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Evaluation of five various technologies of PV panels for Si production using Sahara sand silica source

Mohamed Mostefai*, Department of Electrical Engineering University of Saida, University Moulay Tahar of Saida, BP138, En-Nasr, Saida 20000, Algeria

Yahia Miloud, Department of Electrical Engineering University of Saida, University Moulay Tahar of Saida, BP138, En-Nasr, Saida 20000, Algeria

Abdallah Miloudi, Department of Electrical Engineering University of Saida, University Moulay Tahar of Saida, BP138, En-Nasr, Saida 20000, Algeria

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Abstract

The Sahara Solar Breeder (SSB) project is a joint Japanese-Algerian universities project to utilise the plentiful sand and solar energy in the Sahara desert. In the context of the SSB project, a Sahara Solar Energy Research Center was created at the University of Saida in Algeria. This centre is equipped with the meteorological monitoring system, the outside photovoltaic panels evaluation systems and the underground temperature measurement system. In this paper, a description of these types of equipment of this centre is presented. Also, some important data such as irradiance, temperature, energy, I–V curves and underground temperature measurement are presented and analysed. Finally, a discussion on the usefulness of these data for the SSB project will be discussed.

Keywords: Sahara Solar Breeder project, solar irradiation, air temperature, underground temperature, PV module, I–V curve

* ADDRESS FOR CORRESPONDENCE: **Mohamed Mostefai,** Department of Electrical Engineering University of Saida, University Moulay Tahar of Saida, BP138, En-Nasr, Saida 20000, Algeria. *E-mail address:* mostefaimed@yahoo.fr

1. Introduction

The idea of the Sahara Solar Breeder (SSB) project consists of constructing industrial plants in the Sahara desert that would extract silica from the sand and use it to produce photovoltaic panels. The first solar panels are going to be used to construct photovoltaic power plants. On the other hand, the principal object of this project is to construct sufficient plants until the breeding plan can deliver 100 GW of electricity to supply 50% of the world's electrical demand by 2,050. This energy will be delivered via an High Temperature Superconductor (HTSC) cable to transport the produced DC current electricity over 500 km (Koinuma, Tsubouchi, Itaka & Stambouli, 2013; Miloud, Miloudi & Mostefai, 2011; Miloud, Miloudi & Mostefai, 2014a; ssb-foundation; Stambouli, Khiat, Flazi & Kitamura, 2012).

Meteorological data such as air temperature, solar irradiation, wind speed and relative humidity play a significant part in the design of the photovoltaic installations. For this reason and in the context of the SSB project, a Sahara Solar Energy Research Center (SSERC) was mounted in the University of Saida (Algeria). This research centre is equipped with the necessary facilities to carry out this project such as the meteorological monitoring system, the outside photovoltaic panels evaluation system and the underground temperature measurement system. These systems constantly acquire most important parameters such as wind, solar irradiance, panels temperature, I–V curves, underground temperature and much more data, which are automatically saved and analysed (Campbell Scientific; Miloud, Miloudi & Mostefai, 2015).

However, this paper involves the evaluation of newly installed photovoltaic panels based on five various technologies and a meteorological station at the University of Saida which is situated at so-called gate of the Sahara. These installations have been initiated for the assessment of the ability of PV and solar of the Algerian desert as part of SSB project.

Solar modules generally show a gradual degradation when installed outdoors and exposed to real weather conditions and sunlight. The outside photovoltaic panel system is set to measure the characteristics and maximum output power of photovoltaic modules under the natural sunlight and weather conditions (Campbell Scientific).

The second essential element of the SSB project is the transportation of energy from the south (Sahara) to the north, and the idea is to use underground superconducting cables. The purpose of the underground measurement system is to determine at which depth the temperature will be the most stable (Koinuma et al., 2013; ssb-foundation).

In this paper, a description of SSERC is presented. Firstly, we presented the weather station, the PV measuring system and then the underground measurement system. Secondly, an analysis of the results obtained from different systems is detailed. Finally, we conclude with an analysis of these data that will affect installation of photovoltaic systems, and the usefulness of these data for the SSB project will be discussed.

2. Solar energy research centre presentation

Files should be in the context of the SSB project, and SSERC is created at the University of Saida. This centre is equipped with the following:

- Meteorological monitoring system,
- Outdoor photovoltaic panels evaluation system,
- Underground temperature measurement system.

This section describes all of these types of equipment.

2.1. Weather measurement station description

Campbell scientific climate stations (Mostefai, Miloud & Miloudi, 2013a; 2013b) have become the universal standard for climate and meteorology. They are complete parts of monitoring and forecasting systems worldwide. Figure 1 shows a photo of the Campbell scientific weather station installed in the University of Saida in the context of the SSB project (Campbell Scientific).

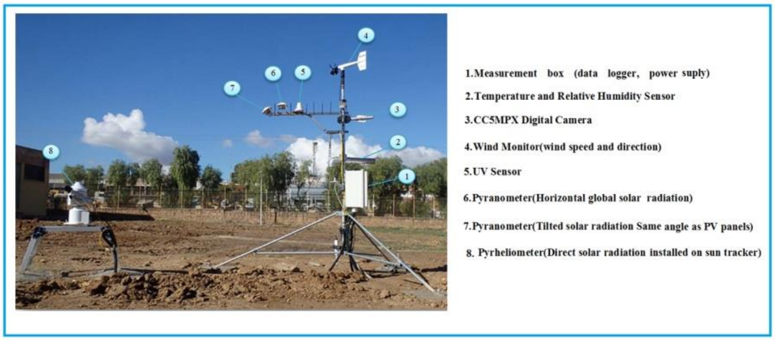

Figure 1. Weather station installed in the University of Saida

2.2. PV measurement system description

The outside photovoltaic module assessment system is based on the PV Analyzer PVA11270 made by Nippon Kernel System Co., Ltd. The PV Analyzer PVA11270 is destined to measure the I–V curve and panel back-side temperature to evaluate the performance of each module under real weather condition and the natural sunshine (Miloudi, Mostefai & Miloud, 2014b; Mostefai, Miloud & Miloudi, 2015). The outside photovoltaic module evaluation system consists of five types of PV modules, one thermocouple positioned in backside of each panel and pyranometer (inclined same angle as PV panels). Figure 2 shows a photo of the PV modules installed.

Figure 2. PV modules installed

I–V curves for each panel are measured one by one successively. By tuning the time interval, start, finish time of the day, the system measures all modules continued for a long time. Data are saved on a memory card installed on the PV analyzer or communicated to the PC via a LAN cable (Figure 3).

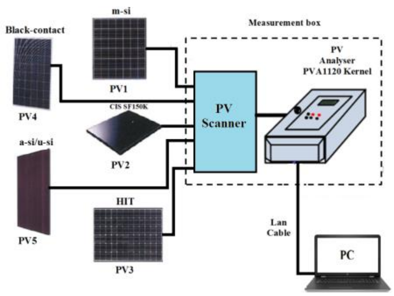

Figure 3. PV measuring system

Table 1 summarises fundamental characteristics for the five modules. In this table, Pmax is the maximal power of the module, Isc is the short circuit current, Voc is the open circuit voltage, Ipm is the current for maximum power, Vpm is the voltage for maximum power, PV No. is the number of PV modules, m-Si is the monocrystalline, CIS is the copper indium selenium, HIT is the hetero junction with intrinsic thin layer and a-Si/u-Si is the hybride (see Table 1).

Table 1. Characteristics for the five modules

PV No.	Type	Manufacture	Width (mm)	Length (mm)	Height (mm)	Pmax (W)	Isc (A)	Voc (V)	Ipm (A)	Vpm (A)
1	m-Si	Kyocera	1,168	990	36	165	8.53	26	7.9	20.9
2	CIS	Solar frontier	1,257	977	35	150	2.2	108	5.47	42.7
3	HIT	Sanyo	1,580	812	35	233	5.84	51.6	8.36	24.94
4	Back contact	Sharp	1,318	990	46	208.5	8.94	30.6	1.85	81.5
5	a-Si/u-Si	Kaneka	1,240	1,008	40	110	2.5	71	2.04	54

2.3. Underground temperature measurement system

The measurement system with a data logger was mounted on September 2013 at the University of Saida (Figure 4). The underground temperature sensors were positioned at different deepness starting from 20 to 275 cm to measure the temperature (Campbell Scientific; Miloud et al., 2015; Miloudi et al., 2015). Figure 4 shows the underground temperature system.

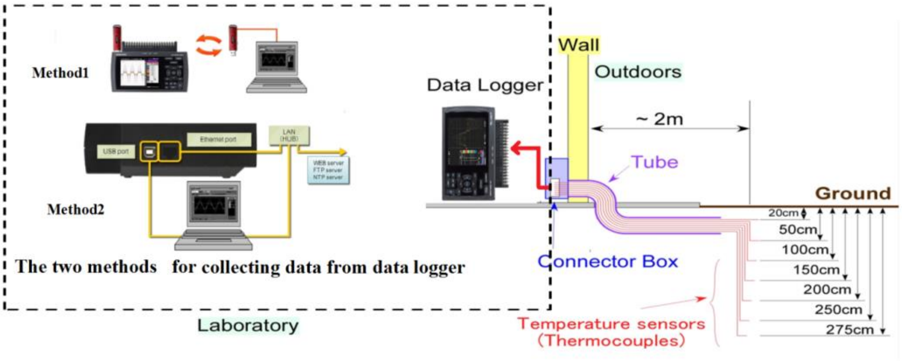

Figure 4. Underground temperature system

3. Results

3.1. Meteorological data

The following figures show the results obtained from the meteorological station. In these figures, we can see the most important meteorological data like temperature and solar radiation, and these figures represent the data for 4 years from 2014 to 2017.

Figure 5 shows the variation of the ambient temperature per year. We note that the maximum temperature is around 43°C and the minimum temperature is nearly 0°C during the night.

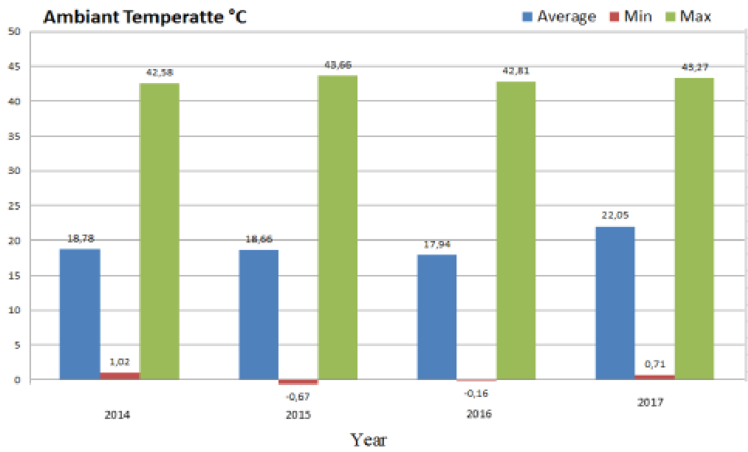

Figure 5. Variation of the ambient temperature per year

Figure 6 shows the big difference between the ambient temperature and the temperature of the panels. In fact, the maximum temperature can easily reach 90°C and the minimum temperature can go down to −5°C.

This large margin between the maximum and the minimum temperature must be taken into account in the design of the photovoltaic system. As we know, very low temperature can destroy the materials and very high temperature decreases the efficiency and will affect the system.

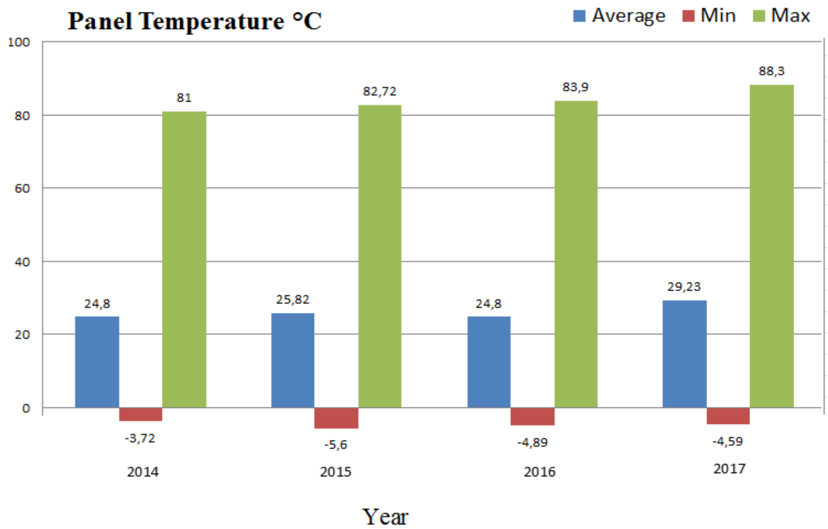

Figure 6. Variation of the PV panel temperature per year

Figure 7 shows clearly the variation of the energy received for each m^2 during the years 2014–2017. The maximum energy is received between the months of March and September. The minimum energy is received in the months of January and December.

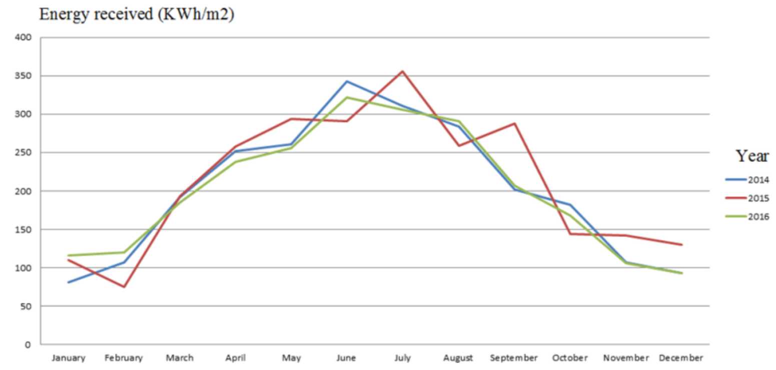

Figure 7. Energy received per m^2 per year

According to Figure 8, the average energy received during the year is of the order of 2,000 kWh for each m^2.

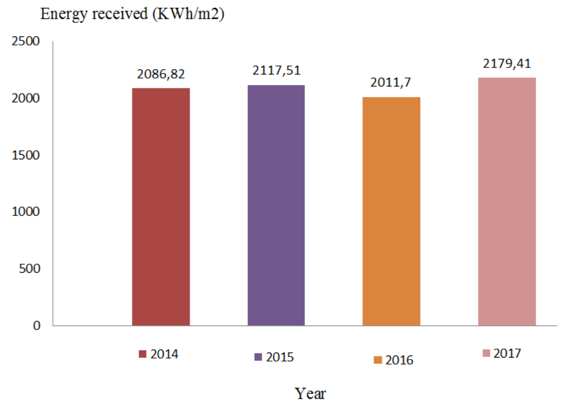

Figure 8. Average energy received during the year

3.2. PV data

Figure 9 indicates an example of variation of the energy produced by each panel during the year 2016.The maximum energy is delivered between March and September.

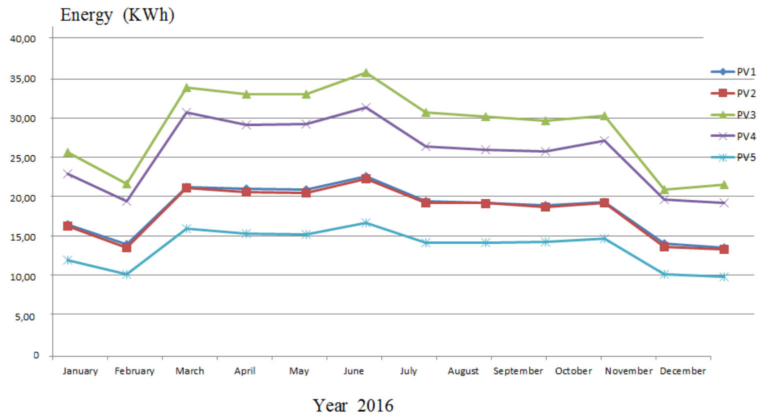

Figure 9. Average monthly energy produced by each panel during the year 2016

As shown in Figure 10, the HIT (heterojunction with intrinsic thin layer) technology panel from Sanyo provides more power compared to other types of panels during different years.

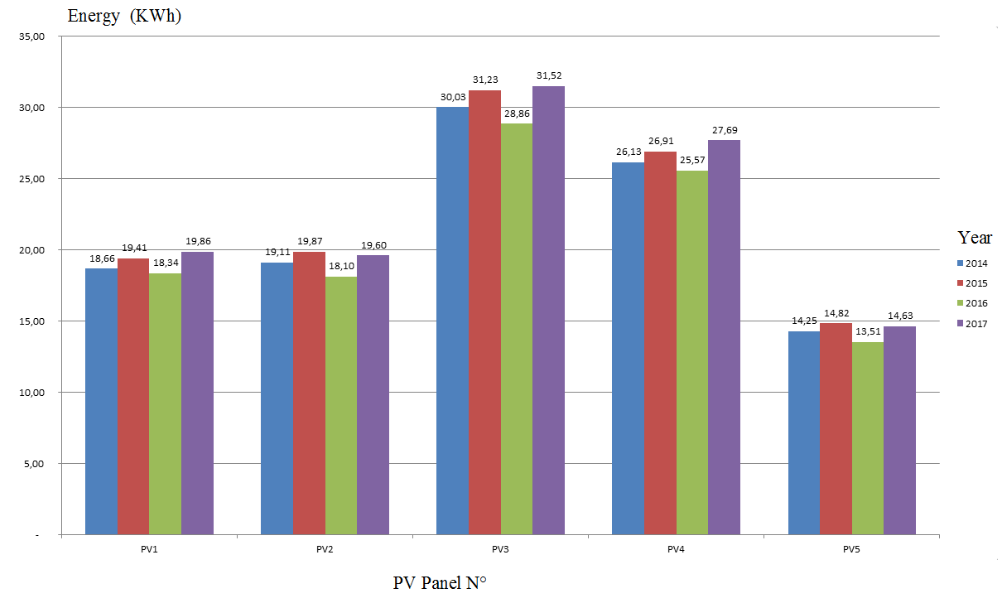

Figure 10. Average monthly energy produced by each panel per year

In Figure 11, panel 3 produces the greatest power of about 380 kWh during the year and the hybrid technology panel from Kaneka produces the low power of about 170 kWh.

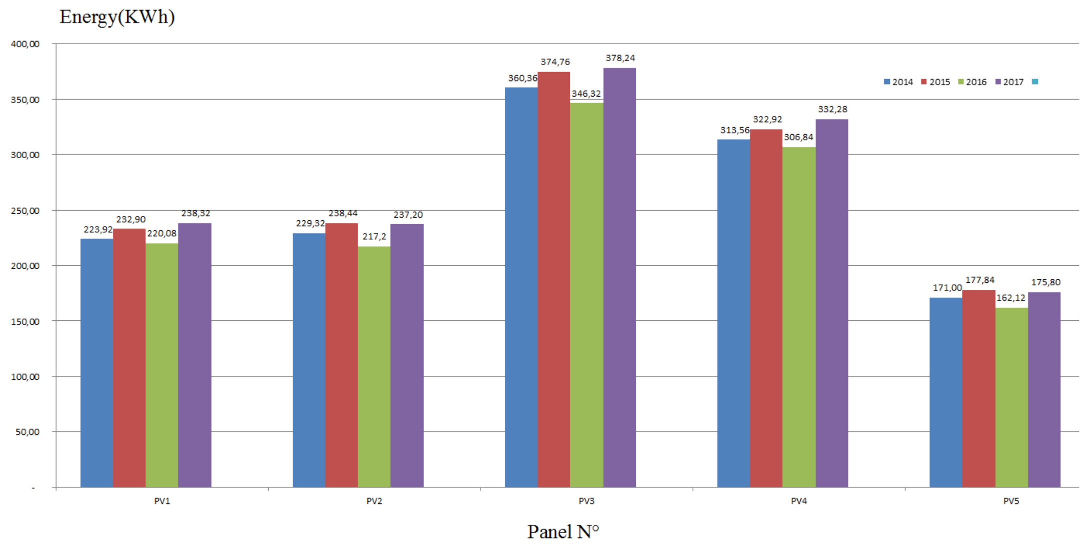

Figure 11. Average energy produced by each panel during the year

To compare the performance of the five technologies, we will calculate the power produced for each panel at each m^2, and the results are shown in Figure 12. As seen in Figure 12, panel no. 3 has the best performance.

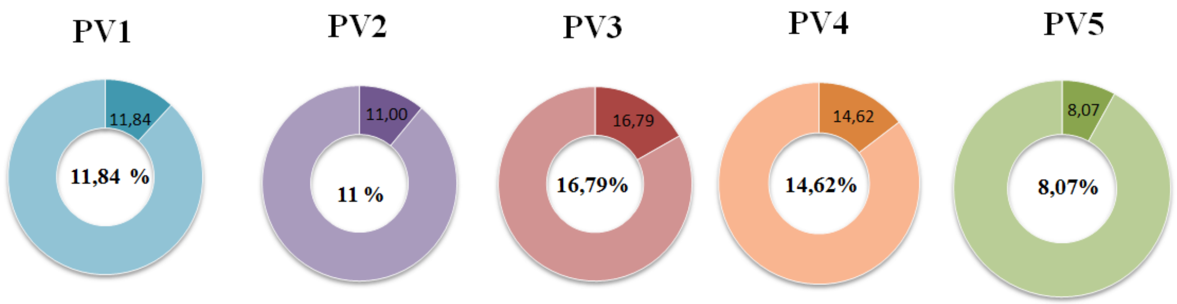

Figure 12. Average efficacy of each panel in % of the energy received

To demonstrate the effectiveness of different panels, we have compared the calculated efficiency with the manufacturer's performance (see Figure 13). As shown in Figure 13, the panels have a slight difference between the manufacturer's efficiency and the calculated one. The best performance obtained is from panel no. 3.

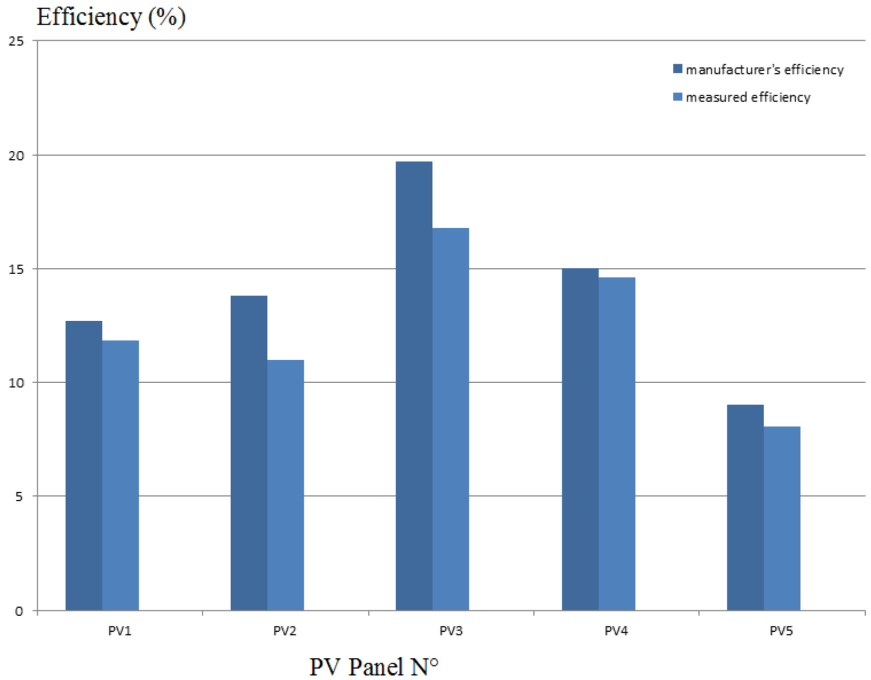

Figure 13.Comparison between the calculated and the manufactured efficiency

3.3. Underground data

Figure 14 shows the underground temperature per year. The results show clearly that the temperature begins to stabilise from the depth of 150 cm and when reaching a depth of 250 cm the temperature is almost stabilised and that is what we are looking for.

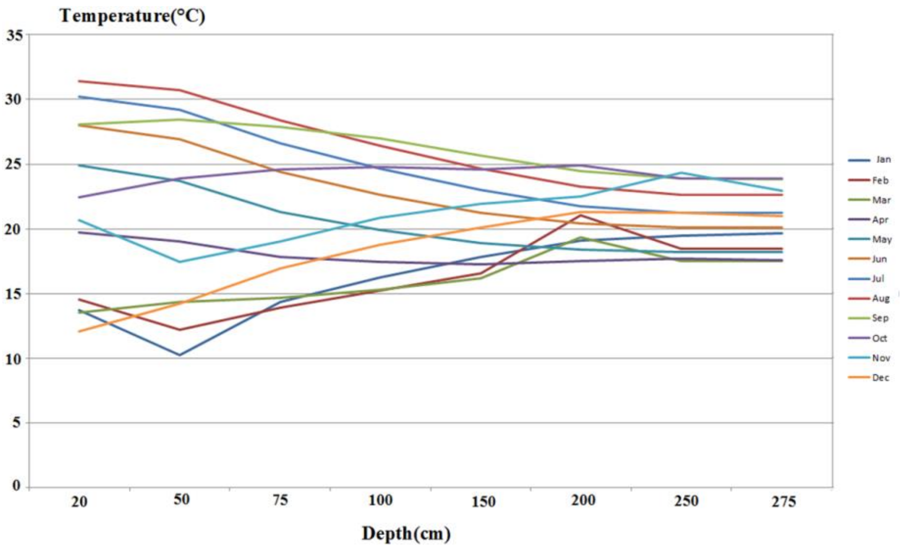

Figure 14. Average underground temperature per year

These data will be very useful for the HTSC cables, which will be used in the Sahara desert to transport the produced DC current electricity over a distance of 1,000 km to the north.

4. Discussion

In this paper, a description of SSERC is presented. This research centre is created at the University of Saida in the context of the SSB project. Firstly, we presented the weather station, the PV measuring system and then the underground measurement system. Secondly, an analysis of the results obtained from different systems is detailed.

The weather station data show a large gap between the ambient temperature and the temperature of the panel where the maximum temperature can easily reach 90°C and the minimum temperature can fall to −5°C.

The results of the weather station also show that the energy collected at the research centre is of the order of 2,000 kWh for each m^2 per year. At the same time, the average energy produced by the best panel is around 360 kWh per year. These results also show that the panel with Sanyo's HIT technology has the best performance for four years (2014–2017) and the Kaneka hybrid panel has the lowest efficiency.

According to these data obtained from the underground temperature system, the temperature stabilised at a depth of 250 cm and that is what we are looking for. These data will be very useful for the HTSC cables which will be used in the Sahara desert to transport the produced DC current electricity to the north over a distance of 1,000 km.

5. Conclusions

The SSB challenges for this very interesting project are as follows:

1. Construct Si production plants using the Sahara sand silica source.
2. Double the yearly production of silica every two years, to reach half a million tons after 40 years.
3. Double the yearly production of PV cells every two years, to reach half a million of 500 kWp PV after 40 years.
4. Using HTSC cables to transport the produced DC current electricity over 500 km.

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