PV-Solar Power Generation in Educational Institutions

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Abstract. The PV solar system on the rooftop of buildings is a good source of renewable electric energy. Iraq has very large number of educational institutions with large non-invested rooftop with shortage of electrical energy supply. The present work aims at construction a simulation for PV-System action installed on rooftop of educational institutions in Baghdad using Green Power Solution (GPS) and PV-Syst programs. Based on the surface area of the schools’ roofs, the GPS program estimated three main PV-Systems which can be carried out, 63kW, 50kW, and 30kW in order to supply the electric power to selected school. Due to allocating few hours for school’s studying time along the year, the suitable PV-System is on-grid connection. The results indicated that the annual system performance ratio is 81.9% and the annual output power of these systems were 111.0 MWh/year, 88 MWh/year and 51.4 MWh/year respectively, 19.3MWh/year of them was consumed for this school and the rest is a feedback for grid. This green generation reduced the amount of emission CO₂ by 73.981 tons, 62.216 tons and 36.3398 tons per year for systems 63kW, 50kW and 30kW respectively. The results also appear that the initial capital cost of each system can be recovered during the first six years of system operation.

Keywords: PV-Solar system, performance of PV- module, PV-Feasibility study, rooftop solar system, Carbon dioxide emissions.

1. Introduction

Electric generation by PV Solar system is one of the suitable means in a generation the power in Iraq, due to the negative environmental influence of fossil fuel, shortage in supply of electric energy, losses on the transformation sector, and the shortage between the generation of energy and increasing of demand [1]. Iraq has a high rate of solar irradiation and the maximum value of irradiation distributed in the south and mid of it, the average annual irradiation of Baghdad is about 5.27 kWh/m²/day [2]. The Iraqi Ministry of Electricity has adopted a new policy by generating solar power at the center of loads in city where the domestic sector and government buildings are the largest in energy consumption. The most important projects are the 1MW project at the Ministry of Electricity and the 100 kW project in the oil training center department and other smaller projects [3]. Hashim et al achieved an assessment and evaluate the performance of 15 kW system for 12 months period of the year 2018 under Baghdad environment and compare it with simulated software of PV system, the anual energy yield was 23.77 MWh/ year, it is found that the total of annual energy yield forecasted by PV-Syst software was 24.08 MWh/ year, annual average performance ratio was75.55% with system efficiency of 13.27% [4]. Mensah et al presented a study of a Grid-Tied of PV solar system in the northern part of Ghana at
Navrongo. They found that performance ratio was 70.4% and the mean annually generated energy was 3547.8 MWh and payback period time is found to be 14.95 years [5]. Environmentally, there are many factors influence negatively on solar PV performance such as increasing in environment temperature [6], and dust [7, 8]. On the other hand PV solar systems can reduce the emission of CO₂ [9, 10]. Dondariya et al, modeling and study the feasibility of the system in the proposed location. These can be done on the various available software platforms and the reports generated can be used to compare and get the best-suited model among them in implementing the same at field level [11]. Many projectors had achieved for a green generator in the world. Tesla with support from the South Australian Government is developing a network of up to 50,000 home solar PV and Power wall battery systems across South Australia – all working together to form the world’s largest virtual power system. A virtual power system is a network of home solar photovoltaic (PV) and battery systems working together to generate and store energy, and feed energy into the grid. [12]. Lazaroiu et al, 2016, studied and analyzes the optimized operation of a virtual power system owner on the day-ahead market for maximizing his overall profit. The virtual power system is composed of distributed energy resources with variable produced power, energy storage systems, and classical generating units [13]. Al-Khazzar study the performance of a 5 KW Photovoltaic grid tied system is suggested to cover the demand of an Iraqi primary school. The PV-Syst simulation software is selected, the performance ratio for the system in Baghdad is 0.825 and about 9.82MWh is generated by the system per year, 62.7% is consumed by the load and the remaining is injected to the national grid. The results showed that the primary capital cost is $5,442 which is repaid after five and a half years [14]. Alfahed et al, study the 4.0kW stand-alone Solar PV system for providing electricity to a sample home in the Haur Al-Hammar region in the south of Iraq, by using mathematical equations with Excel worksheet and PVsyst 6.68 software simulation package [15]. The present work aims at build a simulation for green generation by PV-Solar system installed on rooftop of schools using Green Power Solution (GPS) amd PV-Syst programs.

2. System Description

The number of public school buildings in Iraq in 2013 are (17435), including (2520) in Baghdad [16]. The schools in Iraq (kindergartens, primary, intermediate, preparatory) ranging from a small area to a large area. The school chosen for the present study with unused rooftop is a secondary school (Al-Maqdam) (33.3489923, 44.4739866) in the Al-Baladiyat district in Baghdad. The study achieved by a PV-Syst. There are several hundred of schools having same design and area, Figure 1 shows the satellite image for the school location.

![Figure 1. Satellite image for the school located in Baghdad- Iraq](image-url)
The first system designs to generate 63kWh and the number of modules are 225. The solar panels are considered to be southward, the ideal direction for fixed systems, as shown in Figure 2a. The tilt angle for modules is 15o to suitable for the summer season where the energy demand is Maximum in Iraq. The second designs with number of modules are 178. The system designs to generate 50kW. The solar panels are considered to be southward as shown in Figure 2b with tilt angle for modules is 15o. From the figure we observe the full exploitation of the surface area of the school. The third design with the number of modules is 104, the system designs to generate 30kW. The solar modules are considered to be southward as shown in Figure 2 c with tilt angle for modules is 15o.

![Figure 2. Schema of systems a-63kW, b-50kW, c-30kW.](image)

The solar modulestype that can be used isREC 280TP (280W) which is efficient and bear high temperatures. The specification of the PV module is listed in Table 1.

| Parameter                | Value       | Parameter                | Value       |
|--------------------------|-------------|--------------------------|-------------|
| Dimensions               | 1958*9991*50(mm) | p<sub>max</sub>            | 280(W)      |
| weight                   | 27 (kg)     | Temperature coefficient V<sub>OC</sub> | -0.31(V/°C) |
| No.of Cells              | 72 (in series) | Temperature coefficient I<sub>sc</sub> | 0.045% /°C  |
| I<sub>sc</sub>            | 9.40(A)     | Temperature coefficient P<sub>max</sub> | -0.39 %/°C  |
| V<sub>OC</sub>           | 39.2(V)     | Module efficiency         | 17%         |
| I<sub>mp</sub>           | 8.78(A)     | NOCT                     | 44.6(°C)    |
| V<sub>mp</sub>           | 31.9(V)     | Type of cell              | Pc-Si       |

Component of 63KW, 50KW and 30KW system is listed in Table 2.
Table 2. Component of 63KWh system.

| Component | Name               | Count(63KW) | Count(50KW) | Count(30KW) |
|-----------|--------------------|-------------|-------------|-------------|
| Inverters | SuunyTripower      | 6(60.0 kW)  | 4(40KW)     | 3(30KW)     |
|           | 10000TI(SMA)       |             |             |             |
| Strings   | 10 AWG(Copper)     | 12(200.8 m) | 10(193.4m)  | 6(154.9m)   |
| Module    | REC Solar, REC280TP| 255(63.0 kW)| 178(49.8KW) | 104(29.1KW) |

3. Estimation of the energy production

The practical short circuit current $I_{sc}$, and practical open circuit voltage $V_{oc}$ are given as [18, 19].

$$I_{sc}(GT) = I_{sc}(STC) \times GT \quad \text{in } 1 \text{ KW/m}^2$$  \hspace{1cm} (1)

$$V_{oc}(T_c) = V_{oc}(STC) - 0.0023 \times \text{number of cell} \times (T_c - 25)$$  \hspace{1cm} (2)

Where (GT) is the solar irradiance, STC is a standard test conditions.

The output power ($P_{out}$) of the PV solar module is given by the following equation [14, 15].

$$P_{out}(GT, T_c) = I_{sc}(GT) \times V_{oc}(T_c)$$  \hspace{1cm} (3)

4. Energy Demand of the School

The school has 24 rooms, only 16 rooms use and the others using as storage. Table 3 shows the details of the equipment and their wattage. The total daily power that required supplying by the solar system is estimated at 138.4 kWh/day.

Table 3. Daily Power required

| Name of equipment | No | Consumption Watt | Total Consumption kWh | Hours of operation | Total Consumption kwh/day |
|-------------------|----|------------------|-----------------------|-------------------|--------------------------|
| Air-condition     | 4  | 3000             | 12                    | 8                 | 96                       |
| Lamp              | 70 | 40               | 2.8                   | 8                 | 22.4                     |
| Fan               | 17 | 100              | 1.7                   | 8                 | 13.6                     |
| Refrigerate       | 4  | 200              | 0.8                   | 8                 | 6.4                      |
| Laptop            | 2  | 100              | 0.2                   | 8                 | 1.6                      |
| Water pump        | 1  | 370              | 0.37                  | 1                 | 0.37                     |
| Server            | 1  | 15               | 0.015                 | 6                 | 0.09                     |
| Mobile charger    | 2  | 5                | 0.01                  | 1                 | 0.01                     |
| Printer Mach      | 2  | 720              | 1.440                 | 1                 | 1.440                    |
| Sum               |    |                  | 19.335                |                   | 141.91                   |
The school is open only 168 days per year and closed for 197 days, the real demand of energy for a year is 23.848MWh/year; also the suitable connection for this system is on grid connection or hybrid connection due to the longtime of closing of schools.

5. Results and Discussion

The amount of annual incident solar irradiance with tilt angle 15° is 1964.1MWh. The monthly solar irradiance and temperature in Baghdad city as shown in Figure 5. Through the study duration in Iraqi schools (October-May) the average temperature is not hot between (10°-30°) as shown in figure 3 and therefore does not require a high cooling voltage but only lighting and fans and electric heater instead than air-condition, which does not consume so much of system power during the study season. The increase in temperature causes a decrease the power in summer with an increase in the amount of solar irradiance in same time. The increase in output power in summer months where the school is closing leads to supply the grid by the power at a peak load of energy in Iraq.

![Figure 3. The monthly solar irradiance and temperature in Baghdad city.](image)

The average loss in power due to the increasing in temperature is about 7.6%. The average of ambient temperature is 24.2°C where the average operating Cell temperature is 36.1°C during the day. Also an important source of losses in power production is the accumulation of dust and dirt on the solar panel, which about 2.0% of the production. The total loses of solar power production is 17.2%. Figure 4 illustrates all sources of energy loss in the system.
Figure 4. Sources of the system losses.

The AC power for every month for a system of 63kW, 50kW and 30kW are shown in Figures 5, 6, and 7 respectively.

Figure 5. The AC power for every month of year for a system of 63kW.
The AC annual output power produced from systems 63 kW, 50kW and 30kW were 111.0 MWh, 88 MWh and 51.4 MWh respectively, with annual operating hours of 4540, 24 kwh/year of them was consumed for school services and the rest were a feed of grid. In the hot summer season where the longest sunny days are actualized and due to high incident solar radiation the gain in output power was higher than the loss in power that caused by heat. The cost of establishing the solar power system (mechanical and electrical components, mechanical and electrical works) is 1$ per watt in Iraq market. The cost of the solar power systems 63kW, 50kW and 30kW were 63000$, 30000$ and 50000$ respectively. Investment of the rooftop of the school provides free space of 225m$^2$, 178m$^2$ and 104 m$^2$ for systems 63kW, 50kW and 30kW respectively. The price per square meter of school land is 1250$ and therefore the project cost is reduced by 281250$ (342.6%), 172500$ (345%) and 100000$ (333%) for systems of 63kW, 50kW and 30kW respectively.

The subsidized price of production power is 0.1$ per KWh in Iraq, the annual price of producing solar power in the present systems were (11100$, 8800$ and 5140$ for systems of 63kW,
50kW and 30kW respectively. The design cost of three systems could be refunded after about (5.67) year and the solar system could work more than 25 year.

By GPS program, the performance ratio for the system was 81.9%. The monthly reduction of emission of CO$_2$ by the production of solar power is shown in figures 8, 9 and 10 for systems 63kW, 50kW, 30kW respectively.

Figure 8. Reduction of emission of CO$_2$ with solar power for a system of 63kW.

Figure 9. Reduction of emission of CO$_2$ with solar power for a system of 50kW.
by using solar power instead of fossil fuel in the present system, the annual amount of emission CO$_2$ reduce by 73.981 tones, 62.216 tones and 36.3398 tones for systems 63kW, 50kW and 30kW respectively. The system’s performance was compared with other installed PV system to have a good idea of PV solar system performance in current study as shown in Table 4.

Table 4. Performance Study Comparison of PV Systems in Different Countries

| Location | Power (kWp) | Type of PV technology | Energy yield MWh/year | PR (%) | Payback | Ref                      |
|----------|-------------|-----------------------|-----------------------|--------|---------|--------------------------|
| Iran     | 5           | Poly-crystallineSi    | 9.428                 | 11.6   |         | Korsavi et al, 2018      |
| Iraq     | 15          | HITHeterojunction     | 24.08                 | 75     | -       | Hisham, 2019             |
| Iraq     | 5           | poly-crystallineSi    | 9.820                 | 82.5   | 5.5     | Al-Khazzar, 2018         |
| Ghana    | 2500        | poly-crystallineSi    | 3547.8                | 70.4   | 14.95   | Mensah et al, 2019       |
| Iraq     | 63, 50, 30  | poly-crystallineSi    | 111.0, 88, 51.4       | 81.9   | 5.67    | Present study            |

Also, the system can be a free realistic science lab for the school. This laboratory can explain the photoelectric phenomenon, semiconductors, types of (solar) battery connection, types of energy and the relationship between them and the conversion from photovoltaic to electrical and thermal energy, voltage, current, power and power, direct, alternating current, etc.

6. CONCLUSION
Iraqui environment is a benefit for green generation and it can invest the rooftop of educational institutions to generate electric power by PV-Solar systems for these institutions and supply the grid with additional power. The localized green generation reduces transport power losses and reduces the emission of CO$_2$.

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