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Simulation and Exergy Analysis of a Small Scale Seawater Desalination/ Electricity Production Prototype Powered with Renewable Energy

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Abstract

The objective of the FP6 Open-Gain project is to develop a new model-based optimal system design approach to economically improve the overall performance, dependability, reliability and availability of co-generating water-electricity plants powered by renewable energy for remote arid areas using a high level of automation to meet specific cost requirements and to disseminate the new technology in Mediterranean and Middle East/Northern Africa Countries. The design of a small scale prototype in Tunisia for RO desalination and hybrid power generation from conventional (e.g. Diesel GenSet) and renewable energy sources (e.g. wind energy conversion and photovoltaic power generation) will help to gain real experience with the new system concept characterized by flexible design, fast implementation, energy efficiency and low emissions. The challenge of such systems stems from the integrative character for the solutions: Usually only simultaneous water and power production and hybrid utilization of conventional and renewable energy sources make reliable and cost-effective solutions feasible. The integrative character of the engineering approach is illustrated by a case-study concerning a 48 m³/day seawater Reverse osmosis desalination plant on the east Mediterranean coast of Tunisia nearby Burj Cedria with additional power supply to the consumers of the water. The water and power cogeneration process is powered from PV and wind energy conversion including short time battery storage and a backup Diesel generator.

Keywords: *Keyword One, Keyword Two, Keyword Three, etc. (minimum 3 keywords)*

1. Introduction

Systems analysis environments for pre-feasibility and feasibility studies assessment based on local infrastructure, climate, load profile and economic boundary conditions are necessary tools in order to identify opportunities for reliable and competitive integration of renewable energies with conventional power supply to medium and small scale water treatment processes. On one hand, the Mediterranean and MENA areas are experiencing the most ambitious implementation program for central large scale water desalination plants to improve supply to a growing population and industry. On the other hand, the development of extended arid remote areas on a large territory asks for de-central solutions integrating water and power generation locally. Such settlements of few hundred people with no grid power connection at reach may have a simultaneous problem of water and power supply. In general, freshwater distribution and electricity production from Diesel GenSets depend on long distance transport by trucks of water and fuel respectively. The OPEN-GAIN EU FP6 project stands for Optimal Engineering Design for dependable Water and Power Generation in Remote Areas using Renewable Energies and Intelligent Automation [1]. The OPEN-GAIN global objective is "To develop a new model-based optimal system design approach to economically improve the overall performance, dependability, reliability and availability of co-generating water-electricity plants powered by renewable energy for remote arid areas using a high level of automation to meet specific cost requirements and to disseminate the new technology in Mediterranean Participant Countries and Middle East and Northern Africa wide", i.e.:

1. To design a fault-tolerant, dependable water-electricity cogeneration concept for remote arid areas based on renewable energy supplies

2. To design an energy management subsystem to combine different renewable energy sources and supplementary conventional energy sources such as diesel power generators.

3. To develop a dynamic mathematical model for analysis, design and control purposes and to carry out simulation experiments for the whole system

4. To develop a Decision Support System for the integration of the plant at site conditions

5. To develop strategies for real-time control, supervision, remote monitoring and diagnosis of components as well as for the whole plant.

6. To build a laboratory prototype to gain real experience with the new system concept.

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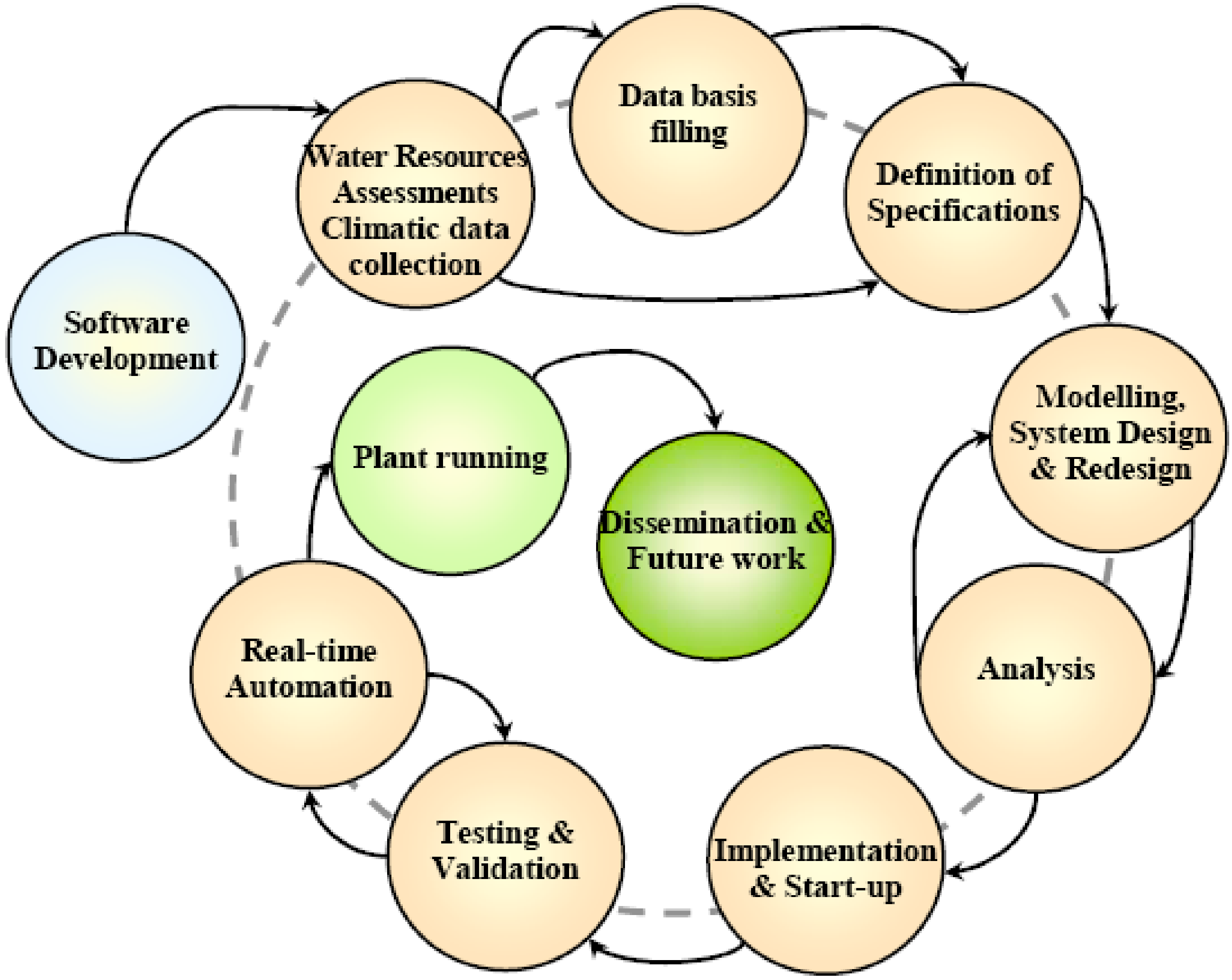

Fig. 1. OPEN-GAIN project management cycle [1]

We used the second law based tool, i.e. Exergy analysis, for hybrid system components efficiency computation and homer software for simulation and optimization purposes. Homer, which stands for hybrid optimization model for electric renewables [4] helps design off-grid and grid-connected systems and performs analyses to explore a wide range of design questions:

- Which technologies are most cost-effective?
- What size should components be?
- What happens to the project's economics if costs or loads change?
- is the renewable resource adequate?

Homer finds the least cost combination of components that meet electrical loads. It simulates thousands of system configurations, optimizes for lifecycle cost, and generates results of sensitivity analyses on most inputs.

2. Hybrid System Configuration and Loads

The hybrid system consists of renewable sources combined with energy storage and secondary power source needed for meeting electrical loads and water demand. The main components are the:

- Photovoltaic modules (Wuxi 81x185 Wp=15 kWp)
- Wind Turbine (Proven 15 kW)
- Diesel Engine (GMI,Perkins/Linz 19.5 kVA)
- Inverters (SMA windy boy, sunny island)
- Batteries (PVX, 12x120Ah)
- RO Unit (SETA, 5 kW)

Burj Cedria (Tunisia) site water demand is estimated at 48 m^3/day while the electricity user profile is shown in Fig. 3.

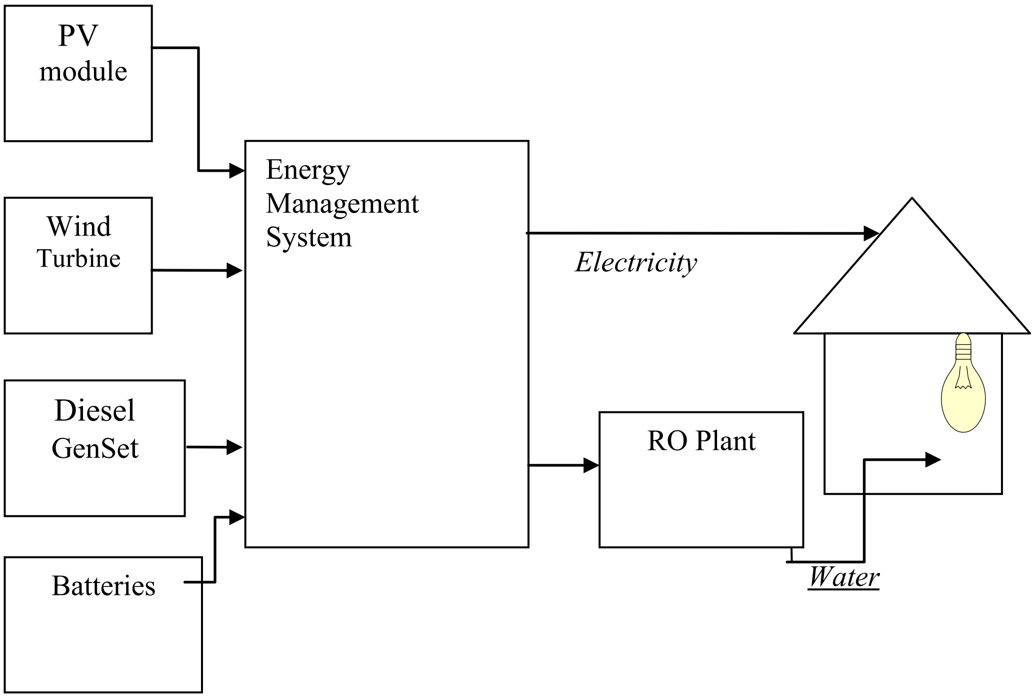

Fig. 2. OPEN-GAIN hybrid system configuration

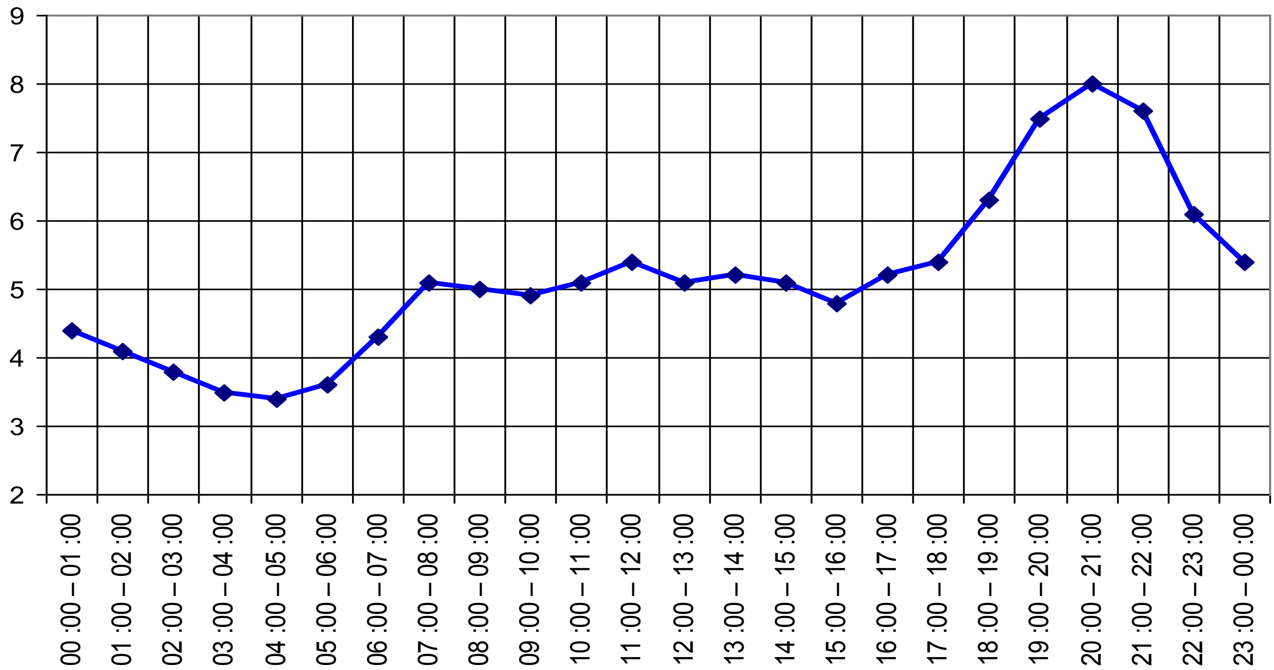

Fig. 3: OPEN-GAIN Burj Cedria daily kWh electricity consumption profile

3. Renewable Resources Assessment

Measurement of wind speed at a height of 20 m., solar irradiation and ambient temperature were conducted in the site of Burj-Cedria (nearby Tunis) for the 12-12-2007 to 18-12-2008 period. Figures 4-6 show the annual distribution of these parameters.

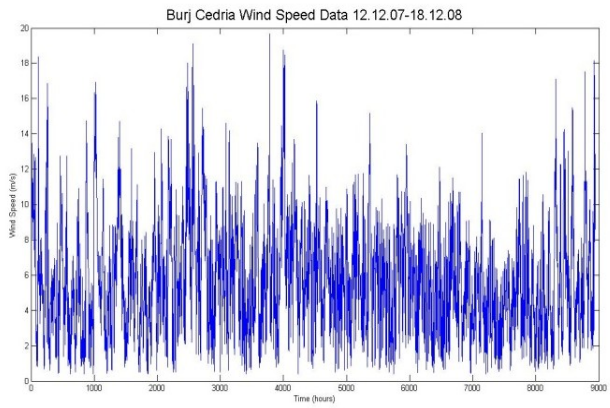

Fig. 4: OPEN-GAIN Burj Cedria site measured hourly wind speed data

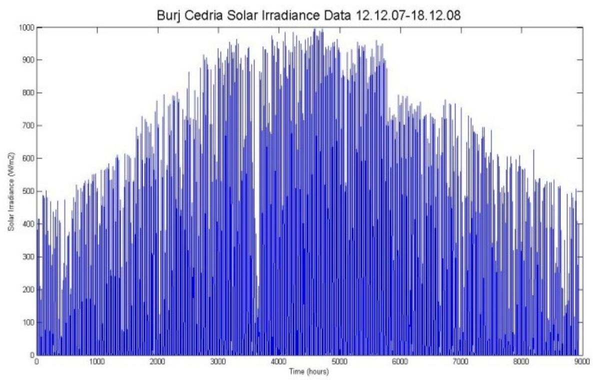

Fig. 5: OPEN-GAIN Burj Cedria site measured hourly solar irradiance data

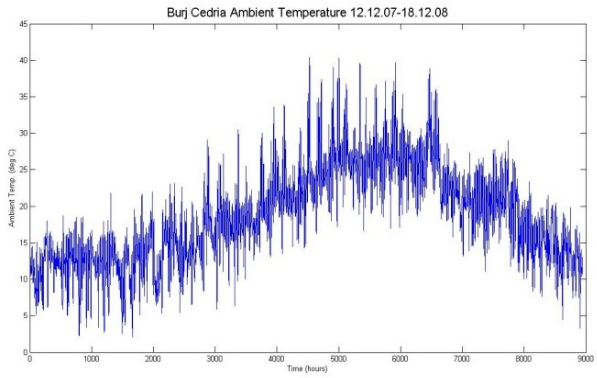

Fig. 6: OPEN-GAIN Burj Cedria site measured hourly ambient temperature data

4. Results

Fig.7 and Table 1 show the monthly averaged electricity production for the whole considered year. The renewable energy fraction is around 65% while we notice a larger contribution of the fossil energy during winter months.

The use of hybrid systems for energy production is justified on many levels: technical feasibility, economic viability and above the obvious environmental benefit offered by this alternative, especially for rough and isolated site. Concerning the environment impact, the fraction of the energy produced by renewable resources is more than half of total production, which significantly reduces the amount of fuel use and consequently reduce emissions of polluting gases. This reduction is 61.2% for CO_2 and NO_x.

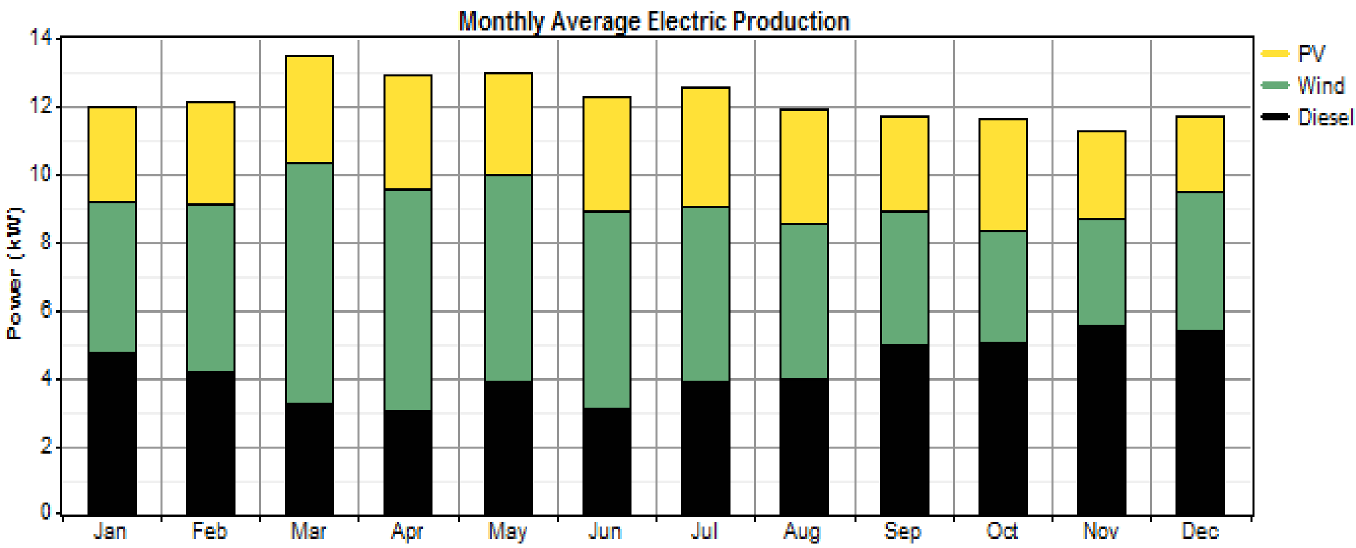

Fig. 7: OPEN-GAIN Burj Cedria site Hybrid system monthly averaged power production

Table 1. OPEN-GAIN prototype power production

Power Production	Value
RE Fraction	**65.0 %**
Wind Turbine	40.5 %
PV	24.5 %
Diesel Genset	35.0 %
Total Energy production (2008)	**108,884 kWh/year**
Wind Turbine	44,120 kWh/year
PV	26,681 kWh/year
Diesel Genset	38,083 kWh/year
Energy consumption	89,059 kWh/year
LEC	0.277 $ / kWh
Excess electricity	10.2 %

Economically, the specific cost of energy and the annual cost of the installation are more important in a conventional system (diesel only) than in the hybrid system. On the other hand, the use of such installation is strongly linked to the available potential of renewable energy, which justifies the presence of Diesel Genset in all possible configurations, this means that Renewable energy alone does not guarantee the satisfaction of demand at any time of year, especially for autonomous systems. The wind generator is more appropriate for this site: its output is greater than that of PV, with the same installed capacity (15 kW), it is also higher than the production of diesel while the exergy analysis shows a better efficiency. Figure 8 shows the exergy efficiencies of the three sources of energy (PV, Wind turbine and Diesel Genset) based on the first and second laws of thermodynamics. The exergy concept tool gives the true efficiency and is recommended in engineering systems design and analysis. The sensitivity analysis allowed us to predict the operation of the hybrid system for small and / or periods of high potential renewable.

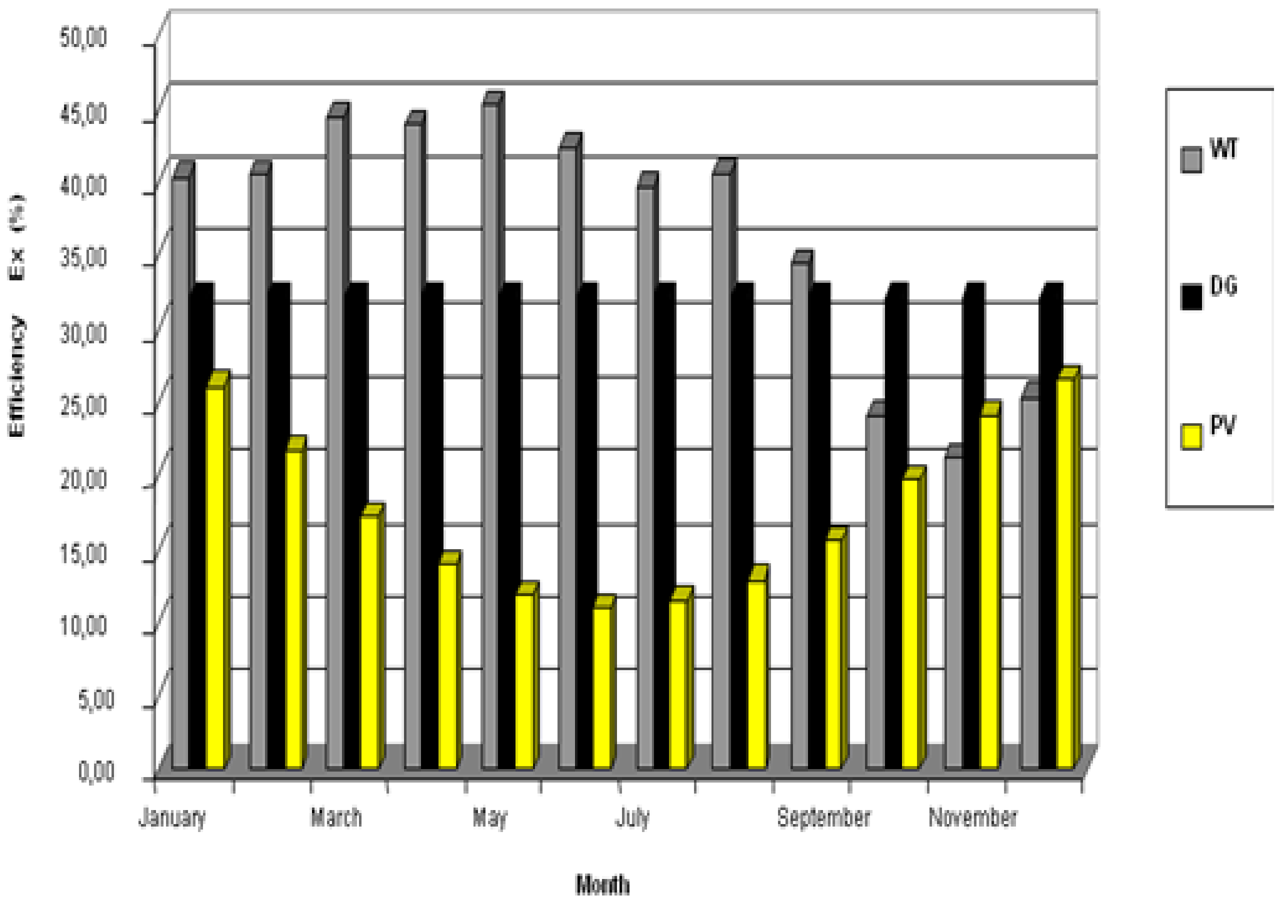

Fig. 8: OPEN-GAIN prototype exergy efficiencies of PV, Wind and Diesel GenSet

5. Conclusion

The first pre-feasibility results of simulations under HOMER environment with a case study is concerned with a 48 m^3/day seawater Reverse osmosis desalination plant on the east Mediterranean coast of Tunisia nearby Burj Cedria with additional power supply to the consumers of the water. The water and power cogeneration process is powered from PV and wind energy conversion including short time battery storage and a backup Diesel generator. The technical performance simulation predicts more than 65% fraction of the renewable energy contribution to the annual demand. The next step of this work is the modelling and the simulation of the hybrid system performances under ECOSIMPRO environment. Naturally, these case study can be extended to other south Mediterranean countries sharing the same conditions.

Acknowledgements

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References

[1] OPEN-GAIN project proposal manual 2007

[2] A. Sadi – Seawater desalination share among water and market policy changes in Algeria. Desalination Vol. 165 (2004) pp. 99-104.

[3] G. Bravo, Trends of Desalination Bids for RO plants in North Africa: The Case of Algeria, EuroMed 2004 conference on Desalination Strategies in South Mediterranean Countries, Marrakech, Morocco, 30 May–2 June, 2004

[4] HOMER Brochure, NREL, march 2004.

[5] J. Rheinländer, E. Perz, O. Goebel, Performance simulation of integrated water and power systems – software tools IPSEpro and RESYSpro for technical, economic and ecological analysis, European Conference on Desalination and Environment: Fresh Water for All, Malta, 4-8 May 2003.

[6] E. Perz, S. Bergmann, A simulation environment for the techno-economic performance prediction of water and power cogeneration systems using renewable and fossil energy sources, EuroMed 2006, Desalination Strategies in South Mediterranean Countries, Montpellier-France, 21-25 May, 2006.

[7] Y. Cerci, Y. Cengel, B. Wood, N. Kahraman, and E. S. Karakas Improving the Thermodynamics and Economic Efficiencies of Desalination Plants Minimum Work Required for Desalination and Case Studies of Working Plants Agreement No. 99-FC-81-0183. Desalination and Water Purification Research and Development Program Final Report No. 78 University of Nevada Reno, Nevada November 2003