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DESIGN AND ANALYSIS ON-GRID PHOTOVOLTAIC SYSTEMFOR NAJAF PROVINCE - IRAQ

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ABSTRACT

Researchers around the world are now working to develop renewable energy sources to use instead of traditional fossil fuels to avoid global warming. Photovoltaic technology is one of the main renewable energy source in the world. In spite of fast developing, the energy amount generated by photovoltaic systems still small comparing to world need. In this work, for the purpose of addressing the acute shortage in the supply of electricity in Iraq as well as to reduce greenhouse emissions by increasing the proportion of renewable energy from the total energy mix, a grid-connected 3 KW photovoltaic system are built to install on the roofs of houses and residential units at Najaf City-Iraq as the proposed location. PVsyst simulation software from PV_{SYST} SA have been used to design and simulate photovoltaic system. Module orientation, system components, and other design parameters are evaluated. The various losses such as temperature losses, module quality losses, wiring resistance losses, are determined in addition to calculating performance ratio.

Keywords: renewable energy, solar energy, photovoltaic system, PVsyst, Najaf.

INTRODUCTION

Renewable energy is the energy taken from the Earth's unlimited natural resources, such as wind and sunlight. This energy is not harmful to the environment and consider the clean alternative to traditional fossil fuel-based energy. Solar energy, Wind energy, Water flow energy, Ocean energy, Geothermal energy, and Bioenergy are examples of renewable energy[1]. In addition to low maintenance requirements, renewable energy won't run out and has many environmental and health benefits. In places where the sun shines for long hours, solar energy considered the main source of renewable energy[2]. The solar energy can be got by using Solar Photovoltaic (PV) panels as a part of solar power system.

As a result of the rapid development in solar technology field, many people have begun to use solar systems. There are several different types of solar energy systems around the world, and the solar system on the grid is the most widely used [3].

On grid solar system is a solar power system which is connected to the utility grid. An on grid solar system consists of solar panels, inverters, grid connection equipment, and net meter. Unlike off grid power systems, an on grid solar system didn’t includes battery [4]. The solar array absorbs the sunlight and converts it into electricity as a result direct current will be generated in it. The inverter converts the direct current to alternating current. These system work in collaboration with the power grid. In the case when there is not enough sunlight to meet needs, the system runs on the power supplied by the grid. In the case when there is enough sunlight and, the power generated will be more than needs, the extra power will be routed to the grid. The net meter is an important part in this system. It is a device that records the energy consumed from the grid and the energy supplied to the grid and calculate the net value [5].

2. ON-GRID SOLAR SYSTEM

On-grid solar systems or Grid-connected solar systems are the most common used systems by businesses and homes. On-grid solar systems are connected to the grid across distribution board and common solar inverters which convert the direct current to alternating current [6].

When the solar system-generate power more than home need, the extra power is transferred into the public grid across the distribution board which is connected to the inverter. These systems do not need batteries, since they are connected to the public grid, which acts as a large battery that an oversupply of generated power is transported to it while it also supplies the home with power when the generated power in the solar system is less than home need. An on grid solar system consists of the following components:

2.1 PV Array Module

The Solar cells use light energy to generate electricity through the photovoltaic effect. Wafer-based crystalline silicon cells and thin-film cells are used by most modules [7]. Cells need to be rigid in order to protected from mechanical damage, so, it covered by glass while some modules that based on thin-film cells are semi-flexible. In order to get a desired voltage, the cells are connected in series, and then in parallel to increase the current. 90 percent of worldwide solar cells production are produced from crystalline silicon. It made of multi crystalline and mono crystalline silicon. The rest 10 percent is made up of thin-film technology [8]. GG1H-290 Bifacial PERC 60 cells - Double Glass module from GTC Solar Turkey was selected for this work. Figure 1 shows the relation between efficiency and Irradiance for selected module.

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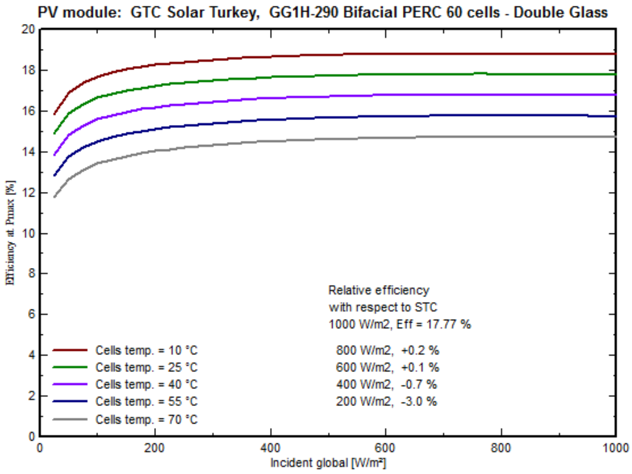

Figure-1. Efficiency versus Irradiance for selected PV module.

2.2 Inverter

The inverter is very important part of a grid connected solar cell system. The inverter converts direct current that extracted from the solar cells to alternating current at the suitable voltage and frequency for feeding into the public grid or for supplying loads. The best quality inverter must be chosen, the main considerations in on grid inverter choice are its maximum power and its efficiency. Ingecon Sun 2.5 HF inverter from Ingeteam was selected for this work. Figure-2 shows the relation between efficiency and AC output power for selected inverter.

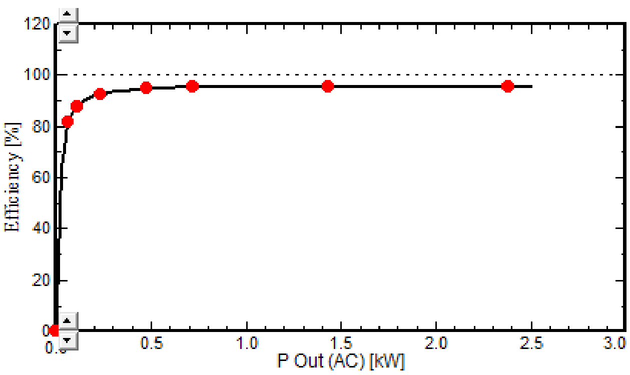

Figure-2. Efficiency versus AC output power for selected inverter.

2.3 Grid Connection Equipment

Connection equipment include main distribution panel which is represents the connection point between home electrical network and utility grid, DC Disconnect, Overcurrent Protection (Fuses and/or breakers), Ground Fault Protection, and AC Disconnect.

2.4 Net Meter

Net metering is a way of measure the power from multi sources like renewable and utility grid. Grid-connected solar systems allow the system owner to use both sources (solar cell system and utility grid). The net meter measures power injected into the grid when sun shines and the power taken from grid when the load needs more power or during the night. In the past, analog meter was used, this meter would spin forwards when consumed power is from the grid, and backwards when the power produced from solar array. The meter reading would be "net out" the difference at the end of each period [9]. Today the analog meter replaced by the digital meter with the same concept.

3. SYSTEM CONFIGURATION

To build on grid solar system, the components are connected as shown in Figure-3. This configuration ensures parallel operation with electric utility grid. The principle component in this system is the inverter. By the inverter the DC power which produced by the solar cell array is converted into AC power which must be consistent with the requirements of the utility grid. A distribution panel represents interface between the solar system AC output circuit and the utility grid.

This allows output power of the solar system to supply on-site loads, or to feed the grid when the solar system output is more than the on-site loads requirements. when the requirements of on-site loads are more than the solar system output, the grid utility will be supply the balance of power required.

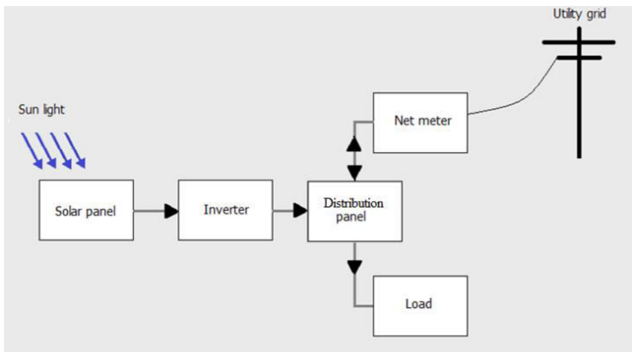

Figure-3. System configuration.

PVsyst V6.85 software from PVSYST SA used in this paper. PVsyst is a software package for data analysis of complete PV systems. It can process some types of solar system (on-grid, off-grid, pumping, and DC-grid PV systems). PVsyst software includes extensive PV systems components and meteo databases, in addition to tools using in general solar energy systems. PVsyst version 6.85 used in this work [10].

4. SIMULATION AND RESULTS

The proposed site is Hayy al Furat which located at Najaf city, Najaf province, Iraq. The parameters of geographical location are listed in Table-1.

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Table-1. Hayy al Furat - Najaf geographical parameters.

Site	Najaf
Country	Iraq
Region	Asia
Source	Ḥayy al Furāt_MN72mod.SIT - Meteonorm 7.2
Latitude	32.0217;°
Longitude	44.3502;°
Altitude	38;m
Time Zone	3;GMT

Figure-4 shows the daily-hour horizon line drawing for Najaf. Also it shows the height of sun at specific hour of the day and month with respect to azimuth angle.

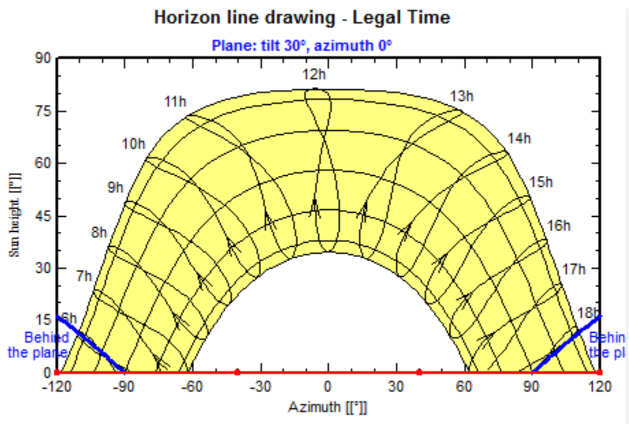

Figure-4. Solar paths at Najaf.

PVsyst software includes two databases, Meteonorm 7.2, and NASA-SSE, the meteorological data file can be got from one of these databases. Horizontal global irradiance, and ambient temperature are the required parameters in the meteorological file. Another parameter, horizontal diffuse irradiance, and wind velocity are optional parameters, these optional parameters make the result more accurate. Table-2 shows the acquired meteorological data from Hayy al Furat- Najaf site based on Meteonorm 7.2 database.

Table-2. Monthly Meteo for Hayy al Furat.

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	WindVel m/s
January	85.9	37.09	10.64	2.9
February	104.2	51.82	13.73	3.3
March	150.9	70.73	18.97	3.5
April	172.3	82.08	23.99	3.6
May	196.8	97.80	30.66	3.6
June	210.5	93.95	34.38	3.8
July	208.7	97.61	36.76	3.8
August	200.0	88.32	36.50	3.2
September	169.2	68.95	31.79	2.9
October	129.0	61.16	26.65	2.8
November	96.2	41.36	17.58	2.7
December	81.3	34.52	12.47	2.7
Year	1805.1	825.39	24.57	3.2

Figure-5 shows the simulation parameters and main results. The annual production of PV system will be 4684 kWh/yr and the performance ratio will be 0.789.

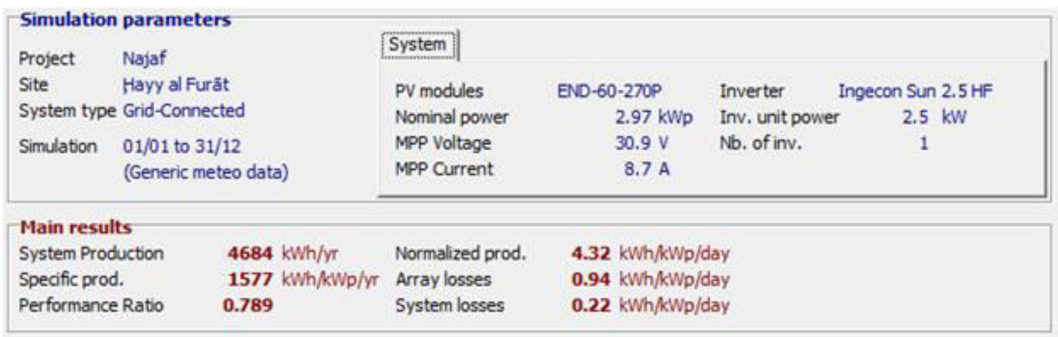

Figure-5. Simulation parameter and main results.

From Table-3, it can be note that the performance rate of the system decrease during the summer months to reach the lowest value (0.771) in August which is the hottest month in the year at the selected location (Najaf). It can also be noted that the performance rate of the system increase during the winter months to reach the highest value (0.884) in December which is the coldest month in the year at the selected location. This shows that the performance ratio of the system is inversely proportional to temperature.

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Table-3. Energy use and Users' needs.

	E_Grid kWh	PR
January	319.8	0.868
February	339.1	0.854
March	425.9	0.819
April	423.8	0.795
May	428.1	0.767
June	430.0	0.748
July	427.9	0.739
August	439.5	0.736
September	426.2	0.755
October	373.2	0.787
November	340.7	0.839
December	309.8	0.862
Year	4683.9	0.789

PVsyst software calculates all types of the losses and shows them in a diagram which is represent system loss flow chart as shown in Figure-6. The diagram includes three parts, the first part (upper part) of the diagram includes optical losses, the second part (middle part) includes array losses, and the third part (lower part) includes system losses.

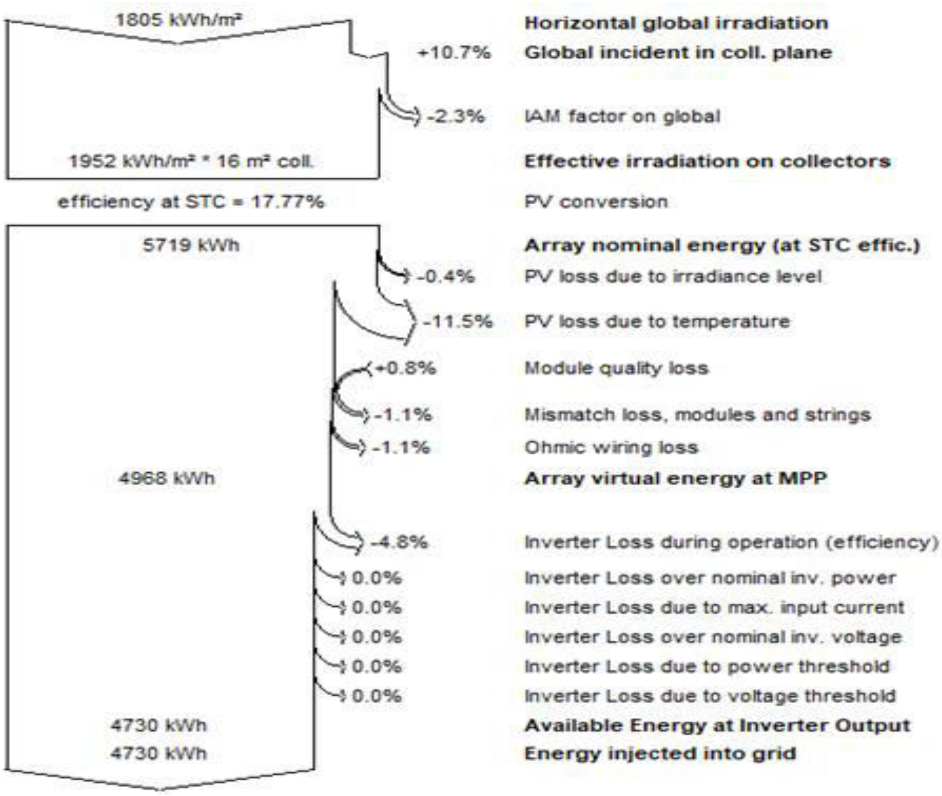

Figure-6. Loss diagram over the one year.

In the system analysis, performance ratio (PR) plays an important role. Figure-7 shows the performance ratio of the system for each month of the year. This figure shows that the period from October to March, which represent the winter months of selected site (Najaf) has the highest performance ratio, while the period from June to September has the lowest performance ratio. Total system performance can be got in form the performance ratio.

Figure-8 represents production graph which shows the value of normalized productions in each month of the year, also PV-array losses, system loss, and produced useful energy is explained with different colors. This graph shows that in the period from April to September, the highest energy generated in the year, while in the period from December to January is the lowest generating energy, On the other hand in the periods from February to March and from October to November, a good amount of energy generated. Total energy of the system can be predicted from this graph.

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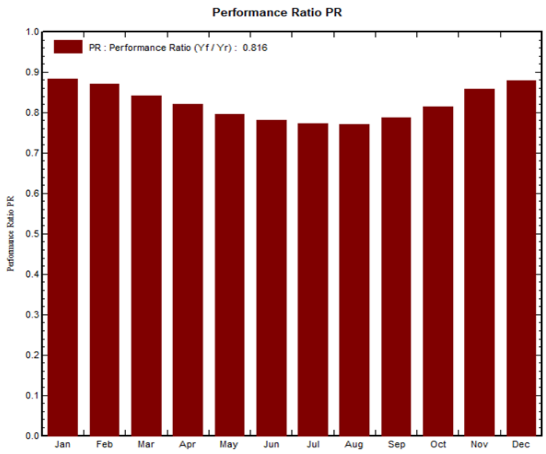

Figure-7. Performance Ratio(PR).

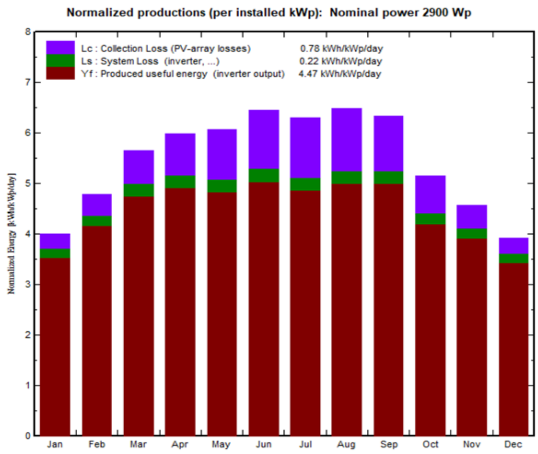

Figure-8. Normalized production per month.

Figure-9 shows a good correlation between the daily irradiation in the collector plane which represented on the x-axis, and the system's production which represented on the y-axis with minimum dispersion. Each point on the graph represents the production of one day.

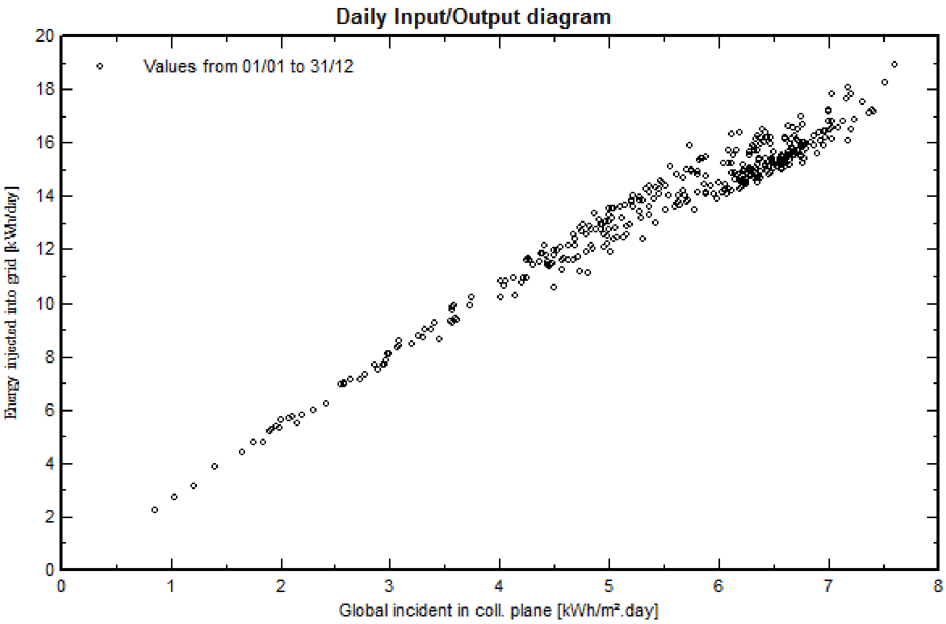

Figure-9. Daily input/output diagram.

5. CONCLUSIONS

Depending on data of design simulation which generated by the PVSyst software, the best tilt angle was 30º and the best azimuth angle was 0º for the Najaf location. Using 270W END-60-270P Si-poly - Double Glass module and 2.5 kW Ingecon Sun 2.5 HF inverter for system building, the performance ratio was 0.789 and the annual system power production collection was estimated at 4684 kWh per year.

There are more than 100000 houses and residential units at Najaf City, the roof area of each of them is more than 25 square meters. In the case of installing this system for each housing unit, we get power production of 297 megawatt hour. The total need of Najaf city is 850 Megawatts hour so, the energy amount generated by photovoltaic systems will be 35% from city need.

The use of photovoltaic systems in Najaf is possible and effective because Najaf has about 300 sunny days a year, but it requires funding. The most important constraint is the cost, as the cost still exceeds the capacity of ordinary Iraqi citizens without government assistance or bank loans.

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