in the Table. 14, we found that all loads are suitable for the system, but there is one case that is the best for the system, as it obtained the payback period and the highest return on investment, and it is in the case of high consumption, where it obtained a Payback Period of 7.49 and an investment return of 13.3%. as shown in Table. 7.

**Table. 7 The important criteria in the results of the system at high consumption**

| | high consumption |
|---|---|
| **System Size (kW)** | **8** |
| **Total Produced Energy from PV system (kWh)** | **31922** |
| **Estimated Cost (SAR)** | **35600** |
| Annual Consumption (kWh) | **57264** |
| Annual Energy Drawn from Utility Network (kWh) | **34378** |
| Annual Produced Energy from PV system to feed the load (kWh) | **22886** |
| Total Savings in The First Year (SAR) | **4752** |
| Annual Exports (kWh) | **9035** |
| Annual Exports (SAR) | **632** |
| Simple Payback Period | **7.49** |
| Return On Investment (%) | **13.3** |

Through this research, we obtained factors that help us to obtain a better choice of production capacity suitable for the required loads, so we need choose a system that fed the daily need of loads and not more production because it will be exported to the grid, and this will increase the cost value and reduce the value of the return on investment because it had low the export price at 0.07 SAR which is not feasible in the current period.

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