OPTIMIZATION OF ELECTRIC POWER GENERATION OF A WIND-SOLAR HYBRID SYSTEM

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ABSTRACT

In this article, the hybrid system studied is a combination of two renewable energy sources: photovoltaic and wind. This kind of system is mainly used in autonomous mode in isolated sites. During the day, the photovoltaic generator ensures production, while at night, the wind picks up and the wind turbine takes over, thus compensating for the name productivity of the panel. For the photovoltaic conversion chain, a neural controller is used to monitor the maximum power point, this technique has shown its robustness in the face of variations in external disturbance, it has uniform gaits in steady state. The great advantage of this combination is that our controller quickly reaches the optimal operating point without having to know the power curve or measure atmospheric conditions. For the wind conversion system, it operates at variable speed coupled to a synchronous permanent magnet generator using the fuzzy controller, its performance in terms of speed and precision makes it a better control option than conventional controllers. The latter also need to know the wind speed and the optimal characteristics of the turbine, unlike the command which does not require this data. The change in wind speed can have an effect on the stability of such a mechanical system, yet the flexibility of fuzzy logic has resulted in less loss. The power delivered by each source is controlled by having incorporated maximum power tracking commands. In terms of hybridization, the two sources complement each other at the same time, the pursuit of maximum power for each of them to give a better performance for the whole system.

Keyword: - *MPPT , AC-DC Converter , DC – DC Converter, Optimization , Hybrid Energy, Wind/Solar hybrid system.*

1. INTRODUCTION

The "MPPT" device corresponds to a control strategy allowing the maximum power of a nonlinear electric generator such as the photovoltaic and wind system to be monitored. Faced with the intermittence of the two sources, it is necessary to develop independent tracking algorithms for each of them. Many concepts have been introduced to effectively reach this maximum power point for both systems. However, we propose to focus on energy yields which notably offer the so-called intelligent algorithms: in particular the algorithm based on fuzzy logic for the wind conversion system, as well as the algorithm based on the neural network for the system photovoltaic conversion.

2. THE MPPT CONTROL ON THE PHOTOVOLTAIC CONVERSION SYSTEM

2.1 Characteristics of the photovoltaic generator

For the simulation, we have synthesized a model of a photovoltaic generator. A single module is insufficient to supply electrical equipment. It then failed to associate the modules in series to obtain a higher voltage. The generator is therefore composed of 11 modules in series, each of which contains 60 silicon cells which has an open circuit voltage of 0.6 [V]. Which gives us the following characteristic curves:

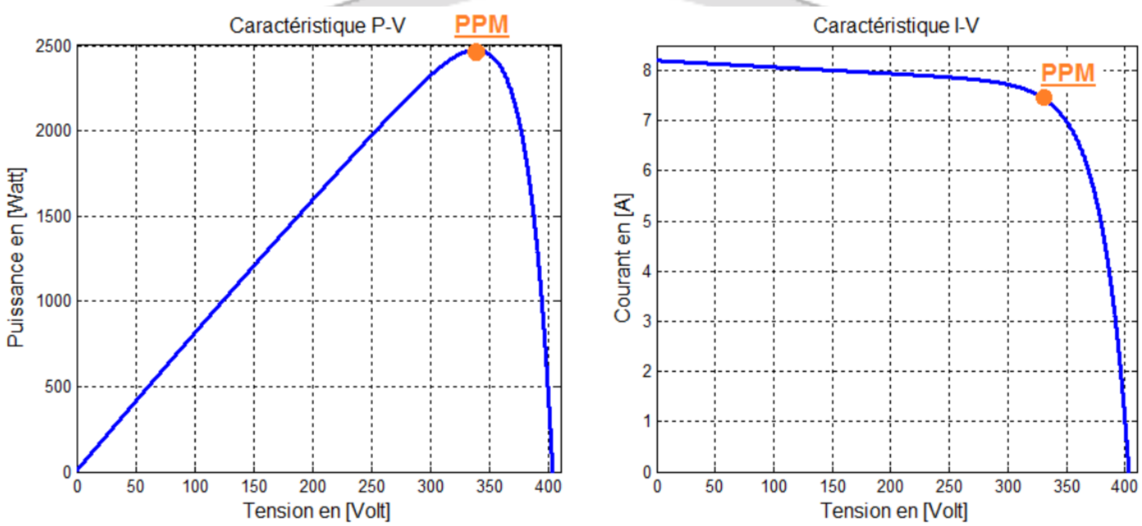

Fig -1: Characteristic curves P-V and I-V of the photovoltaic generator

Here we find special values such as the peak power of approx. 2475 [W]. The I-V characteristic shows the following values for this photovoltaic generator: short-circuit ±8.2 [A]), open-circuit voltage (±405 [V]) and current at the point of maximum power (±7.6 [A]).
Since the maximum output power of a solar panel varies with the weather conditions, there is a need for a controller associated with an adaptation stage that continuously searches for the MPP (Maximum Power Point), acting on the voltage or current regardless of the sunlight and temperature. To this end, there are many tracking techniques available.

2.2 Choice of neural structure

In the neural network implementation, the input variables chosen are the couple (Vpv, Ipv) as a function of the sunshine (G), of the temperature (T); and the output will be the reference voltage that will be used in the pulse width modulation. Because these variables are relevant to the variation of the output. So in our work, we proposed a multilayer neural network with:
• two inputs: Vpv and Ipv
• a hidden layer with ten neurons (after several experimental tests)
• an output layer to a neuron, corresponding to the reference voltage
For the transfer function, the sigmoid function was used for the intermediate layers and the linear function for the output layer.

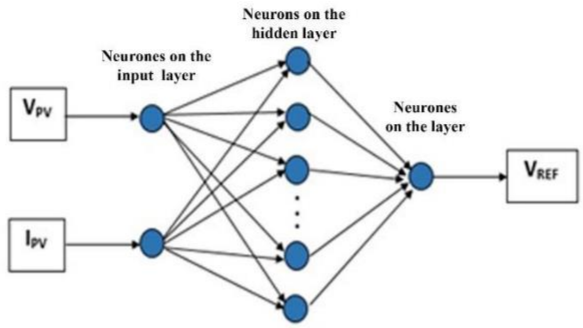

Fig -2: Neural structure for MPPT control

2.5 The neuronal network

Having a data base of the behavior of the inputs and the output of the GPV (such as: inputs: [Vpv, Ipv]; the target output: d), one can proceed to the creation of the network while launching then the “file.m Which contains the functions of the Matlab toolbox for neural networks in order to perform learning. After learning, with the command "gensim (net)", we get the following block:

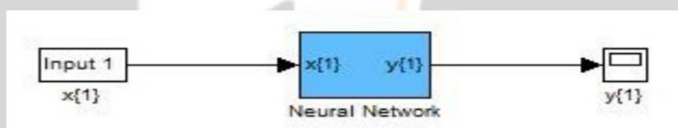

Fig -3: Simulink block of the neuron network

By introducing this block in the control system for the converter we have this:

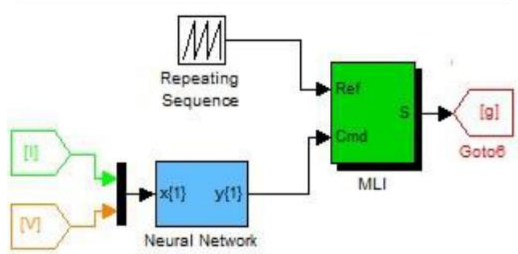

Fig -4: Control block

- V is the voltage and I is the current from the PV generator
- g is therefore the switching command of the booster converter

2.6 Result of the lawsuit on the photovoltaic generator

The reference voltage is obtained from the linear relationship between Vopt and Voc of the PV module:

Vopt = kv.Voc (1)

Where kv is a voltage factor which depends on the GPV used and the operating temperature. Generally, for Si GPVs, kv is between 0.71 and 0.78.

The optimal current is calculated by the following relation :

Iopt = ki.Icc (2)

Where ki being the current factor which depends on the GPV used, generally between 0.78 and 0.92.
The following figures show the output values of power, voltage and current for a pair of temperature and sunshine data equal to
(25◦C, 1000W / m2).

• Voltage

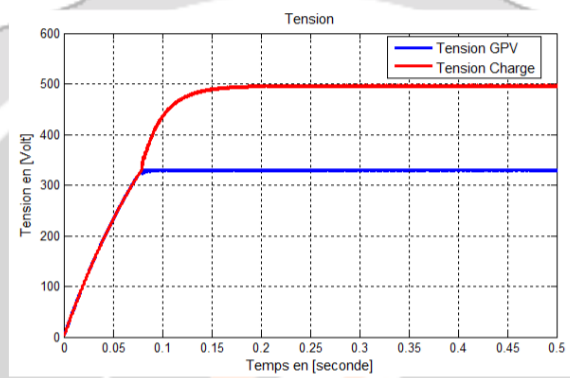

Fig -5: Trend of the voltage under the effect of the RN-based algorithm at (25◦C, 1000W / m2)

We note that the chopper controlled by the algorithm supplied at its output, a voltage higher than that provided by the photovoltaic generator. The regulation presents a good performance : precision, speed and stability as well as a good ability to pursue.

• Current

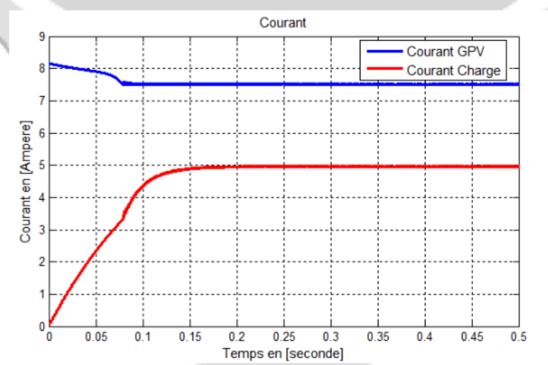

Fig -6: Current shape under the effect of the RN-based algorithm at (25◦C, 1000W / m2).

The current varies inversely with the voltage so that their product always gives the maximum power desired. We can see that the current at the point of maximum power is of the order of 7.6 [A] as it is described in the table characterizing the panel.

• Power

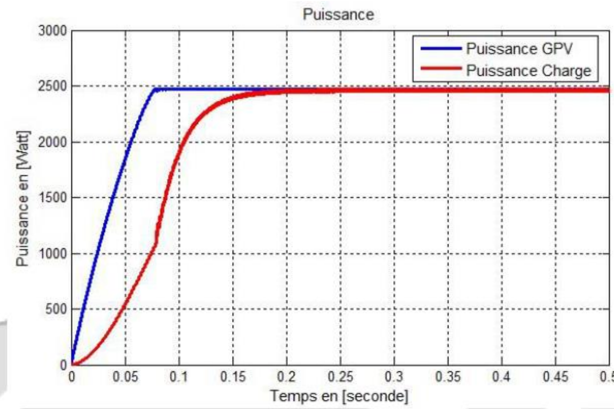

Fig -7: Rate of power under the effect of the RN-based algorithm at (25◦C, 1000W / m2).

With their ability to adapt to unknown situations through learning, we see that neural network control shows a good compromise between characterization and calculation efficiency. Its robustness, its speed and the precision of its outputs allow it to give correct decisions and avoid cases of indecision which can appear in other tracking algorithms such as P&O. After 0.2 [s], the power at the maximum power point is reached, that is to say at 25◦C, 1000W / m2 there is 2475 [W] of power for an optimal torque (voltage, current) of the GPV, (323 [V], 7.6 [A]).

To have a criterion for assessing the efficiency of our algorithm, let's vary the sunshine

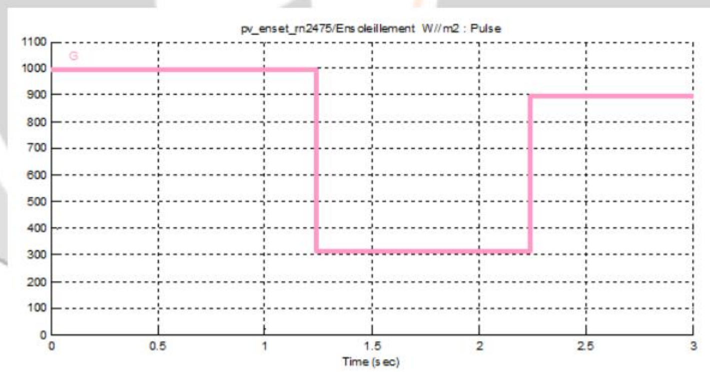

Fig -8: Variation of sunshine

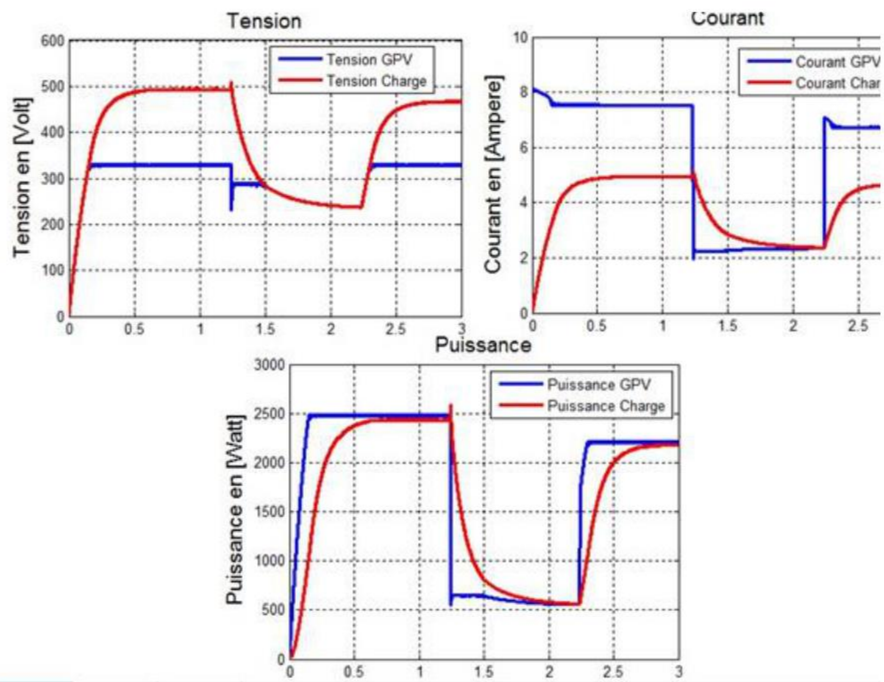

Fig -9: Response of the system to a variation in sunshine (25◦C).

During the first sunshine rating of 1000 [W/m2], the peak power is reached, with an optimal GPV voltage of 323 [V] and an optimal current of 7.6 [A]. We therefore have 0.6 [s] for system stability. When the solar irradiation decreases to 315 [W/m2], after a period of time of 0.7 [s] we have an optimal power of 555 [W] for optimal values of 237 [V] in voltage and 7. 54 [A] in current. And the last value attributed to the sunshine is 895 [W/m2], which allows us to extract an optimal power of 2200 [W].

The difference between the optimum power and that obtained using the MPPT device is caused by losses due to the series connection of several modules. As for power peaks, the sudden change in such power can only lead to insignificant transient regimes. But also the approximation, however small, that remains when determining the series and parallel resistances can have consequences for the entire system. However, in the real case, sunshine jumps are rare or even non-existent. But despite this, in this study we were able to limit these peaks to ±5% of the maximum power value. Unfortunately, limiting the peaks slowed down the MPPT regulation and increased the static error by a few watts. So we had to find a good compromise between accuracy and speed. Here the response time becomes 0.5 to 0.7 [s].

3. THE MPPT CONTROL ON THE WIND CONVERSION SYSTEM

3.1 The general objective of the MPPT command on the wind system

Earlier, we saw that the recovery power of wind turbine generators is limited by the Betz limit, which is about 59% of the kinetic energy of the wind. The power coefficient Cp, takes this limit into account, as well as mechanical friction losses, and varies according to the speed of the turbine. This is why it is essential to monitor the operating point at maximum power, acting on the mechanical part via the blade pitch angle or on the electrical part via the control of the electrical machine via the power electronics.

For example, the figure below shows the extrema that the MPPT follows of a three-blade wind turbine with variable wind speed. The bell-shaped power curve, given for each wind speed, has a maximum power point defining the optimum power curve

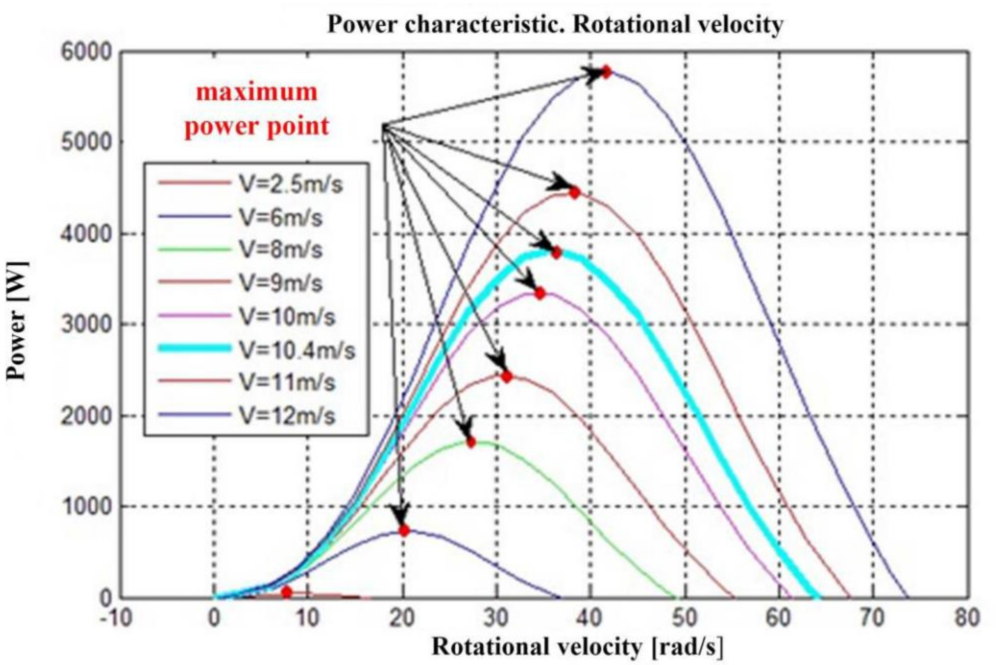

Fig -10 : Point de MPPT d'une éolienne tripale avec différentes vitesse vent

3.2 Principle of power maximization based on fuzzy logic

The behaviour algorithms to be held to converge to the optimal point depend on the variations in power ΔP and speed ΔP. Based on the linguistic rules set up, the tracking device measures these two variations and then proposes a change **Ω**ref of the wind turbine rotation speed setpoint **Ω**ref . To sum up, a reference rotation speed (resulting from the analysis of the behaviour of the MPPT device) is imposed on the turbine even if the wind speed varies. The behaviour equations are as follows:

$$\Delta P = P[k] - P[k-1]$$

$$\Delta \Omega = \Omega[k] - \Omega[k-1]$$

$$\Omega_{ref} = \Omega[k-1] + \Delta\Omega_{ref}[k]$$

Let's take an example of a maximum power point search rule:

- if we measure a power increase (ΔP > 0) after a positive speed increment, we must continue to accelerate the canopy ¡ΔP > 0¢. The left side of the P-curve is located on the left (**Ω**).

- if, on the other hand, a decrease in power is measured as the rotation speed increases, the canopy must be decelerated with a negative increment in order to return to the optimal point of power. This time we are on the right side of the curve.

We can then say that the variation results from the change in the rotation speed which is either in the positive or negative direction. At the same time, this variation can be small or, on the contrary, large, depending on the operating position in relation to the point of maximum power. In relation to this, the value of the speed setpoint is increased either slightly or greatly in the direction which increases the power.

3.3 Result of the continuation on the wind conversion system

With the models in Chapter 3 of the wind turbine and the permanent magnet synchronous machine, the wind system can be simulated. The speed control laws are applied to the IP controllers and supplemented by the previously described fuzzy MPPT maximum power point finder. The evolution of wind speed as a function of time is modelled by an analytical function or generated by a static law from the measurement data for a given site. However, in a theoretical modelling context, the duration of the profile must be limited to reduce the simulation time. In this study, we will represent the evolution of wind speed by a scalar function that evolves over time, modelled in a deterministic form by a sum of several harmonics :

$V(t) = Vm+0.2\sin(0.1047t)+2\sin(0.2665t)+\sin(1.293t)+0.2\sin(3.6645t)$

Where Vm is the average wind speed. Here we took as average wind speed 9 m/s.

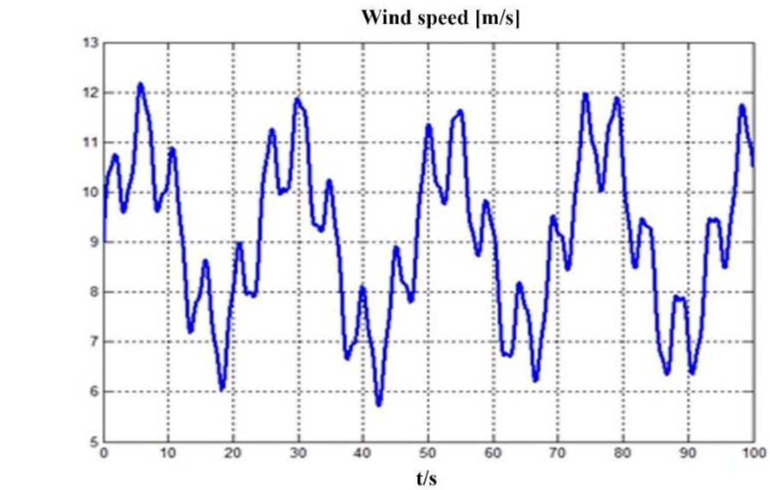

Fig -11 : Wind test sample

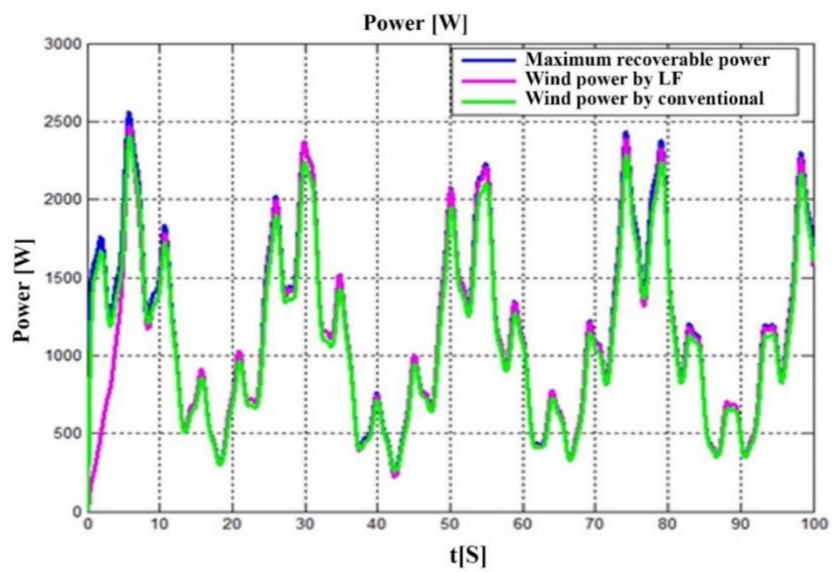

Fig -12 : Powers from tracking methods

We find that the power from our fuzzy controller is almost identical to the optimum power that the turbine should have. However, the difference between the recoverable power and the power obtained from the tracking control is caused by the inertia of the wind system. The performances obtained (stability, precision, response time) are satisfactory for such an electromechanical system.

The efficiency curve gives an overview of the quality and success of the fuzzy MPPT control :

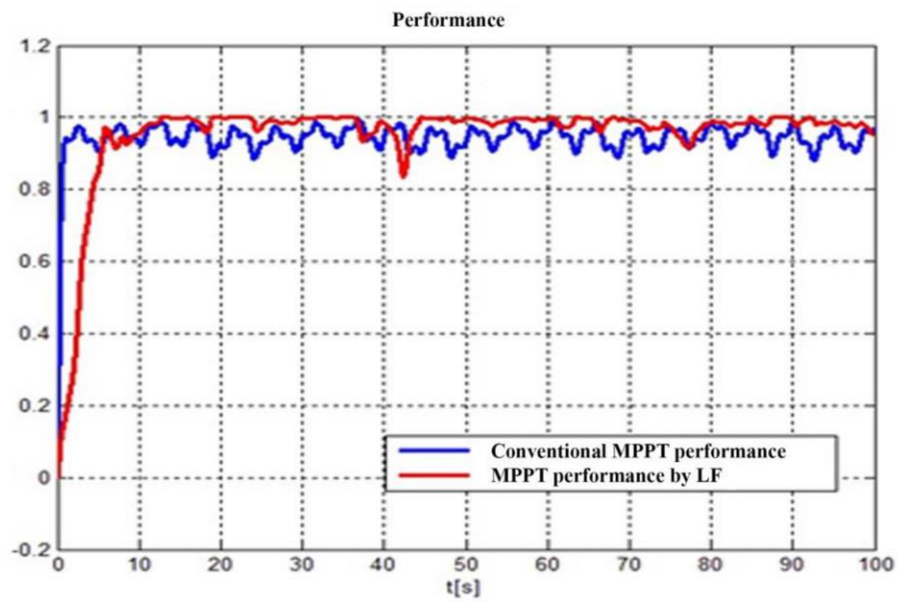

Fig -13 : Yield

4. HYBRID SYSTEM

In this study, the hybrid system studied is a combination of two renewable energy sources: photovoltaic and wind power. This type of system is mostly used in stand-alone mode in isolated sites. During the day, the photovoltaic generator provides the production, while at night, the wind rises and the wind turbine takes over, thus compensating for the non-productivity of the panel. Storage techniques are alternatives that can be put in place to ensure continuity of production.

The power delivered by each source is controlled by incorporating maximum power point tracking controls.

As a result, the hybrid package is optimized.

Since maximum power tracking has been achieved, the topology of the hybridization is to be chosen according to the case and the load requirement. Here is an example of a simulated isolated system topology.

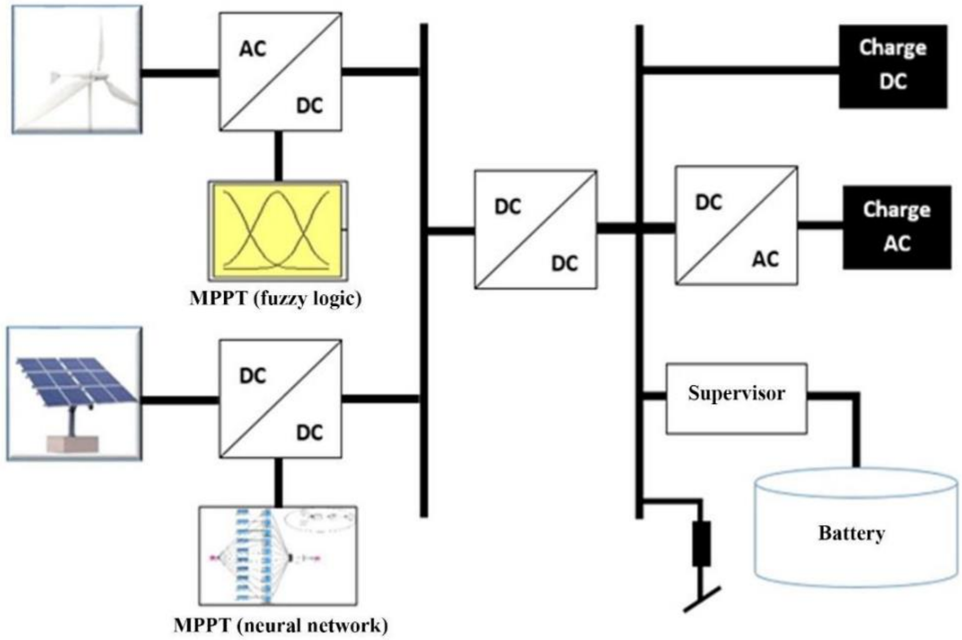

Fig -14 : Example of hybrid topology with two renewable sources

Here is a wind variation and a sunshine variation proposed in order to highlight the complementarity that can exist between our two renewable sources.

Fig -15 : Sunshine [W/ m2]

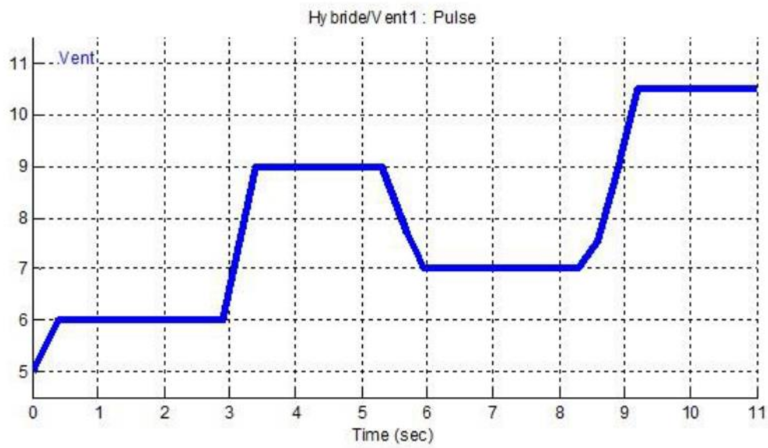

Fig -16 : Wind speed [m/ s]

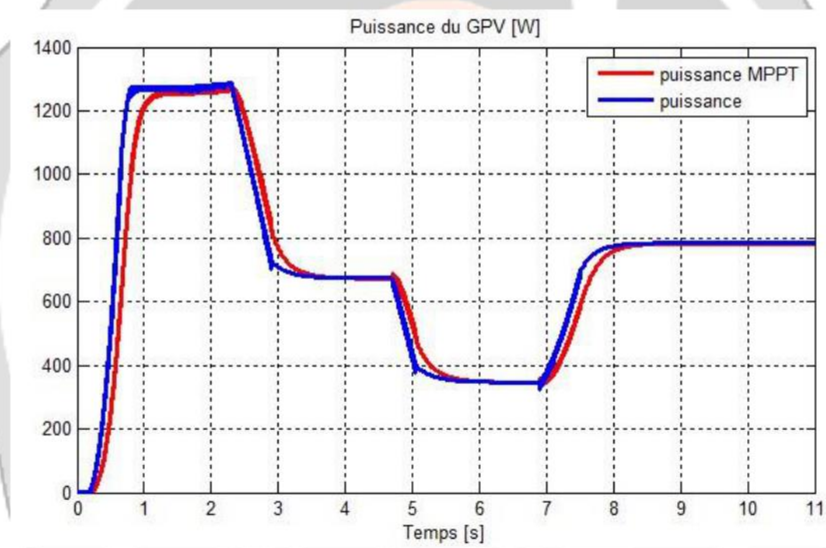

Fig -17: Power of the GPV [W]

We can notice that the power of the photovoltaic panel is well controlled to follow the optimal value according to the variation of the sunshine, so we always have a maximum power in all conditions. Our neural controller has optimized the output of the photovoltaic system. We also note the absence of power peaks, since there is no jump in the rate of sunshine that we have chosen

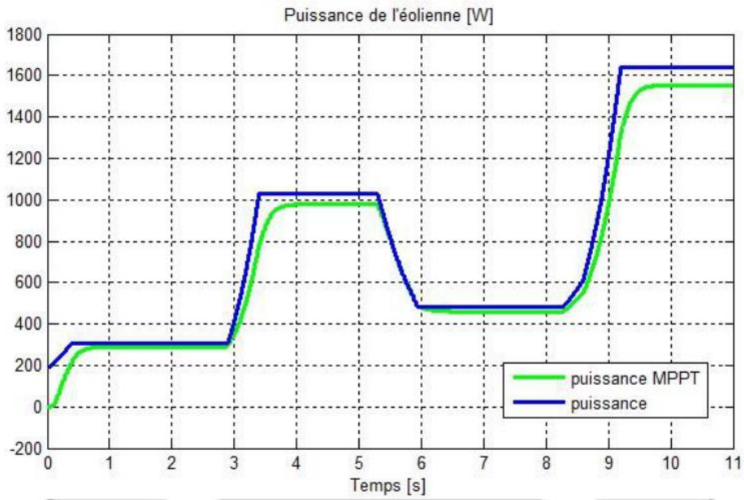

Fig -18 : Power of the wind turbine [W].

Similarly, the fuzzy controller for tracking the wind turbine's PPM worked well to extract maximum power according to wind variations. Recall that the observed discrepancy between the maximum power and the power obtained by tracking is mainly due to the inertia of the wind turbine.

$$V_{hybrid} = \begin{cases} V_{solar}\ , \ si & V_{solar} > V_{eolian} \\ V_{eolian}\ , \ si & V_{eolian} > V_{solaire} \end{cases}$$

Which induces the following appearance:

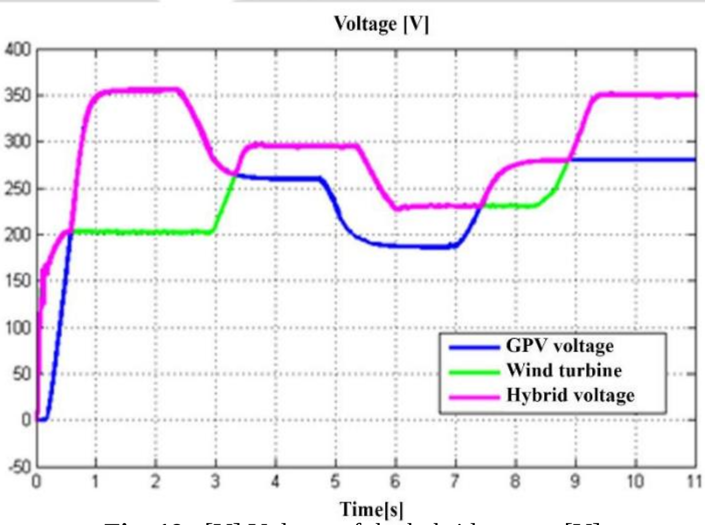

Fig -19 : [V] Voltage of the hybrid system [V].

From 0 to 0.58 [s], the voltage of the assembly increases with the wind turbine voltage, then from 0.58 to 3.32 [s], it follows the voltage of the photovoltaic panel. From 3.32 [s] to 7.42 [s], it follows the voltage of the wind turbine.

From 7.42[s] to 8.85[s], the panel voltage exceeds the wind turbine voltage. And finally, from 8.85[s] to 11[s], the wind turbine voltage is higher than the GPV voltage.
And at the output of the inverter, the constant withstand voltage on the DC bus is transformed into an AC signal of 220 [V] at 50 [Hz]:

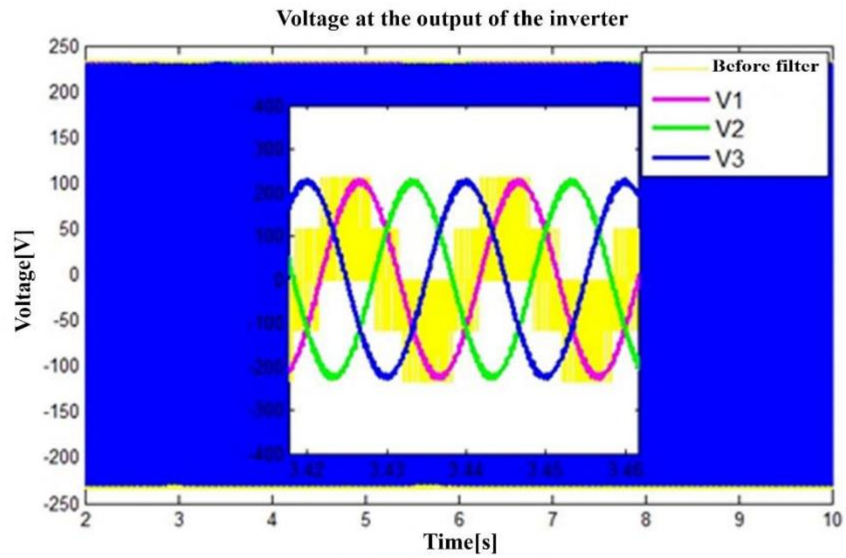

Fig -20 : Output voltage of the inverter [V]

Et pour la puissance nous avons l'allure suivante :

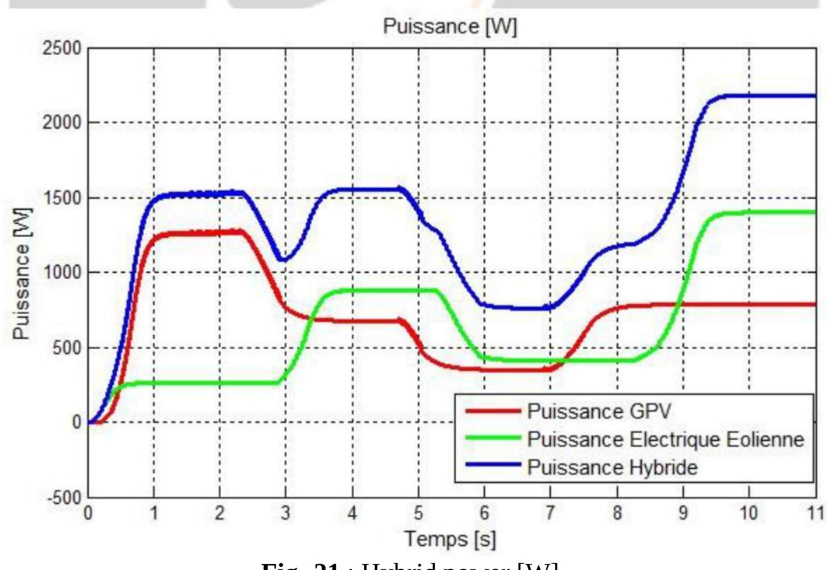

Fig -21 : Hybrid power [W].

It can finally be deduced that wind and photovoltaic renewable systems are complementary.
Simulation results have shown a good behaviour in the face of climatic variations. These variations showed a good efficiency of the maximum power tracking systems of the PV generator and the wind turbine. Satisfactory results have been obtained for the optimization of our two renewable energy sources. It should also be noted that the use of a storage system is indispensable for purely renewable hybrid systems. Let's analyse the case of our power rate:

if the demand is for example 1500 [W], the surplus energy at the time interval 3.8 [s] to 4.8 [s] and 9 [s] to 11 [s] can be recovered in a storage system. The energy thus stored can make up for energy shortfalls in production in relation to demand, as is the case between 5 [s] and 9 [s]. And moreover, if these energy surpluses are not stored, they will be discharged in the discharge resistor (Dumpload) as lost energy.

5. CONCLUSIONS

The study presented in this chapter demonstrates the feasibility of converting wind energy to full power. The simulation results show a fast and accurate tracking of the optimal GSAP speed to generate maximum power. The same is true for the conversion of photovoltaic energy. The success of maximum power tracking can be seen.
In terms of hybridization, we observe that the tracking of maximum power for each of them to give a better efficiency for the whole system. Note that the MPPT optimization of the two sources does not depend on the form of hybridization adopted. However, other types of optimization may be necessary, for example if there is a storage system in the topology, a load supervisor or power control is useful.

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