# Smart design and dynamic control of the optimal component in a grid connected hybrid PV/Wind turbine system

**Oumelkheir BOUCHIBA*, Tahar MERIZGUI, Bachir GAOUI, Saliha CHETTIH, Ali CHEKNANE**

Semiconductors and Functional Materials Laboratory,
University Amar Telidji of Laghouat B.P. 37G, Laghouat 03000, Algeria

***Corresponding author:**
Oumelkheir BOUCHIBA

email: o.bouchiba@lagh-univ.dz

**Abstract:** In the current research, we present a new developed Matlab/Simulink toolbox for power electronics to evaluate and improve the control of grid connected PV systems, and in grid connected hybrid system PV/wind turbine (WT). During the work, we carried out the development of a comparative study between two configurations with and without using the MPPT control system. Our focus is to describe the most important order to provide a new developed toolbox in our simulation results and find the best one model in terms of efficiency. The required power generated by the hybrid model system is supplied to feed the grid and AC load and to also optimize the time response of the system study by improving the filter parameters incorporated in our simulation results. This current research focuses on enhancing the performance of wind turbines using the maximum power point tracking P&O method, since our results indicated better performance wind turbine potential in the targeted region.

**Keywords:** Power grid, Performance, Wind power, PV power, Maximum power point tracking.

## 1. Introduction

Nowadays, the idea of "energy", in particular "electrical energy", has become increasingly important to humanity. Thus to the given current pace of electricity consuming, and in order to limit the use of fossil fuels and the use of nuclear energy plants, several countries have turned to renewable energies (Abderrahim, 2019; Ahmed & Miyatake 2006). Matlab/Simulink supplies a strong graphical interface for verifying and building new connecting models as well as new control strategies in grid connected PV System, and in grid connected hybrid system PV/WT. Here, the content of the main libraries from this toolbox is briefly shown. Then, some simulation results using the developed models are shown (AL-ghussain et al., 2020; Arul, Ramachandaramurthy & Rajkumar, 2015). The first step required in grid connected PV or hybrid PV/wind turbine System presented by the geographic choice of the site. In observance to everlasting significance of PV power system; it is worth saying that PV conversion is a better likely solution (Bonanno et al, 1998; Bouchiba et al., 2020). On the other hand, various connections for distributed energy conversion for PV installation by defining the fundamental characteristic of the PV system, as the worth the PV panels require for the photovoltaic system. Otherwise, the properties of the wind are interesting for the study of the full system of wind energy conversion, to know the characteristics of a site, it is essential to have measurements of the wind speed and its direction over a long period of time (Bouchiba et al., 2021; Chen, Cheng & Wu, 2006). Many studies have concentrated on the achievement analysis (Pradipta & Riawan, 2018; Rougab, Cheknane & Abouchabana, 2021) of demonstration systems and the evolution of dynamic power converters, such as battery management, inverters and MPPTs (Seghir, Chandra & Miloud, 2018; Sharma et al., 2018). Several simulation programs (Sherpa & Rai, 2015) are obtainable, which permit the optimum sizing of hybrid system PV/WT. Optimization methods could proceed a perfect role in utilizing them efficiently. Probabilistic approach, linear programming and graphic construction techniques (Yuus & Alsoufi, 2020; Zerari et al., 2021) are examples of optimization methods that have been well educated for techno-economically optimum hybrid system HS PV/WT for both types. The recent state of art HS PV/WT technological expansion is the outcome of activities in different areas of study, such as advances in electrical energy conversion, efficiency, reliability, system quality, automatic controllers, and minimization of maintenance demands. Also through the development of multilateral HS PV/WT simulation software. The aim of this work is to develop a new design,

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management and control requirement of the HS PV/WT. This Paper also depicts a discussion through providing criteria to system optimization on HS PV/WT modeling; and providing an overview of software tool applied for optimal sizing.

## 2. Model set up

The key model of the theory of semiconductors that mathematically characterize the I-V of the PV cells as follows (Chen, Cheng & Wu, 2006; Karaki, Chedid & Ramadhan, 1999).

$$I = I_{PV.cell} - \frac{I_{0.cell}\left[\exp(\frac{qV}{\alpha KT}) - 1\right]}{I_d} \tag{1}$$

$$I_d = I_{0.cell}\left\{\exp\left[\frac{qV}{A}.k\,T\right] - 1\right\} \tag{2}$$

Where, $I_d$ = diode current (A), $I_{PV,cell}$ = the current created via incoming light (A). $I_{0,cell}$ = is the converse saturation of the diode (A).

The solar panels are composed of various linked PV cells and the control of the characteristics at the terminals of the practical organize demand the implication of extra condition to the requiqite form:

$$I = I_{pv} - I_0\left[\exp\left(\frac{V + R_s I}{\alpha V_t}\right) - 1\right] - \frac{V + R_s I}{R_p} \tag{3}$$

With, $I_{PV}$ and $I_0$ present the PV and saturation currents of the solar cell.

$V_t = N_S.k.T/q$ present the thermal voltage of the solar cell. Ns present the connection of cells in series. $R_S$ present the series resistance of the solar cell and $R_P$ is the parallel resistance.

$$I_{pv} = \left(I_{pv,n} + k_I \Delta_T\right)\frac{G}{G_n} \tag{4}$$

where, $G_n$ and G represent the solar irradiation created current at the normal case (in STP 25°C and 1000 W/m$^2$).

where ΔT = T−Tn, T is real temperature and Tn represent the nominal temperatures in K. G represent the solar energy at the system surface (W/m$^2$), and $G_n$ represent the nominal irradiation (W/m$^2$). The diode saturation current Io could be described as:

$$I_0 = I_{0,n}\left(\frac{T_n}{T}\right)^3 \exp\left[\frac{qE_g}{\alpha K}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right] \tag{5}$$

$$I_{o,n} = \frac{I_{sc,n}}{\exp\left(\frac{V_{oc,n}}{\alpha V_{t,n}}\right) - 1} \tag{6}$$

$$I_0 = \frac{I_{sc,n} + K_I \Delta_T}{\exp\left(\frac{V_{oc,n} + K_v \Delta_T}{\alpha V_t}\right) - 1} \tag{7}$$

The $V_{t,n}$ represent the thermic energy voltage of Ns series associated PV cells at the nominal temperature $T_n$. Where $K_V$ and $K_I$ represent the energy current and voltage coefficients respectively.

The WT transforms wind power to mechanical power through a torque exercised to a drive train. A pattern of the wind turbine system is needful to estimate the torque and energy output for a given wind speed WS and the impact of WS divergence at the generated torque. The torque T and power generated through the WT in the period $V_{min}$ present the minimum of WS, while $V_{max}$ present the maximum of WS are duties of the wind turbine blade air pressure, radius R, coefficients of power $C_P$ and $C_q$ and $V_{wind}$ wind speed.

$$P_m = C_p(\lambda,\beta)\frac{\rho A}{2}V_{wind}{}^3 \tag{8}$$

Where $C_P$ represent the power factor and describe the capability of the WT to produce power from the wind system. $C_q$ is known as the torque factor and could be expressed as:

$$C_q = \frac{C_P}{\lambda};\ \lambda = \frac{R.\omega}{V_{wind}};\ T = \frac{P_m}{\omega} \tag{9}$$

Where,

$C_P$ = Coefficient of power, $P_m$ = Mechanical output energy, β = Blade pitch angle.

ρ = Air density (kg/m$^3$), $V_{wind}$ = Wind speed (m/s), A = Turbine space m$^2$.

λ = is tip velocity ratio, R = Radius of turbine area (m), T = represent the torque of WT system, ω = Angular frequency of rotary turbine (rad/sec).

The Cp (λ, β), which concerns at λ and β, defines how much of the wind active power could be apprehended/contained through the WT. A nonlinear model characterize Cp (λ, β) as:

$$C_P(\lambda,\beta) = C_1(\frac{C_2}{\lambda_i} - C_3\beta + C_4)e^{\frac{-C5}{\lambda i}} + C_6 \tag{10}$$

## 2.1. Power electronics in grid connected PV system

Based on topological structure between GPV, DC–DC boost converter (in order to obtain high voltage gain), and DC-AC converter (in order to obtain AC voltage), we have a new description focused on discussing the basic operating principles of the proposed study (Koulali et al., 2019; Koutroulis, Kalaitzakis & Voulgaris, 2001).

To simplify this circuit for our study, the following conditions are assumed:

- Determine the PV influencing point (VPN, IP) to MPP;
- Efficiently step up $V_{PV}$ to a higher DC power voltage VDC;
- Efficiently generate AC product power current iac in phase through the AC grid voltage vac;
- Balance the median energy distribution from the photovoltaic array to the grid.

### 2.1.1. Maximum power point tracking (MPPT)

The MPPT method of our circuit is founded on the amendment of the yield cycle of DC/DC Boost which is obtained for the consecutive of the product power voltage and current cycle calculation as shown in Figure 1, and Figure 2 respectively (Liu & Wang, 2017; Luna-Rubio et al., 2018).

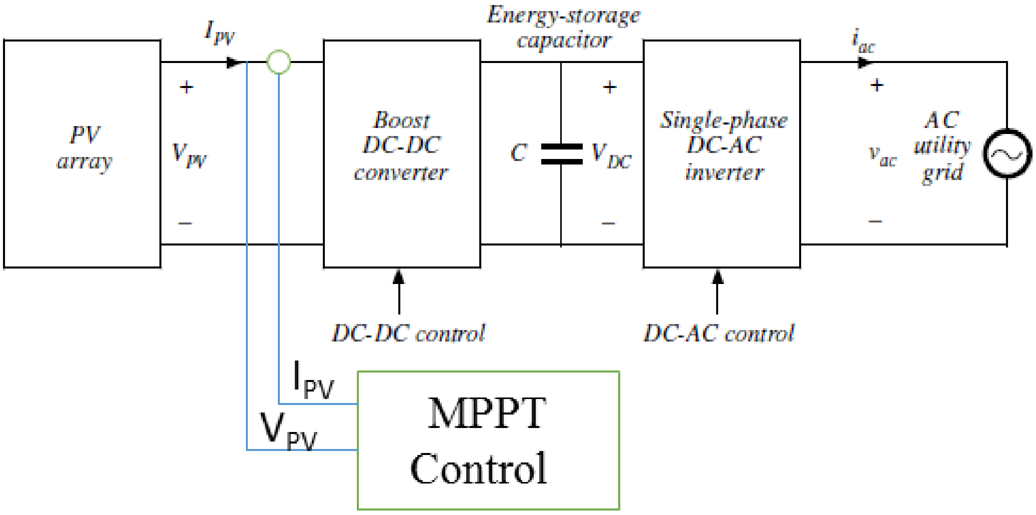


**Figure 1.** Control scheme of the grid connected system PV by using the MPPT

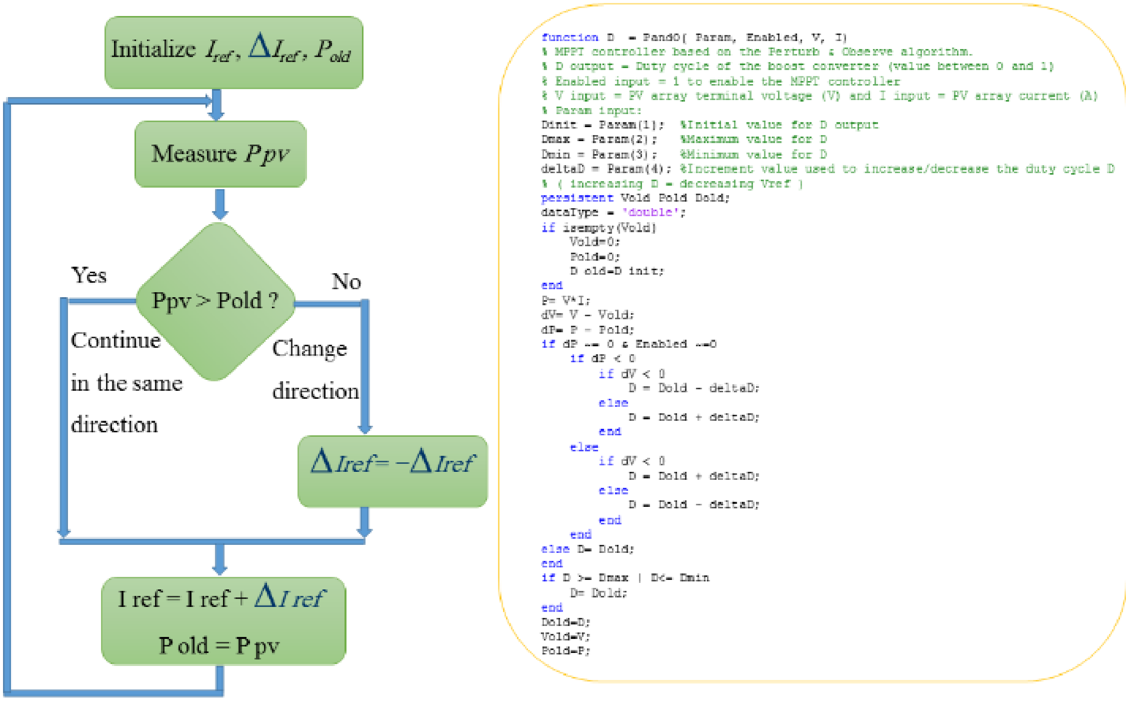


**Figure 2.** Initiating the MPP tracking algorithm in our study

Solar panels are linked in series and in parallel, which are eligible to produce more electrical energy. Thus, a parallel and series linkage of PV panels are prerequisite in our study as shown in Figure 3.

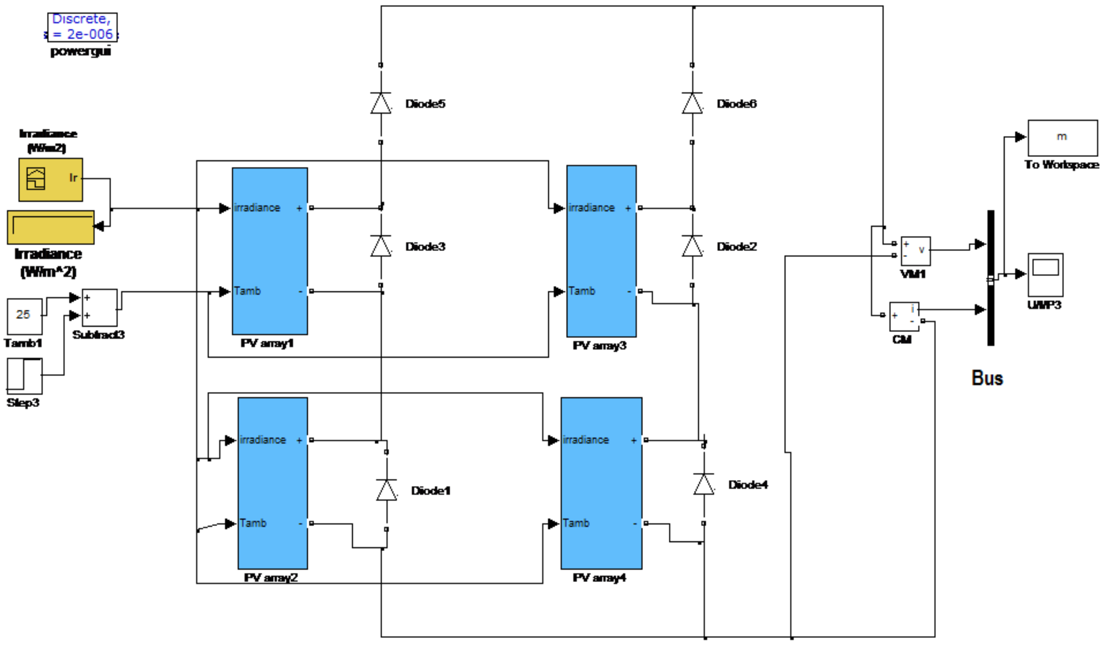


**Figure 3.** MATLAB/Simulink diagram for the connection of PV modules

In addition, we use the most simple central converter configuration as shown in Figure 4, where PV modules is linked to a one DC/DC adapter. The central converter configuration is generally applied by the main feature of the arrangement, which is the low cost and the facility of maintenance of the inverter. In addition, other configuration presented by the string converter configuration as well appear in Figure 5, each string contains its own converter (Manukonda & Gorantla, 2018; Maouedj et al., 2019).

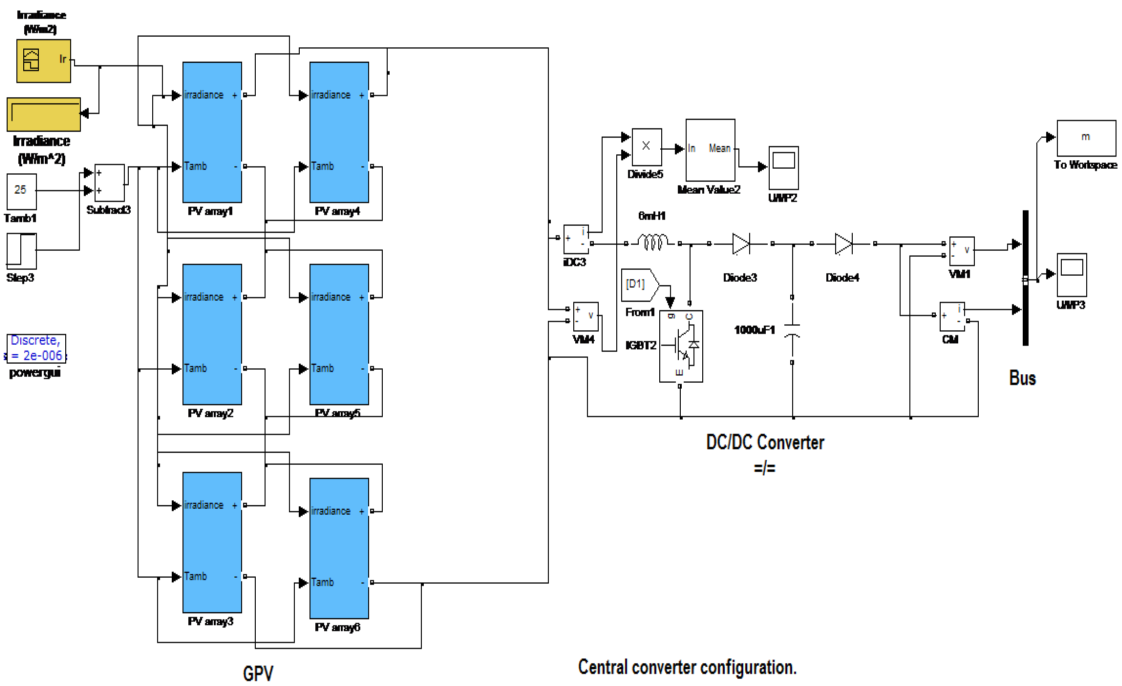


**Figure 4.** MATLAB/Simulink diagram for the central converter configuration

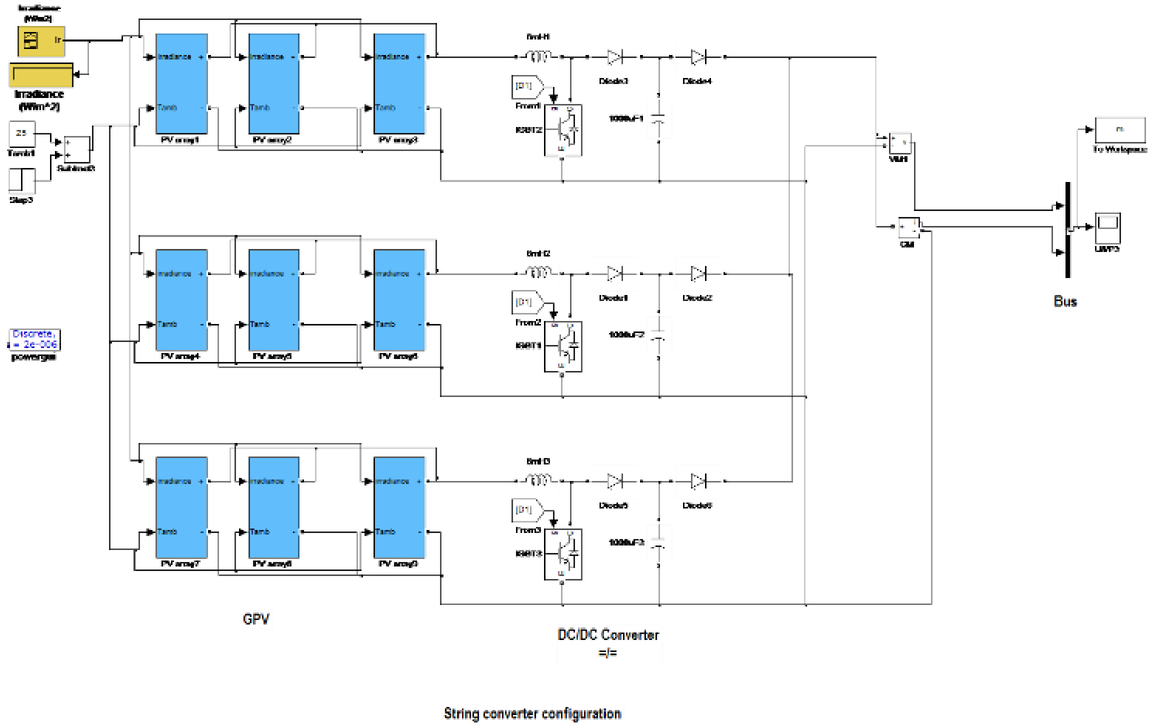


**Figure 5.** MATLAB/Simulink diagram for the string converter configuration

## 2.2. Proposed system configuration in grid connected hybrid PV/WT System

Figure 6 shows the order of the control system and its hybrid power. The hybrid system depends on a PV panel, a WT, MPPT control, power electronic converters for accommodating the energy related with the hybrid power source, and a grid interface inverter.

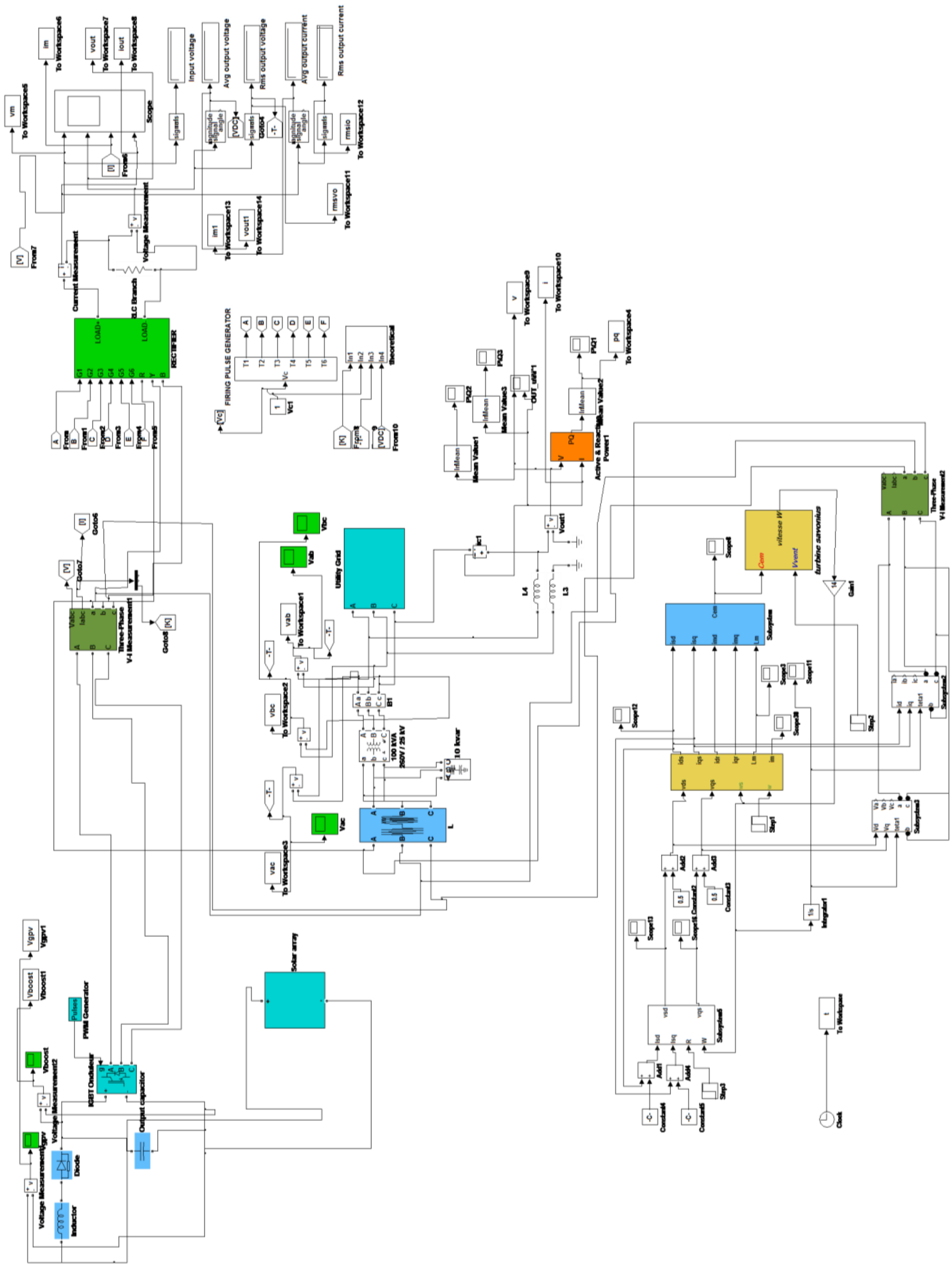

**Figure 6.** MATLAB/Simulink diagram for configurating our proposed hybrid system

## 3. Simulation results and discussions

MATLAB software environment is applied in the current research for showing the proposed mechanism authenticity on the hybrid renewable energy grid linked system.

In this part, we demonstrate our simulation results of the proposed hybrid renewable energy system which represent a PV array model connected by a WT, which is carried out. In our study the inputs like solar radiation SR (w/m$^2$), temperature (K°), and WS (m/s$^2$) are considered varies with a stable AC load in near grid and are examined for simulation. The irradiation 1200 to 900 W/m$^2$, temperature 25ºC/298°K, for PV and WS of 10.85 to 8.85 m/s are specified as inputs to the simulated hybrid system and load factors (Marouani, Echaieb & Mami, 2012; Ogunjuyigbe, Ayodele & Akinola, 2016). The output of energy obtained from PV/WT systems displays an improvement in their performance by P&O method, which appears of high efficiency with the fast varying weather conditions of WS and SR. It is remarkable to reference that the pulsation is high through the incremental change in SR, where the high voltage variation appears from 0.1 to 0.35 second by using P&O technique, which has a command to delay the stability of the PV/WT system at MPPT. The proposed PV/WT system shows the essential results of the utility grid powers, currents, and voltages and that the hybrid renewables sources study is synchronized with the utilities grid. The HS PV/WT combining mutable wind speed and solar radiation should be incorporated to equipping continuous energy to the load with optimal design of HS PV/WT controller. This HS PV/WT control unit is additionally useful and appropriate over other control units because it takes minimal computation load which minimizes the fail problem of the system. The system is simulated for 0.9 second, the results are as follows:

Figure 7 shows the characteristics of the output power voltage for different values of solar irradiation and temperature which are resulted from PV array and which, connected in series by means of DC/DC converter know as Boost, represent the link of conversion concerned in our work. We could clearly observe the impact of the weather conditions, when the PV array works in practice near its optimum MPP for important value of solar radiations and low temperature. Thus, it could electronically be observed via changeable duty cycle of the DC adapter in the scope 0 to 1. Figure 8 shows the output energy voltage the construction presents and the evaluation of performance a DC to AC inverter by efficiency work applied in several status, where rise large currents and switching frequencies are required. The main objective of the AC inverter is to convert the energy generated by the array solar module from a DC-supply into a 3-phase alternating voltage and current as it appears in Figure 9.

Figure 10 shows the characteristics of the nonlinear $V_{ABC}$ three phases voltage generated and fed in grid by our proposed diagram circuit study, when it presents high efficiency due their smart component used to readiness utility in both AC current-voltage and to its abilities in several areas like our work as shown in Figures 11 and 12. Thus, AC output energy voltage is taken from the piles of the full bridge inverter next to the L-C filter. With the purpose to gain the same sinusoidal output, energy voltage-current waveform are carried out.

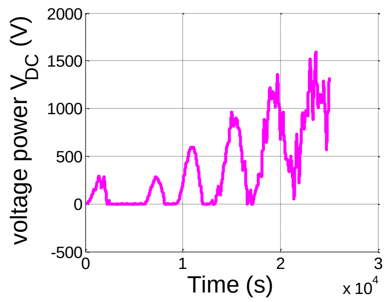


**Figure7.** Simulation results of DC power voltage

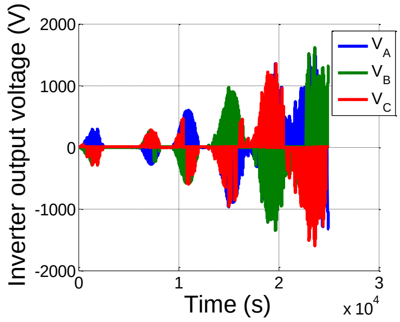


**Figure 8.** Simulation results AC Inverter output power voltage

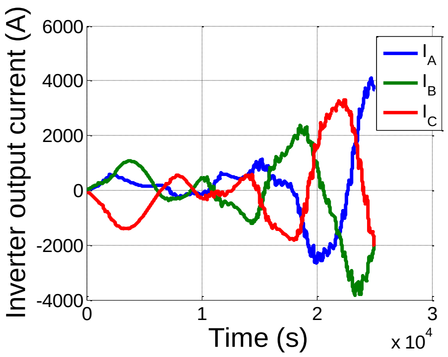


**Figure 9.** Simulation results of AC Inverter output power current

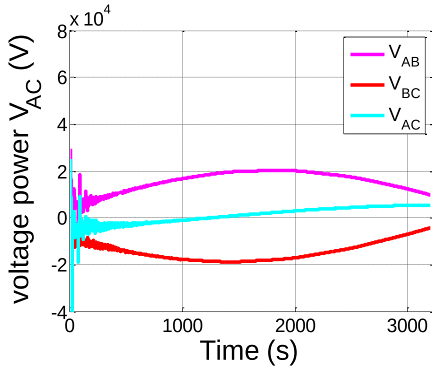


**Figure 10.** Simulation results of power voltage in grid connected hybrid PV/WT system

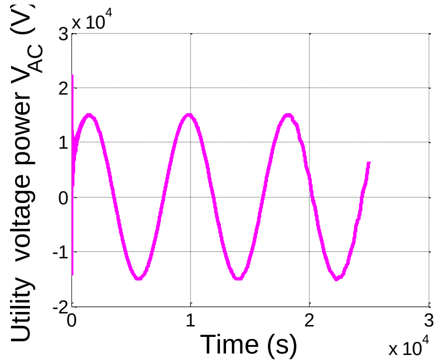


**Figure 11.** Simulation results on utility power voltage in grid connected hybrid PV/WT system

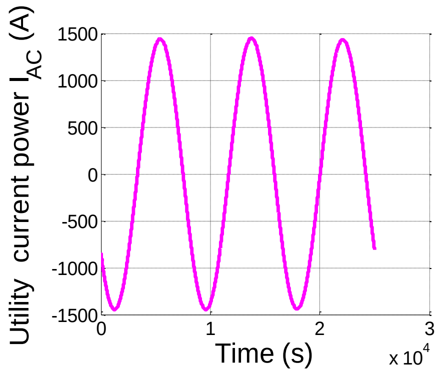


**Figure 12.** Simulation results on utility power current in grid connected hybrid PV/WT system

Figure 13 shows active and reactive energy in grid connected hybrid PV/WT system, which confirms a valid control performance. In order for energy transportation and apportionement to be achieved, considerable potential is made to command the reactive power. This is mostly automatically achieved through turning inductors/capacitor rows in and out, through regulating the excitation of the generator, and via other means applied in our simulation results. As observed, when active power (Watts) is decreased, the control is adjusted to increase reactive power (KVAR). Hence, injected power from the hybrid PV/WT system to the grid contrived into active and reactive energy part grid displays a reasonable valid system. Offered system receives the advantage of the capacity to restore reactive power. This is obviously fine that the P&O method successfully decreases the current and voltage oscillation. There are reduced variations in the system due to their weather conditions, through the system reaction with the P&O algorithm.

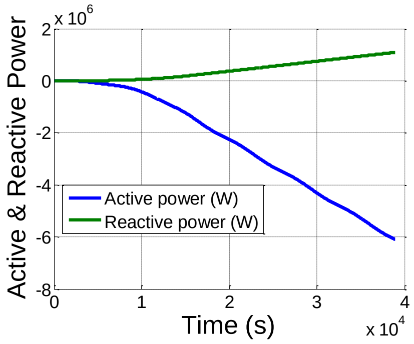


**Figure13.** Simulation results of active and reactive power distribution in grid connected hybrid PV/Wind turbine system

Figures 14 and 15 display the simulation results of the grid load power voltage and current. As the voltage descend, with the growing loading, the energy out declines. This in turn influences the frequency causing it to descend. This oscillation of power, voltage, current and frequency can last for more time (measured in seconds) for our simulation studies. Through this time frequency, response will start to rule to regain the frequency. Our circuit is carried with efficient ability and the system has been particularly designed to breed the best level of estimated values to testing display independent configuration of each output phase: frequency, harmonics, voltage rise/ constant, and current rise/constant along with an overall suit of other toolboxes used in our diagram proposed on MATLAB environment. So, the P&O algorithm that we used here is the best performance of current and voltage output.

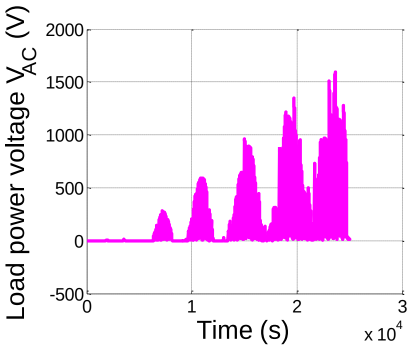


**Figure 14.** Simulation results of grid load power voltage

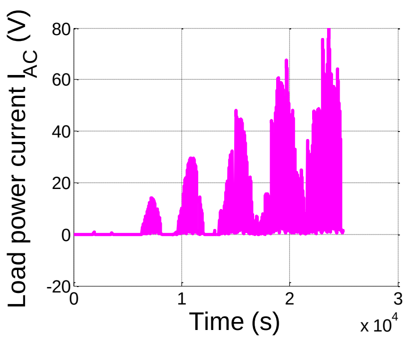


**Figure 15.** Simulation results of grid load power current

# 4. Conclusions

In order to optimize the process of wind farms, certain measures should be taken into consideration. In this paper, we have studied the mode of enhancement and estimated the process response of control in grid connected hybrid system PV/WT with the variables in weather conditions such as solar irradiation, speed wind, under load permutation has been consumed. The simulation results of our proposed models show that the hybrid system performance is very encouraging and concrete with those found in the literature. The proposed study used authorized the control for to find the WT/PV voltage or WT/PV current in which a WT/PV system delivers high power under a given solar irradiance/wind speed. The proposed control scheme based on the P&O method is carried out to enhance the achievement of MPPT through the best tracking efficiency and high adapter control for the extracted current, voltage and power with fast varying weather conditions in grid connected hybrid systems. This enhancement is due to improve the eligibility of the system and decrease the continual oscillations of the current, voltages and power.

### Conflict of Interest

Herewith authors have confirmed that this article has no conflict of interests.

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**Oumelkheir BOUCHIBA** earned his PhD degree in Electrical Engineering from the University of Amar Telidji in 2021. She joined the faculty of Technology at the University of Amar Telidji, Laghouat (Algeria), in 2012. Her general research interests are in the area of renewable energy systems and optimization techniques.

**Tahar MERIZGUI** was born in Laghouat, Algeria, in 1991. He received the master degree in renewable energies from the University of Laghouat, in 2015 and the Ph.D. degree in materials and renewable energies from University of Laghouat, in 2020. His research interests are in the subject of microstructure property relations for novel hybrid composites. As well as the development of innovative composite materials for multifunctional applications and renewable energy systems.

**Bachir GAOUI** was born in Laghouat, Algeria, in 1989. He received the master degree in Electrical engineering from the University of Laghouat, in 2014 and the Ph.D. degree in materials and renewable energies from University of Laghouat, in 2018. His research interest includes the development of innovative composite materials for multifunctional applications and renewable energy systems.

**Saliha CHETTIH** earned her PhD degree in Electro-technology from the University of Amar Telidji. She joined the faculty of Technology at the University of Amar Telidji, Laghouat

(Algeria), in 2008 where she is currently a professor. Her research interests optimal power flow, Artificial intelligence and optimization techniques.

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**Ali CHEKNANE** is a Full-Professor at the Amar Telidji University of Laghouat-Algeria. He has completed his PhD in physics. He has 20 years of graduate and postgraduate teaching experience at the university on a temporary, associated and permanent position. He has published many papers in various journals and conference proceedings on renewable energy subjects.