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Technical Assessment Of A Photovoltaic Panel And A Wind Domestic Turbine Systems In Morocco

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Abstract: This paper presents a general methodology of optimizing the energy performance of a photovoltaic panel in five different cities in Morocco, by varying its slope and azimuth. A domestic wind turbine is also studied in Casablanca. For the same capacity, simulations in TRNSYS software prove that photovoltaic panels have a better yield than the domestic wind turbines. These wind generators can be coupled with the photovoltaic system in order to lessen the intermittence of the photovoltaic production at night and during short cloudy days.

Keywords: Photovoltaic, Wind Power, Optimization, Sensitivity Analysis, TRNSYS

1. INTRODUCTION

Morocco benefits from a remarkable potential in renewable energies thanks to its suitable geographical position. In fact, our national rate of sunshine is the ninth best in the world: Morocco's 710,000-km2 lands profit from a range of 2800 and 3400 hours of sunshine per year. The Moroccan Agency For Solar Energy (MASEN) evaluates the Moroccan technical potential of solar energy to 20,000 MW. However, the actual installed capacity is only estimated to 180 MW in 2016 (MASEN, 2018).
Among the various available technical solutions to exploit the energy of the sun, photovoltaic technologies make it possible to convert the sunlight into electricity, and global efficiencies are typically around 14-16% for polycrystalline modules.
Many Moroccan authors studied the performance of PV installations; K. Attari and al. presented an evaluation of a grid-connected photovoltaic (PV) system installed on the roof of a government building located in Tangier, Morocco (Attari, 2016). D. Lahjouji and al. optimized the tilt angle for maximum solar energy collection in Ifrane, Morocco (Lahjouji, 2013).
In the framework of the study, a PV system is modelled in TRNSYS transient simulation program using a PV panel (Type 94) and a typical meteorological year (TMY2) conditions (with Meteonorm software data). The panel performance is studied and optimized in five different cities in Morocco: Casablanca, Fez, Tangier, Ouarzazate and Marrakech, using genetic algorithms. These cities are located in five different climatic zones according to the Moroccan thermal regulation for buildings (ADEREE, 2015).
The global installed capacity of wind turbines was about 318,1 GW by the end of 2013. Morocco has launched, on June 28, 2010 an ambitious wind energy program, aiming to grow the wind plants to 2000 MW by 2020. The commissioning of the first wind farm in Morocco took place in 2000 (Abdelkhalek Torres Farm in Tetouan, 50.4 MW) (ATLAS ADEREE,

2018). Many other wind energy generation projects were completed since then: Amougdoul in Essaouira (60 MW), Tangier wind farm (140 MW), Houma (50 MW)…
Mohamed Oukili and al. performed a comparative Study of the Moroccan Power Grid Reliability in Presence of Photovoltaic and Wind Generation. They conclude that wind and solar power sources to be used in order to save fossil fuel and increase the total energy generation in Morocco (Oukili, 2013).

Consequently, the second chapter of this article will shed the light on the study of a domestic wind turbine, with a capacity of 1Kw in Casablanca, using the type 90 of TRNSYS and the weather data (wind and direction speed) collected by Meteonorm in a weather station located in Casablanca.

2. STUDY AND OPTIMIZATION OF THE ENERGY PERFORMANCE OF A PV PANEL

2.1 Weather data

Meteonorm7 software generates the weather data used in this paper.
Meteonorm is a complete, worldwide climatological database. The software enables data generation of hourly values for any place in the world (Meteonorm, 2018). The user can synthesize these data in an output file compatible with TRNSYS software.
For Casablanca, Tangier, Fez, Ouarzazate and Marrakech, radiation data cover respectively the period 1991-2010. Figures 1 to 5 show the global and diffuse radiations evolution in the five cities.

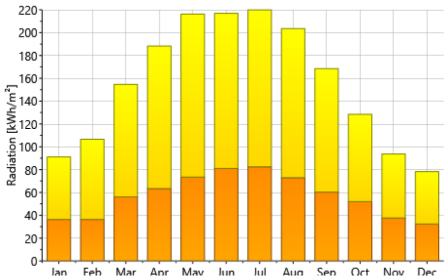


Figure 1: Global (yellow) & Diffuse (orange) radiations in Casablanca;

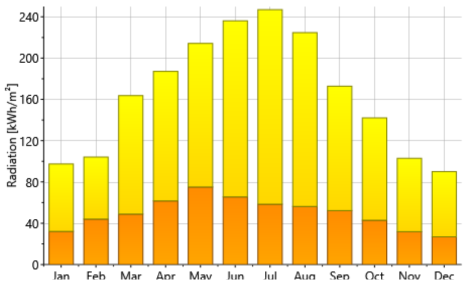


Figure 2: Global (yellow) & Diffuse (orange) radiations in Fez;

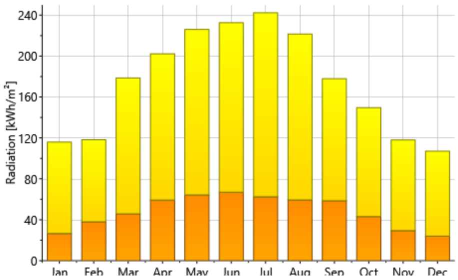


Figure 3: Global (yellow) & Diffuse (orange) radiations in Marrakech;

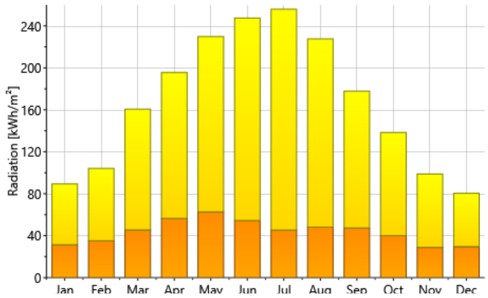


Figure 4: Global (yellow) & Diffuse (orange) radiations in Tangier;

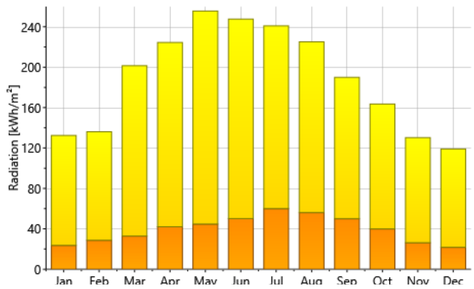


Figure 5: Global (yellow) & Diffuse (orange) radiations in Ouarzazate;

These cities and Morocco in general, benefit from a very important global radiation (255 kWh/m² per month at its highest in Ouarzazate). Morocco is then an attractive country for investing in solar technologies.

2.2 TRNSYS model and initial results

In our case study, we chose a photovoltaic panel produced locally in Skhirat, Morocco by PV Industry, subsidiary company of Jet Energy and specialized in Photovoltaics.

These panels have a surface of 1,94m² (1,952 x 0,992 m²) and a 300Wc per-unit power. The TRNSYS model is showed in the figure 7.

1	Module short-circuit current at reference conditions	8.88	amperes
2	Module open-circuit voltage at reference conditions	44.82	V
3	Reference temperature	298	K
4	Reference insolation	1000	W/m^2
5	Module voltage at max power point and reference conditions	36.3	V
6	Module current at max power point and reference conditions	8.26	amperes
7	Temperature coeficient of Isc at (ref. cond)	0.064	any
8	Temperature coeficient of Voc (ref.	-0.327	any

Figure 6: PV Industry 300Wc polycrystalline module parameters in TRNSYS

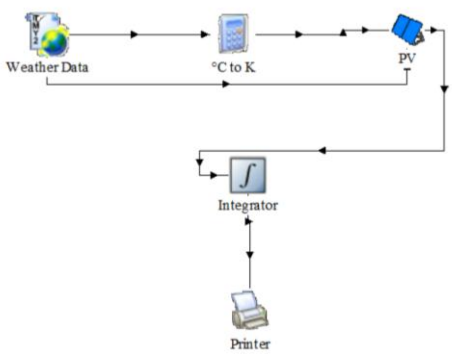


Figure 7: TRNSYS model

We will study the performance of a single photovoltaic panel in the five cities, with an initial slope and azimuth of 0° (horizontal panel, south-faced). The results are presented in the figure 8.

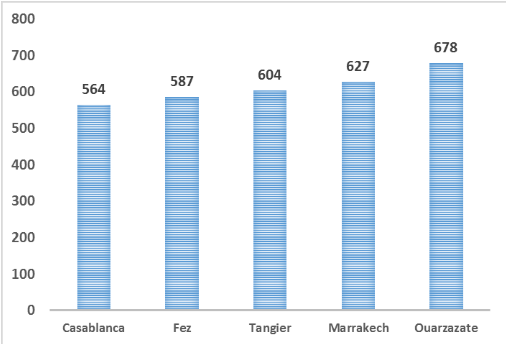


Figure 8 – Energy output in kWh in the five cities

In the following paragraph, we will use a sensitivity analysis approach to determine which of the two studied parameters (slope and azimuth) has the most influence on the energy performance. Then, we will optimize it by studying them in their variation intervals.

2.3 Sensitivity Analysis

Systems simulated on dynamic thermal simulation (DTS) tools present many input parameters. In order to optimize a chosen output of these tools according to the combinations made up of input parameters, sensitivity analysis allows the identification of the parameter or set of parameters that have the greatest influence on the model output, and thus not to study the parameters which have a low influence on the model (École Chercheur Mexico, 2010). Sensitivity analysis helps determining how a digital model answers variations intervening on its inputs (Looss, 2011).

Sobol sensitivity analysis determines the contribution of each input parameter and their interactions to the overall model output variance. The sensitivity of the output compared to the parameters is given by various orders indices of sensitivity.

Among these indices, the total order index allows to study both the effect of the parameter alone and the effects of its interaction with all the other parameters on the variation of the output.

We developed algorithms on the OpenSource programming language Python, in order to adapt our case study to the algorithms of the SALIB library (Sensitivity Analysis Library) available on GITHUB (Herman, 2017).

The studied parameters are:

- Slope (from 0 horizontal to 90° vertical);
- Azimuth (from 0 south to 360° south);

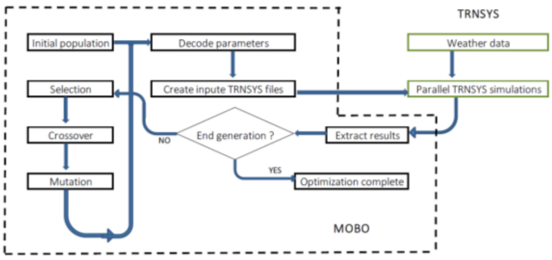
Figure 9 –Sensitivity analysis first and total indexes

We notice that the two parameters have almost the same first order index (same influence when varying one parameter and fixing the other).
The total index of the azimuth is although higher than the total index of the collector slope. The panel azimuth has then a slightly higher influence on the energy yield than the panel slope.
The second order index shows also that there is a high interaction between these two parameters.

2.4 Optimization using MOBO Software

In this paragraph, we carry out a coupling of the TRNSYS software with MOBO (Multi-Objective Building Optimization tool) optimization tool, developed by the Technical Research Centre of Finland (Palonen, 2013).
To perform the optimizations, we will use the genetic algorithms GA (in specific the non-dominated sorting genetic algorithm NSGA-II), coupled to the Hooke-Jeeves algorithm (Deb, 2001). GA reflect the process of natural selection where the fittest individuals are selected for reproduction in order to produce offspring of the next generation (Dubrow, 2010). The Hooke-Jeeves algorithms perform modified iterations of Hooke and Jeeves until no further progress is forthcoming.

Figure 10 – Coupling TRNSYS / MOBO GA



The table below shows the optimization results in the five cities.

Table 1 - Optimization results

City	Azimuth (°)	Slope (°)	Optimized Yield (kWh)	Initial Yield (kWh)
Casablanca	0	29,52	629	564
Fez	0	31,21	663	587
Tangier	0	31,97	690	604
Marrakech	358,4	30,32	704	627
Ouarzazate	0,05	30,81	765	678

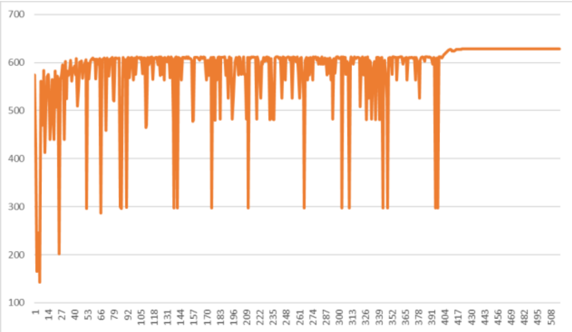


Fig. 11 – Optimization process (510 simulations) of the energy yield in Casablanca

We notice that in the five cities, the optimal orientation of the panel is south (0°), and the optimal slope is around 30°.

By optimizing these two parameters, we gain around 12% of the annual electricity production.

2.5 Comparison with random search algorithm

The random search algorithm randomly varies the values of the two parameters within their intervals of variation, until reaching the number of simulations specified by the user.

With 500 simulations, the optimal combination is:

- Yield : 627 kWh;
- Azimuth : 355°;
- Slope : 29.55°;

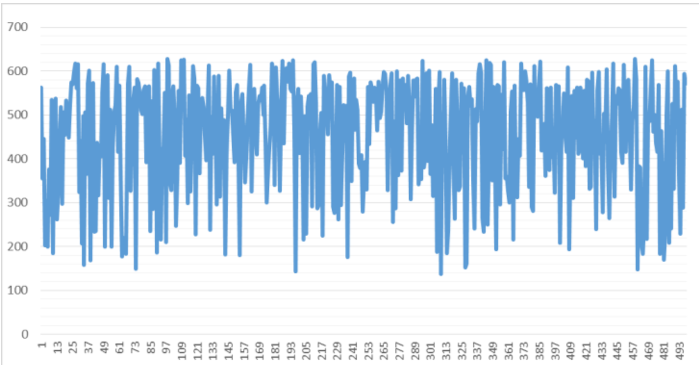


Figure 12 – Random search algorithm

We notice that the random search algorithm permits having a good approximation of the optimal value (627 kWh instead of 629 kWh), although the NSGA-II algorithm is more efficient.

2.6 Effect of the temperature on the yield

We studied below the effect of variation of the temperature (from -5°C to 45°C) on the electrical output of the most efficient hour of the year. The figure 13 shows the results obtained with the random search algorithm.

We notice that the yield is decreasing while increasing the ambient temperature. The optimal operating temperature is 5°C.

The PV panel is losing around 8% of its efficiency when passing from 5 to 45°C.

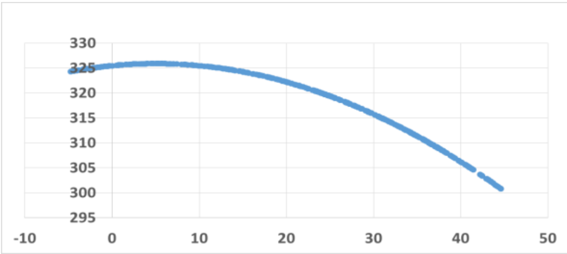


Figure 13 – Effect of the temperature on the electrical yield of 1 hour (in Watt)

Domestic Wind Turbine Study

Solar energy is generally not enough alone to supply the needed energy, especially during the night and in the short gray days of winter. Moreover, according to local weather statistics, wind speed increases in winter, so that solar energy and wind energy can complement each other. In addition, small wind turbines have a rather simple manufacturing technology and require less land area (Elnaggar, 2017).

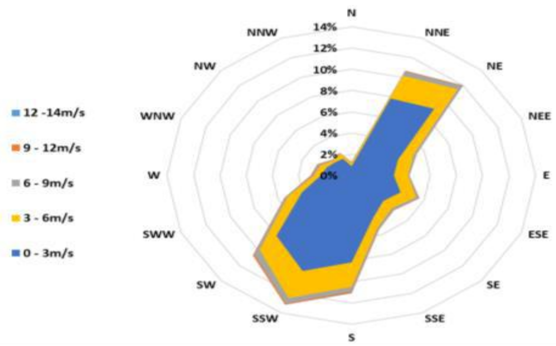
For these considerations, we will study in this section a domestic wind turbine installation in Casablanca.

Weather station

The weather station used in this study is located in Casablanca, its coordinates are 33,6°N / -7,7°E, 55m.

Figure 14 below shows the wind rose and the wind speed evolution in Casablanca.

Figure 14 – Wind rose in Casablanca



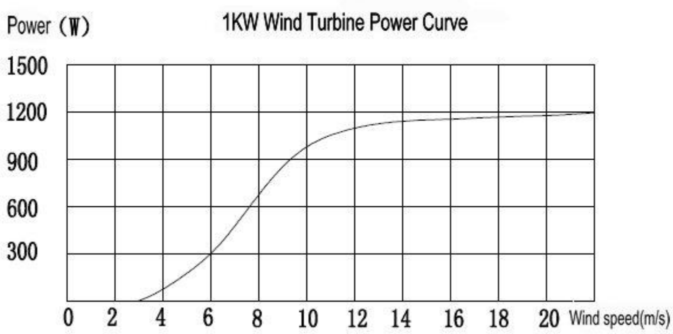


Figure 15 – Wind speed distribution in Casablanca

Then, the preponderant wind directions in Casablanca are NNE, NE, SW, SSW and South.
In the figure 15, Y-axis shows the sum of hours per year (for a total of 8760 hours per year) and X-axis refers to the wind speed in m/s.

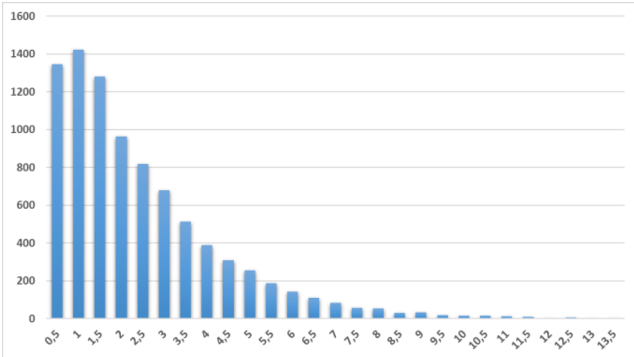


Figure 16 – TRNSYS model

Domestic wind device and TRNSYS model Weather station

In this paragraph, we will study the performance of a 1kW wind Turbine (HUMMER 1kW wind generator). The TRNSYS model and the characteristics of the generator are detailed below (HUMMER, 2018).

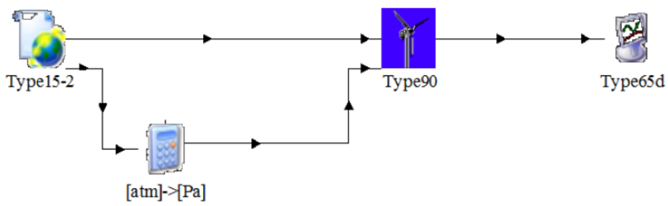


Figure 17- HUMMER 1kW Power / wind speed curve

3. RESULTS

The figure 18 shows the hourly wind power generation in Casablanca (in Watts).

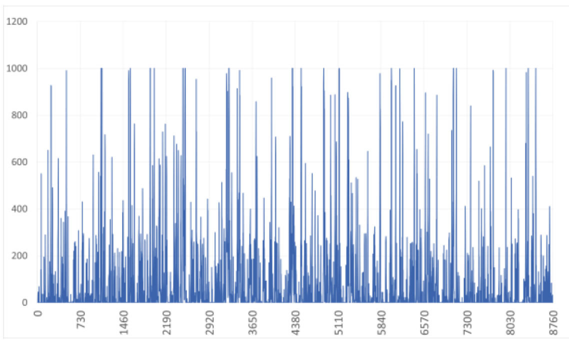


Figure 18 - Hourly cumulative power generation (8760 hours per year)

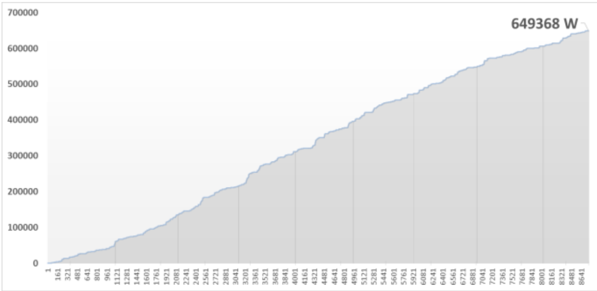


Figure 19 – Hourly power generation (8760 hours per year)

The annual electrical production is then around 650 kWh, for the 1kW domestic wind turbine, while a single photovoltaic panel may produce the same yield as showed above.
We deduce then that for the same capacity, photovoltaic panels have a better annual electric yield than the domestic wind turbines in Casablanca.
However, these domestic wind turbines can be coupled with a photovoltaic installation, in order to lessen the intermittence of the photovoltaic production at night and during short cloudy days (Figure 20).

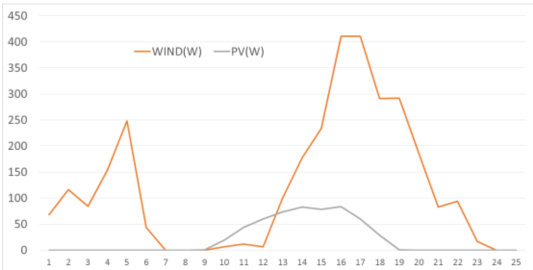


Figure 20 – PV and wind yield in the 31th of December

4. CONCLUSIONS

The sunlight harvesting and the photovoltaic applications are interesting in Morocco, due to the important global radiations received by its surface. In the scope of this work, we studied the energy performance of a PV panel manufactured locally in Skhirat by PV Industry. The electric output was optimized following the intervals of variation of the panel slope and azimuth. It was proved that a south-facing panel, with a slope of around 30° gives the best annual energy yield. A sensitivity analysis performed in the city of Casablanca, shows that the azimuth influences more the annual yield than the slope of the panel.
Furthermore, Meteonorm collected weather data in the Meteonorm station of Casablanca (wind speed and direction) were used to study a domestic wind farm of 1kW. The simulation gives an annual production of around 650 kWh, which is almost the production of a single-unit photovoltaic panel. For the same capacity, photovoltaic panels have than a better yield then the domestic wind turbines in Casablanca. These two technologies can be coupled in order to lessen the intermittence of the photovoltaic production at night and during cloudy days.

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