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RESEARCH ARTICLE

COST ANALYSIS OF A PHOTOVOLTAIC PLANT CONNECTED TO A 315 KW SOLAR GRID IN ERBIL, KURDISTAN, IRAQ

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ABSTRACT

Most of the world's energy supply comes from non-renewable energy sources based on fossil fuels such as oil, coal and gas. In the last three decades "Global Warming" has become a major concern for the future of the Earth and its environment. Dependency on fossil fuels to generate electricity to match the escalating demands of increasing populations has resulted in a massive rise in pollution and damage to the environment. Therefore, reliance on fossil fuels needs to be reduced by efficient energy management and replacement with renewable energy sources. Solar energy has emerged as a promising candidate. It is clean, environmentally friendly and an inexhaustible supply. To satisfy increasing load requirements combined solar and conventional power generation systems are now being implemented as grid connected energy systems. In this paper a cost analysis for a possible 315 KW grid connected solar photovoltaic plant by developing a system based on estimations for a chosen area is presented. The specifications for the equipment needed are based on the availability of the components within the region.

INTRODUCTION

Solar energy is particularly attractive due to the abundance of solar radiation [1]. If it can be harnessed it can potentially fulfil all of the global energy demand. It is environmentally friendly and does not require extensive and expensive infrastructure to implement since solar systems are installed and generate electricity on-site compared to power stations many kilometres away from the point of use. Solar cell efficiencies [2] are rapidly improving with the developments in nanomaterials and their reliability increasing and these will mitigate towards implementing solar solutions [3]. Photovoltaic solar energy can provide the capability to generate electricity in a reliable, quiet and clean manner. A photovoltaic system has photovoltaic cells, which convert light energy directly into electrical power. This system is expected to have a major impact on energy generation in the near future. However, the successful integration of solar technology into the current energy structure depends on a detailed understanding of its potential and limitations. Even though the literature on solar energy and PV grid connected systems is vast, the calculation of electricity generation potential by modern technology of PV is essential to carrying out energy analysis showing the scenario for future energy supply, its financial implications and legal frameworks to support the industrial production of PVs. The generation system of Grid interconnection for photovoltaic (PV) power has the advantage of effectively utilizing the power generated. However, the technical needs of the system of the utility power grid and the PV system requires a guarantee of PV installer safety and the utility grid reliability. Ganguli *et al*. (2009) estimated grid quality for the potential of solar PV power generation and its cost analysis for regions of West Bengal [4]. This work studied the usefulness of solar radiation and potential of the area with the aim of developing a system, which is consistent and reliable. The specifications of equipment were also suggested and analysis of the cost has been carried out. Elhodeiby *et al*. (2011) showed the 3.6kW performance analysis of rooftop grid connected system of solar photovoltaic in Egypt [5]. The system was under observation for one year and all the electricity generated was fed into the 220 V, 50 Hz low voltage grid supplied to the users. Picault *et al*. (2009) overviewed the current literature on grid connected systems [6]. Key points to be considered were based on topology, upgradeability, degraded mode operation, performance under shaded conditions, and cost of investment and the participation of ancillary service participation. The methods suggested can be adjusted to the consumer requirements and photovoltaic plant expectations. Furthermore, these evaluation guidelines

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can support grid-tide PV system users to select the most suitable topology for their applications based on weighting the evaluation principles, Bolduc et.al presented a paper on a grid-connected PV system performance capable of energy storage [7]. A 1kW amorphous photovoltaic system has been run in a grid-connected mode with energy storage. The aim of the development of the system and experiment on performance was to investigate the additional value of the grid-connected system, which has been saved with battery energy store. These values will be considered against the added system costs and inefficiencies incurred when the battery is charging and discharging.

Kumar *et al* (1993) worked on photovoltaic systems and presented a discourse in the USA with international activities regarding solar photovoltaic systems [8]. After a general review of the types of systems and output characteristics, many different types of systems were discussed and classifications provided based on photovoltaic systems. A brief discussion including design, modeling, and the economic consideration is also presented. The global status of PV system technology was discussed with appropriate view of the future scenarios considering also the assessment was covering some specific areas for future research and development. Other studies by Román *et.al* (2006) have been presented on grid-connected PV system performance with energy storage [9]. A 3kW amorphous photovoltaic system has been running in a grid-connected mode with energy storage. The main aim of these developments of the system and performance experiment is to examine the additional value of a grid-connected system and connected with dispatchable battery energy storage. Finally, these values will be taken into consideration when seen against the added system cost and inefficiencies may occur while the battery is charging and discharging. This paper presents an original study of the potential, costs analysis and implementation of a photovoltaic system connected to a 315 KW grid in Erbil.

MATERIALS AND METHODS

To carry out the cost analysis for a 315 KW grid connected solar photovoltaic plant in Erbil, Kurdistan, Iraq, the amount of solar irradiation during the months of the year and over the whole year has to be estimated. This data was utilized in our previous work [10] and assuming that the effective solar energy is available for approximately six hours during the day. The output power available for utilization depends on the efficiency of the PV modules used. Analysis [10] showed that the efficiency values of 15.1% can be taken currently with different types of PV modules. A grid connected photovoltaic system is designed with the available components for the estimated plant capacity from a suitable available chosen area. Using equipment available in the region a method of design is presented.

RESULTS AND DISCUSSION

Solar irradiation and energy output

Solar irradiation for the Erbil region varies throughout the year and is shown in Table 1 below.

Table 1. Average monthly solar irradiation

Month	Daily irradiation kWh/m^2/day
Jan	3.69
Feb	4.16
Mar	5.12
Apr	5.46
May	6.06
Jun	6.62
July	6.52
Aug	6.51
Sep	6.32
Oct	5.12
Nov	4.11
Dec	3.47
Total	63.16
Mean	5.26

The data above shows the irradiation for the whole year has been plotted in Figure 1.

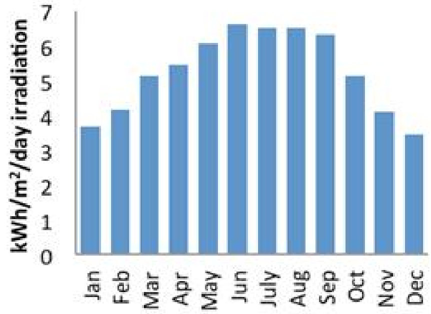


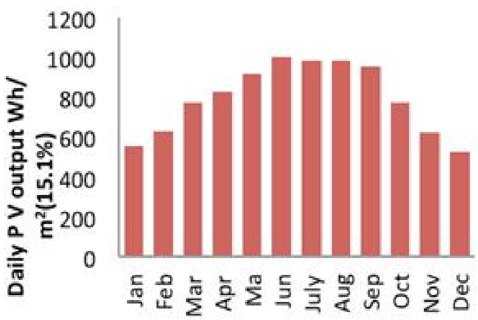
Figure 1. Daily solar irradiation for each month of the year

The daily photovoltaic output from the solar module based on an efficiency of 15.1% gives the corresponding potential energy in Table 2. The peak months are in the summer months of June, July and August and the lowest months are December and January.

Table 2. Monthly Power output

Month	Daily PV Output Wh/m^2 (15.1%)
Jan	557.19
Feb	628.16
Mar	773.12
Apr	824.46
May	915.06
Jun	999.62
July	984.52
Aug	983.01
Sep	954.32
Oct	773.12
Nov	620.61
Dec	523.97
Total	9537.16
Mean	794.76

The corresponding output graph is shown in Figure 2.

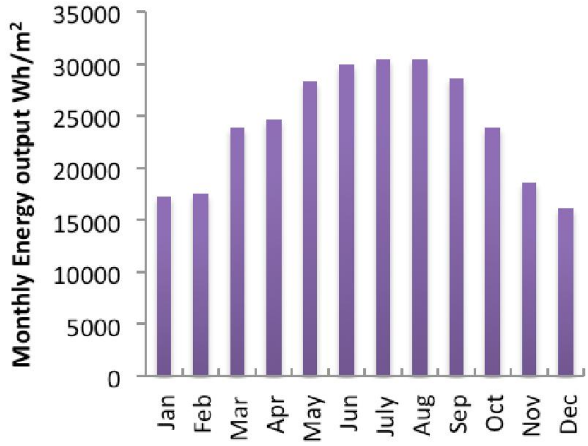


The monthly energy output and the corresponding total energy output can be computed for the available area and are shown in Table 3.

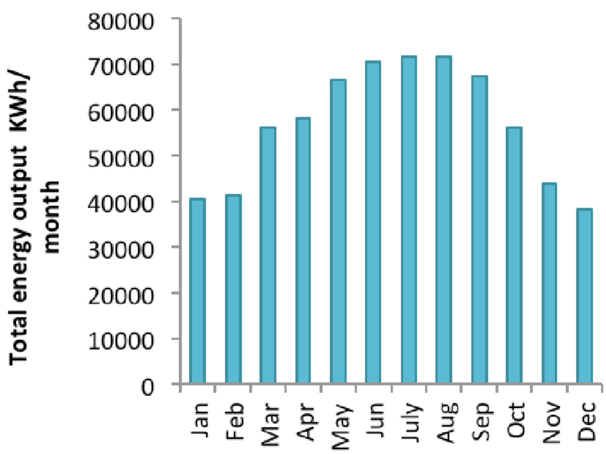
Table 3. Monthly energy output and total energy output using available area

Month	Monthly Energy Output Wh/m^2	Energy output in Erbil, KWh/month
Jan	17273	40574
Feb	17583	41314
Mar	23967	56298
Apr	24734	58100
May	28367	66634
Jun	20989	70444
July	30520	71691
Aug	30473	71581
Sep	28630	67252
Oct	23967	56298
Nov	18618	43734
Dec	16243	38155
Total	290369	682075
Average	24179	56840

The graphs below show the above data.



The total energy output for the chosen available area is shown in figure 4.



Cost analysis for 315KW grid connected solar photovoltaic plant

To compare further the long-term benefits of such a solar PV system, the recuperating costs and the long-term profits can be estimated. Assuming that the 315 KW plant operates for six hours per day and the charge for 1KWh of electricity is around 15p this then gives an annual potential income of around £ 103, 478. This shows that to recuperate the initial investment made would take approximately five years. The average life span for our solar PV system is assumed around twenty years so this system would then generate a net profit of around £ 1.5 million over this time period.

Cost analysis of 315 KW Solar PV System	
Solar Panels	Price of solar panel = £ 0.95/watt Use 150 watt panels, 2100 panels Cost, £ 0.95 x 150 x 2100 = £299,250
3-Φ Inverter	One piece for 315KW inverter unit Price is £ 0.25/watt Cost, £ 0.25 x 315000 = £78,750
3-Φ step-up Transformer	One piece for 315KW. Price is £ 0.20/watt Cost, £ 0.20 x 315000 = £63,000
Subtotal	£ 441, 000
Extra system requirements (switches, wires etc.)	Multiply by 15% (0.15) Cost, £441,000 x 015 = £66, 150
Total Estimate	£ 507,150

Conclusions

It has been shown that the city of Erbil, in the region of Kurdistan, Iraq has on average a good amount of Irradiation throughout the whole year around 5.3kWh/m^2/day. With the appropriate chosen area, a solar photovoltaic plant system with an output of 315KW can be designed. The cost analysis has shown that approximately half a million pounds is needed to set up such a plant size. It has been shown that using current values for the cost of electricity, the initial investment could be recuperated within five years. Thereafter, the system can generate approximately hundred thousand pounds a year in income. There may be some variations in the actual income generated when maintenance and repair costs are taken into account. The findings are important considerations for both governments and private enterprises considering renewable energy sources for the electricity needs of its population in the near future.

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