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Distributed Grid-Connected PV System: Electricity Production Assessment under Algerian Weather Conditions

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Abstract

As in all worldwide level, renewable energies in Algeria, including photovoltaic energy, are attracting increasing attention. Load management (LM) and distributed generation (DG) using renewable energy sources, such as PV, CF and wind power, and their integration into the electrical power system has advantages such as low distribution losses, better energy quality and high reliability. This paper is about a simulation study to analyze the energy assessment of a grid-connected photovoltaic system (GCPVS). The system with 1 MW capacity are simulated and analyzed based on solar resource, tilt and azimuth angles for each area and using Si-crystalline and CIS technologies under different weathers conditions in Algeria (Algiers, Chlef, Tlemcen, Tamanrasset and El Oued). The system configuration is simulated using the new version of PVGIS to account for PV plant energy output assessment. The obtained simulation results were discussed as per monthly and yearly values based on PV cell technologies, optimized tilt and azimuth angles.

Keywords: Solar energy, PV energy assessment, PV grid-connected, PV cells Technologies, PVGIS tool.

1. Introduction

Today, the renewable energy system (REPS) is becoming popular with increasing energy demand and concerns about greenhouse gas emissions (CO_2) into the environment that will cause global warming and climate change [1]. The primary purposes of renewable energy resources integration are environmental advantages. Also, because distribution lines cause significant losses, distributed generation (DG) come with some advantages like: better power quality, low distribution losses and high system reliability [2].

Statistical data show that PV systems are now developing in three main categories: (1) small PV systems (1–5 kW) used in private homes; (2) medium PV generators integrated in commercial, industrial and office buildings (usually 10–250 kW) and: (3) centralized PV power plants or large-scale grid connected system ranging (100 kW up to 5 MW) [4]. Large-scale grid connected PV systems are generally connected to the utility on the medium (20 kV/35 kV) or high-voltage side (110 kV), with the rated capacity ranging from 1 MW to hundreds of megawatts or even more [2,10]. The most of the newest photovoltaic systems installed nowadays are connected to the utility grid type [10].

Until 2012, the installed PV capacity all over the world exceeded 100 Giga-watt (GW) [11]

2. Renewable Energy Statue in Algeria

As mentioned in the introduction section, the Algerian government is now looking to reduce the economy's dependence on the hydrocarbon sector, which represents 98% of the country's hard currency income [12].

Due to the abundant sunshine throughout the year, especially in the Sahara region (Total potential daily energy of 16,555.48 TWh), the climatic conditions in Algeria are favourable for the development of renewable energy mainly solar energy, this is broadly confirmed by the world energy council (WEC) [13] and from [14–18] as shown in Table 1.

As shown in Fig. 1(a), the total share of RE sources, which are occupying increasingly important places, is expected to increase annually to meet the goal of 40% of electricity production by 2030 [19].

From the year 2011 to 2030, the programmer of energy generation is shown in Fig. 1(b).

Table 1. Solar potential in Algeria

Areas	Coastal	High plains	Sahara
Surface (%)	4	10	86
Area (km^2)	95.270	238.174	2,048,279
daily sunshine duration (h)	7.26	8.22	9.59
Average duration (h/y)	2650	3000	3500

Average energy ($kWh/m^2/y$)	1700	1900	2650
Solar daily energy density (kWh/m^2)	4.66	5.21	7.26
Potential daily energy (TWh)	443.96	1240.89	14,780.6 3

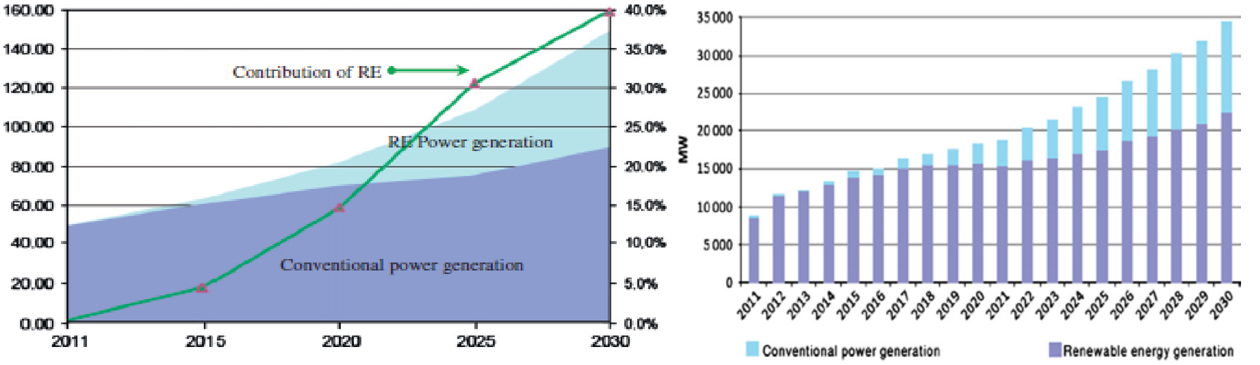


Fig.1. a) Contribution of RE for power generation, b) Structure of the national power generation in MW [19]

2.2.Proposed Cases Study

This study provides the evaluation of the performance of a grid connected system for some areas in Algeria which is Algiers, Tamanrasset, Chlef, Tlemcen and El Oued. Author in [20] used the monthly average clearness index parameter to define the different climatic zones, these four zones with different climatic conditions in Algeria are bound in the following limits [21]. With, K_{tm} is the monthly average clearness index.

Zone I : $K_{tm} \leq 0.548$

Zone II : $0.548 < K_{tm} \leq 0.609$

Zone III : $0.609 < K_{tm} \leq 0.671$

Zone IV : $K_{tm} > 0.671$

The geographical data and distribution of climatic zones for the five selected sites located in Algeria are presented in Table 2.

Table 2. Geographical data and climatic zones for the selected sites [21, 23].

Name of site	**Lati (°)**	**Long (°)**	**L. a. m (m)**	**Climatic zones**
Algiers	36.3	3.15 E	25	I
Tlemcen	34.5	1.19 E	810	II
Chlef	36.08	1.17 E	112	II
El Oued	33.21	6.5 E	84	III
Tamanrasset	22.4	5.31 E	1378	IV

2.2.1. PV Grid Connected System

Fig. 2 shows the schematic view of the grid connected PV system consisting of PV modules, DC-AC converter and grid utility [24].

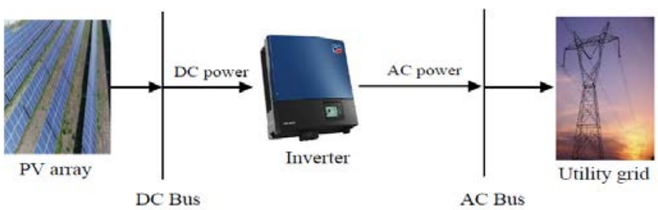


Fig. 2. PV Grid connected system scheme

These PV materials include several types of PV technologies such as Crystalline Silicon (mono-crystalline and polycrystalline), thin films (amorphous silicon (a-Si), cadmium Telluride (CdTe) or copper-indium gallium-selenide (CIGS)) [25]. In this paper Si-crystalline and CIS technologies are simulated, the available solar radiation and ambient temperature of the location have major impact on the output power of the PV array. Equation (1) shows the array's instantaneous output power [26, 27].

$$P_{pv}\left(t\right) = P_{peak}\left(\frac{G\left(t\right)}{G_{St}}\right) - \alpha_T\left[T_c\left(t\right) - T_{\mathrm{St}}\right] \times \eta_{inv} \times \eta_{wire} \quad (1)$$

While, the rated power of PV array is represented by P_{peak} and the temperature coefficient of PV power is represented by which can be acquired from the data sheet [28]. T_c represents the temperature of the PV cell, which can be calculate from equation (2).

$$T_c(t) - T_{ambient} = \frac{T_{\mathrm{standard}}}{800} G(t) \quad (2)$$

The total daily DC energy generated by the PV system (Edc) can be calculated with the following equation.

$$E_{dc,d} = \sum_{t=1}^{t=T_{\mathrm{rp}}} V_{dc} \times I_{dc} \times T_r \quad (3)$$

Where; Tr = the recording time interval, Trp = the reporting period N = the number of operating days of plant in a month. The monthly DC energy generated by the PV system is given by.

$$E_{dc,m} = \sum_{d=1}^{N} E_{dc,d} \quad (4)$$

The total daily AC energy generated by the PV system (Eac) which is fed into the utility grid is given by.

$$E_{ac,d} = \sum_{t=1}^{t=T_{\mathrm{rp}}} V_{ac} \times I_{ac} \times T_r \quad (5)$$

The monthly AC energy generated by the PV system is given by.

$$E_{ac,m} = \sum_{d=1}^{N} E_{ac,d} \quad (6)$$

Inverter efficiency is given by.

$$\eta_{inv} = \frac{P_{\mathrm{ac}}}{P_{\mathrm{dc}}} \quad (7)$$

Where; P_{ac} and P_{dc} are the power output delivered by the inverters fed into the utility grid and power output delivered by the PV modules respectively [29].

2.2.2. Simulation Procedure

Computer based simulation were more advanced and useful tools for hybrid renewable power systems analysis and the operation performance assessment under varying climates and capacities [30, 31]. Several commercial software packages are available to study off-grid and grid-connected renewable energy systems, as well as PVGIS, this last one is used in this paper [32].

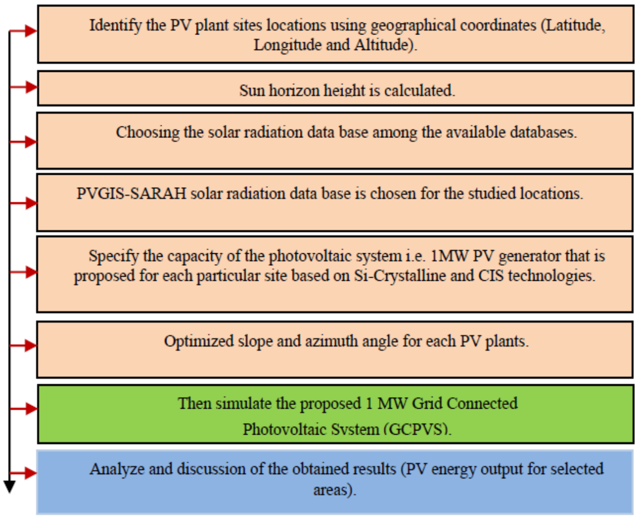


Fig. 3 . Simulation methodology of 1MW grid connected PV system

In this paper, Photovoltaic geographical information systems (PVGIS), a European commission based simulation tool is adopted for proposed 1MW PV system assessment and simulation. The PVGIS simulation procedure adopted for analysing the proposed system is shown in Fig. 3.

3. Results and Discussion

Results of the proposed 1 MW grid connected photovoltaic system were shown based on monthly and annual solar radiation, PV cell technologies, PV system capacity and optimized slope and azimuth angle as inputs values.

3.3.1. Locations Optimal Tilts Angles and Orientations

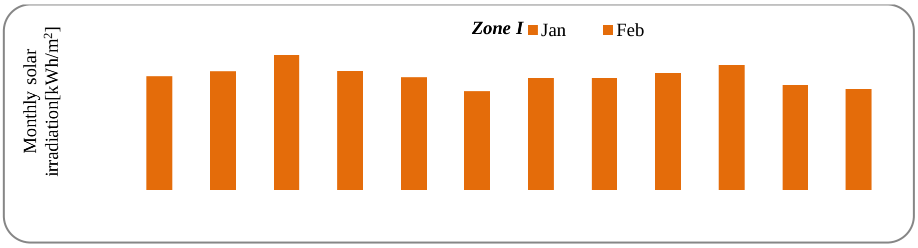
Tilt angle is optimized and chosen in such a way that maximum potentials can be harvested.

Table 3. Optimal orientation and inclination angles

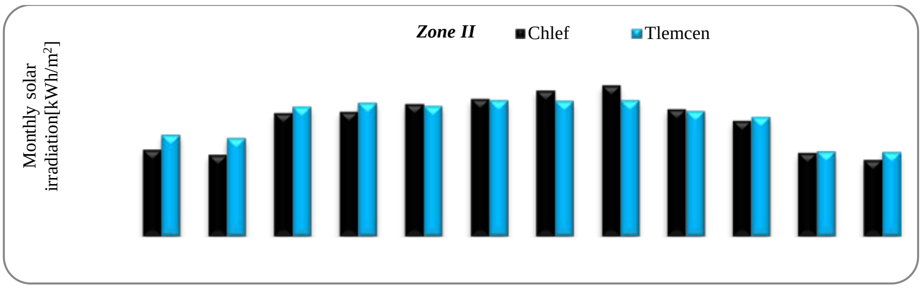
Locations	Optimal Inclination Angle (°)	Optimal Azimuth Angle (°)
Algiers	30	-7
Tamanrasset	24	-10
Tlemcen	32	-12
Chlef	32	-4
El Oued	32	-5

3.3.2. Monthly Solar Irradiation on a Fixed Plan

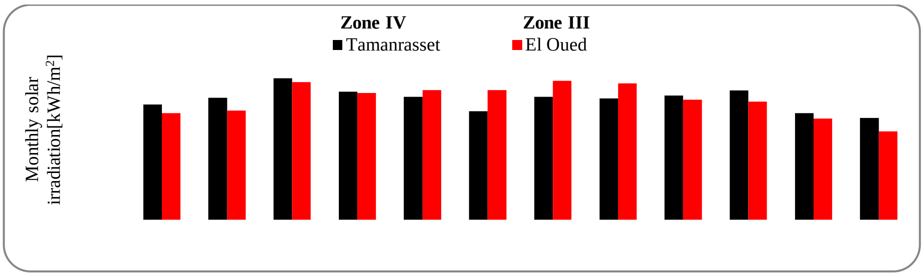
Figure 4 is clearly represents the monthly variation of the solar irradiation data in [kWh/m^2] with respect to the optimal tilts angles for the chosen locations as fellow.



(a)



(b)

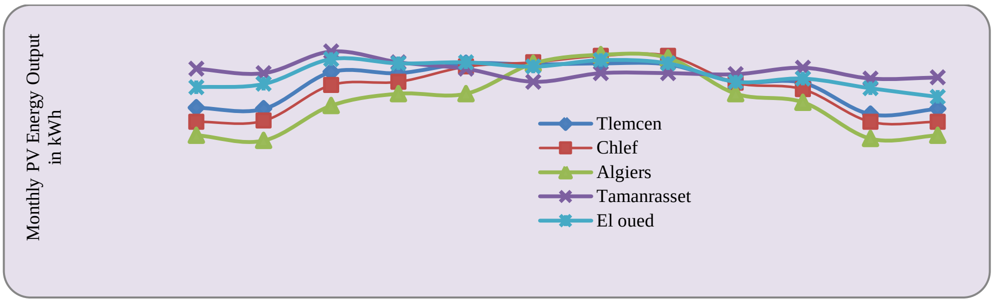


(c)

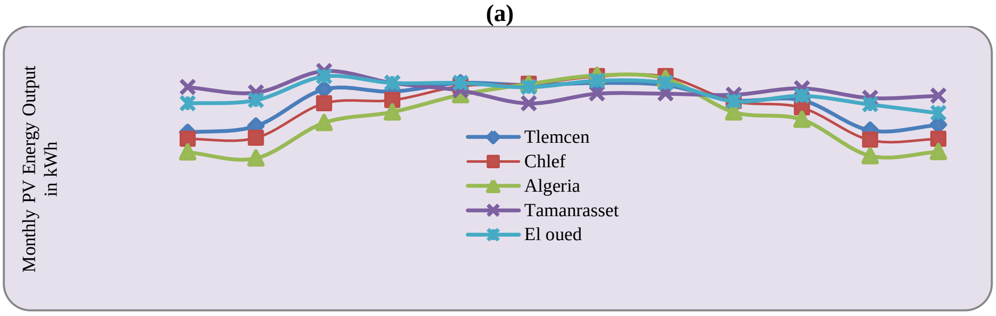
Fig. 4. Monthly solar irradiation for each zone at optimal tilt angle

3.3.3. Monthly Energy Production

Energy productions from the 1MW PV system using SIC and Silicon crystalline on a monthly basis is shown in the Fig. 5. We can see that, there is a variation in electricity generation from the year, this variation is possible due to the effect of local weathers parameters.



(a)



(b)

Fig. 5 . PV electrical energy production for studied areas using CIS technology, b) PV electrical energy production for studied areas using Si-crystalline

3.3.4. Annual PV Energy Output

As a comparison results between Si-crystalline and CIS technology in terms of electricity generation, the injected energy into grid from the designed 1 MW photovoltaic power plant on yearly basis for studied regions as shown in Fig. 6.

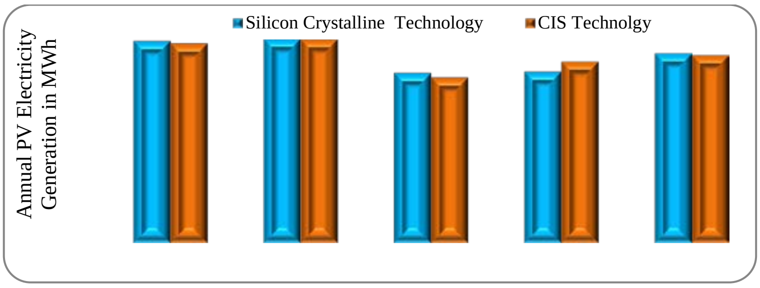


Fig. 6. Annual PV energy output for selected areas using Si-crystalline and CIS technology

4. Conclusion

From this study, it can be concluded that, feasibility studies are necessary before going for the practical installation, tilt and azimuth angles should be taken into consideration as they were comes under the influential factors, and also temperature effect.

The findings from the study of this installation indicate that grid connected PV power plant is technically feasible for electricity generation and could play a role in energy mix of the country in the future. As a future perspective, the study can be carried out using the various PV module technologies with appropriate installation methods (Tracking system) for PV system performance improvement.Based on this study, the following conclusions were drawn:

- Based on the monthly energy output, an average energy output of 139750 kWh, 135083 kWh, 125358 kWh, 150500 kWh and 149000 kWh respectively for Tlemcen, Chlef, Algiers, Tamanrasset and El Oued when Si-crystalline is used.
- The difference in the monthly average production between the two PV modules is 1584, 3000, 417 and 2084 kWh respectively for Tlemcen, Algiers, Tamanrasset and El Oued, noted that Si-crystalline modules recorded highest performance. Except in the region of Chlef, when CIS PV module is better than Si-crystalline, the difference is 1583 kWh in term of monthly average output.

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