INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH
K. Boubaker et al., Vol.3, No.2, 2013

Short-Term Perspectives for Hybrid Wind/Solar/Geothermal Renewable Energy

K. Boubaker*‡, A. Colantoni** , E. Allegrini**, L. Longo**, S. Di Giacinto**, P. Biondi**

*Unité de physique des dispositifs à semi-conducteurs, Tunis EL MANAR University

**Department of Agriculture, Forest, Nature and Energy (DAFNE), University of Tuscia

mmbb11112000@yahoo.fr

‡ Corresponding Author; K. Boubaker, Unité de physique des dispositifs à semi-conducteurs, Tunis EL MANAR University, 2092 Tunis, TUNISIA, +(216) 71 811418, mmbb11112000@yahoo.fr

Received: 19.04.2013 Accepted: 20.05.2013

Abstract- Tunisia is a country where the electrical network serves quite all the territory. Nevertheless some isolated loci need to be supplied in energy and the country is still an energy-dependent country with modest oil and gas reserves. In this context, Tunisia will have to increase its power production capacity by both building additional conventional power plants and developing solar, geothermal and wind capacities. In this study, a simple algorithm is implemented in order to propose a scheduled plan for establishing wind/solar/geothermal energy units taking into account availability, territorial constraints and time extent.

Keywords- Hybrid wind-solar system, Optimization, Renewable energy, wind/solar/geothermal energy units.

1. Introduction

Non-conventional energy sources are a master key in targeting energy security, sustainable development, and environment preservation [1-5]. Costs of fossil fuels have forced public and private agents to move toward other energies RES. Solar, wind and geothermal energies are inexhaustible and fuel-free sources which do not cause pollution in electricity production and are easy to install in isolated areas [6-7].

Although Tunisia's actual energy picture hardly includes renewable energies, growing unmet domestic demand makes this country a viable market for non-conventional plants in the medium-to long-term.

Tunisia had a present contribution of hydroelectric power plants and wind power installations which did not exceed 60 MW and 10 MW, respectively. The remaining capacity was wholly accounted for by thermal power stations. Geothermal energy is commonly listed in the literature with unconventional energy resources. Actually, electricity is generated from geothermal energy in 44 countries with an installed capacity about 7300 MW besides direct utilization (space heating, horticulture, fish farming, industry etc.)

The use of geothermal energy in Tunisia has been restricted to direct application (bathing, irrigation and heating) for a long time due to the low enthalpy of sources. The main sources are localized mainly in strewn parts of the country (Hammam Zriba, Hammam Benteljdidi, Jebel Ouest, Hammam Bourguiba, etc.). Some recent studies outlined the fact that geothermal electricity can be produced efficiently in Tunisia through dry steam, flash steam or binary cycle power plants [8-14].

The aim of this study is to identify several optimal locations which can host a hybrid system based on the use of solar, wind and geothermal sources. This goal is successfully reached by setting a short-term scheduled plan for establishing wind/solar/geothermal energy units throughout the territory.

2. Potentials and Resources in Tunisia

2.1. Solar Energy

Tunisia has a tremendous solar potential. The Meteorology National Institute (INM), provided 10-year mean records of synoptic observations for several locations in Tunisia [14]. The provided data encouraged the use of solar panels in commercial and residential installations along with a high scale plant is in El Borma at the Algerian southern frontiers, with a nominal power of 2.1 GW. Solar radiation charts showed that the annual solar radiation is more than 1.7 MWh/m^2 in the whole country and the highest values occur in the southern areas (Gafsa, Gabès, Mednine, El-Borma)

2.2. Geothermal Energy

The use of geothermal energy is not recent in Tunisia. Geothermal sources have been used in bathing and irrigation hundreds of years ago. In the 80s, the local instances started using geothermal energy for greenhouse farming over more than 200 actually with a target of 315 ha by the end of 2016. The geothermal resources in Tunisia are dispersed between the northwest part and the remaining part of the territory.

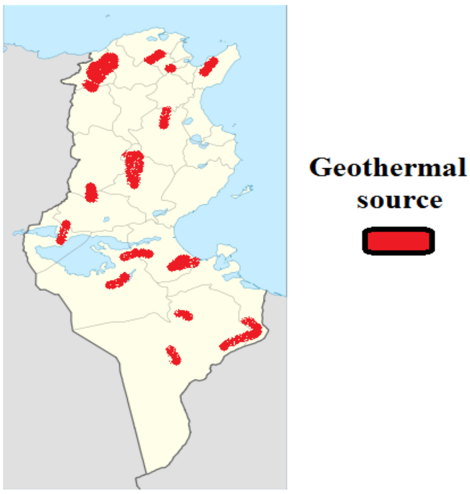

Fig. 1. Geothermal sources loci in Tunisia.

The density of thermal resources is higher in the northwest part than in other parts of the country while the flow is higher in the south (Fig. 1). The geothermal gradient in these resources is in the same range as the world average values.

2.3. Wind Energy

In 2013, there is still one wind farm in Tunisia, in Sidi Daoud (Northen part) near Cap Bon. It has been working since 2000. Average annual wind velocity at this location is 8.4 m/s at 30 ma.g.l. The project was put out to tender in 1996 on the basis of a feasibility study which was drawn up between 1990 and 1992. The wind farm is equipped with 32 turbines each rated at 330 kW each. In 2002 it generated 30 GWh of electricity and later in 2003 it was expanded by the addition of 12 turbines with a capacity of 8.7 GWh. [15].

Since any installation of a wind system is dependent on two natural elements: the site and wind speed, the actual study focused on two important regions in the Tunisian territory along with wind mean speed as per the presented speed roses charts (Fig. 2).

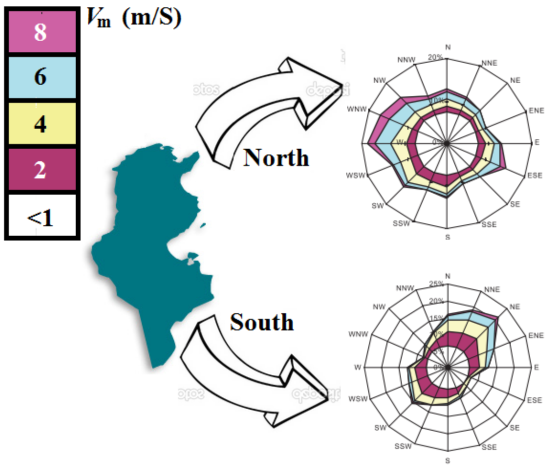

Fig. 2. Wind mean speed roses charts
(North and south of Tunisia)

The evolution of wind energy capacity between 2000 and 2012 is presented in Figure 3.

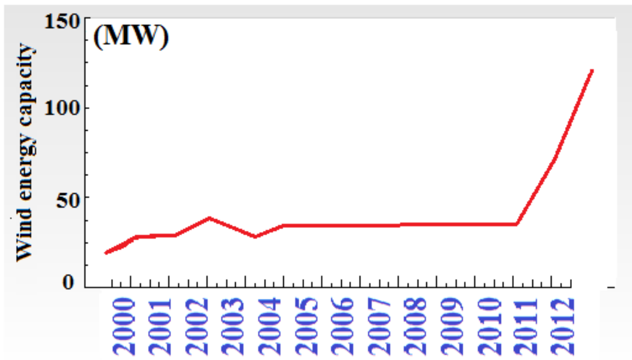

Fig. 3. Wind mean speed rose chart
(North and south of Tunisia)

3. Wind/Solar/Geothermal Hybrid Units Scheme

Wind/solar/geothermal energy units (Fig. 4) are aimed at optimizing supply when many resources are available. With specific regard to power demand, the global target t corresponds to the implementation of approximately 5.4 GW. If all the resources and the projected plants (53-90 MW) are taken into account, the amount of annual required installation should be be equal to 0.3 GW, which is equivalent to the installation of eight plants per year, for a total period of 30 years.

Since actual loci for different kinds of plants do not match along the territory due to resources disparity, this study proposes settling medium-sized hybrid wind/solar/geothermal elementary units whose scheme is presented in Fig. 4.

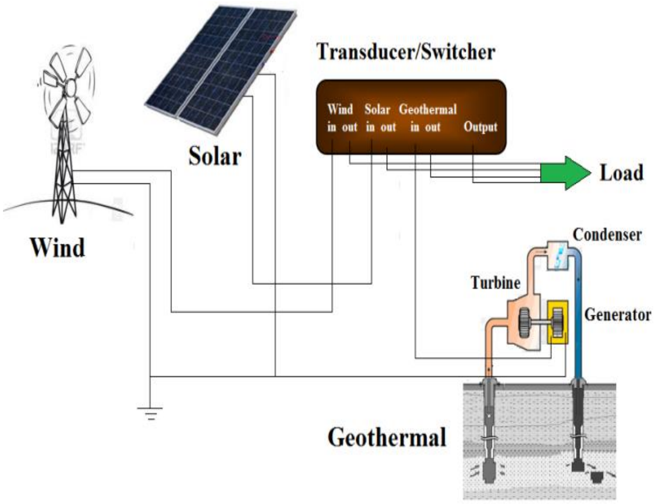

Fig. 4. Wind/solar/geothermal medium-sized unit scheme

4. Optimization Algorithm

The optimization scheme is based on the Boubaker Polynomials Expansion Scheme BPES [16-35] and aims to find a scheduled repartition of wind/solar/geothermal medium-sized units taking into account given constraints. The method consisted of affecting to each unexploited zone, which are at the number M_0, an integer increasing index, along with some aggregates as presented in Table 1.

Table 1. Main optimizing aggregates

Rank	Aggregate	Range
A_1	irradiation level	0-100 %
A_2	wind performance	0-100 %
A_3	Geothermal source	0/1
A_4	Accessibility	0-100 %
A_5	installation history	0/1
A_6	mean costs	0-100 %

For a preset number N_0 of aggregates $A_i\big|_{i=1..N_0}$ the optimization is hence carried out through the Boubaker Polynomials Expansion Scheme BPES [16-35] and a standardized weight function is set as:

$$f(N_0, M_0) = \frac{1}{M_0}\sum_{i=1}^{M_0}\left[\frac{1}{2N_0}\sum_{k=1}^{N_0}\lambda_k \times B_{4k}(r_k A_i)\right] \quad (1)$$

where B_{4k} are the *4k*-order Boubaker polynomials, r_k are B_{4k} minimal positive roots and $\lambda_k\big|_{k=1..N_0}$ are unknown pondering real coefficients.

The BPES protocol ensures the validity of the optimizing test thanks to Boubaker polynomials first derivatives properties:

$$\begin{cases} \sum_{q=1}^{N} B_{4q}(x)\Big|_{x=0} = -2N \neq 0; \\ \sum_{q=1}^{N} B_{4q}(x)\Big|_{x=r_q} = 0; \end{cases} \quad (2)$$

and:

$$\begin{cases} \sum_{q=1}^{N} \frac{dB_{4q}(x)}{dx}\Big|_{x=0} = 0 \\ \sum_{q=1}^{N} \frac{dB_{4q}(x)}{dx}\Big|_{x=r_q} = \sum_{q=1}^{N} H_q \end{cases} \quad (3)$$

with:

$$H_n = B'_{4n}(r_n) = \left(\frac{4r_n[2-r_n^2]\times\sum_{q=1}^{n} B_{4q}^2(r_n)}{B_{4(n+1)}(r_n)} + 4r_n^3\right)$$

The BPES resolution is obtained through four steps by calculating the coefficients, $\lambda_k\big|_{k=1..N_0}$ which maximize the standardized weight function $f(N_0, M_0)$ then determining the rank $i\big|_{i\in\{1,..M_0\}}$ which gives minimal value of the first derivatives of $f(N_0, M_0)$. At this stage, a specific wind/solar/geothermal unit is allocated to the i^{th} location. Iterations continue consecutively until total allocation or reaching time limit.

5. Results and Discussion

The result of the performed algorithm consists of an optimized and well scheduled plan for implementing the net of wind/solar/geothermal under the given constraints (Fig. 5).

It can be noticed that the solution yields a spatial-balanced installation scenario which takes into account an increasing part for the existing geothermal resources, mainly in the end of the period. The units have different capacities, from 48 MW (eastern-south region) to 205 MW (north) depending on the wind and solar potential of that area. The systems will be completed by 2030 taking into account new constraints [36]. Moreover, the most important planned installation concerns the northern part with an approximated capacity of 205 MW in 2025. This step is in good agreement with local plans and dispositions [36-37]. Moreover, since Tunisia is one of the few developing countries to have developed a proactive policy for enhancing renewable energy use, it is obvious that the proposed wind/solar/geothermal plan (Fig. 5) can contribute efficiently help meeting energy requirements in a cost-effective manner as well as reducing Tunisian balance's vulnerability to rising fossil energy costs.

Parallel to the Tunisian Solar Plan (*Plan Solaire Tunisien* -PST) which is planned over 2016, the yielded result (Fig. 5) presents a plausible short-term framework for Tunisia's integration into the both North-Sahara and

Mediterranean zones in terms of renewable energy systems . The approximated total additional power for the 2015-2030 period, is about 450 MW (Fig. 5). This value ensures a valuable reduction of overall energy economic vulnerability, improves the country's energy independence by diversifying supply sources through the integration of the renewable systems and contributes to international efforts in the fight against climate change.

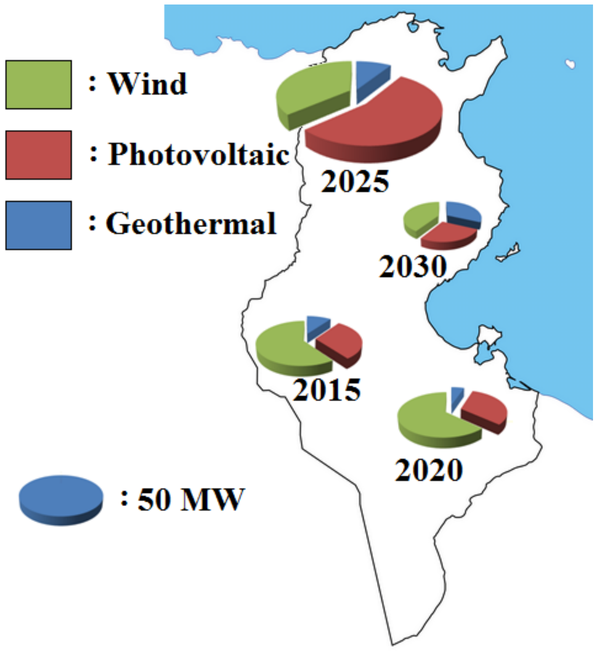

Fig. 5. Algorithm result as a scheduled plan for wind/solar/geothermal units installation.

6. Conclusion

The optimization protocol which has been performed in this study has appeared to be an important tool to evaluate the possible use of wind, solar and geothermal resources in Tunisia. In order to reach this goal, the potential of wind and solar energy has been considered along with geothermal resources and opportunities. The best solution has been mostly a compromise solar, wind energy and geothermal energy. Three clean renewable energy choices that are cost efficient, immediately available and represent a better future.

The present paper shows that Tunisia can decrease the dependence on fossil fuels and, as consequence, ensure a clean and sustainable future.Nevertheless other renewable energies like hydropower and biomass have to be considered in order to enhance model's efficiency.

References

[1] E. Kabalcı, E. Irmak, I. Çolak, "Design of an AC-DC-AC converter for wind turbines", International Journal of Energy Research, Wiley Interscience, DOI: 10.1002/er.1770, Vol. 36, No. 2, pp. 169-175.

[2] I. Çolak, E. Kabalci, R. Bayindir R., and S. Sagiroglu, "The design and analysis of a 5-level cascaded voltage source inverter with low THD", 2nd PowerEng Conference, Lisbon, pp. 575-580, 18-20 March 2009.

[3] S. Roy, H. Gupta, "Geothermal Energy: An Overview", Renewable Energy Akshay Urja, Vol. 5 Issue 5, pp. 19-24, 2012.

[4] Y. Bahri, Rev. Tunisienne de l'Energie, 24 (1991) 37-44.

[5] B. Hadj Sassi, B. Gattoufi., Rev. Tunisienne de l'Energie, 14 (1988) 53-65.

[6] Societe Tunisienne de l'Electricite et du Gaz (STEG). Large scale integration of solar and wind power in Mediterranean countries. MED 2010 Project, Contrat ENK5-CT-2000-00307, Direction of the Studies and Planning, Tunisia.

[7] H. Ben Jannet Allal, Energie et Ecodeveloppement en Tunisie. Report of Helio International.

[8] M. Khasri, L'energie eolienne en Tunisie. Meteorology National Institute (INM), 1986.

[9] G. Czisch, Low Cost but Totally Renewable Electricity Supply for a Huge Supply Area, -a European/Trans-European Example, University of Kassel, 2008 Claverton Energy conference (Bath, UK: University of Kassel). Text at: http://www.iset.uni-kassel.de/abt/w3-w/projekte/LowCostEuropElSup_revised_for_AKE_2006.pdf.

[10] M. Elamouri, F. Ben Amar, A. Trabelsi, Vertical characterization of the wind mode and its effect on the wind farm profitability of Sidi Daoud-Tunisia, Energy Conversion and Management, 52(2011) 1539-1549.

[11] A. Khemiri, M. Hassairi Development of energy efficiency improvement in the Tunisian hotel sector: a case study. Renew. Energy 2005;30(6):903-11.

[12] Trieb F., Müller-Steinhagen H., Kernb J., Financing concentrating solar power in the Middle East and North Africa-Subsidy or investment? , Energy Policy 39 (1) (2011) 307-317

[13] Trieb F., Müller-Steinhagen H., Concentrating solar power for seawater desalination in the Middle East and North Africa, Desalination 220 (2008) 165-183.

[14] M. Elamouri, F. Ben Amar, A. Trabelsi, Vertical characterization of the wind mode and its effect on the wind farm profitability of Sidi Daoud-Tunisia, Energy Conversion and Management, 52(2011) 1539-1549.

[15] B. Brand, J. Zingerle, The renewable energy targets of the Maghreb countries: Impact on electricity supply and conventional power markets, Energy Policy, 39 (2011) 4411-4419.

[16] M. Elamouri, F. Ben Amar, Renewable Energy 33 (2008) 758-768.

[17] J. Ghanouchi, H. Labiadh and K. Boubaker, An attempt to solve the heat transfert equation in a model of pyrolysis spray using 4q-order m-Boubaker polynomials Int. J. of Heat and Technology, 2008, 26, 49-53

[18] S. Slama, J. Bessrour, K. Boubaker and M. Bouhafs, A dynamical model for investigation of A3 point

maximal spatial evolution during resistance spot welding using Boubaker polynomials, Eur. Phys. J. Appl. Phys. 2008, 44, 317-322

[19] S. Lazzez, K.B. Ben Mahmoud, S. Abroug, F. Saadallah, M. Amlouk, A Boubaker polynomials expansion scheme (BPES)-related protocol for measuring sprayed thin films thermal characteristics, Current Applied Physics,2009, 9 (5), 1129-1133

[20] T. Ghrib, K. Boubaker and M. Bouhafs, Investigation of thermal diffusivity-microhardness correlation extended to surface-nitrured steel using Boubaker polynomials expansion, Modern Physics Letters B, 2008, 22, 2893-2907

[21] S. Fridjine, K.B. Ben Mahmoud, M. Amlouk, M. Bouhafs, A study of sulfur/selenium substitution effects on physical and mechanical properties of vacuum-grown ZnS1−xSex compounds using Boubaker polynomials expansion scheme (BPES),Journal of Alloys and Compounds, 2009, 479 (1-2), 457-461

[22] C. Khélia, K. Boubaker, T. Ben Nasrallah, M. Amlouk, S. Belgacem, Morphological and thermal properties of β-SnS2 sprayed thin films using Boubaker polynomials expansion, Journal of Alloys and Compounds, 2009, 477(1-2), 461-467

[23] K.B. Ben Mahmoud, M. Amlouk, The 3D Amlouk-Boubaker expansivity-energy gap-Vickers hardness abacus: A new tool for optimizing semiconductor thin film materials, Materials Letters, 2009, 63 (12), 991-994

[24] M. Dada, O.B. Awojoyogbe, K. Boubaker, Heat transfer spray model: An improved theoretical thermal time-response to uniform layers deposit using Bessel and Boubaker polynomials, Current Applied Physics, Volume 9, Issue 3 (2009) 622-624.

[25] S. Tabatabaei, T. Zhao, , O. Awojoyogbe, F. Moses, Cut-off cooling velocity profiling inside a keyhole model using the Boubaker polynomials expansion scheme, Int.J. Heat Mass Transfer, 45 (2009) 1247-1255.

[26] A. Belhadj, J. Bessrour, M. Bouhafs, L. Barrallier, Experimental and theoretical cooling velocity profile inside laser welded metals using keyhole approximation and Boubaker polynomials expansion, J. of Thermal Analysis and Calorimetry, 97 (2009) 911-920.

[27] A. Belhadj, O. Onyango, N. Rozibaeva, Boubaker Polynomials Expansion Scheme-Related Heat Transfer Investigation Inside Keyhole Model , J. Thermophys. Heat Transf. 2009, 23 639-642.

[28] P. Barry, A. Hennessy, Meixner-Type results for Riordan arrays and associated integer sequences, section 6: The Boubaker polynomials, Journal of Integer Sequences, 2010, 13,1-34.

[29] M. Agida, A. S. Kumar, A Boubaker Polynomials Expansion Scheme solution to random Love equation in the case of a rational kernel, El. Journal of Theoretical Physics, 2010, 7, 319-326.

[30] A. Yildirim, S. T. Mohyud-Din, D. H. Zhang, Analytical solutions to the pulsed Klein-Gordon equation using Modified Variational Iteration Method (MVIM) and Boubaker Polynomials Expansion Scheme (BPES), Computers and Mathematics with Applications, 2010, 59 2473-2477.

[31] A. S. Kumar, An analytical solution to applied mathematics-related Love's equation using the Boubaker Polynomials Expansion Scheme, Journal of the Franklin Institute, 2010, 347, 1755-1761.

[32] S. Fridjine, M. Amlouk, A new parameter: An ABACUS for optimizig functional materials using the Boubaker polynomials expansion scheme, Modern Phys. Lett. B, 2009, 23, 2179-2182

[33] A. Milgram, The stability of the Boubaker polynomials expansion scheme (BPES)-based solution to Lotka-Volterra problem, J. of Theoretical Biology, 2011, 271, 157-158.

[34] M. Benhaliliba, Benouis, C.E., Boubaker, K., Amlouk M., Amlouk, A., A New Guide To Thermally Optimized Doped Oxides Monolayer Spray-grown Solar Cells: The Amlouk-boubaker Optothermal Expansivity ψab in the book : Solar Cells - New Aspects and Solutions, Edited by: Leonid A. Kosyachenko, [ISBN 978-953-307-761-1, by InTech], 2011, 27-41.

[35] H. Rahmanov, A Solution to the non Linear Korteweg-De-Vries Equation in the Particular Case Dispersion-Adsorption Problem in Porous Media Using the Spectral Boubaker Polynomials Expansion Scheme (BPES), Studies in Nonlinear Sciences, 2011, 2 (1) 46-49.

[36] A. Ghezloun , N. Oucher , S. Chergui, Energy policy in the context of sustainable development: Case of Algeria and Tunisia, Energy Procedia 18 (2012) 53-60.

[37] E. Khalfallah, Les énergiesrenouvelables en Tunisie : enjeux et perspectives, Energie-Francophonie, N° 71-deuxième trimestre 2006.