A COMPARISON OF ENERGY GENERATED FROM PHOTOVOLTAIC PANEL FOR TWO TECHNOLOGIES INSTALLED IN A REMOTE AREA OF KUWAIT

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ABSTRACT
A survey was conducted to locate a suitable site to install a meteorological station in the desert of Kuwait. A meteorological station was installed with two pyranometers that provide global and diffused irradiation on the horizontal plane as well as the global irradiation at an inclination angle of 20°. The meteorological station also measure wind speed and direction and ambient temperature as well as temperature of a photovoltaic (PV) panel for two technologies: First Solar (CdTe) and Suntech (c-Si). The station was autonomous and powered by built-in-battery that was charged using the two installed PV panels. The collected data were automatically transmitted to the research facility through mobile communication. A panel cleaning protocol was conducted to enable the experts to define the best optimized cleaning schedule for a future PV power plant in Kuwait. The conclusions of this protocol will help the experts to define the panel sourcing and cleaning strategy for future PV power plants in Kuwait. Collected data are drawn, analyzed, and studies. The two PV panels installed on the meteorological station enabled the experts to validate all theoretical models and PV panel supplier’s specifications in the climatic conditions of Kuwait by simply analyzing the output power of each panel and comparing it with theoretical computation. This is particularly important in an environment which is quite different from PV panel manufacturer’s standard conditions of use. Results of the study are set to provide specific parameters for better understanding of the exact sun radiation or the effect of dust, aerosols, humidity and temperature. It will therefore reduce the uncertainty of the computation and increase the project’s bankability. Irradiance and temperature will be correlated with satellite database in hourly or daily bases, in order to correct these databases and have long term and representative data of the site.

2. SITE SELECTION
A survey of KISR’s Sulaibiya research site was conducted in coordination with the engineers from the General Services Department at KISR to locate a suitable site to install the meteorological station. The station was installed at coordinate (29° 9’52.51”N and 47° 43’32.44”E) Figure 1 [1].

3. METEOROLOGICAL STATION DESCRIPTION
The exact composition of the meteorological station is the following: two pyranometers sensor measuring the global irradiation on the horizontal plane and on the 20° inclination plane (will enable precise assessment of the direct and diffuse sun radiation);

- 2 temperature sensors measuring the temperature of the PV power module and the temperature of the ambient air;
- 1 humidity sensor;
- 1 rain sensor;
- 1 sensor for the duration of sunshine;
- 1 anemometer measuring the wind speed at 4m;
- 1 inclination sensor;
- 1 modem to transmit data daily.

KEY WORDS
Meteorological station, global irradiation, diffused irradiation, photovoltaic

1. INTRODUCTION
The Kuwait Institute for Scientific Research (KISR) and EDF Energies Nouvelles (EDF EN) installed in Kuwait a meteorological station that was used to precisely compute the quantity of energy to be generated from a photovoltaic (PV) power plant at a selected site. Hence, the exact evaluation of energy potential of a future PV power plant is a complex but crucial task. The study utilized the climate measurements collected from the Civil Aviation Administration, however, in order to improve the computation; KISR and EDF EN have decided to invest in a dedicated on-site measuring station developed by EDF EN engineers, which will be operated during one year at least. The station will allow the experts to better take into account all micro-sitting effects in the energy production forecast such as the exact sun radiation or the effect of dust, aerosols, humidity and temperature. It will therefore reduce the uncertainty of the computation and increase the project’s bankability. Irradiance and temperature will be correlated with satellite database in hourly or daily bases, in order to correct these databases and have long term and representative data of the site.
The meteorological station will also measure wind speed and direction and ambient temperature as well as temperature of a PV panel for two technologies: First Solar (CdTe) and Suntech (c-Si). Figure 2 shows gives general information of the two modules installed in the meteorological station [2] and [3]. Above this, an original soiling process had been developed internally, in order to precise in advance the expected soiling losses according to the very local conditions, and to anticipate an optimal strategy for the 20 years of cleaning. All these instruments will allow the experts to reduce the uncertainties drastically, considering that soiling losses, modules behavior, transposition factor and tilted irradiance will be estimated with the greatest accuracy as possible.

The station will be autonomous and power thanks to the built-in battery that will be charged using the two installed PV panels. Last but not least, all hourly measurements will be automatically transmitted to the data analysis center laboratories through GSM communication. Figure 3 shows the station design.

4. PANEL CLEANING PROTOCOL

A panel cleaning protocol will enable the experts to define the best optimized cleaning schedule for a future PV power plant in Kuwait [4]. Tests will be performed thanks to cleaning sessions organized each week, each 2 weeks or each month, depending of the season with the two main panel technologies: thin film and crystalline. The conclusions of this protocol will help the experts to define a panel sourcing and cleaning strategy for future PV power plants in Kuwait.

5. DATA AND RESULTS

The installed meteorological station enabled the experts to perform the following four tasks:

A - The 12 to 18 month’s collected raw data were used to calibrate and correlate other meteorological data sources. It was possible for the experts to use the data with a better accuracy satellite data or other local former meteorological-stations and therefore rebuild a 5 to 10 years historical data-base of Kuwait’s solar irradiation.

B - Using this historical data base, experts will be able to produce a Prediction Energy Report that will include P50, P75 and P90 which represent the minimum expected production of the contemplated PV solar power plant with a probability exceeding 50%, 75% and 90% respectively. Such computation can be made with any kind of module (using PV panel supplier’s specifications) and will therefore help the experts to propose the best technology for future renewable energy projects in Kuwait. These data will be used by the experts in the projects business plan to define an electricity tariff that allows reasonable project economics [5].
Figure 3: Design of the meteorological station.

Figure 4: Monthly global horizontal irradiation for different region in the world (value determined with PVGIS)
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**Figure 5: Monthly comparison between Al Mutla and Sulibiya stations**

- Transposition factor (depends on the sun’s and panels’ position);
- Shading losses: the data collected from the meteorological station will help the experts to design optimized structures that will reduce those losses and therefore increase electricity generation;
- Reflection losses: as the incoming radiation is mainly non-perpendicular to the tilted surface, there are some reflection losses;
- Temperature losses: the solar module’s power is given for a module’s temperature of 25°C\(^1\) and decreases when temperature increases. Temperature losses are expected to be significant in Kuwait;
- Soiling losses: soiling of the modules has an effect on the production of the power plant. In our particular case, the combination of a desert environment and little rain results in high soiling losses. This phenomenon grows worse when the modules have a metallic frame, which retains the dust; this is the case with Suntech modules. First Solar modules are frameless and less affected. Both will be tested on this meteorological station;
- Mismatch losses: all the modules of one string got to work at the same current, which is fixed by the module of lower current. As all the
modules don’t have exactly the same power, all the modules of one string will operate at the conditions fixed by the lower power module;

- Cabling losses: these losses depend on the length, diameter and connectors of the cables. The plant design is meant to reduce these losses;
- Inverter losses: conversion from DC to AC is responsible for losses estimated with the efficiency curve of the inverters. The conversion loss decreases with the increase of the inverter load;
- Transformer losses: as the voltage at the inverter output needs to be increased, transformer losses need to be considered;
- Performance degradation: the modules’ evolution along the years results in a loss in efficiency. The manufacturers give a constant of power degradation per year for their modules. Due to the extreme conditions, the degradation is higher than in Europe.

6. CONCLUSION

The meteorological station gives a better understanding of the solar conditions available in Kuwait. Those recorded data will help the experts to have a more reliable model in order to estimate and/or validate the feasibility and financial study of a potential solar power plant in Kuwait [7]. The recorded data clearly shows that both technologies can work in desert conditions with some advantages and inconveniences for each technology. Even though the silicon panel has a better efficiency at standard test condition (STC), this advantage is reduced at normal conditions due to the lower temperature coefficient and the better yield with the diffuse radiation of the thin film panel. However the final choice of technology will depend on the specific production of each technology and the availability and cost of land.

REFERENCES


C – Verification of the theoretical computation model, the two PV panels installed on the meteorological station will enable experts to validate all theoretical models and PV panel supplier’s specifications in the climatic conditions of Kuwait by simply measuring the output power of each panel and comparing it with theoretical computation. This is particularly important in an environment which is quite different from PV panel manufacturer’s standard conditions (T° = 25°C, irradiance = 1000 W/m2, A.M. = 1.5).

D – Comparison with other sources, Kuwait is located in one of the sunniest areas of the world. An analysis using PVGIS\(^1\) to compare radiation of different locations indicates that Kuwait potential is much higher than in European and North Africa regions shown in Figure 4. A comparison has been done with another meteorological station. The station selected is the KISR station located in Al-Mutla [6]. The years 2005 to 2010 have been used and monthly average in order to compare with the installed meteorological station at Sulaibiya. Figure 5 shows the compared data for the generated power and a graphic representation of the data. These results show that the irradiance is in the same order of magnitude that the Sulaibiya station. The relative difference is -0.5% during the period of April though December.

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\(^1\) Photovoltaic Geographical Information System (PVGIS) is an internet-based geographical information system. It covers not only Europe but also Africa and parts of South-West Asia. The underlying data bank for Europe includes a digital altitude model and climatic data with a spatial resolution of 1 km.