RESEDINTAIL CONSTRUCTION POWERED BY PV GRID-CONNECTED SYSTEM

I. Etier, A. Al Tarabsheh, A. Atyat, B. Abu Al-Haw, M. Al-Shatte,M. Abd Al-Qader, O. Al-Rousan, T. Al-Maharmeh, Y. Al-Saidi.*

The Hashemite University, Electrical Engineering Department, 13115 Zarqa, Jordan.
*Corresponding author: etier@hu.edu.jo

1. ABSTRACT

This paper aims to design a solar photovoltaic (PV) grid-connected system that can handle out the electrical load of a residential construction. The parameters that are taken into account are; the available roof area, existing solar radiation, sizing of PV modules and inverters, and payback period. This paper also calculates the proper area of the PV panels that can be handled within the available roof area. The efficiency of the PV panels in this work is 14.2%. Since the yearly global solar radiation at Amman at inclination angle of 30^o is 2250 kWh/m^2, the energy supplied from this study in one year is 50.2 MWh.

2. INTRODUCTION

Photovoltaic systems can be divided into Stand-alone and Grid-connected PV system. The stand-alone PV systems are used in areas that are not easily accessible or have no access to electricity mains but also where simple grid connection is less economic or not necessary for the application wanted. An inverter may also be included in the system to convert the direct current (DC) generated by the photovoltaic modules to the alternating current form (AC) required by normal appliances. Stand-alone systems are (telecommunication, water pumping, street furniture, illumination, etc.) and rural domestic applications (isolated housing). This system is mostly used in remote or rural areas where the main electricity supply from the utility is not available. Virtually any electrical load can be met with a photovoltaic power system, realizing each system may have specific requirements. Energy storage (batteries) may be required. But there are no technical reasons that preclude photovoltaics from generating electricity for any load, given that sufficient physical area for collectors, solar access, and money are available for the application. The role for photovoltaics in the stand-alone and grid-connected PV is very different, and the design decisions and performance requirements are very different as well. [1]

Applications that fall into the all photovoltaic electric power system category can be both ac and dc, and may or may not have some sort of storage. The design of these stand-alone systems requires that the photovoltaics generate enough electricity to supply 100% of the electrical energy at the site.

3. GRID-CONNECTED PV SYSTEM

Photovoltaic systems can also be connected to the local electricity network. The electricity generated by the photovoltaic system can either be used immediately (e.g. for systems installed on offices and other commercial buildings), or can be sold to one of the electricity supply companies. Power can be bought back from the network when the solar system is unable to provide the electricity required (e.g. at night). [2]

The Grid-connected system is used for its simplicity in design and installation, high efficiency, low cost, longer lifetime, and reliability. Figure 1 shows the main components that comprise any PV system which are:

1. The PV modules convert the sun’s energy to direct current (DC) electrical energy.

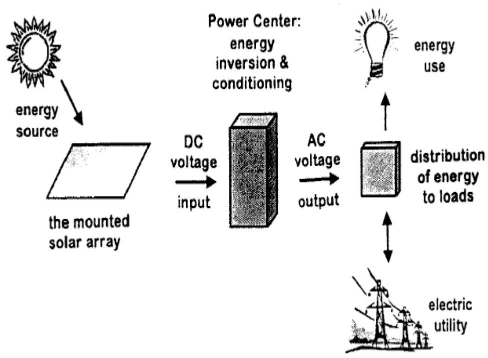

Figure 1: System components.

2. The MPPT (Maximum Power Point Tracker) tracks the time varying maximum power point of the solar array.
3. The power center custom- configured for the system, will include:
   a. A low- distribution inverter transforms the DC to AC.
   b. A connection to your breaker panel.
4. The system data monitor shows how much energy is flowing in from the sources and out to the loads.

5. The balance of system hardware consists of wiring, termination, ground fault interrupt, surge protection, and DC/AC disconnects.

6. MPPT ALGORITHM

In order to track the time varying maximum power point of the solar array depending on its operating conditions of insulation and temperature, the MPPT (maximum power point tracking) plays an important role for the PV systems. A variety of MPPT schemes differ in their complexity, speed of convergence, number of used sensors, cost, and type of implementation and domain of application. [3]

7. PV SYSTEM INVERTER

Inverters convert the direct current (DC) created by the solar modules into alternating current (AC) suitable for the grid. At the same time, they monitor and regulate the feeding of the current into the grid, automatically disconnecting the PV generator from the grid in the event of a fault or grid failure. The first stage of the conversion is the DC/DC acting as MPPT, and the second is DC/AC which injects this power to the grid with low THD. [3]

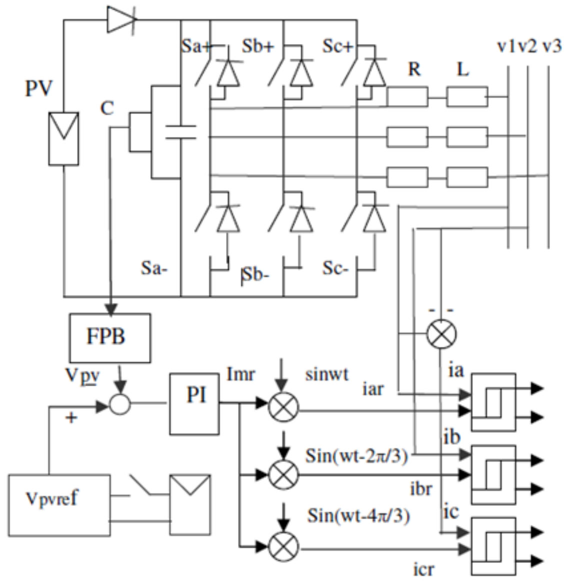

Figure 2: The power circuit of a grid connected PV system.

The inverter has the following characteristics:

1. The balanced three phase's power source represents the power grid.
2. The DC/AC voltage source inverter (VSI) and R-L components simulate the effect of connecting transformer in the circuit.
3. The DC side consists of a photovoltaic (PV) power source.

8. PI CONTROLLER

In order to implement the control algorithm in closed loop, the dc side capacitor voltage is sensed and then compared with a reference value, the obtained error $e = V_{pvref} - V_c$ is used as input for PI controller as shown in the block diagram of Figure 3. The diagram represents a 2^{nd} order system where the response of MPPT of such system depends on the pole assignment of PI control loop.

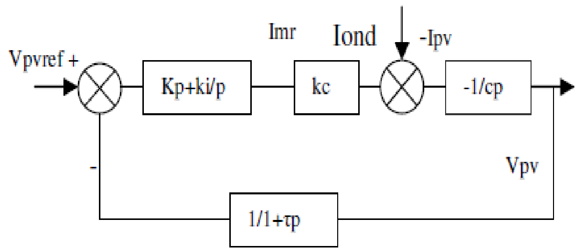

Figure 3: PI controller block-diagram.

The aim of the PI controller is to give a fixed current versus a variable radiation, as shown in the Figure 4, where the PV generator is simulated during a decrease of radiation.

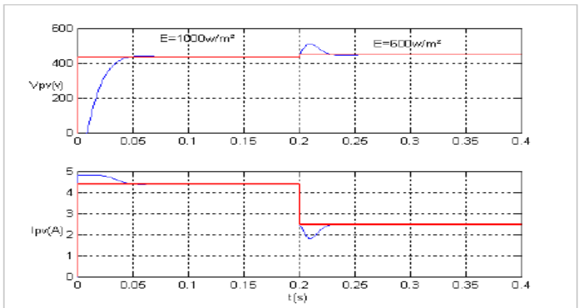

Figure 4: Output current and voltage of PV generator during a decrease of radiation.

9. CASE STUDY

In order to achieve the optimum design, we have to determine the available area, and fully understand the electrical load. The case study in this work is a residential construction (villa), located in Amman at region called Bader. The area of the land is 2720 m^2; in our project we considered the roof of the building only, as shown in Figure.5.

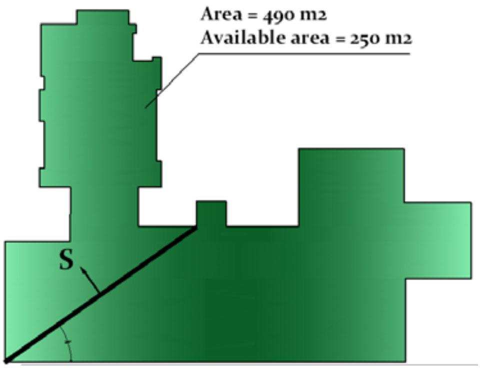

Figure 5: Available area and direction of the south.

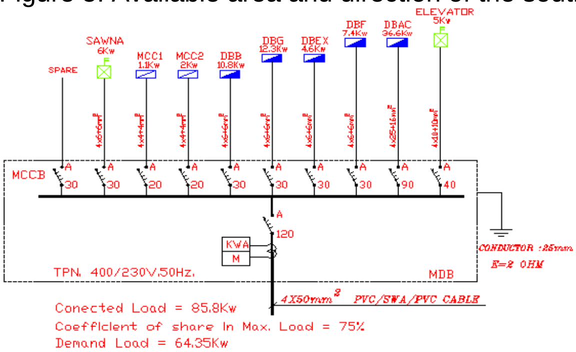

Figure 6: Main distribution board [6], [7]

The connected electrical load in the villa is 85.8 kW. In order to determine the maximum demand load, a coefficient $\gamma = 0.75$ has to be multiplied by the load itself. The result is 64.35 kW. The main distribution board is shown in Figure.6.

10. SYSTEM DESIGN

The yearly global solar radiation at Amman at inclination angle of 30^{o} is 2250 kWh/m^{2}[4], the global solar radiation depends on many factors (location, climate, altitude……). To know how much power the PV can produce, we calculate the number of solar modules that the available area can handle taking in account:The direction of the south:

1. The problem of the shadow of the modules itself.
2. Some architectural considerations.

The calculations for three types of solar modules are shown in table 1. [5]

Module power ±5%	Type (1)	**Type (2)**	Type (3)
Watt (peak hour)	50	**145**	180
Size (mm) (L×W×D)	1000 ×500×45	**1495×670 ×45**	1600 ×800 ×45
Area (m²)	0.50	**1.00**	1.28

Table1: Types of solar modules.

In this paper, the calculations for type (2) are explained, and at the end of this section, the results of the other two types will be mentioned.

The first step is calculating the maximum shadow of the solar module. The smaller solar altitude angle, the longer shadow we will get.

In Amman, the smaller solar altitude angle is 35^{o}, and the related calculated shadow is 2.37m.

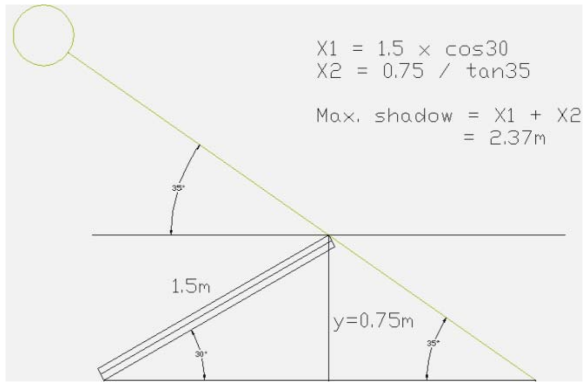

Figure 7: Front view.

The line of solar panels makes an angle of 35^{o}, so one has to calculate the horizontal distance X_h, as shown in Figure.8, where it equals 4.13 m.

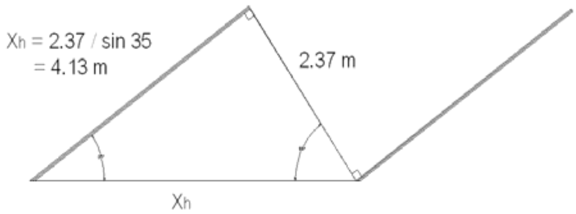

Figure 8: Top view.

The aim in this section is to find the area of a rectangle that contains the module itself and its maximum shadow. By this we can find the number of solar panels that the available area can handle.

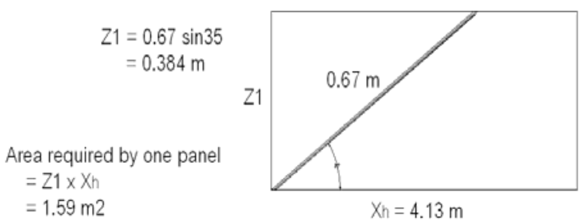

Figure 9: Top view for one solar panel.

Figure.9 shows that the area required by one panel is 1.59m^{2}. Keeping in mind that the available area = 250 m^{2}. So the number of panels is 250/1.59 = 157 panels. The watt-peak P = 145 W and in average, there are 6 peak hours at Amman. Then, in one year, the energy =157×145×6×365=49.9 MWh.

Another way for calculations, is that the number of PV 157, and the area of one panel = 1 m^2. So we have 157 m^2 of solar modules. The yearly global solar radiation at Amman at inclination angle of 30^o is 2250 kWh/m^2. Then, in one year, the energy = 157×2250×103×0.142= 50.2 MWh.

The efficiency of the PV panels is 14.2%. The difference between the two calculated energies is due to the tolerance in the modules' power.
This was for type (2). We made the calculations in the same procedure for type (1) and type (3). The results were:

For type (1) » E = 34.6 MWh / year.
For type (3) » E = 48.9 MWh / year.

11. FINANCIAL ANALYSIS

The parameters that are taken into consideration in the financial analysis are; PV array size, installed price and output, some economic assumptions, cost of fossil fuel alternative, the payback period and the market potential model. In this system, we don't need to use a charge controller since the batteries are not included in the grid-connected system. This leads to reduce the total cost and the total area for insulating the PV system.
The lifetime of PV modules according to IEEE1262 is (20-30 years.). Keeping in mind that PV modules only seeing (6-8 hr.) of active use per day. The installed watt costs (3$) i.e 145 W/module, and 157 modules are needed. Then 145×157×3 =68,295 $. The inverter costs in average (4,000 $). So, the PV system installation will cost initially: 72,295+ (5%)*maintenance=73741 $* maintenance.
In average, the residential construction's electrical consumption in one month is (2693 kWh). So the bill value is 422.5 $. Our system generates in one month 4167 kWh. Then, the difference is 1474 kWh monthly. Assume that the 1 kWh by is sold 0.28 $, then the gain= consumption × buying tariff + difference*selling tariff=2693×0.16+1474×0.28 = 837.75 $ (monthly). Payback = Initial cost/Gain = 73741 / 837.75 = 88 months. The initial cost can be back in about 7 years.

12. CONCLUSIONS

In this work, we presented a study for connecting PV modules to power a residential construction. We took into account all possible parameters in the design and we found that a pay-pack period of 7 is needed to get back the initial cost of the PV system pending the subsidized system of the government.

13. REFERENCES

[1] Yu-Kang Lo Ting-Peng Lee Kuan-Hung Wu " Grid Connected Photovoltaic System With Power Factor Correction" Industrial Electronics, IEEE, 2008 Volume: 55 Issue: 5, page(s): 2224 – 2227
[2] Quaschning, V., 2005 Renewable Energy Systems. Earthscan London
[3] Zhou Dejia; Zhao Zhengming; Eltawil, M.; Yuan Liqiang " Design and control of a three-phase grid-connected photovoltaic system with developed maximum power point tracking" Applied Power Electronics Conference and Exposition, 2008. APEC 2008. Twenty-Third Annual IEEE, page(s): 973 - 979
.[4] Annual report of 2008, NEPCO, National Electric Power Company, Amman-Jordan.
[5] Philadelphia Solar, Amman-Jordan.
[6] BAHA, Engineering Consulting, Amman-Jordan.
[7] TAHHAN & BUSHNAQ, Architecture & Civil Engineering Consulting, Amman-Jordan.