Optimized Configuration of a Hybrid Photovoltaic-wind System Integration

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Abstract: Hybrid Photovoltaic-Wind system (HPWS) is becoming the most current renewable energy sources used to power an electrical load demand, hybridization help to take all their advantages through reaching the best compromise between technical and economic criterion. In this paper, a thorough analysis of one-year weather situation and energy performance for two locations (Rabat and Tangier) is performed for sizing and integrating HPWS. The target is consisted to find the optimized hybrid configuration capabilities to ensure the electrical load demand of the laboratory prototype. The TRNSYS/Matlab has been used to simulate the annual performance of different configurations of HPWS and provides the optimum configuration, which ensures supplying the load demand. Moreover, the analysis of the dynamic simulation results allows having a visibility of the hybrid system requirement and the integration cost, besides to evaluate the economic aspect of each optimized solution. The hybridization of two sources of energy can in some cases reduce the cost of installation and energy. As result: for the same load profile, and for two coastal sites spaced 250 km apart, two different system requirement has been identified, PV=9kWp-Wind=1kW for UIR Rabat and PV=3kWp-Wind=3kW for FST Tangier. And also two different capital cost has been found: 17215 € for UIR Rabat and 14695 € for FST Tangier.

1 INTRODUCTION

Various renewable energy sources can be combined such as solar and wind, a single energy source based system can be more costly and less reliable than a hybrid system. Numerous study showed a realistic application of the hybrid system for electrical energy generations (El Azzaoui, M., Mahmoudi, H., Boudaraia, 2016)(Sanajaoba & Fernandez, 2016). Different criteria can be applied to make the choice among various system components of the hybrid power plant, such as an economic constraint and optimization sizing approaches (Anoune, Bouya, Astito, & Abdellah, 2018). It becomes most common that researchers use deterministic methods for sizing the hybrid Photovoltaic-Wind system and provide the optimized configuration as a solution to the problem of sizing optimization (Yang, Lu, & Burnett, 2003)(Anoune, Laknizi, Bouya, Astito, & Ben Abdellah, 2018). Numerous studies have been carrying out using TRNSYS (TRNSYS, n.d.) software, to evaluate the output performance of a photovoltaic and wind power plant according to the solar / wind field of the desired area. Weather data

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files in TMY format and the required load demand are used as input to simulate the long-term hybrid system performance. B. Quesada et al. (Quesada, Sánchez, Cañada, Royo, & Payá, 2011) presented a validation study witch examine an experimental result using measured data of a photovoltaic installation occurred in the Polytechnic University of Valencia along two successive years, confronted with simulation results of a designed system based on TRNSYS. Gregoris Panayiotou et al. (Panayiotou, Kalogirou, & Tassou, 2012) modeled a renewable system through TRNSYS in order to determine an adequate size for the location under examination. In this respect, TRNSYS can be considered as a performant and scientifically recognized tool. A large number of studies have been conducted for the sizing and management of a renewable facility, witch its simulation results have been validated by an experimentation setup, but these studies are limited to the evaluation of photovoltaic systems and not the hybrid system based on two or more renewable energy sources which are the subject of interest.

In this paper, one-year weather analysis and energy performance of Rabat and Tangier are performed for sizing and integrating HPWS, which supplies an electrical load demand. The aim is to compensate the heat loss from the bitumen tank. The developed model can estimate the annual performance of the possible system configuration, and provide the optimized solution, finally, the weather data analysis and the annual energy performance for the chosen configuration of each location is illustrated and discussed, and moreover, payback period is estimated.

2 OVERVIEW OF THE ADOPTED HYBRID TOPOLOGY

The Hybrid inverter is the heart of the hybrid electrical system, it includes several subsystems inputs and outputs which serves to power the ELD. This hybrid power system combines solar panels, wind system, and grid with another subsystem such as storage system and AC output. The functional diagram below shows the adopted hybrid topology (Fig: 1).

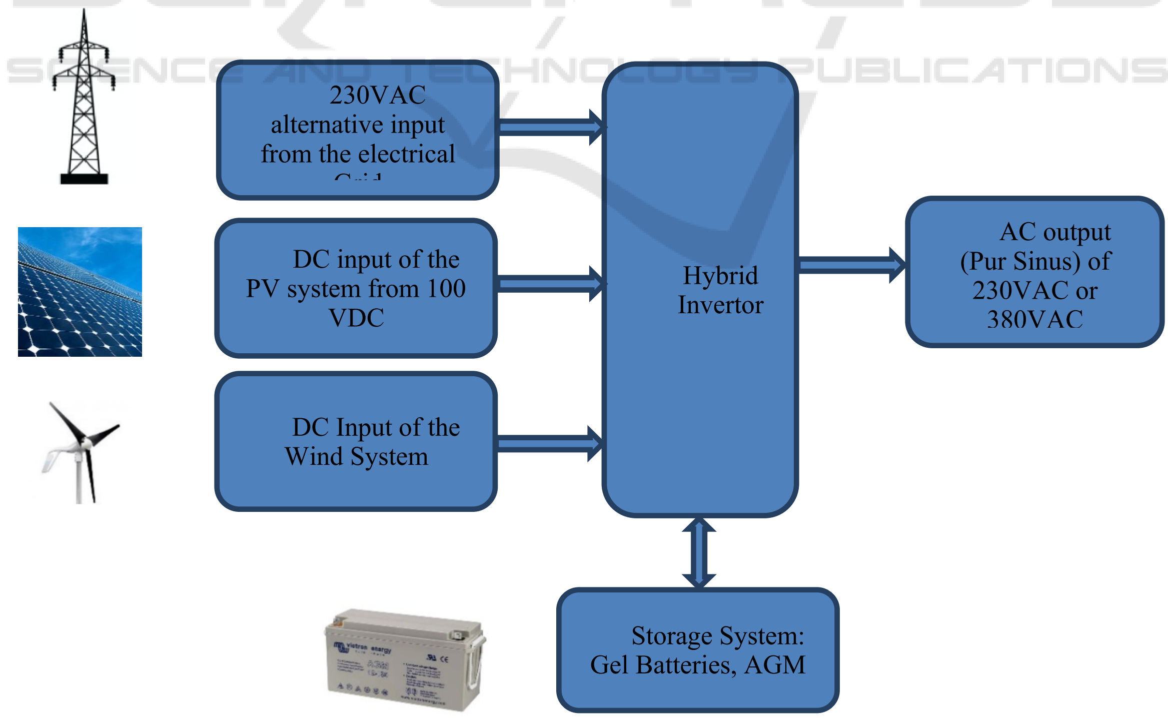

Fig 1: functional diagram of the adopted hybrid topology.

3 SIZING A HYBRID SYSTEM USING A DETERMINISTIC APPROACH

The target of this comparison study is proposing the optimum size of HPWS under the constraints of the maximum power reliability and the minimum system cost. This HPWS helps to power the electrical consumption of the laboratory prototype. The adopted sizing method is the deterministic approach which is performed by analyzing the dynamic simulation obtained by TRNSYS and Matlab. Three parameters help to obtain the optimized configuration of the desired hybrid system; firstly, the metrological input mainly the global irradiation, the wind speed and the temperature of the potential plant location (Fig: 3, 4 and 5). Secondly, the electrical demands profile (Fig: 2), which explains the behaviour of electrical power consumption during the day. Finally, the hybrid system configuration which define the technical characteristics of the sizing solution.

Two locations have been identified as potential plant location; the first one is an area close to the technical hall in International University of Rabat (IUR), Morocco. The second one is the campus of the Faculty of science and technology in Tangier (FST), University of Abdelmalek Essaadi (UAE) Tangier, Morocco. The chosen location will host the future laboratory prototype.

The yearly average solar energy per day in Rabat and Tangier is 5.47 kWh/m², 5.26 kWh/m² respectively. The maximum and minimum ambient temperatures are 22.6 °C / 12.7 °C and 20.7 °C / 11.3 °C in July and January, respectively. The yearly average ambient temperature is 17.9 °C and 18.15 °C respectively; finally, the yearly average wind speed at 10 m hub height is 3.14 m/s and 5.9 m/s respectively in Rabat and Tangier (Fig.3, 4 and 5).

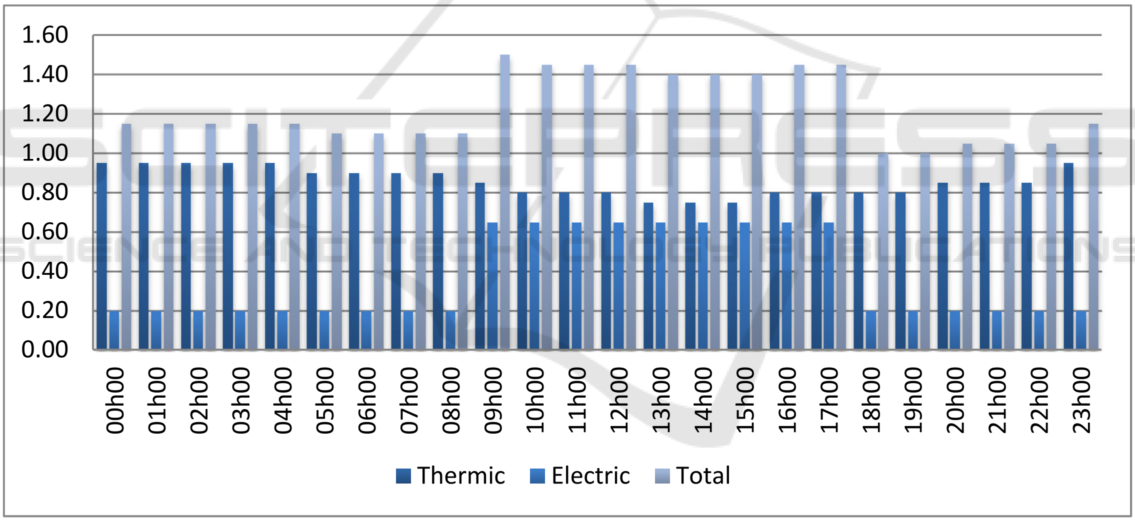

Figure 2: the electric load profile of the laboratory prototype.

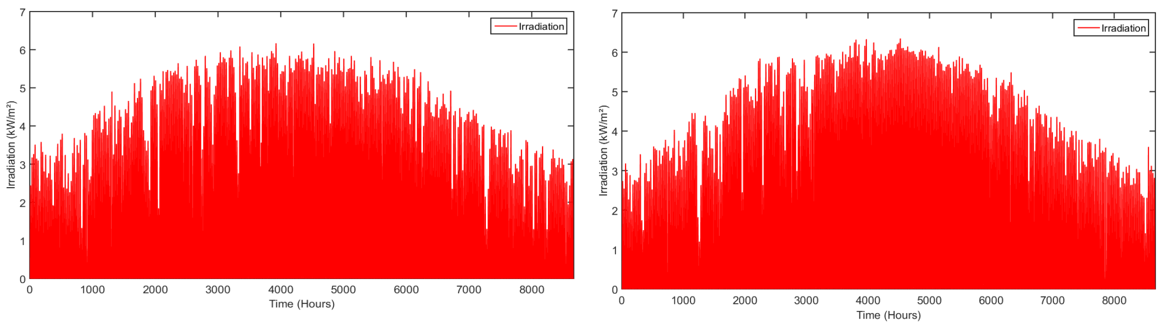

Figure 3: Hourly time series irradiation data for UIR Rabat (Left) and FST of Tangier (Right).

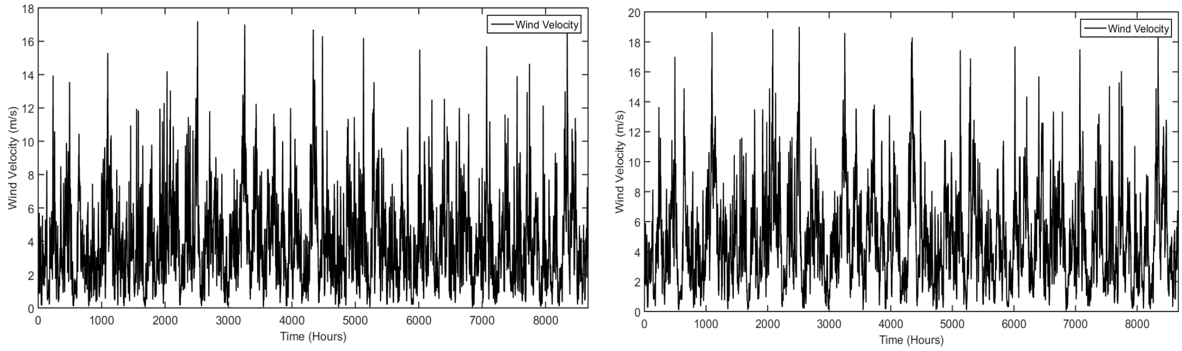

Figure 4: Hourly time series of wind speed for UIR Rabat (Left) and FST of Tangier (Right).

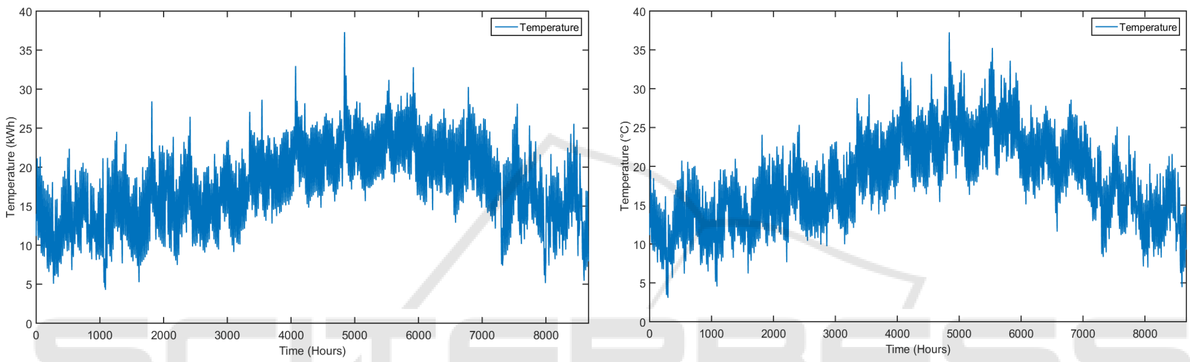

Figure 5: Hourly time series of Temperature for UIR Rabat (Left) and FST of Tangier (Right).

4 RESULT AND DISCUSSION

The target of the laboratory prototype is remained to maintain a constant storage temperature of bitumen at 160 °C by compensating their thermal losses, The total of electrical energy requested per day is around 29.4k Wh. This load data behavior is used for performing the simulation.

The dynamic simulation of the energy produced by the hybrid Photovoltaic wind system is illustrated in (Fig 6 & 7), these simulation results are obtained using the designed model in TRNSYS and are plotted using the Matlab program. The developed TRNSYS model is used to provide weather data simulation and energy output from the hybrid system (Fig.6), The optimized solution for (IUR Rabat) is composed of 9 kWp of Photovoltaic panel and 1 kW of Wind turbine, the total energy output during a year from the photovoltaic array and wind turbine is estimated at 9581 kWh and 1404 kWh respectively, which means a total of 10822.85 kWh/Year.

In another hand, The optimized hybrid system configuration for Tangier is composed of PV= 3 kWp and WT=3 kW, the simulation results of the and energy output from the hybrid system (Fig.6), it is noted that for the FST Tangier site, the potential of the wind is very high compared to the UIR Rabat site and may be as high as 5.9 m/s in annual average. The yearly average of energy production from a Photovoltaic array is 3269,14 kWh, while the yearly average of energy production by the wind turbine is 7833.63 kWh year, then this hybrid configuration produces 11102,78 kWh/year which is superior to the electrical demand by the prototype 10822.85 kWh/Year.

The total cost of any renewable power plant is considered as a mandatory criterion to decide the hybrid system configuration, Table .1 resumes the prices of all component and services for the chosen configuration (Amine, n.d.).

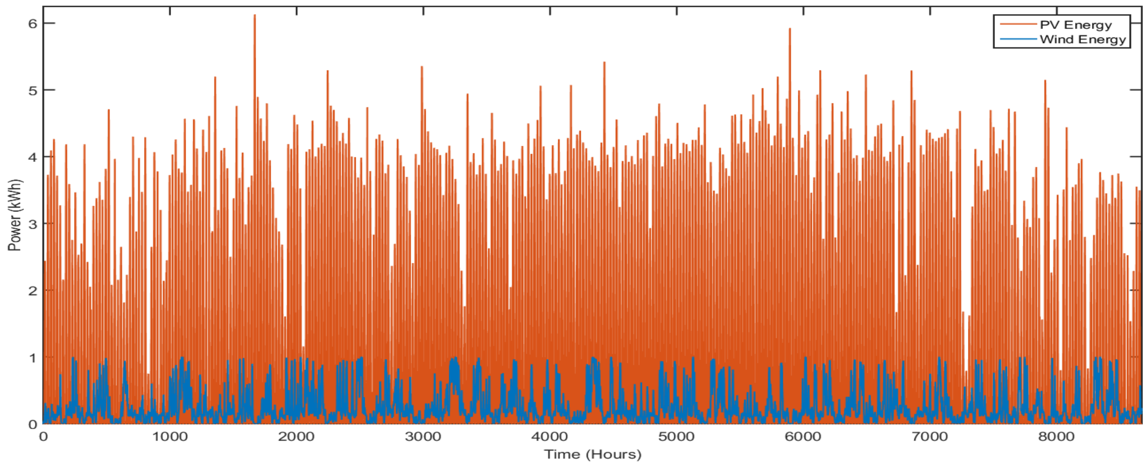

Figure 6: Dynamic simulation of annual energy production of PV=9kWp-Wind=1kW (UIR Rabat).

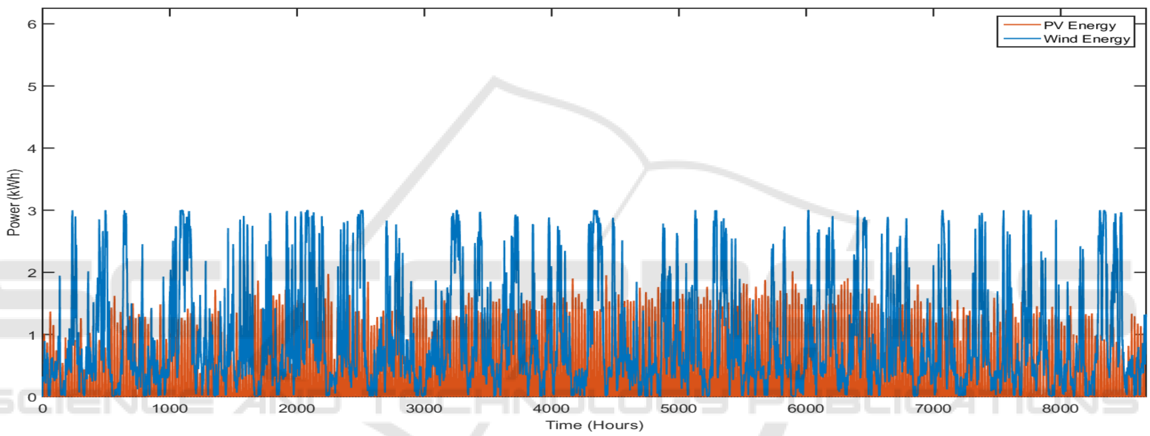

Figure 7: Dynamic simulation of annual energy production of PV=3kWp-Wind=3kW (FST Tangier).

The economic evaluation is considered as important criteria to evaluate the feasibility of any project with regard to its economic benefits. In this study, the payback method is used to evaluate economically the considered hybrid system for each chosen location see (Table 2). The payback period is generated following equation 1:

$$PBP = \frac{\ln\left(\frac{C_S i_f}{E_S C_f}+1\right)}{\ln(1+i_f)} \qquad (1)$$

Table 1: Cost of the hybrid power plant

	PV panel 250 Wp	Price of PV U (250W)	Total Price of PV array	Price of Wind turbine	Battery Bank (15kWh)	Inverter/ Charger 5 kW	Inte gration Cost	The total cost of HPWS
Rabat	36	155 €	5 580 €	2 000 €	2 235 €	2 800 €	4 600 €	17 215 €
Tangier	12	155 €	1 860 €	5 300 €	2 235 €	2 800 €	2 500 €	14 695 €

Table 2: Comparison result of calculated payback period

	Cost of the system (€)	Energy saving (kWh)	Cost of electricity (€/kWh)	Electricity inflation (%)	Payback (Years)
Rabat	17215,00	10985,76	0,097	8,5	10,59
Tangier	14695,00	11102,78	0,097	8,5	9,44

As mentioned at the beginning of the paragraph, the optimal requirement configuration seems differentiated in the chosen location, UIR Rabat has 9kW of Photovoltaic Array and 1 kW of Wind turbine, but FST Tangier has 3kW of Photovoltaic Array and 3 kW of Wind turbine which justify the price of each hybrid system. Moreover, the integration cost consists of all service providers and equipment relating to structural Photovoltaic-Wind supporting and installation/wiring. After analyzing these results, it is deductible that each chosen location has a specific system requirement as the optimal solution of the sizing problem.

5 CONCLUSION

In this paper, the authors are focusing on sizing and integrating an HPWS to supply an electric load demand profile, The target of this size is providing an optimized configuration (Photovoltaic and Wind size), which can power supply the laboratory prototype with the lowest cost of required equipment and the higher power reliability. The dynamic simulation allowed visualizing the long-term electrical production of different HPWS configuration, then selecting the optimized solution of each chosen location. As result, for the same electric load demand and for two coastal cities (IUR Rabat & FST Tangier) which distance of 250 km, two different configurations are found to meet the energy requirement, 9kWp of Photovoltaic array and 1kW of wind turbine as an optimized solution for IUR Rabat with a total cost of integration system around 17 215 €, besides, 3kWp of Photovoltaic array and 3kW of wind turbine as an optimized solution for FST Tangier that have a total cost of integration equals to 14 695 €, hybridization of two renewable power sources allowed to reduce the total cost of integration in Tangier (2520 €) compared to the installation cost in Rabat.

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