Performance Analysis and Techno-Economic Optimization of Green Energy Systems for Remote Areas in the Maghreb

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Abstract

All interventions that enhance livelihoods of poor rural families in remote areas of the Maghreb will positively impact standard living, involve technological solutions, and likely enhance agricultural production, which in turn can further contribute to poverty reduction. Hybrid green energy systems (HGESs) have been more exploited to supply a mobile base transceiver station (BTS) by clean electricity, or assess the energy availability in smart grids (SGs) of such areas. In this paper, a HGES has been modeled to produce energy from PV/Wind HGES in grid-connected BTS or SG sites, using MATLAB to solve a theoretical model, and simulated with a suitable configuration for performance analysis and optimal sizing. A techno-economic simulation, carried out using the HOMER package, has evaluated such HGES feeding BTS or SG in a remote area-prototype (RAP) of the Maghreb, and optimized the size and assess hybrid PV-Wind system based on weather conditions for RAP. The results may impact rural livelihood and improve standard living of people in such countries.

Keywords Sustainable energy · Hybrid energy System · Assessment · HOMER · Matlab · Maghreb

Introduction

Nowadays, energy is the crucial factor impacting countries' economic development, where energy demands have been growing sharply. [1] As a result of climate change, the world is facing to energy security, and dealing with social, economic, technological, environmental, risk management, and geopolitical problems that need to be solved [2]. Developing hybrid systems for renewable energy conversion has solved most of these problems in developed countries, provision of health services, distance education, staff development/support, using information technology to deliver/enhance services to rural/

remote communities, in training and education, telemedicine, to improve life quality of disadvantaged persons. [3] This was achieved thanks to adequate telecom infrastructure powered by hybrid green energy systems (HGESs) with low energy consumption and power loss. [4]

In developing countries, however, financial losses due to unbalance cost result in power losses shortening equipment life for industrial customers. [5] Manufacturing productivity suffer mostly from electricity interruptions and power quality. [4] Nevertheless, telecom networks (TNs) are required in remote areas of such countries, after that network operators have established mobile services in the emerging markets [6]. Likely, smart grids (SGs) in these areas are notably important, in face of increasing energy supply-demand stress with rapid urbanization and increase in life quality [7, 8].

In remote areas, high-voltage power grids (HVPGs) feeding costly microwave and base transceiver station (BTS) equipments [9–11], or SGs monitoring energy consumption and efficiency of HVPGs using TNs, are needed [12–16]. However, TNs mainly expanded to highest remote forests in these areas, are confronted to their non-existence and the instability or even inadequacy of HVPGs [17], that need huge budgets to be upgraded/reformed [18]. Luckily, these elojned regions own abundant solar and wind, so as HGESs remain an

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ideal choice to power supply BTS equipments fed by HVPGs, or feed SGs controlling HVPGs consumption, hence save such costly equipments [19]. Besides major consumption issues TNs suffer from being long depended on diesel generators (DGs), that operate expensively, at low levels of efficiency, and produce high CO₂ emissions [20]. Reversely, SGs involve load-, distributed- and energy storage-resources, and mainly include solar and wind HGES generation, and manageable distributed resources generation [21], so as to lower operating cost and reduce greenhouse gas and pollutant emissions [22]. Hence, it is necessary to prevent such situation harmful for both TNs and SGs. For instance, mobile operators need unremitting electrical power supply to keep TNs continuously functional, ovoid their failure by interrupting supply electricity during load-shedding periods, thus deploy DGs in BTS sites as backup power supply [23]. Africa to which the Maghreb belongs, has intently suffered from a lower urbanization rate and [break power supply systems](#), continuing to roll out 4G networks, while the globe communication industry attests today a stiff competition and stagnating revenue growth, to define 5G network requirements. Motivated by relevant works [24–30], in the context of lowering the energy cost and enhancing the network operation, we have chosen three (3) remote areas from the Maghreb: (Ras El Oued, Cherb Errih, and Ain Amara), owning closest location details and nearest average climate and daylight, situated at an altitude of 890 m (<https://earth.google.com/>) (<https://www.ncdc.noaa.gov/> and <https://weatherspark.com/>), to be studied as a unique case study within a *remote area-prototype* (RAP), as given in Fig. 1.

Strong efforts have to be made by our developing countries to reduce energy costs and improve the network operation in such remote areas, optimize energy cost, convert indoor BTS into outdoor one, eliminate using air conditioners, install energy efficient equipment, and exploit HGESs to feed TNs in the mentioned RAP [31–34].

Hypothesis and Goals of the Study

Besides having social costs, emigration of skilled people (mainly belonging to remote areas) from the Maghreb can prevent this region from investing in human capital. Improving rural livelihoods, beyond economic impacts, can boost agricultural industry, bring employment opportunities, hence limit emigration towards the developed world. On another hand, foreign tourists are usually getting lost in deserts and rural areas of the Maghreb. To help them safely enjoy their holidays and avoid probable critical situations, HGESs supplying BTS must be configured to localize them. This study has the following two main objectives:

It describes results of a photovoltaic (PV) cell model using Matlab-Simulink approach, and a techno-economic solution

of employing hybrid HGESs to power a mobile telecom BTS in RAP, evaluated by HOMER software. Performance analysis and feasibility of a techno-economic solution is predicted, where an HGES alternative to DGs for BTS exhibit higher reliability and lower cost of energy production [35–39].

It aims also to answer a question: How best to harness TNs that reduce rural isolation, apply socio-technical approaches to strengthen SGs in remote areas of the Maghreb, and improve rural livelihoods? The novelty here is also that:

- Deep/high mountainous areas with insufficient rural electrification (like RAP here) may be probably targeted by tourists often lost (or attacked by malefactors), or scientists that gather information on roosting and foraging ecology of forest bats (threatening nearby agriculture) in such mountain environment.
- Conventional energy plants in the Maghreb are prone to external economic forces, which made this region depending on such energy sources to experience unpredictable variation in electricity supply to feed TNs whose performance is affected with such handicap, and TNs have to generate electricity for properly operating by using GRESs.
- Identifying techno economic criteria for the modeled GRES reveals wind turbines of weak contribution to supply TNs, compared to PV panels, and assessing the energy availability in SMGs of such areas are here of prime interest.
- Rare are researches optimizing configurations of HGES models to power supply TNs, or reversibly assess energy in SGs in the whole Maghreb. From literature and gaps noticed in works recognized above, here an in-between study is performed to analyze performance and techno-economically optimize power HGESs costs for TNs in a RAP of such key-region, as gate between Europe and Africa.
- A PV-based HRES on the basis of two objectives Matlab/Homer software is predicted to properly size and optimize performance that is estimated for optimal configurations with minimum net present cost (NPC) and leveled cost of energy (LCOE). This study reveals that such HRES has reasonable environmental benefits and is economically feasible.
- Basing on comparison annual wind speed price with LCOE and NPC, the sensitivity analysis carried out here favorite PV-based RESs as promising candidates for TNs in RAP.

PV System Modeling and MPPT

PV RERs, implemented with different topologies and control methodologies, are classified into two main categories: grid

Fig. 1 Geographical locations and global climate of *a*) Ras El Oued (Taza) Morocco ($34^{\circ}10'04''\text{N}$, $3^{\circ}59' 09''\text{W}$), *b*) Cherb Errih, Mascara, Algeria ($35^{\circ}28'26''\text{N}$, $0^{\circ}09'40''\text{E}$), and *c*) Ain Amara, El-Kef, Tunisia ($36^{\circ}12'28''\text{N}$, $8^{\circ}45'44''\text{E}$). Average wind speed, respectively: *a*) 8.3 to

7.3 mph; *b*) 8.4 to 9.5 mph; *c*) 9.6 to 8.3 mph, all windy in March and mi-November to mi-December. Low-to-High ranges of temperature in July: *a*) ($20\text{--}35^{\circ}\text{C}$), *b*) ($19\text{--}36^{\circ}\text{C}$), *c*) ($16\text{--}34^{\circ}\text{C}$). (<https://earth.google.com/>) (<https://www.ncdc.noaa.gov/> and <https://weatherspark.com/>)

and standalone connected applications [40], so as in the latter type a DC–DC converter is used between a DC load and PV sources for maximum power point tracking (MPPT) purposes [41]. In the standalone scheme, batteries as storage elements are necessary for the night hours, to solve the issue of installing a lot of panels to provide the energy that the load require [42], but these require frequent replacement [43], which increases the overall system cost [41]. Hence, a grid-connected topology is preferred, since it can be implemented

by directly via coupling inverters to grids without including DC–DC converters [44]. Extensive computation requirements are disadvantaging the MPPT techniques that may be monitored by the MPPT system which choose the most appropriate one according to environmental conditions and application/load requirements. To simulate the model V_{oc} , I_{sc} , V_m , I_m are needed, however, the PV system required accurate data to improve the performance of our HGES.

Fig. 2 PV cell one-diode equivalent circuit [47] (a) and schematic of the PV system (b) by Simulink

Here, PV cells offer lower output voltage, and the PV source is available in sixty (60) series cells panels and a single array to provide sufficient power to the BTS. Although parameters of PV cells can be estimated by using double and triple diode models [45] to describe the PV module behavior, the well known one-diode model (Fig. 2) is adopted here [46], so that:

$$I_{Out} = I_{PV} - I_S \left[\exp \left(\frac{q(V_{Out} + I_{Out}R_S)}{kT_{Cell}A} - 1 \right) - (V_{Out} + I_{Out}R_S) / R_{SH} \right] \quad (1)$$

Where, I_{PH} , I_S , q , k , T_{Cell} , A , R_{SH} , and R_S are respectively the photocurrent, dark saturation current of the cell, electron charge ($1.6 \times 10^{-19}C$), Boltzmann's constant ($1.38 \times 10^{-23} J/K$), cell's working temperature, ideal factor, shunt resistance, series resistance. The photo generated current, mostly depending on solar radiation and working cell temperature, is: [47].

$$I_{PV} = [I_{SC}(T_{ref}) + K_I(T_{cell} - T_{ref})] \cdot G \quad (2)$$

Where $I_{SC}(T_{ref})$, G , K_I and T_{ref} are respectively the short-circuit current of the cell at reference temperature ($25^\circ C$) and standard radiation ($10^3 W/m^2$), the temperature coefficient of cell's short circuit current, the reference temperature of the cell, and the solar insolation (G in kW/m^2). Additionally, the diode reverse current as a function of the cell temperature is

$$I_r = \left[\frac{I_{SC}(T_{ref})}{e^{\left(\frac{qV_{OC}}{kAT_{ref}} \right) - 1}} \right] \cdot \left[\frac{T_{cell}}{T_{ref}} \right]^3 \cdot e^{\left(\frac{qEG \cdot \left(\frac{1}{T_{ref}} - \frac{1}{T_{cell}} \right)}{kA} \right)} \quad (3)$$

With a first term giving the reverse saturation current. The considered PV module has n_s in series and n_p cells, and in parallel configuration, respectively (here n_s and n_p are 60 and 1), as the equation below characterizing the I-V behavior for a simplest model describes [48], basing on Eqs. 2 and 3.

$$I_{Out} = n_p I_{PV} - n_p I_r e^{\left[\frac{q(n_p V_{Out} + n_s I_{Out} R_S)}{n_p n_s k T_{ref} A} - 1 \right]} \quad (4)$$

Table 1 Characteristics of Solar World SW250 Mono module

Parameters	Specifications
Maximum Power point (MPP) (P_{max})	250.355 W
Voltage at peak power (V_{max})	31.1 V
Current at peak power (I_{max})	8.05A
Open circuit voltage (V_{oc})	37.8 V
Short circuit current (I_{sc})	8.28A
Temperature coefficient of Short circuit current (K_I)	0.042% / $^\circ C$
Ideality Factor (A)	1.3
Length x Width x Height [mm]	1675x1001x34
Number of cells	60
Cell size [mm]	156 x 156
Cellular Material	Si-mono

Fig. 3 P–V characteristics of PV modules under: *a)* different radiations and constant temperature (25 °C), *b)* temperatures and constant radiation (1000 W/m²)

Where I_{Out} and V_{Out} are the output current and voltage. To observe effects of varying various parameters, a SW250 Mono module [49], with manufacturer specifications provided in Table 1, of 250 W is considered. From I–V and P–V characteristics, MPP picks are displayed regarding to power changes due to irradiation and temperature variations, and PV panel parameters at MPP are shown, such as the corresponding optimal voltage (V_M) and current (I_M), open circuit voltage (V_{OC}), and short circuit current (I_{SC}). At SC condition, I_{PV} (Eq. 2) flows through R_{SH} and R_S , since the diode does not conduct, essentially simplifying the circuit to a current divider. However, At OC condition, there is no voltage drop across the

R_S and I_{PV} mainly flows through the conducting diode. It is worth mentioning that neither I_{sc} nor V_{oc} are affected by the change of R_s , and the MPP moves to the right, so as the MPP power P_{max} should be in reverse proportion to R_s , which is in accordance with the fill factor $FF = P_{max}/(V_{OC} \cdot I_{SC})$. Due to simplicity, Newton Raphson method [47] is used to calculate I_{out} current (Eq. 1). Figures 3, 4, 5 depict typical I–V and P–V characteristics of a single diode module model (Fig.2) under various irradiances and atmospheric conditions of temperature.

Figures 3 (a) shows the presented model I–V curves of the Solar World SW250 Mono at four different irradiances (400,

Fig. 4 I–V (upper panel) and P–V (lower panel) characteristics of the PV module under different radiations and constant temperature (25 °C)

Fig. 5 I–V (left) and P–V (right) characteristics of the PV module under different temperature conditions and constant radiation ($G = 1000 \text{ W/m}^2$)

600, 800, and 1000 W/m^2) and constant temperature (25°C), while Figs. 3 (b) illustrates model I–V curves at four (4) different temperatures conditions (0, 25, 50, and 75°C) and constant irradiation (10^3 W/m^2), indicating three key operating points: I_{SC} , V_{OC} and P_{MPP} . The results proved that simulated I–V and P–V characteristics accurately matches with those provided by fabricants, and acquiring I–V parameters from accurate discrete model with system functions is possible.

Matlab-Simulink calculates and analyze the output current and power of different PV module model using typical electrical parameters (I_{SC} , V_{OC} , K_f) of the chosen module. With an increases of radiation, module short circuit current increases

proportionally while there is an insignificant increment in the open circuit voltage (Fig.5), which leads to an increase in P_{max} , as shown in Fig.3. Contrary to an observed increase of the output voltage (V_{OUT}) when.

the irradiation increase with increasing of temperature, V_{OUT} decreases with the p–n junction voltage temperature dependence. Hence, V_{OC} owns a negative temperature coefficient (TC) of $-0.33\%/^\circ\text{K}$, since higher temperature results in larger I_{PV} , the output current (I_{OUT}) has a characteristic of positive TC, of $0.042\%/^\circ\text{K}$ [50]. Since, V_{OUT} and I_{OUT} change with irradiance, effects of changing of temperature and irradiance should be considered in the PV module model [51]. It is worth noting that when one aims to achieve I–V and P–V

Fig. 6 Waveforms of PV Module voltage and current

Fig. 7 a) General configuration, and b) Daily BTS (load) profile of the PV/wind HGES

characteristics at/under various temperatures and irradiances, Hermann-Wiesner method for I–V translation should be used [52]. An enhanced current pulsation smoothing parallel active filter (CPS-PAF) operation has been studied [53], in case of AC-PV module consisted of a single stage current source flyback inverter and PV module with electrical characteristics under 10^3 W/m^2 , 25°C and AM of 1.5: $P_{\text{DC}} = 113.6 \text{ W}$, $V_{\text{DC}} = 33.235 \text{ V}$, I_{DC} (value of PV generator current at MPP) of 3.418A, $I_{\text{SC}} = 8.28 \text{ A}$, $V_{\text{OC}} = 37.8 \text{ V}$ (Table 1). The inverter was selected based on high power factor regulation, very high power density, high efficiency, and simple structure [53–57]. Figure 6 shows simulation waveforms of the chosen PV module output current and voltage. The results show satisfactory elimination of the low frequency PV current and voltage ripple performed by the enhanced CPS-PAF configuration [53].

Techno-Economic Evaluation

Recognizing the extreme importance of rural areas, hub of agricultural production in areas of poverty, and within the Maghreb economies, this study tends to reduce power supply and communication costs, with an end goal of poverty reduction in the context of improved livelihoods [58]. In terms of network coverage and tremendous impact on operation cost of running systems, Maghreb countries have not fill a positive role in the growth of TNs, due the current status of electric power infrastructure [31]. Standalone PV electrification systems can play a key role in a developing RAP of the Maghreb, where sun is shining and wind is blowing during almost the whole year [59]. To determine

how different renewable, and hybrid systems interact with end-use demand, and based on availability and potential of RERs in RAP, HOMER (Hybrid Optimization Model for Electric Renewable [60]) software was used to model a hybrid energy system (HGES). Using Homer, Previous theoretical works on HGESs includes optimization and life-cycle cost [61–65], modeling, design methodology and size optimization of PV based standalone grid connected systems [66–69].

Moreover, Rozlan et al. [70] have optimized a stand-alone HGES, and other works [28, 71–74] have performed the techno economic feasibility analysis of different combinations of PV-wind hybrid systems. In terms of feasibility analysis, our system performed using HOMER.

was designed to power either a BTS and/or a SG, with load total capacity found to be 37 kWh/d. To model the PV/wind HGES and decide its components size [49, 75], a peak load of 1.71 kW is considered. HGES is calculated basing on an hourly simulation under cycle charging strategy and in load following strategy, as well. The load is supplied by the solar PV and the wind turbine supplies the load when the batteries are discharged. The schematic diagram of the HGES utilized in the present study, and the daily average load profile are shown respectively in Figs. 7 a and b. HGES components are 3 kW solar PV system [48] with integration of 1 kW small wind turbine (Bergey BWC XL.1 [75]), providing a power production that depends on cut-in/cut-out speed, rotor diameter, hub height and wind speed (Fig.1) available for one from the three locations [76]. Scaled data of [77] to consider long-term annual averages, HOMER involves a clearness index from latitude and longitude of RAP.

Fig. 8 Daily Solar Radiation with Clearness Index

Fig. 9 RAP monthly average electric production

Figure 8 shows a monthly variation in solar radiation with the clearness index. These data serve as input to the HOMER for the analysis. The average daily solar radiation data with clearness index. Daily solar radiation ranges from 4.21 to 5.27 kWh/m²/day and yearly average of 4.75 kWh/m²/day. The most and least global solar irradiance is observed in July and January, respectively. Quarterly average wind speeds are respectively found to be 3.75 m/s, and ranged from 3.26 (in August) to 4.24 m/s (in December (<https://www.ncdc.noaa.gov/> and <https://weatherspark.com/>)) [77]). Average monthly profiles of wind speed for the three locations RAP including, is given in Fig. 1. The productions of HGES components are 15.143 kWh/year (solar) and 0.849 kWh/year, with contribution percentage of 94.7% and 5.31%, respectively. AC primary load, in turn, consumes yearly 12.556 kWh/year. Monthly average electric production of RAP is shown in Fig. 9 that illustrates the total annual electricity production from the grid, wind turbine, and solar PV systems in kWh/y. Renewable energy penetration effects on the consumption from the grid can be clearly seen. At RAP, the annual electricity production from HGES is mostly due to the high output power, specifically from the PV module. To reduce energy costs and improve BST or SMG operation, HOMER optimizes the NPC of a HGES, given by:

$$NPC = C_i + C_r + \sum_{t=1}^N \frac{C_o + C_f}{(1+i)^t} - C_{sv} \quad (5)$$

With C_o the operation and maintenance cost, C_i , C_r the initial and replacement costs respectively, and i and N the discount rate and project life time respectively, and C_{sv} the salvage value, i.e. the present value of all revenues HGES

earns over its lifetime, and the terms before are the present value of all costs HGES incurs over its lifetime, including fuel costs, emissions penalties, replacement costs, capital costs, *operation and maintenance (O&M)* costs, and costs of buying power from the grid [20, 78]. Since it is of interest to discuss the electricity purchasing and selling for each month during the year, HOMER simulation requires financial parameters, and costs revenues include salvage value and grid sales revenue [79]. Results of NPC and LCOE are obtained as a solution by HOMER analysis, that are refined further by performing sensitivity analysis. The main economic output, total NPC (TNPC), is calculated by summing the total discounted cash flows in each year of the project lifetime [80]. TNPC is the value by which HOMER ranks system configurations for optimization results, and the basis from which it calculates the total annualized cost and LCOE [62, 81]. In turn, the annualized cost $AC = NPC + CRF$, function of capital recovery factor (CRF) and TNPC, are used to analyze HGES, so as LCOE and COE are given by Eqs. 6 a, b [76, 82] as follows

$$LCOE = \frac{\text{Capital} \times CRF + O\&M}{\text{Energy generated}} = \frac{\text{Capital} \times CRF + O\&M}{8760 \times \text{CapacityFactor}} \quad (6a)$$

$$COE = TNPC \times CRF / \sum_{t=0}^{8760} E_{gen}(t) \quad (6b)$$

Besides simulating, HOMER also optimizes based on specific parameters given as inputs so that it provide a best combination scheme resulting in a much better performance in terms of techno-economic aspects. The operating cost (OC) is the annualized value of all costs and returns other than initial

Fig. 10 Cost summary of wind/PV HGES at RAP

Table 2 Cost parameters of components

Component	Capital (€)	Replacement(€)	O&M (€)	Fuel (€)	Salvage (€)	Total (€)
Bergey BWC XL.1	4796,70 €	5108,69 €	112,32€	0,00 €	−4230,30 €	5787,41€
HOMER Combined Dispatch	160,000,00 €	0,00 €	196,025,43 €	0,00 €	0,00 €	356,025,43 €
redT 15 kW-75kWh Energy Storage	89,39 €	0,00 €	2246,45€	0,00 €	0,00 €	2335,84 €
SolarWorld250SW 250 Mono	10,843,07 €	0,00 €	5348,53€	0,00 €	0,00 €	16,191,60 €
System Converter	433,39 €	583,28 €	235,99€	0,00 €	−237,01€	1015,65 €
System	176,162,54 €	5691,97€	203,968,73€	0,00 €	−4467,31€	381,355,93 €

capital costs. HGES options, cost of energy generation, comparing between wind/PV contribution, and impact of energy generation from renewable energy systems on the livelihood of RAP have been reported here. The TNPC, LCOE and OC are 381.355,90€, 0.9296€, and 6.280,62€, respectively. An initial capital for HGES is estimated to be 176.163 €. Figure 10 shows a cost summary, where wind/PV HGES could be estimated as a most economical configuration. The cost of energy of HOMER is 0.214 €/kWh.

HGES in RAP is optimized here by considering different sensitivity parameters; Sensitivity analysis helps provide information on optimize systems for particular sensitivity variables. By varying the solar irradiation and wind speed, a sensitivity analysis was performed via simulating long-term

implementation and searching components' sensitivities. Based on wind speed, solar irradiation, and grid electricity price (€/kWh) sensitivities, emissions, renewable fraction, NPC, and COE are simulated. Sensitivities were set respectively over 3.5–8 kW/m²/day, 6.9–8.8 m/s and 0.084–0.336 € ranges, to analyze the feasibility of our HGES analyzed based on emission reduction and cost saving. HGES in RAP is feasible where grid electricity prices reveal to be more expensive, however global solar irradiation seem to sufficient. The results show that PV panels contribute highly than wind turbines, i.e. the solar energy impacts the configured HGES. As Fig. 10 shows, the cash flow summary of all components aims to a same load. It is worth noting here that cost parameters of various systems/components are based on data collected from

Fig. 11 Yearly PV and wind power outputs for RAP

previous published literature and assumptions. When involving PV-wind HGES, installation cost is convenient with the optimized configuration for RAP. Components' cost details are listed in Table 2, where 9.92 kW of PV arrays, one wind turbine of 1 kW, and power converter of 2.1 kW. The yearly productions are 15.143 kWh/yr (PV ~ 94.7%), 0.849 kWh/yr (Wind ~ 5.31%), versus a yearly consumption of AC and DC primary load of 12.556 and 0 kWh/yr, respectively. The total rated capacities, mean outputs, capacity factors of the PV module and wind turbine respectively of (9.92;1) kW, (1.73;0.0969) kW, and (17.4;9.69)%.

Figure 11 shows daily PV and Wind power outputs over a year. Power outputs increase with a reduction of total NPC and decrease of system's LCOE as well, showing that with a change in sensitivity variables component capacities increase, and therefore a change in the system configuration. Hence, a PV-Wind HGES proves to be the cheapest option compared to other systems. Energy costs for a grid-connected HGES are found to be less expensive compared to DG-based supply for similar load profiles, and the wind-turbine (though of less initial capital) has less contribution than that of the PV-source to supply a BTS in RAP. The results of optimization have that HGES is feasible and can provide reliable energy supply to RAP.

Conclusion

A first task of this paper was to model and simulate a PV module to be applied for a BTS or a SG at a remote area-prototype in the Maghreb, according to PV cells fundamentals, with model implemented on a MATLAB/Simulink environment. MPP was tracked effectively using single diode model of less simulation time due to simplified simulation structure and easy implementation. All parameters are evaluated in a good agreement with manufacturers' data sheet, which impact positively the HGES's performance. The study aimed also goal to study an integration of solar PV and small wind turbine assess the economic and financial feasibility all cases in terms of cost of energy. It has been proved that the proposed HGES is financially feasible with significant reduction in emission of greenhouse gases from grid energy supply. HOMER was suitable for carrying out techno-economic, feasibility, optimization and sensitivity analyses of stand-alone HGESs. The second task of this paper presents an overview of the current status of Maghreb's power generation in remote areas and a possible increase in the demand for electricity for the near future. Finally, It is worth nothing that any lack of technological infrastructure basis will have significant impacts on standard of living in rural and remote areas at the regional levels.

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