Smart Grid and Renewable Energy, 2013, 4, 366-377
http://dx.doi.org/10.4236/sgre.2013.44043 Published Online July 2013 (http://www.scirp.org/journal/sgre)

Scientific Research

Comparative Study of the Moroccan Power Grid Reliability in Presence of Photovoltaic and Wind Generation

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Received April 3rd, 2013; revised May 3rd, 213; accepted May 10th, 2013

ABSTRACT

The photovoltaic sector in Morocco is a serious option for the future. The integration of this type of energy into the grid has a considerable effect on the adequacy of the grid. The objective of this work is to assess the reliability of the Moroccan power grid at the hierarchical level I (HLI: load coverage under the assumption of infinite node) using a non-sequential Monte Carlo simulation in which photovoltaic generation is introduced. In order to lead such a study, a model was used in order to calculate the hourly solar radiation and to determine the time evolution of the electrical power produced by photovoltaic power plants. Finally, we also compared the impact of both PV and wind generations in terms of adequacy of the Moroccan electrical supply.

Keywords: Reliability; Renewable Energy; Photovoltaic Energy; Wind Energy; Solar Radiation

1. Introduction

Morocco has an acceleration of economic and social development that has led to a significant increase of energy demand. In order to meet its growing energy needs, Morocco has defined a new strategy to secure energy supply and to optimize access, while rationalizing use and protecting the environment. To reach these goals, four major steps are planned by the Moroccan Energy Strategy: diversification of energy supply, development of domestic energy resources, especially renewables, exploiting the potential of energy efficiency in key sectors of the economy and, finally, the integration of renewable energies in the electricity markets. Renewable energy is thus a major component of the new energy strategy of the kingdom. Indeed, Morocco has great potential in renewable energy whose exploitation will cover a substantial part of its growing needs and help to protect the environment by replacing fossil fuels. In 2020, the expected installed capacity in renewable energy will represent 42% of the installed base. Among those 42%, 14% will particularly come from photovoltaic generation. This kind of fluctuating energy has a major effect on the operation and power quality of the electrical system due to its dependence towards the day/night alternation (no electrical generation during nights) and due to the highly fluctuating behavior of such a kind of generation (highly sensitive to passing clouds, ···).

This paper is organized as follows. Firstly, a model is used to estimate the hourly solar irradiance. This estimation is based jointly on the geographical coordinates of the site of Ouarzazate and the use of JAVA SOLARCALC MODEL. Thanks to the estimation of the solar radiation, the photovoltaic electric power can be calculated via the temperature of the cell. Subsequently, in order to quantify the impact of the previously calculated photovoltaic generation on the system ability to cover the load, a non-sequential Monte Carlo simulation is presented and developed on MATLAB. Then, thanks to the implemented tool, it is possible to closely analyze, from the load coverage point of view, the impact of an increased penetration of photovoltaic generation in the Moroccan power grid. Finally, we make a comparative study with the impact of a massive introduction of wind generation on the electrical system reliability.

2. Determination of the Photovoltaic Electrical Power

2.1. Estimation of the Solar Radiation

The calculation of the PV power is based on the knowledge of the solar radiation. In order to estimate the latter, there are number of methods including the approach Kurt and Spokas [1]. They estimate the solar radiation on the basis of a previous method set by Campbell and Norman [1]. Practically, the total solar irradiance can be separated into two basic components: the direct solar radiation (G_{Bh}) and the spread solar radiation (G_{Dh}). The addition of these two contributions in the total incident solar radiation (G_B) is represented by:

$$G_B = G_{Bh} + G_{Dh} \tag{1}$$

The local intensity of a solar ray beam is determined by the angle between the direction of the sunlight ray and the surface of the earth. The position of the sun is given by the angle between the location of the sun and the normal to the surface, referred to as the zenith angle (Ψ).

$$\begin{aligned}\cos(\Psi) &= \sin(\phi)\sin(\delta_{sd}) \\ &+\cos(\phi)\cos(\delta_{sd})\cos\left[0.0833\pi(t-t_{sn})\right]\end{aligned} \tag{2}$$

where ϕ is the latitude of the considered area (Radians), t is the time (Standard time), t_{sn} is the solar midday time and δ_{sd} is the declination solar angle defined as follows:

$$\begin{aligned}&\sin(\delta_{sd}) = 0.39785 \\ &\times\sin\left[4.869+0.0172J+0.03345\sin(6.2238+0.0172J)\right]\end{aligned} \tag{3}$$

where J is the calendar day with $J = 1$ for 1 January and $J = 365$ for 31 December (Or 366 in the bissextile years).

In order to calculate the direct solar light, the following equation is used [1]:

$$G_{Bh} = G_{Ph}\cos(\Psi) \tag{4}$$

G_{Ph} is the solar radiation received on a surface that is perpendicular to the incoming rays. The model chosen for G_{Ph} is deducted from Liu and Jordan (1960) [2], where radiation beam (G_{Ph}) is given by:

$$G_{Ph} = G_{oh}\tau^m \tag{5}$$

G_{Oh} is the solar constant (1360 W/m^2), τ is the atmospheric transmittance, and m is the optical mass air. The latter is given by the following relationship [1]:

$$m = \frac{P_a}{101.3\cos(\psi)} \tag{6}$$

P_a is the atmospheric pressure on the site and ψ the zenith angle. The average barometric pressure was estimated from the following relationship [1]:

$$P_a = 101.3\mathrm{e}^{-\frac{a}{8200}} \tag{7}$$

a is the elevation of the site (in meters).

However, only a portion of the solar radiation beam directly reaches the soil surface. The other part is reflected or absorbed by atmospheric gases, clouds, and dust particles. Some of these radiations are then re-dispersed towards the earth and are designated as the scattered radiation (G_{Dh}). Campbell and Norman [2] established an empirical relationship on basis of the Liu and Jordan work [3] to calculate spread radiation. This relationship is given by:

$$G_{Dh} = 0.3\left(1-\tau^m\right)G_{oh}\cos(\psi) \tag{8}$$

Figure 1 shows the evolution of hourly solar radiation in W/m^2 estimated for the site of Ouarzazate, by applying the model described above.

2.2. Determination of the Temperature of the Photovoltaic Cell

The cell temperature is calculated using most frequently the concept of NOCT (Normal Operating Cell Temperature) (Nolay, 1987) [4] given by the producers of photovoltaic modules and defined by the following equation:

$$T_{\text{cell}} = T_a + (\text{NOCT}-20)\left(\frac{G_B}{800}\right) \tag{9}$$

The NOCT is defined under the following conditions: wind speed $v = 1$ m/s, ambient temperature $T = 20$˚C and solar irradiance $G_B = 800$ W/m^2 (ASTM, 1998, Myers *et al.*, 2002) [5]. T_a is the air temperature (˚C).

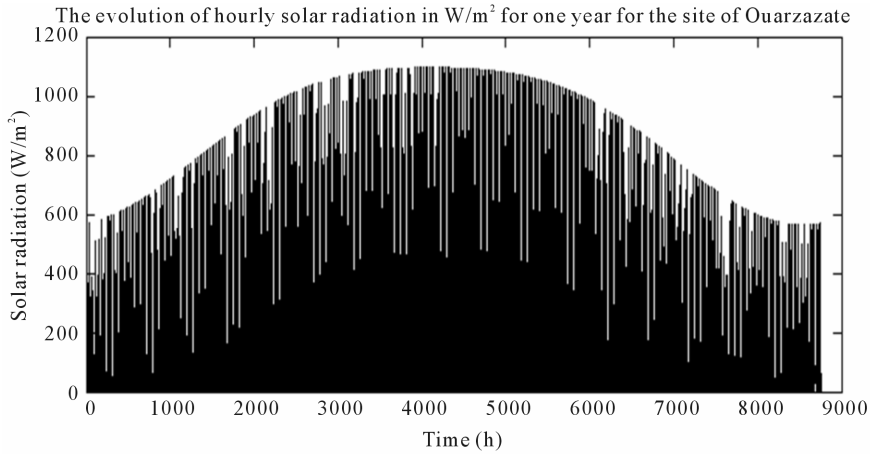
In order to determine the evolution of the hourly air temperature T_a, it is modeled by a uniform distribution between the minimum ($T_{\min}$) and maximum ($T_{\max}$) measured temperatures for each month given in **Table 1**. **Figures 2** and **3** respectively represent the time evolution of the air temperature and the temperature of the cells for the site of Ouarzazate.

2.3. Calculation of the Generated PV Electrical Power

It is obvious that the operation and performance of the PV generator is based on the extraction of the maximum power output of the PV system. The models describing the behavior of PV modules maximum output power is more practical to evaluate the PV system. In this section, we present two approaches frequently used by many research and compare them to determine the best adopted to extract the maximum PV power.

2.3.1. First Approaches

In this approach, the estimate of the photovoltaic power generated is performed using the global solar radiation, the ambient temperature and the manufacturer's data for the PV modules as model input, the power output of the PV array, P_{pv}, can be calculated using the following



(a)

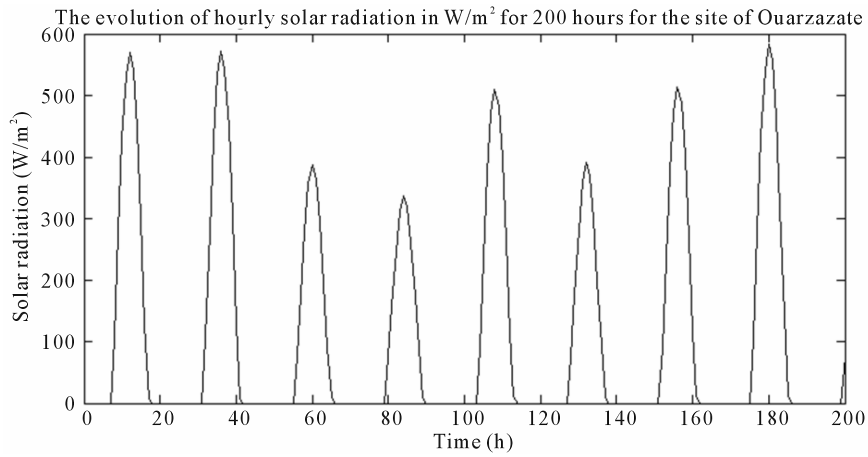


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Figure 1. The evolution of hourly solar radiation in W/m² for the site of Ouarzazate. (a) For 8760 hours; (b) For 200 hours.

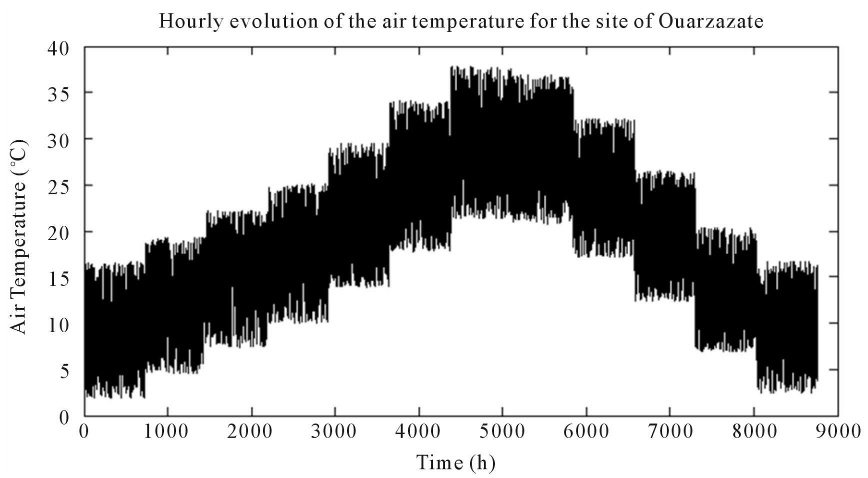


Figure 2. Hourly evolution of the air temperature for the site of Ouarzazate.

equations (Markvard, 2000) [6,7]:

$$P_{pv} = \eta_g \cdot N \cdot A_m \cdot G_B \quad (10)$$

With η_g the instantaneous *PV* generator efficiency, N is the number of solar modules, A_m is is the area of a single module used in a system (m^2) and G_B is the global solar radiation.

η_g is given by the following relationship:

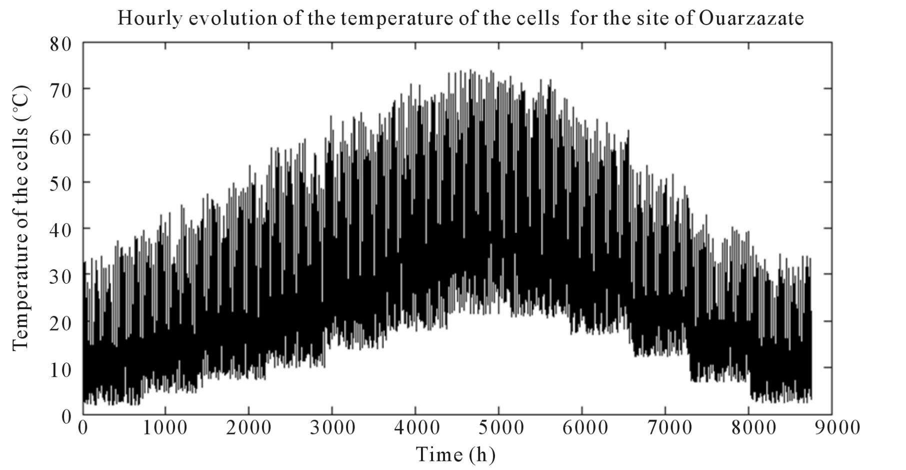


Figure 3. Hourly evolution of the temperature of the cells for the site of Ouarzazate.

Table 1. Monthly minimum ($T_{\min}$) and maximum ($T_{\max}$) temperatures for the site of Ouarzazate.

Month	jan	Feb	mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Temp min (˚C)	01.9	04.5	07.4	10.0	13.8	17.7	21.3	20.7	17.1	12.3	06.9	02.4
Temp max (˚C)	16.6	19.3	22.2	25.1	29.6	34.1	37.8	37.0	32.2	26.5	20.4	16.7

$$\eta_g = \eta_r \eta_{pt} \left[1-\beta_t\left(T_{\text{cell}}-T_r\right)\right] \tag{11}$$

where η_r is the PV generator reference efficiency, η_{pt} is the efficiency of power tracking equipment which is equal to 1 if a perfect maximum power point tracker is used, β_t is the temperature coefficient of efficiency, ranging from 0.004 to 0.006 per ˚C for silicon cells and T_r is the PV cell reference temperature. The cell temperature T_{cell} is given by Equation (9).

Therefore the maximal photovoltaic power produced by the PV module is given by the following equation (12):

$$P_{pv} = A_m \cdot G_B \cdot \eta_r \cdot \eta_{pt} \cdot N\left[1-\beta_t\left(T_{\text{cell}}-T_r\right)\right] \tag{12}$$

2.3.2. Second Approach

In this case, the electrical power produced by photovoltaic modules is determined by using the equations of voltage and current at maximum power point (V_{mp} and I_{mp}) by use of the following equation:

$$P_{mp} = I_{mp} \times V_{mp} \tag{13}$$

This model calculates the reference current and voltage and uses Equation (13). It was developed by Borowy and Slameh (1994, 1996) [8,9]. For the current, the following equation is used:

$$I_{mp} = I_{cc,ref}\left[1-C_1\left(\exp\left(\frac{V_{mp,ref}}{C_2 V_{co,ref}}\right)-1\right)\right]+\Delta I \tag{14}$$

With $I_{cc,ref}$ the short circuit current rating of the module, $V_{mp,ref}$ the rated voltage at nominal power and $V_{co,ref}$ the rated voltage in open circuit operation. The constants C_1 and C_2 are respectively calculated by the following equations:

$$C_1 = \left(1-\frac{I_{mp,ref}}{I_{cc,ref}}\right)\exp\left(\frac{-V_{mp,ref}}{C_2 V_{co,ref}}\right) \tag{15}$$

$$C_2 = \frac{\left(\frac{V_{mp,ref}}{V_{co,ref}}-1\right)}{\ln\left(1-\frac{I_{mp,ref}}{I_{cc,ref}}\right)} \tag{16}$$

With $I_{mp,ref}$, the rated current at nominal power.

ΔI is the current variation. It is given by the following equation:

$$\Delta I = \alpha_0 \Delta T \frac{G_B}{G_{B,ref}} + \left(\frac{G_B}{G_{B,ref}}-1\right) I_{cc,ref} \tag{17}$$

with G_B, the solar radiation, α_0 the coefficient of temperature of the current of the module. The temperature variation ΔT is calculated by the following equation:

$$\Delta T = T_{\text{cell}} - T_{\text{cell},ref} \tag{18}$$

With, $G_{B,ref}$ = 1000 W/m^2 and $T_{cell,ref}$ = 25˚C, respectively, the solar irradiance and cell temperature in normal conditions.

The voltage at maximum power is calculated by the following equation:

$$V_{mp} = V_{mp,ref}\left[1 + 0.0539\log_{10}\left(\frac{G_B}{G_{B,ref}}\right)\right] + \beta_0 \Delta T \qquad (19)$$

where $V_{mp,ref}$ is the nominal voltage at nominal power. β_0 is the temperature coefficient of the voltage of the module.

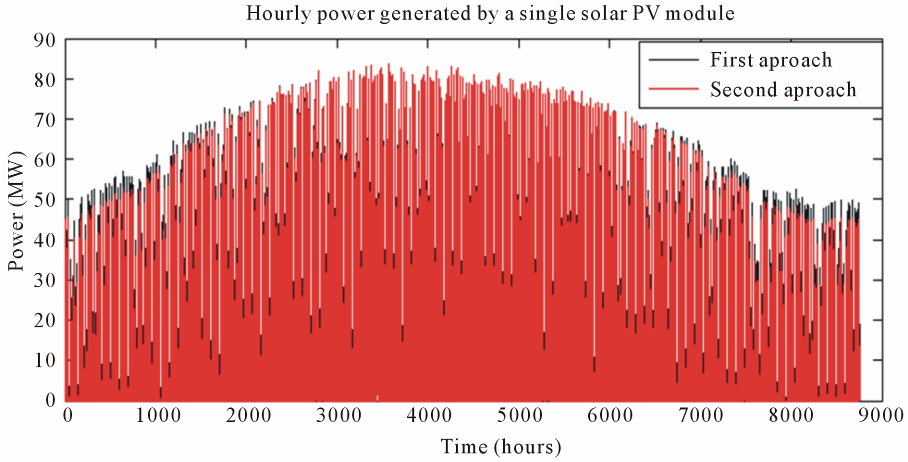
2.3.3. Comparative Study of the Two Approaches

The aim of this section is to compare the maximum hourly power produced by the PV module using the two approaches to choose the best model adopted in our reliability study. In this context, using Equations (12)-(14) and (19), the power produced by a single photovoltaic module is given in **Figure 4** using the two approaches; **Figures 4(a)** and **(b)** represent respectively the hourly evolution of the maximum power produced by a single module for typical year and for the first 200 hours of the year.

The photovoltaic module used in our study is *BP*585*F*. The properties of this module are given in the **Table 2**.

Table 2. Properties of the module BP585F.

Nominal Power (P_{max})	85 W
Nominal Voltage at P_{max} ($V_{mp,ref}$)	18.0 V
Nominal Current at P_{max} ($I_{mp,ref}$)	4.72 A
Warranted minimum P_{max}	80 W
Short circuit current (I_{cc})	5.0 A
Open-cicuit voltage (V_{co})	22.1 V
Temperature coefficient of I_{cc}	(0.065 ± 0.015)%/˚C
Temperature coefficient of V_{co}	–(80 ± 10) mV/˚C
Temperature coefficient of Power	–(0.5 ± 0.05)%/˚C
NOCT	47˚C ± 2˚C
PV generator reference efficiency η_r	14%
Area of a single module A_m	0.625 m^2
The temperature coefficient of efficiency β_t	0.005
The PV cell reference temperature T_r	25˚C



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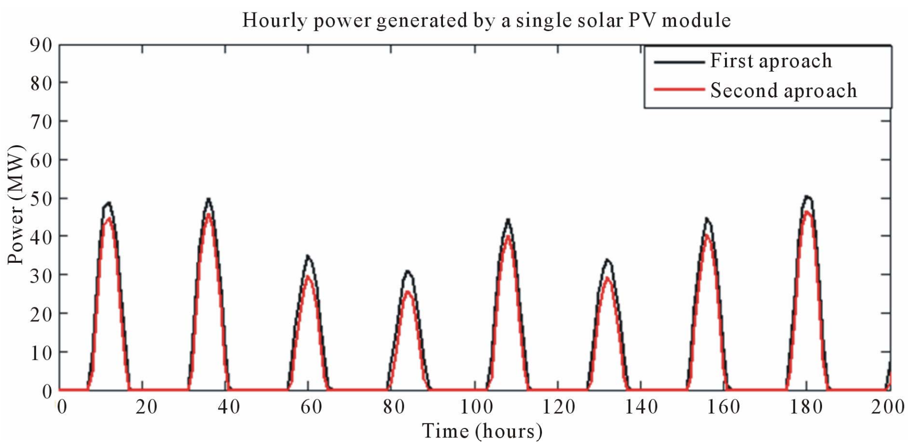


(b)

Figure 4. Hourly power generated by a single solar PV module. (a) For 8760 hours; (b) For 200 hours.

The evolution of the total PV power produced by a photovoltaic park whose installed capacity reaches 250 MW is given in **Figure 5**.

According to **Figures 4** and **5**, we see clearly that the maximum hourly power generated by the PV generators using the first approach is always higher than that obtained by the second approach; these results are consistent with those obtained in reference [10]. Also from **Table 3**, we see that the annual energy produced using the first approach is superior to that obtained by the second approach.

Therefore, the first approach is adopted to extract the maximum PV power.

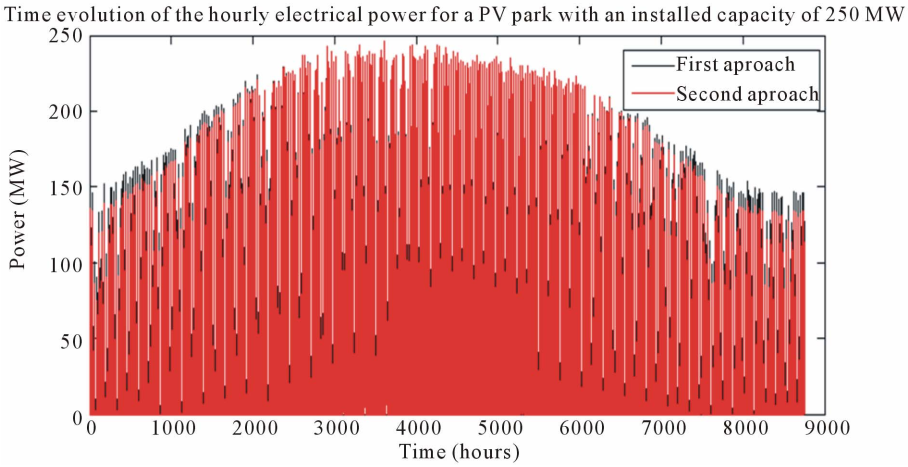
3. Non-Sequential Monte Carlo Simulation

In order to estimate the reliability indices [11] relative to the Moroccan electrical grid, a non-sequential Monte Carlo simulation has been implemented. This simulation models the "life of the grid" as a set of events that change the system state. Note that each generated system state is considered on an hourly basis in our simulation. Moreover, depending on the studied hierarchical level, the events recognized by the algorithm are load changes, possible failures or maintenance of production units (hierarchical level HL1) but also any overloads or unavailability of lines (weather, falling branches, ⋯) in the case of the hierarchical level HL2 (HL2: Generation + Transmission). Note that, in this paper, the reliability evaluation will be limited to the hierarchical level HL-I.

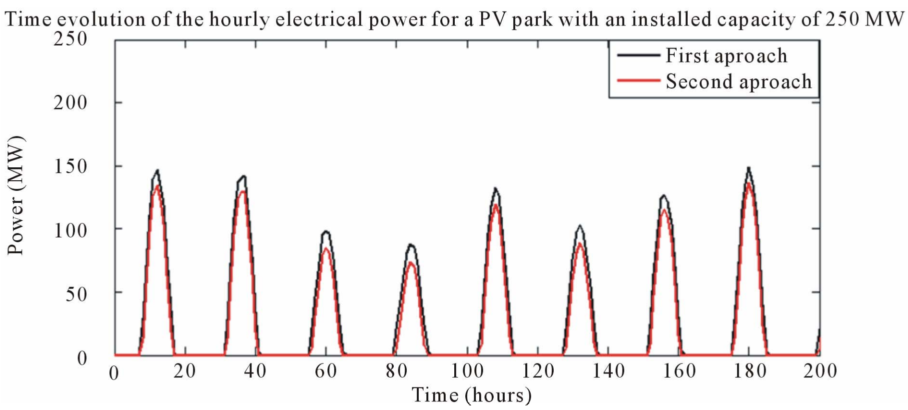
Within the context of our study, each classical generation unit (thermal, gas turbine, ⋯) can be characterized by two distinct states: **fully available** and **unavailable**. During the Monte Carlo simulation, a uniformly distributed (in the interval [0, 1]) number μ is then sampled for each generation unit in order to determine its operational state by use of the following procedure [12]:

Table 3. Annual energy simulated using both approaches.

	Première approche	Deuxième approche
Energie annuelle produite (*GWh/an*)	506.87	471,36



(a)



(b)

Figure 5. Time evolution of the hourly electrical power for a PV park with an installed capacity of 250 MW. (a) Pour 8760 heures; (b) Pour 200 heures.

- If $\mu \leq$ FOR (Forced Outage Rate: rate of unplanned downtime associated with a conventional generation unit), the unit is assumed to be unavailable.
- If $\mu >$ FOR, the generation unit is fully available.
- Therefore, for each system state, the total generated power is equal to the addition of the contributions of each conventional unit (taking into account the availability status of the latter) which are then added to hourly wind power and/or photovoltaic generation.

4. Reliability Indices: Well-Being Analysis of the Electrical System

The electrical system reliability indices are calculated by comparing, during each generated state, the global generated electrical power with the load consumption. The indices considered in our study are called indices of "well-being" of the electrical system. These indices were introduced in 1999 by Roy Billinton [13-15] and expressed in terms of healthy, marginal and risky states by use of the following definitions:

- ***Healthy state*****:** The global available power, even if the biggest generation unit is stopped, can cover the required load within adequate operating conditions of the electrical grid.
- ***Marginal state*****:** The global available power is greater than the corresponding hourly load and permits to cover the latter within adequate operating conditions. However, if the biggest generation unit is stopped, the available power becomes lower than the needed load.
- ***Risky state*****:** The available global power is directly below the needed consumption and does consequently not permit to adequately cover the latter.

During the electrical system "well-being" analysis, reliability indices are defined as follows:

Healthy state probability = $P(H) = \dfrac{n(H)}{N \cdot 8760}$

Marginal state probability = $P(M) = \dfrac{n(M)}{N \cdot 8760}$

Risky state probability = $P(R) = \dfrac{n(R)}{N \cdot 8760}$

where n(H), n(M) and n(R) are respectively the number of healthy, marginal and risky states simulated during the Monte Carlo algorithm and N is the total number of simulated years.

5. The Moroccan Generating Facilities and Evolution of the Load

5.1. The Moroccan Generating Facilities

In this study, we consider the conventional generation park that was in use in Morocco at the end of 2008. The total installed capacity reached 5178 MW (without consideration of the electrical power from wind) divided in 1265 MW of hydraulic type, 2786.2 MW of thermal, 662.8 MW of gas turbine type and 464 MW STEP type [16]. **Table 4** shows the different plants that were composing the production park while **Table 5** establishes the FOR associated with each type of conventional generation [12].

Table 4. The classical generating units considered in the Monte Carlo simulation. (a) Hydraulic park; (b) Thermal park; (c) Gas turbine park; (d) STEP park.

(a)

Hydraulic park	Installed power (MW)
Daourat	17
Imfout	31.2
Sidi Said Maachou	20.8
Al massira	128.0
El kansera	14.4
Takerkoust	12.0
Hassan 1er	67.0
Afourer	93.6
Oued el makhazine	36.0
Moulay youssef	24.0
Bin el ouidane	135.0
Mansour eddahbi	10.0
Allal el fassi	240.0
Idriss 1er	40.6
Al wahda	240.0
Mohammed el khamis	23.2
Kasba Zidania	7.1
Bouarg	6.4
Lau	14.1
Taurart	2.0
Fes amont	1.2
Fes aval	1.9
Sefrou	0.6
Taza	0.6
Meknès	0.6
Autres	97.7
Total Hydraulic	1265

(b)

Thermal park	Installed power (MW)
Mohamadia	600.0
Casablanca	120.0
Kenitra	300.0
Jerrada	165.0
Jorf lasfar I	1320.0
Autres	281.2
Total Thermal	2786.2

(c)

Gas turbine park	Installed power (MW)
Tit Mellil	198.0
Tan Tan port	99.0
Mohamadia	99.0
Agadir	40.0
Tanger	40.0
Tétouan	40.0
Tétouan 33	99.0
Tanger Diezel	6.4
Laayoune	21.0
Autonomous units DDI	20.4
Total Gas turbine	662.8

(d)

STEP park	Installed power (MW)
STEP	464

Table 5. FOR parameter for each type of conventional generation [10].

Type of generation unit	FOR (%)
Hydraulic	1.5
STEP	1.5
GAS turbine	1.2
Thermal	2.5

5.2. Load Evolution

Figure 6 illustrates the time evolution of the simulated power consumption. It was modeled via a uniformly distributed random variable (linear approximation of the monotonic load) taken between the annual peak load and the base consumption [17]. **Table 6** shows the peak load and base consumption in Morocco in 2009.

6. Impact of the Photovoltaic Generation on the of Electrical System Reliability

The first part of this study aims to get the effect of photovoltaic generation on the reliability of the Moroccan power grid. In order to conduct such an evaluation, we launched a non-sequential Monte Carlo simulation (with integration of photovoltaic generation using the first approach) to the classical generation park depicted in **Table 3**. The simulation results are provided in **Table 7**.

Firstly, we note from the results of **Table 7** that, when adding photovoltaic generation (4%) in the electrical system (with consumption unchanged), the probability of finding the system in a risky state decreases ($P(R)$ = 0.0071 without photovoltaic generation and $P(R)$ = 0.0064 with photovoltaic generation), demonstrating the interest of adding solar power as an energy source complementary to the conventional generation already installed (**Figure 7**).

Secondly, we also see from the results of **Table 7** that, when massively replacing conventional generation by photovoltaic generation (the same installed capacity of 5428 MW is maintained; we have simply replaced 20 % of the conventional generation by photovoltaic generation), the risk of not covering the load increases from P(R) = 0.0071 (without PV) to P(R) = 0.0348 (with 20% of conventional generation replaced by PV). This observation is easily explained by the fact that the overall generation of the system becomes more fluctuating and

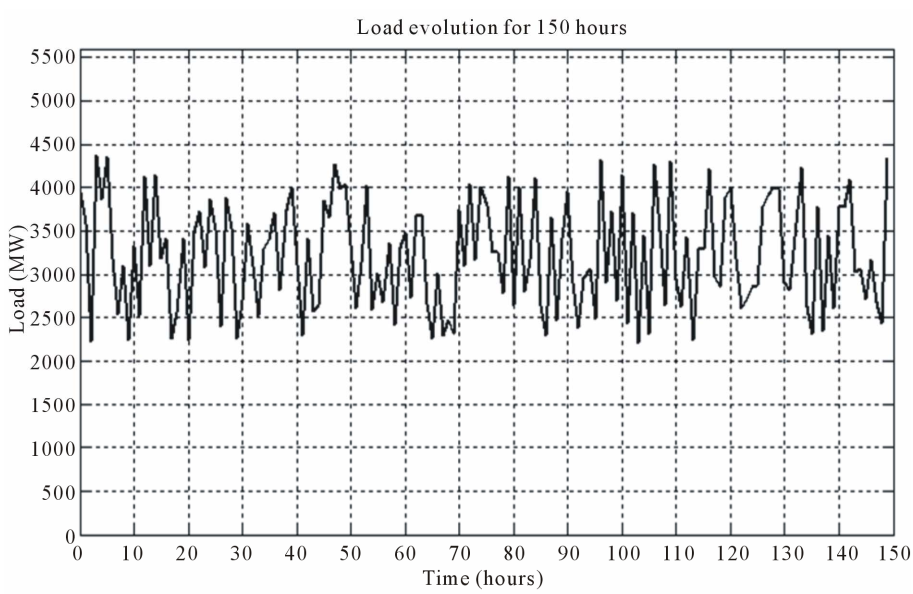


Figure 6. Time evolution of the simulated load for 150 hours.

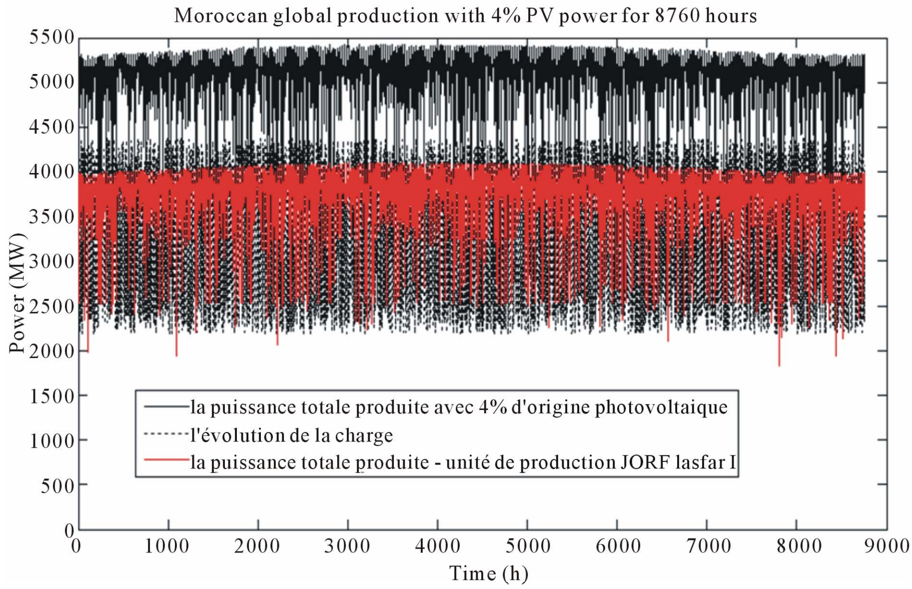


Figure 7. Simulated yearly evolution of electricity generation in Morocco with the addition of 4% of photovoltaic generation.

Table 6. Parameters of the Moroccan load for 2009.

Year	Base load (MW)	Peak load (MW)
2009	2188	4375

Table 7. Results of the Monte Carlo simulation implemented with and without photovoltaic energy for the electric load of 2009.

Reliability indices	Without PV generation	With PV generation	
		Addition 4% of PV generation	Replacement of 20% of conventional generation by PV
P(H)	0.7142	0.7451	0.4623
P(M)	0.2787	0.2485	0.5029
P(R)	0.0071	0.0064	0.0348

logically increases the number of simulated risky states as clearly shown in **Figure 8**.

The second part of our study is to compare the reliability of Moroccan power grid in the presence of photovoltaic generation with the one of the same network in the presence of wind generation (**Figure 9**) [18]. In order to realize such a comparison, we kept the same added capacity (250.4 MW) of renewable generation and we just replaced the power from wind by the original PV. **Table 8** shows the effect of the introduction of these two types of energy on the ability of the system to cover the load.

Based on the results of **Table 8**, we can firstly note that the risk of not covering the load in the case of introducing PV is greater than the one encountered in the case of the introduction of wind generation (P(R) = 0.0064 with PV introduction, P(R) = 0.0061 with introduction of wind generation). This remark can be explained by an absence of sunlight during nights (involving no photovoltaic generation during the night). In presence of PV generation, this result can thus lead to the increase of risky states during this period of time even if it is normally an off-peak period (**Figures 10** and **11**).

Table 8. Results of the implemented Monte Carlo simulation in the presence of photovoltaic and wind generation for the electrical load of 2009.

Reliability indices	With renewable energy	
	Addition of 4% of wind generation	Addition of 4% of photovoltaic generation
Installed capacity (*MW*)	250.4	250.4
Simulated yearly energy (*GWh/an*)	991.25	506.87
P(H)	0.7715	0.7451
P(M)	0.2224	0.2485
P(R)	0.0061	0.0064

Secondly, in terms of energy, we see from **Table 8** that, for the same installed capacity, the annual electrical energy produced by wind farms is greater (almost twice) than the one produced by the photovoltaic parks (991.25 GWh/year with the addition of 4% wind generation against 506.87 GWh/year with the addition of 4% photovoltaic generation). In that way, **Figure 12** shows the simulated evolutions of wind and PV generations. It can clearly be observed that the hourly PV power is quasi always lower than the wind generation, involving thus a

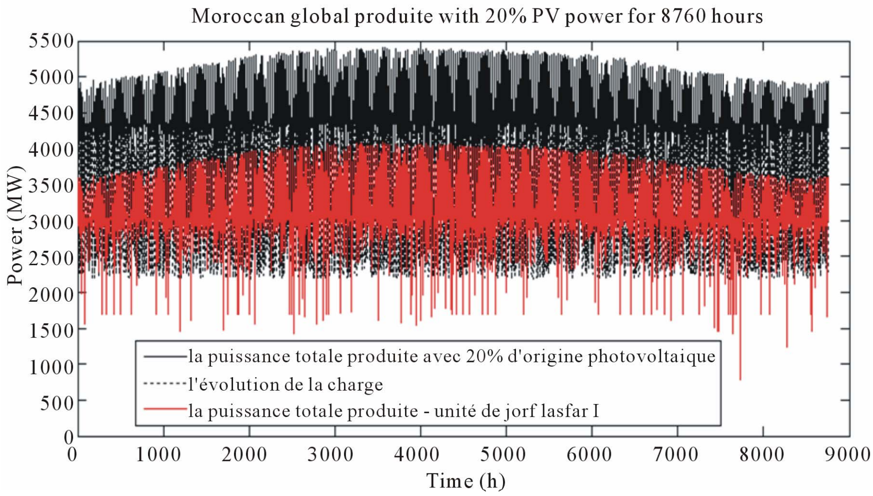


Figure 8. Simulated yearly evolution of electricity generation in Morocco with 20% replacement of conventional generation by photovoltaic generation.

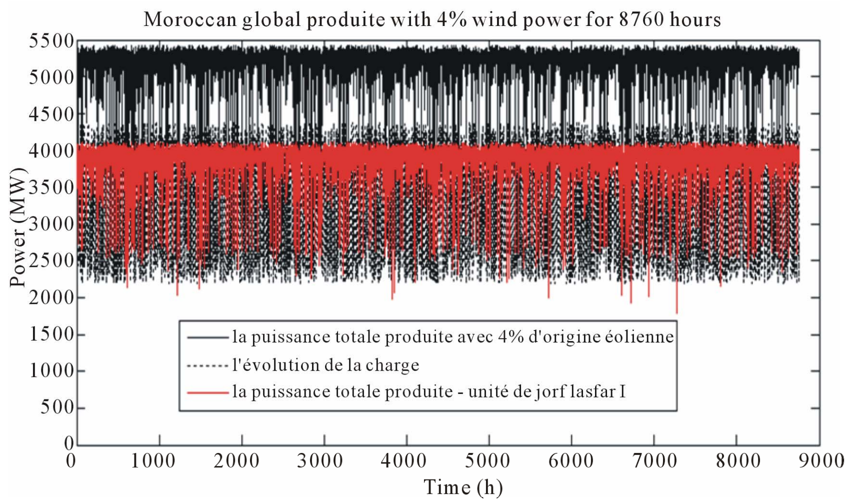


Figure 9. Simulated yearly evolution of electricity generation in Morocco with 4% addition of wind power.

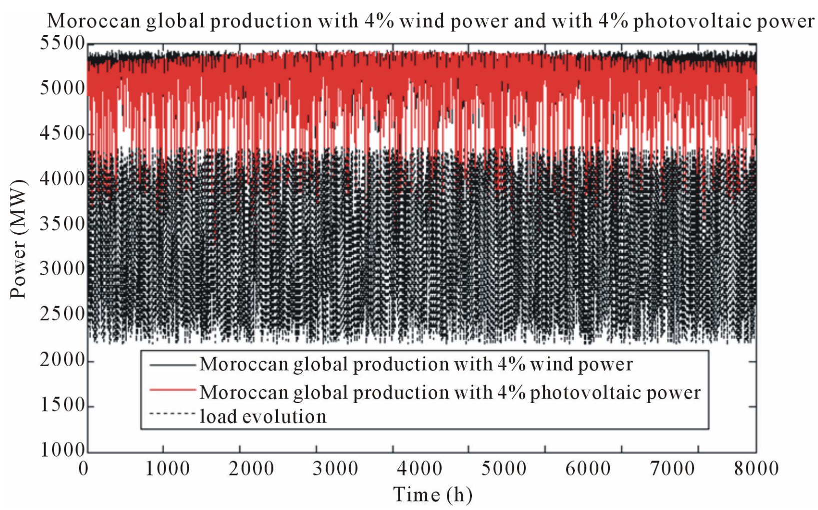


Figure 10. Simulated yearly evolution of electricity generation in Morocco with: - Black (continuous): 4% addition of wind energy; - Red: 4% addition of PV.

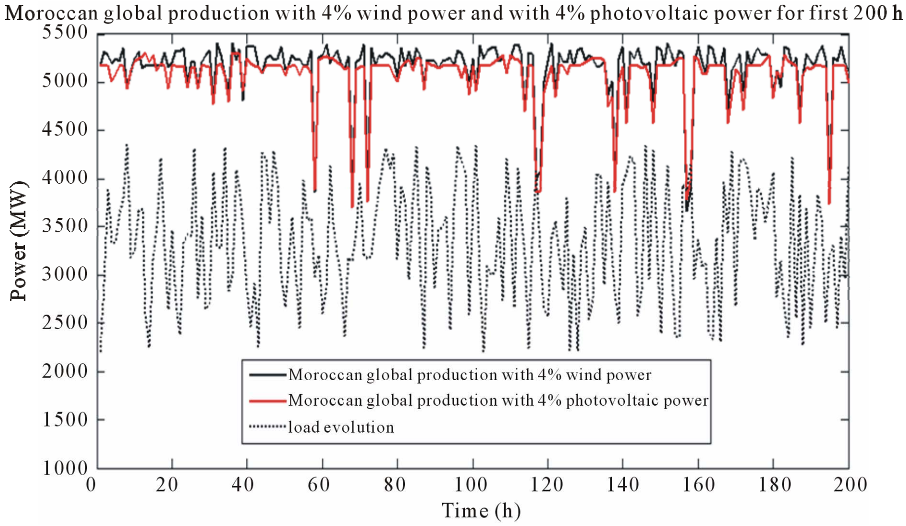


Figure 11. Simulated evolution of the electricity generation in Morocco for the first 200 hours of the year: - Black: 4% addition of wind energy; - Red: 4% addition of PV.

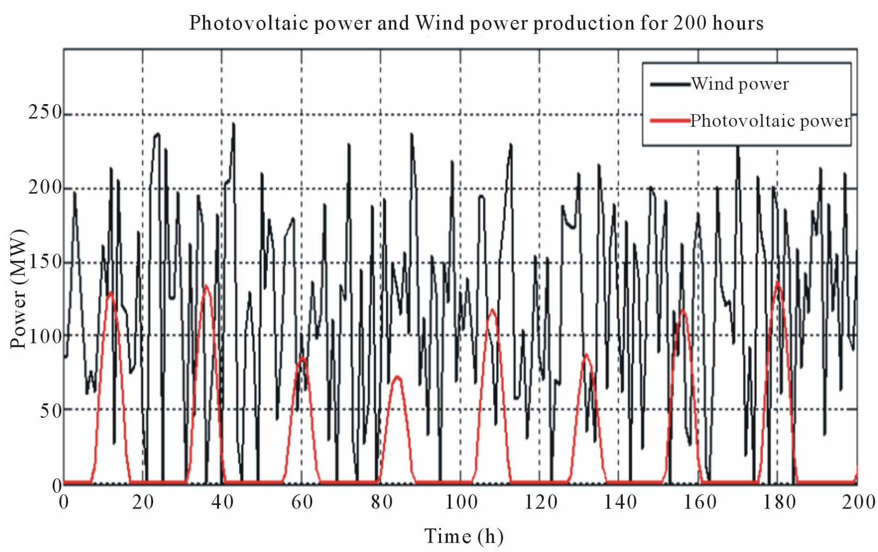


Figure 12. Simulated wind and photovoltaic power for 200 hours.

lower annual energy coming from PV when the integration is made over one year.

7. Conclusion

In this paper, we demonstrate the impact of photovoltaic generation on the reliability of the Moroccan power grid using a non-sequential Monte Carlo simulation and we compared it with the impact of wind power. The first simulation results show that adding photovoltaic generation (without changing the conventional park or consumption specifications) reduces the risk of not covering the load. However, if PV is used to replace conventional generation, we also observed that the risk of load non-recovery tended to increase, demonstrating that PV generation cannot alone replace conventional generation in Morocco. Instead, it should rather be viewed as a booster to enhance the power system in Morocco. Finally, we have deduced that, for the same installed capacity, the probability of not covering the load when introducing PV is higher than the one calculated in the case of introducing wind generation. We also showed that, for the same installed capacity, the annual generated wind energy is greater than the one simulated in the case of photovoltaic generation. From all these results, we conclude that wind and solar power are thus renewable energy sources to be used in order to save fossil fuel and increase the total energy generation in Morocco (thermal, hydro, ···). Moreover, we also show that, to safely meet the future requirements in electricity consumption, the solution has to come from an energetic mix based on the use of conventional AND renewable energy resources.

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