21th International Conference on Renewable Energies and Power Quality (ICREPQ'23) 232

Efficient utilization of solar PV for corporate building in Riyadh, Saudi Arabia

Fahad Saeed Alharthi1,3, Abdulrahman M. Alamoud2.3 P.h.D.

1 Research & Development Department, Saudi Electricity Company, Riyadh, Saudi Arabia. FSHarthi3@se.com.sa

2 Member of the board of directors of RE program, Professor of Microelectronics and Solar PV energy, Electrical Engineering Department, King Saud University, Riyadh, Saudi Arabia. alamoud@ksu.edu.sa

3 RE.MSc program Sustainable energy center, King Saud University, Riyadh, Saudi Arabia.

Introduction

Solar PV penetration in the Kingdom of Saudi Arabia has been increasing thanks to the ambitious goal of maximizing PV share in power by Saudi vision 2030 particularly the PV power plants that reached to low LCOE recently. With this orientation from the government in KSA, many entities started initiatives to install PV rooftop including buildings. Saudi Electricity Company has its HQ at Riyadh located at 24o37'59''N, 46o43'0'E. In December 2018, a PV rooftop system was commissioned at one of its four headquarter buildings with capacity of 277kWp. The building area is 23808 m2 and for the designated offices areas is 18276 m2 with almost one thousand offices. A similar system with same capacity installed on the rest of the main buildings to be four systems with total capacity of 1.108MWp. In this research, only one of the systems has been studied, the system is feeding half of the building's loads and the other half is fed by grid directly. Some of the day's PV generation capacity remains higher than load demand because it has been limited to feed only one half of the building and the surplus energy is not allowed to be injected to distribution grid due to unavailability of regulations for grid interconnection of Solar PV Rooftop system from Water and Electricity Regulatory Authority (WERA) at that time. This study focuses on collecting data of PV generation and loads through Solar PV System monitoring tool "Sunny Portal" [2] and calculating the whole PV generation in case of grid interconnection or using the surplus energy to feeds other loads fed by external grid supply. There are some case studies in KSA for PV systems, which are feeding schools, mosques, malls and factories[1]. However, there is no study focusing on PV performance on corporate or government buildings and their loads nature. This research presents a study to assess the interconnection between PV system and SEC HQ loads and how this system contributes in reduction of electric power consumptions from grid and GHG emissions. The peak loads in corporate buildings usually matches with peak generation of PV. since the working hours are during the daylight. Given the large size of corporate buildings and the different loads inside, it is not possible to cover the whole demand by only utilizing PV. Therefore, this leads to utilizing each watt generated from the system and there is no need for energy storage once it is a day time operation.

Objective

The main purpose of this study is to assess the performance of PV rooftop mounted on a corporate building (i.e SEC HQ) that has its own load profile different from residential or commercial buildings. The study will be conducted by collecting generation and loads data during one year (2021). The objective of this study is to provide a comprehensive image of the loads profile of corporate buildings and how PV rooftop systems can contribute to cover some loads of corporate building by utilizing their roof area. The consumption of these buildings are mostly in daytime which matching the solar radiation intensity. In addition, the PV rooftop project reflects the efforts of S E C to contribute to carbon emissions reduction by exploiting the rooftop areas and this may lead to encouraging private and governmental entities for setting up similar systems for reduction of both electricity bill and carbon emissions.

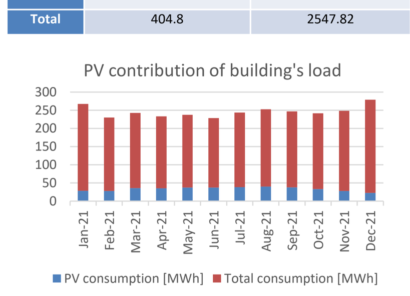
Research Methodology

the design of PV system and architecture followed by data collection methodology through the System database via "Sunny Portal" . The portal provides data for the PV generation as seen from the inverters output, so it is the AC generated energy that is being captured. Therefore, there is a shortage of data regarding the surplus energy in the system database because the inverters have been programmed to meet the load demand only and cannot export the surplus energy to the grid. Therefore, the energy yield from the PV system is estimated by simulation to determine the surplus energy from whole system and its' capacity.

Results & Discussion

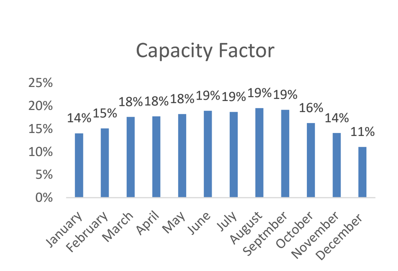
The building loads are varied from time period to another due to the climate conditions and day works as it is a workplace. For the period of the year 2021 the total loads consumptions were 2547.82 MWh. The table shows the loads consumption per month in 2021. The loads have been feeding from three main distribution panels, one of MDP feeding half of the building through distribution grid, the second one feeding the building by PV system and distribution grid and for the third one is being used for emergency purpose. The extracted data from the sunny portal showed that direct consumption from the PV system to feed the loads was 404.2 MWh represent almost 15.8% of the whole building load. While PV system covers some loads the rest was fed directly by the grid with 871.74 MWh representing 84.2% of the total load consumption.

Time period	PV consumption [MWh]	Total consumption [MWh]
Jan	28.9	238.76
Feb	28.1	202.08
Mar	36.2	206.5
Apr	35.3	197.84
May	37.5	200.16
Jun	37.7	190.66
Jul	38.5	205.2
Aug	40.2	212.64
Sep	38.2	209.16
Oct	33.5	208.14
Nov	28.1	220.32
Dec	22.7	256.36
Total	404.8	2547.82



Capacity Factor

The capacity factor is the ratio of the actual annual energy yield of PV array to the energy it would produce when operating at full capacity over one year. Capacity factor estimates the percentage of the PV array that is usable, and the most ideal CF is 50% because of the daily sun availability (almost 12 h at maximum)[3]. The monthly capacity factor ranges between 19% in June, July and August and 11% in December as shown in Figure.



Surplus energy

Due to the limitation of feeding only half of the building, the energy yield from the PV system was not fully utilized such that surplus energy is used to the other half of the building or any loads. The excess energy calculated is enough to provide proper solutions to exploit the full potential of the PV system, the total excess energy for the whole year was around 69.1 MWh. This amount comes according to the PV generated equation:

$$E = A * r * H * PR$$

Where:

E: PV electric energy output

A: Total area of PV modules

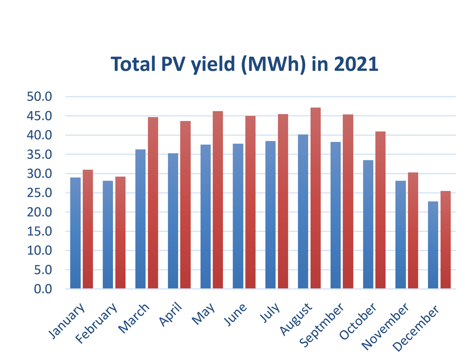
r: PV module efficiency

H: global solar irradiation

PR: Performance ratio

From the equation above, the factor that were given as: the total area is 1710 m^2. The PV module efficiency is 16%. Global solar irradiation was measured for each five minutes and taking in account for intraday. Performance ratio was assumed 0.65 in solar winter season from the beginning of November until the end of February (four months) and 0.75 for the rest of the year. The table and chart below show the comparison between the generated and calculated energy of the PV system for all months in 2021.

Month	PV generated power (MWh)	Calculated PV generation (MWh)	Surplus energy (MWh)
January	28.9	31.0	2.1
February	28.1	29.2	1.1
March	36.2	44.6	8.4
April	35.3	43.6	8.3
May	37.5	46.2	8.7
June	37.8	44.9	7.2
July	38.4	45.4	7.0
August	40.2	47.1	7.0
September	38.2	45.3	7.2
October	33.5	40.9	7.4
November	28.1	30.2	2.2
December	22.7	25.5	2.7
Total	404.8	474.0	69.1



Environment Impact

Producing power from renewable energy such as in this case where PV system is used instead of burning fossil fuel leads to limitation of GHG gases emissions and saving oil barrels to be used for other purposes. KSA has an ambitious target to achieve net zero carbon emissions by 2060, such projects led by governmental and private sectors would support achieving that goal. SEC has issued an annual Environmental, Social and Governance (ESG) report that aims to provide a balanced representation of its ESG performance from 1st of January to 31st of December. The report discloses SEC's sustainability commitments, policies, programs and activities, as well as the contributions that have been made towards important national and international sustainability-related ambitions [4]. GHG gases emissions reduction calculation obtained by considering CO2 production factor to be 0.53 ton/MWh based on ESG report. Therefore, the reduction of emissions for the energy production was 214 tons. Oil barrels saving has been calculated by assuming the equivalent barrel of oil produces 1.62-megawatt hour. Hence, the total saved oil barrels for producing were almost 655 barrels of equivalent oil.

Economic Analysis

Beside the technical analysis of the system, the economic analysis has been carried out to assess the system from all aspects. The system got purchased in 2016 when the prices were quite high compared to present prices, that increased the payback period and levelized cost of energy in study calculations.

Levelized cost of energy.

LCOE is used to compare the kWh cost of different power system technologies. LCOE is estimated by dividing the lifecycle cost of the project by the expected energy output [7].

LCOE = LCC/E grid

Where LCC is the lifecycle cost and E grid is the estimated produced energy for 25 years.

The lifecycle cost includes the initial capital cost, operation, and maintenance cost, as well as the replacement cost minus the salvage value, which is the project value at the system's end of life. It has been calculated to be 820,438 US$. In contrast, E grid is the sum of produced energy during 25 years taking into account the degradation of PV modules as shown in table below which will reach to 80.2% of effective output at the twenty fifth year which is calculated to be 9314.8 MWh.

LCOE = 820,438/9314800 = 0.088 USD/kW.

Payback Period

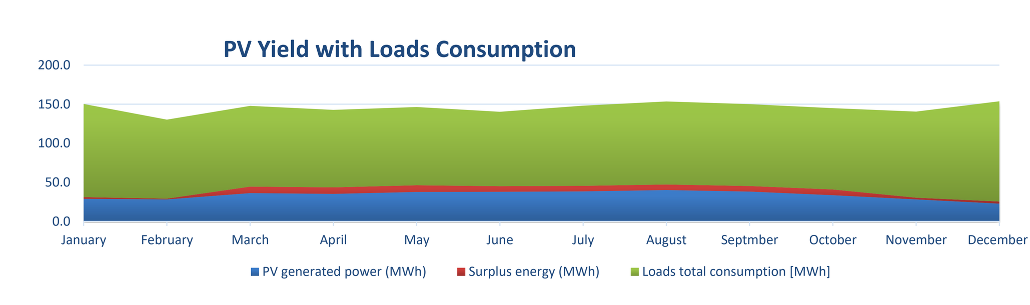
A simple payback period pertains to the period at which the revenue is equal to the investment cost, while a discounted payback period takes into consideration the time value of money. The simple payback period for residential PV systems is given by [8]:

Payback period = (PV price- Fedral ITC) / (Annual PV revenue-O&M)

Payback period = (690,000- 0)/ (34,278 -5,429) = 23.9 years

Conclusion

According to the data mentioned in earlier, the system can produce much more energy in each month. The incremental of energy is 69.1 MWh represents around 15% of total yield energy 474 MWh, which can increase solar contribution to loads feeding by 18.6 %. Such quantity of wasted energy could be utilized to feed the whole building or other surrounding facilities by reprogramming the inverters to export the whole generated energy especially with WERA announcing rooftop PV interconnection with the distribution grid regulations. By utilizing the surplus energy, the value of capacity factor will be increased to reach around 20% for the whole year. As well as GHG emissions reductions and the barrels of oil equivalent values will increase to reach 251 tons of CO2 and 768 barrels of oil equivalent. Moreover, the LCOE will decreased to be reached 0.75 US$/kWh, payback period will decrease as well to be around 19.9 years.



References

[1]Amro M. Elshurafa, Abdullah M. Alsubaie, Ayman A. Alabduljabbar, Shafi A. Al-Hsaien. 2019 "Techno-Economics of solar PV on mosque rooftops: Results from a pilot study in Saudi Arabia" https://www.kapsarc.org/research/publications/techno-economics-of-solar-pv-on-mosque-rooftops-results-from-a-pilot-study-in-saudi-arabia/

[2] sunny portal powered by ennexOS. https://ennexos.sunnyportal.com/login?next=%2Fdashboard%2Finitialize

[3] Almarshoud, A. Technical and Economic Performance of 1MW Grid-connected PV system in Saudi Arabia. Int. J. Eng. Res. Appl. 2017, 7, 9–17

[4] SEC SEG 2021 report, page (29-33) https://www.se.com.sa/arsa/Lists/SustainabilityReport/Attachments/5/SEC%20-%202021%20ESG%20Report.pdf

[5] [11] Ali S. Alghamdi. Performance Enhancement of Roof-Mounted Photovoltaic System: Artificial Neural Network Optimization of Ground Coverage Ratio.

[6] R. Arena, S. Aneli, G.M. Tina and A. Gagliano. Experimental analysis of the performances of ventilated photovoltaic facades.

[7] Abu-Rumman, A.K.; Muslih, I.; Barghash, M.A. Life Cycle Costing of PV Generation System. J. Appl. Res.Ind. Eng. 2017, 4, 252–258.

[8] Drury, E.; Denholm, P.; Margolis, R. Impact of Different Economic Performance Metrics on the Perceived Value of Solar Photovoltaics; National Renewable Energy Lab. (NREL): Golden, CO, USA, 2011.

Acknowledgment

This work has been done thanks to Saudi Electricity Company for their efforts and support.