Analysis of the performance and efficiency of Solar PV system: A Study of the impact of weather and climate conditions

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Abstract:

The performance of solar photovoltaic systems tends to decline if the operating conditions change from the nominal operating cell temperature due to environmental factors. The major factors include temperature and humidity variations, which cause thermal losses and open-circuit voltage drops in photovoltaic panels. This study investigates the correlations between solar photovoltaic performance and environmental factors by quantifying the real-time variables including temperature, humidity, shading, and heat index. Furthermore, the study investigates the difference between real-time measured and theoretically calculated temperature values with the help of weather station data to investigate the impact of temperature difference on the overall percentage power loss of the systems. The panels were installed at site (rooftop) connected to the grid-tied system. Results reveal that the photovoltaic panel temperature has an inverse relation with the dew temperature and the humidity of the surrounding environment. The heat index value was found slightly less at the peak solar hours during the 24 h cycle of the measurement. The difference and relationship between temperature and humidity are measured and losses are highlighted based on the instantaneous occurrence of variables. Based on a difference between measured and calculated shading, results reveal that PV systems faced 7,9% power losses for roof installed PV systems, respectively.

Introduction:

Energy demand is growing exponentially with increasing urbanization, industrialization, and population growth, putting a strain on conventional energy sources and the environment. Renewable and sustainable energy sources are therefore more focused due to less harmful environmental effects to cater to the growing energy challenge across the globe. Solar photovoltaic systems are a cleaner supply of energy with low manufacturing costs and net-zero emission factors. With the low cost of solar photovoltaic technology, photovoltaic modules are presently deployed in the great majority of countries throughout the world. The research activities in the field of energy-related issues are more focused in the current years. According to a recent study from the International Energy Agency (IEA), solar PV technology is expanding faster than any other renewable energy source on the planet. Globally solar photovoltaic capacity additions are anticipated to reach almost 161.7 GW in 2022, indicating a linear projection from the 2015 analysis.2 Solar photovoltaic deployment on the utility side is the leading sector in the overall adaptation of photovoltaics across the globe, expected to increase its share by 69% by 2022 shown in Figure 1 However, the Covid-19 issue in the last couple of years may have caused a short-term slowdown in photovoltaic installations globally, but long-term growth prospects remain bright. Before pandemic forecast regarding impacts of Covid-19 lockdown on distributed PV sector reports that, In the distributed PV industry, a two-month lockdown period would be a high-risk threshold value.

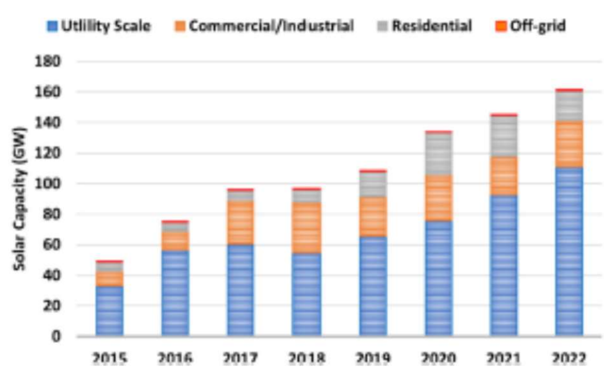


Figure 1 Annual additions to solar photovoltaic capacity by application segment till the year 2022.

The monthly value-added loss reaches 67.69% when the duration exceeds the threshold value, while demand shrinks by 78.69%. Furthermore, 7.18% of distributed PV enterprises would be at risk of failure, and nearly 81% of PV sector employees would be laid off.

There are various kinds of solar panels accessible in the market consisting of polycrystalline, monocrystalline, thin films etc. However, under the same environmental and geographical Conditions, the power output capacity of monocrystalline solar panels-based power plants is 5–7%better than that of existing polycrystalline ones. In prior studies, monocrystalline silicon-based solar photovoltaic technology was expected to account for more than half of the entire solar industry till the last year. The monocrystalline solar panel is made with silicon cells. Solar cells are made of semiconductor material. Due to its low bandgap of 2.37 eV for photo electrochemical water oxidation, strong solar energy absorption of about 10%, and high photocurrent of 7.5 mA/cm2, bismuth vanadate (BiVO4) is a very promising n-type semiconductor to be investigated for photo electrode usage. Solar panels capture energy from the sun and convert it to electricity. The light energy from the sun comes in the form of packets with different wavelength levels called photons. Photons strike on the silicon plate of the panel; some photons having short wavelength are harnessed by the surface of the panel and the panel extract the energy from photons depending upon their efficiency. This phenomenon is widely known as Photovoltaic Effect. It is noteworthy, that not all photons are fully harnessed by the panel surface, some photons having large wavelength gets absorbed into the panel which causes heat phenomena in the panel creating different types of thermal losses. These losses badly affect the thermal efficiencies of solar panels. These different types of losses in photovoltaic module are discussed briefly in next section.

The performance of a photovoltaic module is shaped by two factors: solar irradiation and cell temperature. Aside from these considerations, the performance of the photovoltaic module is also influenced by other factors such as different system losses.

Significance of the research:

The objective of this research is to show the Analysis of the performance and efficiency of Solar PV system also the study of the impact of weather and climate conditions. In this subject, an executed project in Sulaimaneyah has been selected as a sample.

For the Solar system projects many factors require to be considered such as locations, energy requirement, life time, financial aspects and ROIs.

Factors affect Solar Energy:

Several factors can affect solar efficiency and energy, in this research, we briefly provide factors to be considered and effects of the weather conditions to generated energy form Solar system.

- **Latitude and Sun Angle**: the amount of solar energy received at a specific location depends on its latitude and the angle of the sun. Areas closer to the equator receive more direct sunlight throughout the year, while higher latitudes experience variations in solar intensity with changing seasons.

- **Time of Day and Season**: Solar energy production is influenced by time of day and the season. Days are longer in the summer, providing more sunlight for solar energy generation, while winter days are shorter.

- **Weather Condition:** Cloud cover, Rain and atmospheric conditions can affect the amount of sunlight reaching solar panels. Overcast days reduce the efficiency of solar energy production, and rainy or snowy weather can further decrease output.

- **Air Mass:** the solar energy path through the Earth's atmosphere is affected by air mass which is a measure of thickness of the atmosphere that sunlight must traverse. The greater the air mass, the more atmosphere the sunlight has to travel through, Reducing its intensity.

- **Shading:** Obstructions such as buildings, trees, and other structures can cast shadows on solar panels, reducing their efficiency. Proper site selection and installation are crucial to minimizing shading effects.

- **Temperature:** Solar panels are sensitive to temperature and their efficiency decrease as temperatures rise. High temperatures can cause a drop in the voltage of solar cells, leading to reduced energy output.

- **Panel Orientation and Tilt**: The orientation (azimuth) and tilt angle of solar panels affect their exposure to sunlight. Panels are typically installed facing south in the northern hemisphere and north in the southern hemisphere to maximize sunlight exposure.

- **Solar Panel Quality**: The efficiency and performance of solar panels depend on their quality, technology and design. Advances in solar panel technology contribute to higher conversation efficiencies and better performance under various conditions.

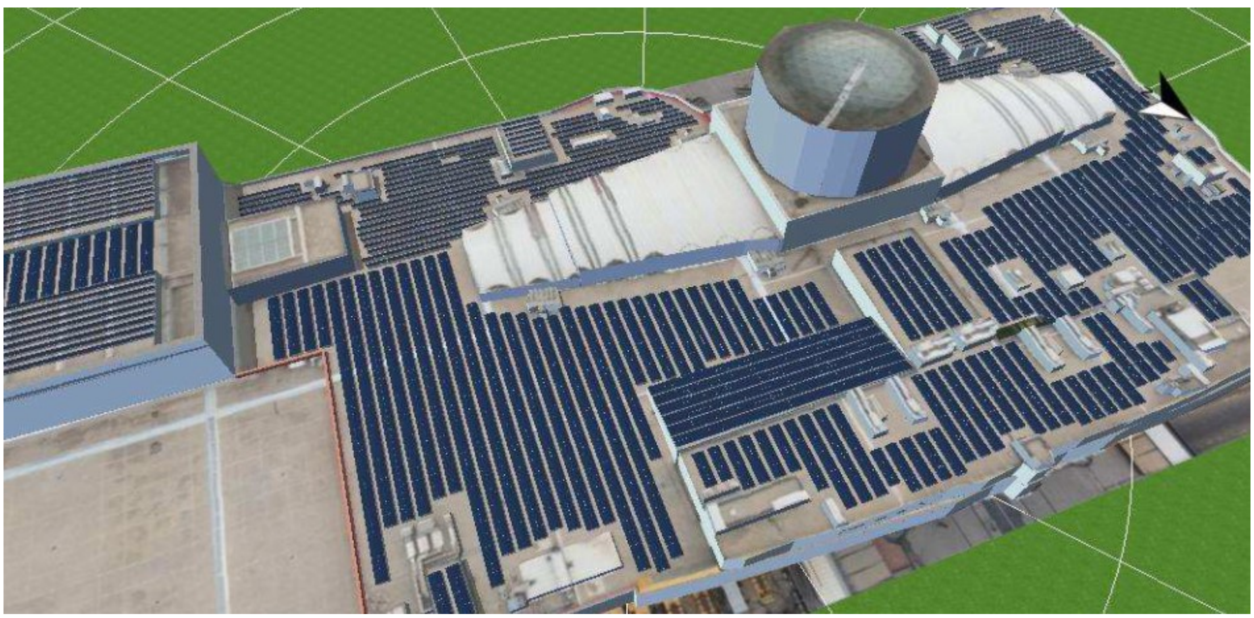
- **Dust and Pollution**: Accumulation of dust, dirt or pollution on solar panels can block sunlight and reduce their efficiency. Regular cleaning is essential to maintain optimal performance.

- **Energy Storage**: The availability of solar energy is intermittent, as it depends on sunlight. Energy storage solutions, such as batteries, are crucial for storing excess energy generated during sunny periods for use during periods of low sunlight or at night.

Understanding and managing these factors is important for optimizing the efficiency and reliability of solar energy systems in different geographical locations and environmental conditions.

Case study: Family Mall Project

In this subject Solar plant solution for the Family mall project is taken for the study. The system power is 2000KWe/2200KWp.it consist of four zones. 4037 Number of Photo voltaic panel has been Used. Each panel has capacity of 545W, mono crystal module with 20 number of 110KW inverter SMA core2 in the system.



General system layout

System selection:

The system is divided in to Four zones. Each zone contained of amount of panels and individual investors. They all connected to each other throughout communication module. The below are calculations and determination of each zones according to their location conditions.

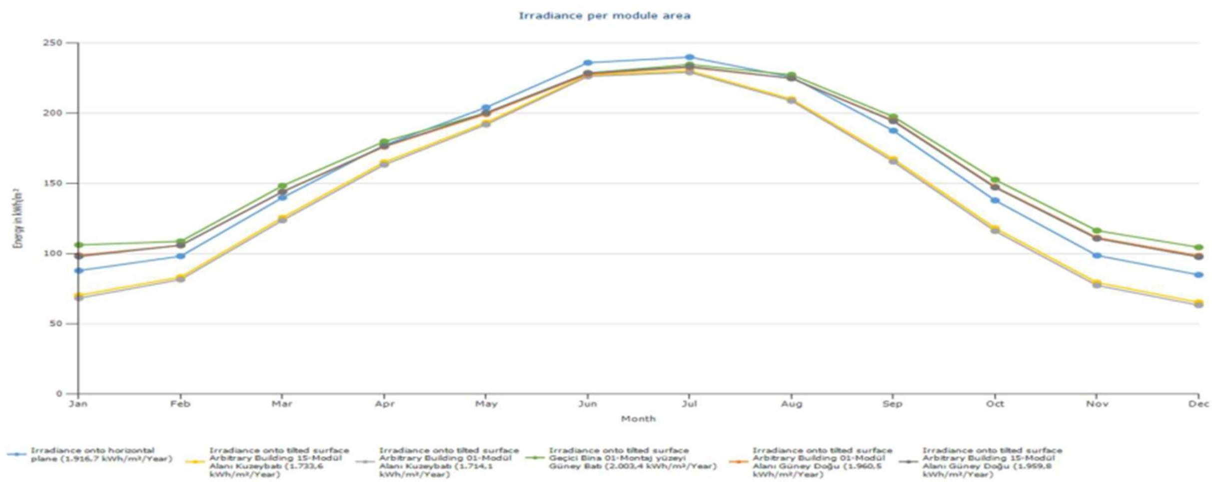
A. Zone One:

The system power 700KWe/774.9KWp. 1422 number of solar panel with 7 number of 110KW inverters has been used.

Zone one system layout

PV System		
PV Generator Output	774,99	kWp
Spec. Annual Yield	1.528,67	kWh/kWp
Performance Ratio (PR)	81,41	%
Yield Reduction due to Shading	7,2	%/Year
Grid Feed-in	1.184.865	kWh/Year
Grid Feed-in in the first year (incl. module	1.170.662	kWh/Year
Standby Consumption (Inverter)	158	kWh/Year
CO_2 Emissions avoided	556.812	kg / year

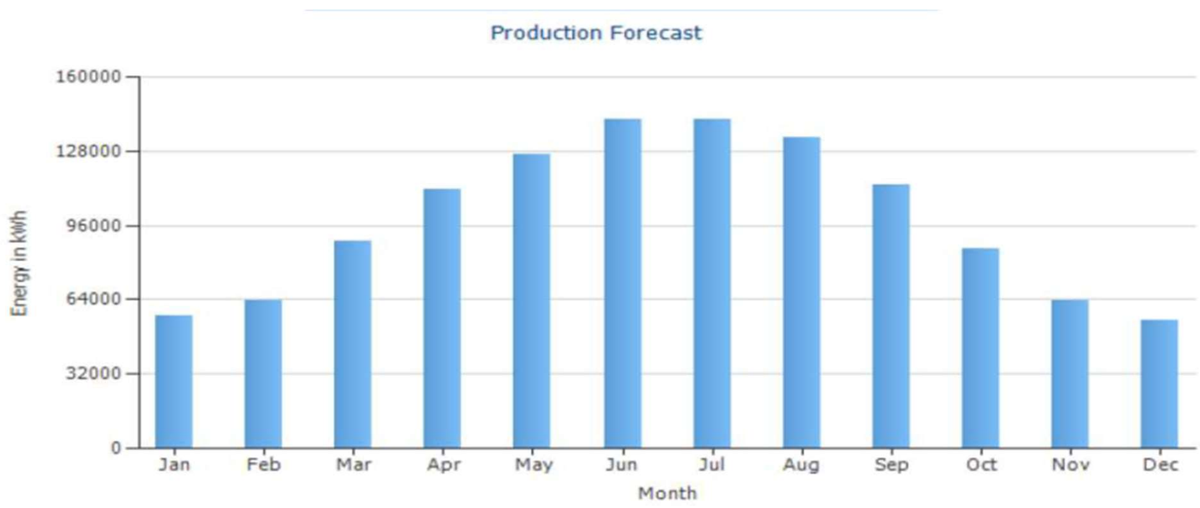
Monthly irradiance values table is below. The system design is southwest, northeast tilting. The system generates approximately energy of 1184,865.10KWh in a year.



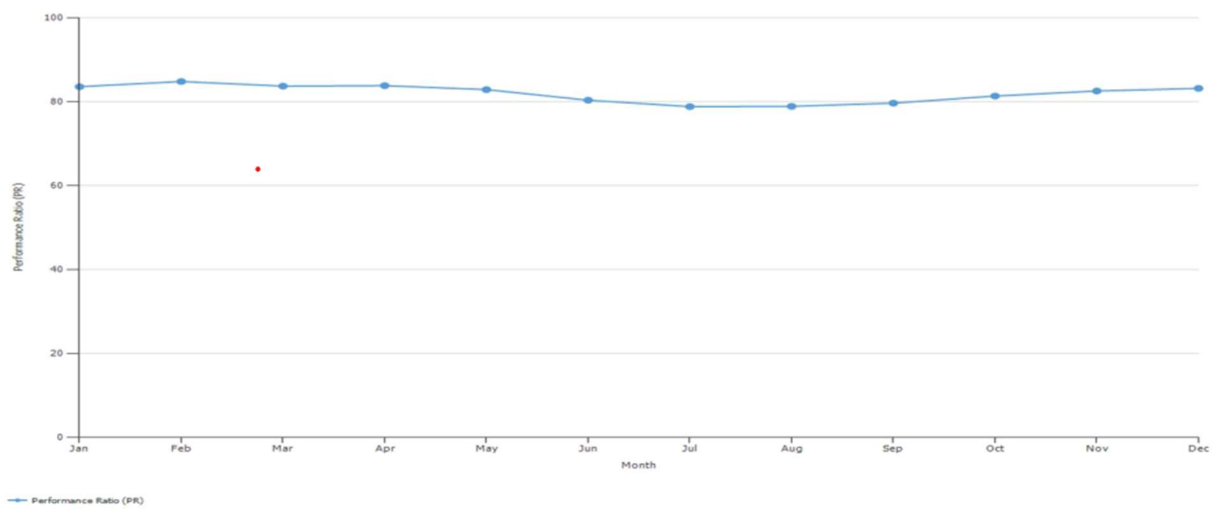
Irradiance per module area

Month	KWh	Performance ratio %
Jan	57,216.7	83.53
Feb	63,806.6	84.77
March	88,944.6	83.67
Apr	111,849.8	83.78
May	126,610.0	82.84
June	141,989.1	80.31
July	141,904.6	78.78
Aug	134,181.3	78.85
Sep	113,630.5	79.61
Oct	85,946.5	81.3
Nov	63,415.3	82.51
Dec	55,370.1	83.13
Total	1,184,865.1	81.41

Zone one Monthly generate energy with monthly Performance ratio



PV Generate Energy (AC grid)



Performance ratio per Invertor

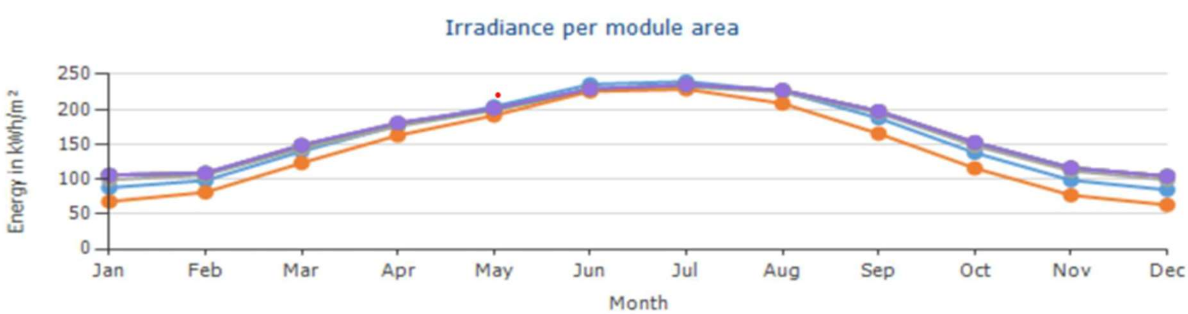
B. Zone Two:

The system power 600KWe/621.3KWp. 1140 number of solar panel with 6 number of 110KW inverters has been used.

Zone Two system layout

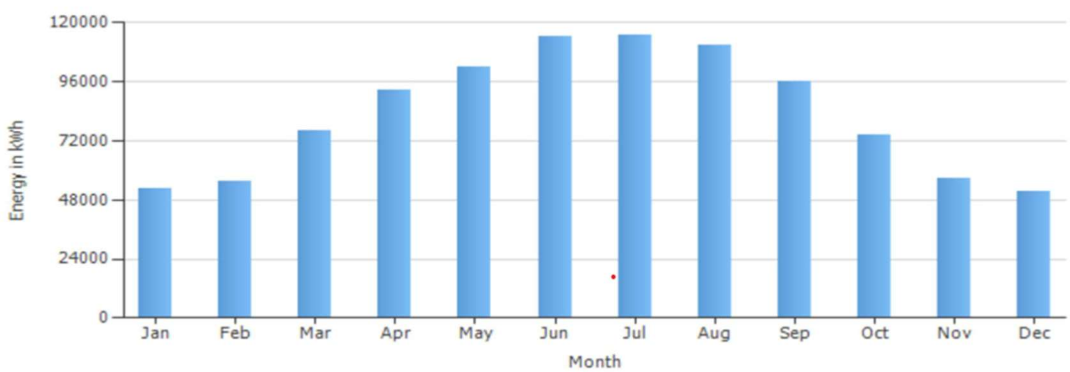
PV System		
PV Generator Output	621,30	kWp
Spec. Annual Yield	1.605,37	kWh/kWp
Performance Ratio (PR)	81,11	%
Yield Reduction due to Shading	7,3	%/Year
Grid Feed-in	997.550	kWh/Year
Grid Feed-in in the first year (incl. module degradation)	985.655	kWh/Year
Standby Consumption (Inverter)	135	kWh/Year
CO_2 Emissions avoided	468.785	kg / year

Monthly irradiance values table is below. The system design is southwest, northeast tilting. The system generates approximately energy of 997,550.4KWh in a year.

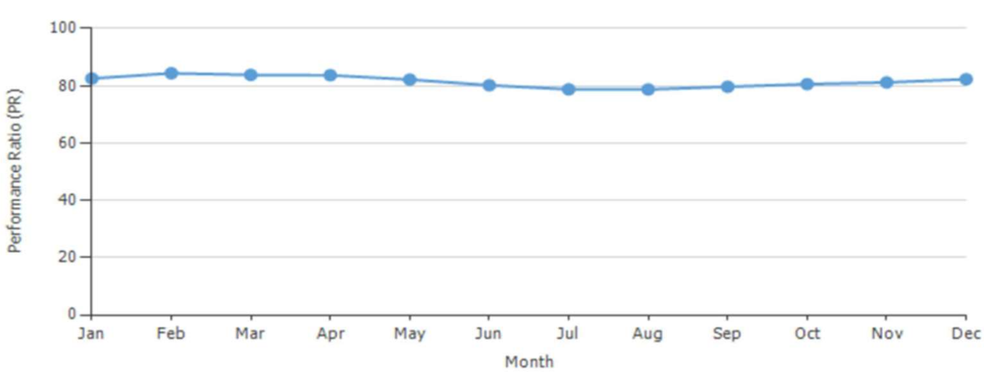


Month	KWh	Performance ratio %
Jan	52,392.0	82.55
Feb	55,659.2	84.37
March	76,005.6	83.78
Apr	92,775.7	83.67
May	102,132.1	82.16
June	114,197.9	80.18
July	114,858.2	78.75
Aug	110,556.9	78.73
Sep	96,350.9	79.64
Oct	74,618.5	80.59
Nov	56,739.5	81.16
Dec	51,264.4	82.29
Total	997,550.4	81.11

Zone Two Monthly generate energy with monthly Performance ratio



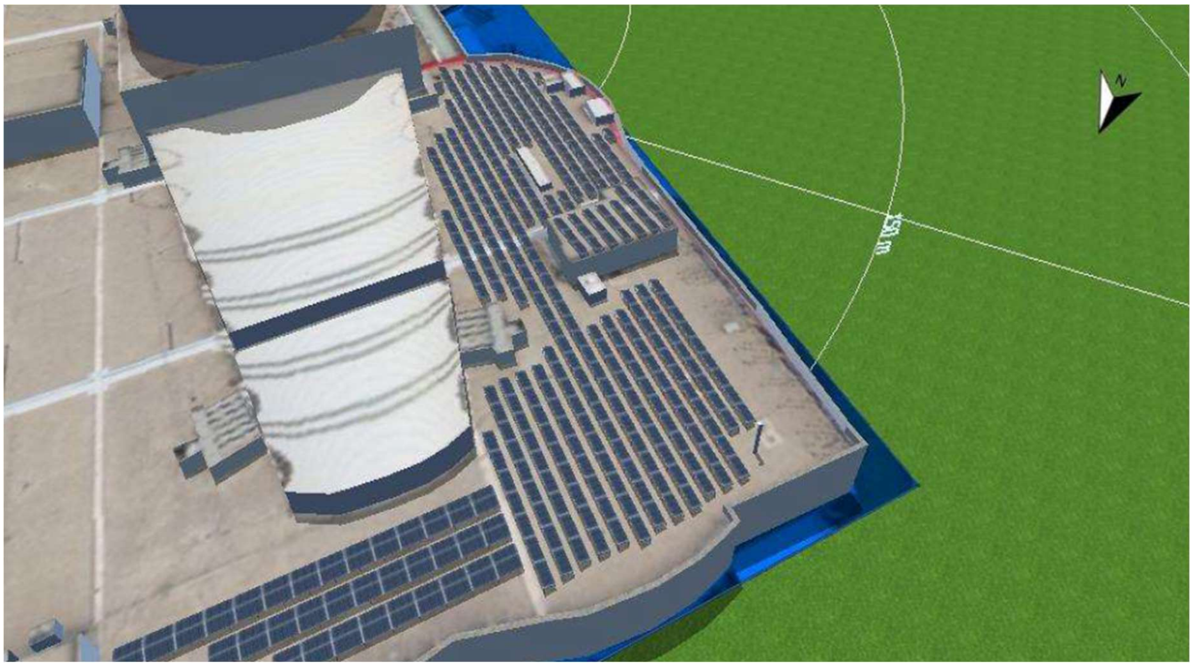
PV Generate Energy (AC grid)



Performance ratio per Invertor

C. Zone Three:

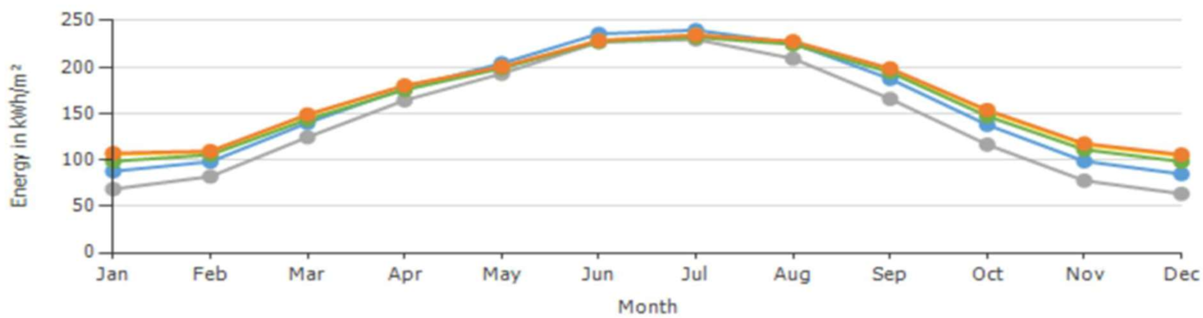
The system power 200KWe/226.75KWp. 415 number of solar panel with 2 number of 110KW inverters has been used.



Zone Three system layout

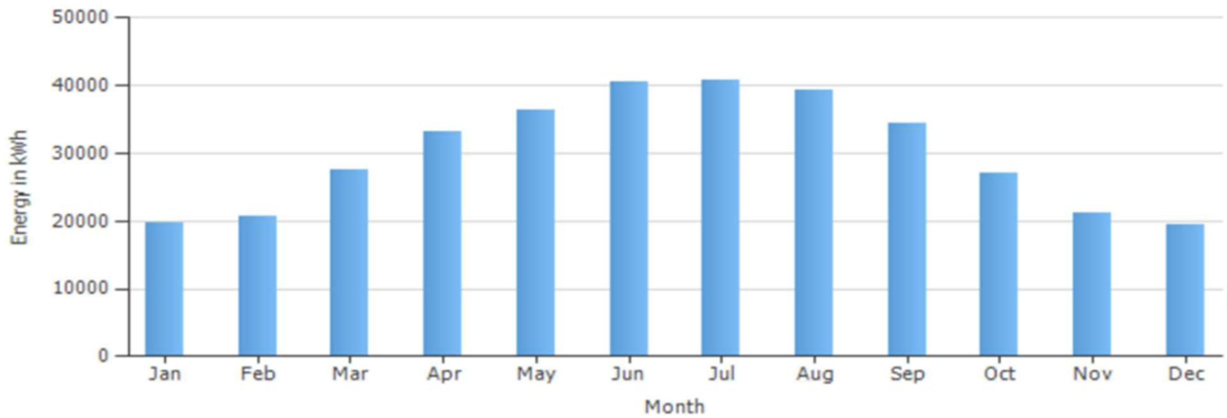
PV System		
PV Generator Output	226,18	kWp
Spec. Annual Yield	1.593,33	kWh/kWp
Performance Ratio (PR)	80,18	%
Yield Reduction due to Shading	7,9	%/Year
Grid Feed-in	360.416	kWh/Year
Grid Feed-in in the first year (incl. module degradation)	356.135	kWh/Year
Standby Consumption (Inverter)	45	kWh/Year
CO_2 Emissions avoided	169.374	kg / year

Monthly irradiance values table is below. The system design is southwest, northeast tilting. The system generates approximately energy of 360,415.70KWh in a year.

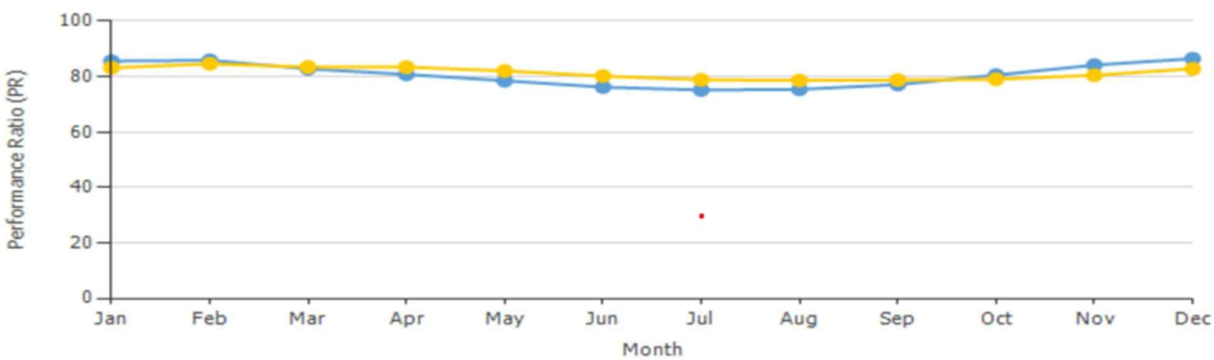


Month	KWh	%
Jan	19,729.4	85.63
Feb	20,619.9	85.89
March	27569.6	82.79
Apr	33,194.2	80.8
May	36,323.8	78.53
June	40,502.3	76.22
July	40,869.2	75.17
Aug	39,413.6	75.4
Sep	34,460.7	77.13
Oct	27,094.7	80.55
Nov	21,188.6	84.17
Dec	19,449.7	86.48
Total	360,415.7	80.18

Zone Three Monthly generate energy with monthly Performance ratio



PV Generate Energy (AC grid)



Performance ratio per Invertor

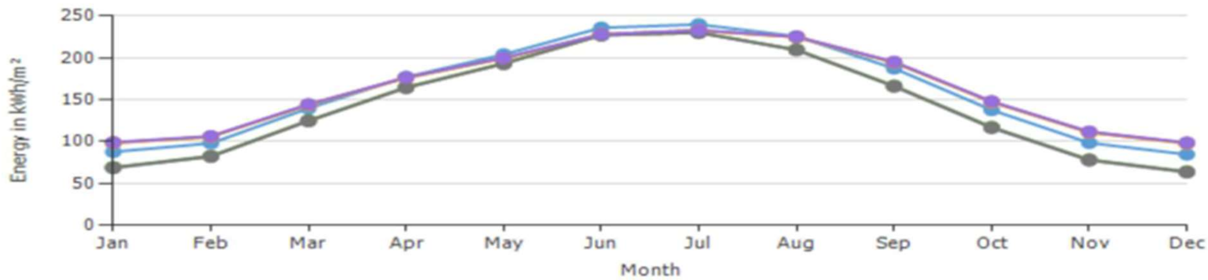
D. Zone Four:

The system power 500KWe/577.7KWp. 1060 number of solar panel with 2 number of 110KW inverters has been used.

Zone Four system layout

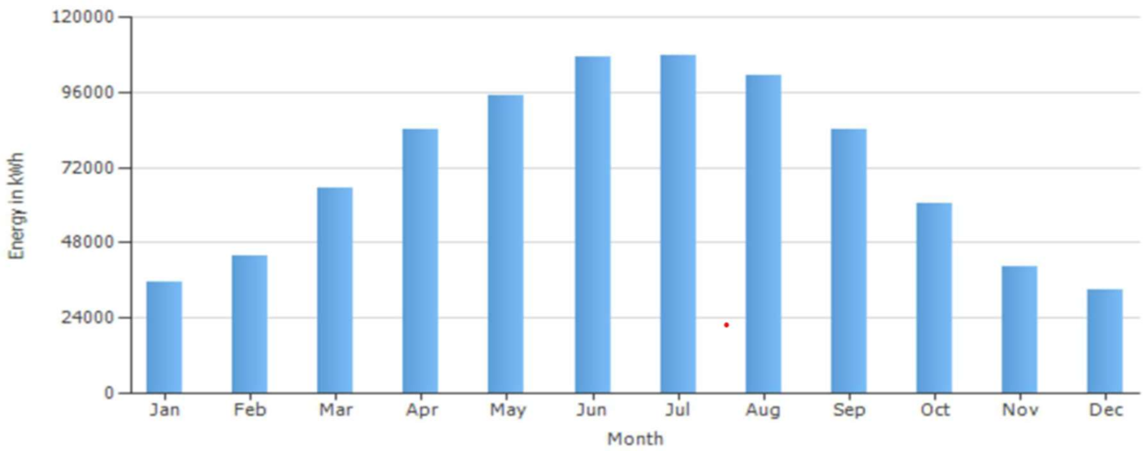
PV System		
PV Generator Output	577,70	kWp
Spec. Annual Yield	1.486,27	kWh/kWp
Performance Ratio (PR)	80,15	%
Yield Reduction due to Shading	8,3	%/Year
Grid Feed-in	858.732	kWh/Year
Grid Feed-in in the first year (incl. module degradation)	848.340	kWh/Year
Standby Consumption (Inverter)	113	kWh/Year
CO_2 Emissions avoided	403.551	kg / year

Monthly irradiance values table is below. The system design is southwest, northeast tilting. It generates approximately energy of 858,732.20KWh in a year.

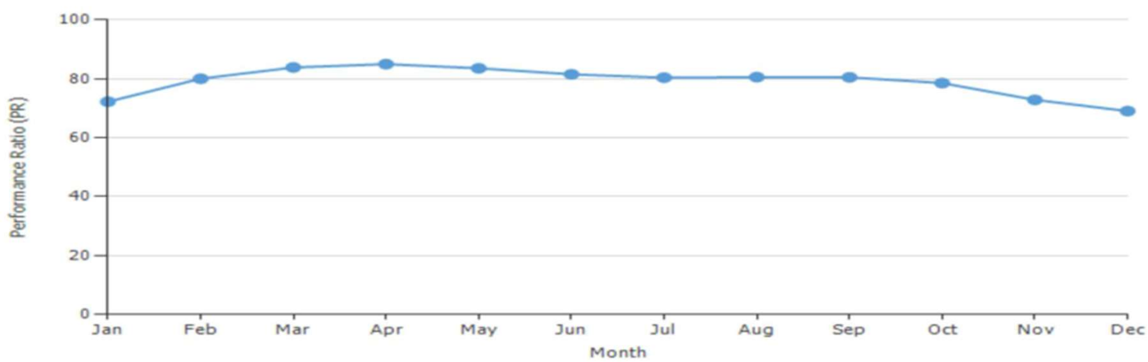


Month	KWh	Performance ratio %
Jan	35,380.8	72.21
Feb	43,920.0	80.03
March	65,483.4	83.83
Apr	84,018.2	84.97
May	95,130.8	83.55
June	107,537.3	81.52
July	107,829.0	80.37
Aug	101,519.0	80.56
Sep	84,394.1	80.49
Oct	60,460.2	78.54
Nov	40,277.5	72.85
Dec	32,781.9	69.05
Total	858,732.2	80.15

Zone Four Monthly generate energy with monthly Performance ratio



PV Generate Energy (AC grid)



Performance ratio per Invertor

Installation of the system:

According to the roof Building installation procedures, height of the mounting supports minimized to 55CM.

Conclusion:

According to the standards, optimum tilt angle for the panels installation was in between 28-35 degree, for north of Iraq. However, due to the power requirement of the project during the operation period, summer time consumption is very high, which means that, the lower the angle of the panel, the better performance in summer is observed. For that reason, 13 degrees has been accepted for the project panel angles. wind load was another aspect that was considered during the mounting of the PV panels specially on the roof top type.

As its seen from previous analysis, due to the climate and weather conditions, performance of the generated energy will be affected massively.

In many projects, calculation of tilt angel made according to standard tilt angle for that area. While many factors, such as season load requirements is not being taken in to consideration as mentioned above.

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