Management and control operation of a wind-diesel hybrid system to power a remote site

A/h Ksentini[#1], E.b Azzag [*2], A Bensalem [#3] and K Allali[*4]

[#] *Hadj Lakhdar-Batna University*
Department of Electrical Engineering,05000 Batna, Algeria.
[1]ninaks23@yahoo.com
[3]bensalem_ahmed_dz@yahoo.fr
[*] *Badji Mokhtar-Annaba University*
Department of Electrical Engineering, PO Box 12, 23000 Annaba, Algeria.
[2]azzag15@yahoo.fr
[4]allali_kh88@yahoo.fr

***Abstract*— Southern Algeria is very large or the presence of a large community living away from the power distribution of several hundred kilometers as Adrar, Ghardaia ... etc.**

Currently the electrical power is provided by generators for domestic consumption and pumping for irrigation of agricultural land. This solution is not beneficial to long-term economic and technical point of view where the integration of a hybrid system based on this wind which is interesting, because the wind speed covers the majority of these sites throughout the year.

The combination of renewable energy with storage elements and generators optimizes power generation systems, both technically and economically, so as to enjoy the wind and minimize fuel consumption. The generator and energy storage elements have the role: to compensate fluctuations of power produced by the wind in the short and long term.

In this article, we will make modeling and energy control system, it allowed us to optimize the strategy of the Hybrid Energy System(HES) and to consolidate the gains to provide proper management of energy sources (wind , diesel, battery), as a function of the load curve of the site.

***Keywords*— Energy management, Hybrid network, Storage, Modeling, Coupling.**

I. INTRODUCTION

Wind energy development is consumer and environment friendly, it requires shorter construction time compared to thermal, nuclear generation and is cost competitive. It becomes one of the most competitive sources of renewable energy.

However, wind power has some disadvantages. For example, wind power is considered an intermittent power supply because wind does not blow 100% of the time. Today, in many parts of the world, the decisions for new capacity installation become complicated due to the fact that finding new sites for generation and transmission facilities of any kind are difficult. Particularly rural areas in the developing world where most of the population is located, most people lack the essential energy services to satisfy most of their basic needs.

The cost of grid connection in these rural areas is very high due to a low density of population; therefore various organizations have turn to explore alternative solutions. [1]

One of the most economical and reliable alternatives is to use diesel power generation, but diesel power generation is very inefficient when the load is a small percentage of the rated power of the engine. The fact that every time, there is a need for power the engine has to operate makes it very inconvenient and reduces the efficiency and lifetime of the power generation system. As a result, wind energy system has been suggested to provide a good solution to supply energy loads in these rural areas. Hence, the role of hybrid power system comes into focus.

Hybrid systems offer different penetration levels, with a large choice of technical solutions. The wind power allows a reduction of the diesel generator rating. Both for reasons of network compatibility and to reduce mechanical loads, many large wind turbines (installed either offshore or onshore) can be operated at variable speed and use doubly fed induction generators.

II. PROBLEM

In most isolated regions in Algeria (Adrar) the diesel generator is the main source of electrical power.

For these regions, the fuel is usually more expensive because it must provide additional transport costs to these isolated places, sometimes inaccessible“Fig.1”. This is why the use of diesel generators combined with a renewable energy source and a storage system is recommended. It is with this objective that fits my article with the use of multiple sources for energy supply system adopted.

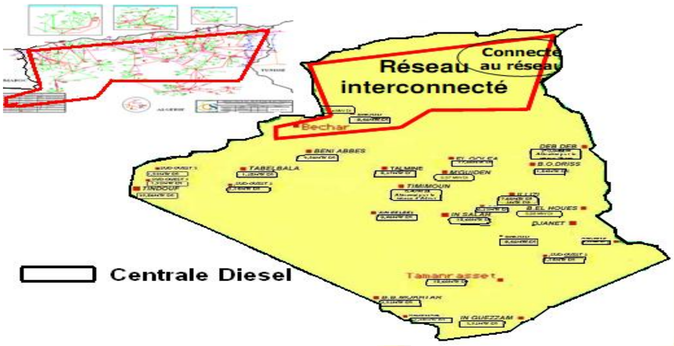


Fig. 1 Distribution of the powerlines and diesel power in Algeria . [5],[17]

III. LOCATION OF HYBRID SYSTEM

To be good sites for implementing this system in Algeria must choose a place is characterized (wind speed, power requirements) of “Fig. 2”.

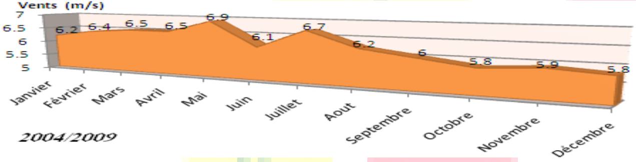


Fig. 2 Monthly averages speed of wind of Adrar.[16]

For this study, a geographical localization is considered with the wilaya of Adrar “Fig.3”, located at the Algerian western south with coordinates following: Longitude 0.28;Latitude 27.82 and covering a total surface of **427.968 *Km*^{2}.**

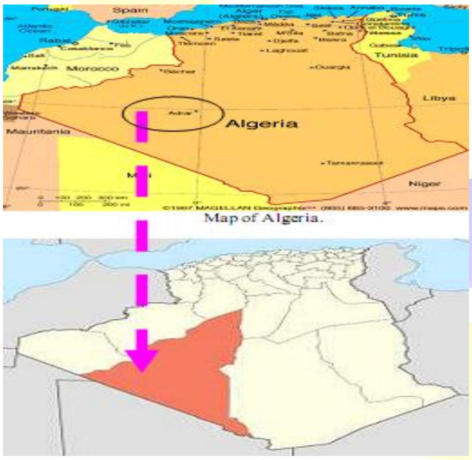


Fig. 3 Map geography of wilaya Adrar [4].

The majority of sites in the wilaya of Adrar could be considered as isolated sites to the vast size and distance from the city and each other. Climatic conditions are extremely difficult to consider another parameter. All this leads us to think of hybrid systems for powering an area in this region [6].

IV. SCHEMES FOR OPERATING A HES

This system consists of a wind turbine with machine double-fed asynchronous (DFIG), the generator diesel (GD) and a battery. Depending on the strength of the wind, 3 operating modes can be distinguished for systems with high penetration “Fig. 4”.

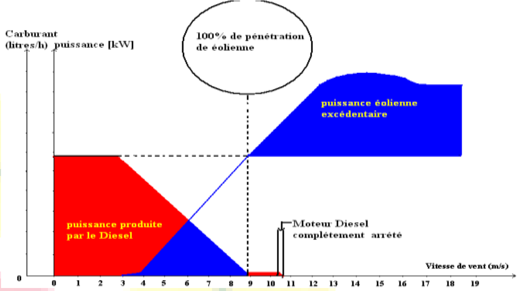


Fig. 4 Variation of energy covered by a system Wind -Diesel and diesel consumption as a function of wind speed [7].

The terms of the commissioning of different sources are presented in the following chart:

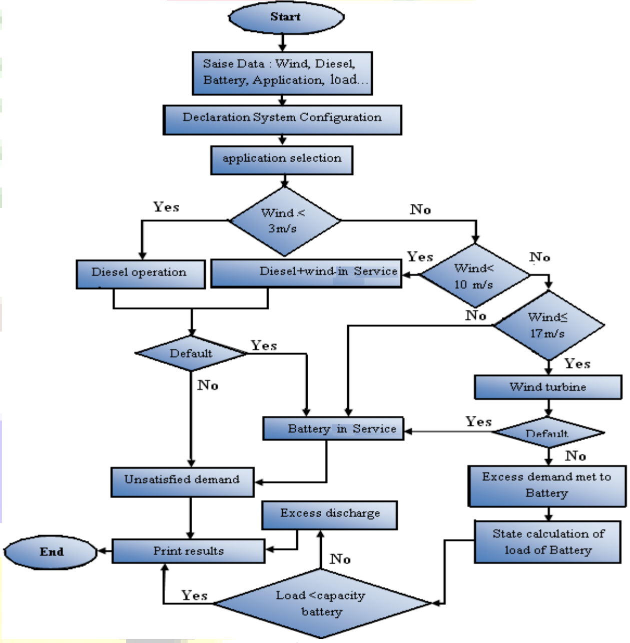


Fig.5 Flowchart of the simulation method .

To achieve this study, we conducted an energy modeling of HES components whose main elements are: wind, generator, storage system (battery), shown in "Fig. 6 ": The connection of these elements is performed at a DC voltage bus. This bus has the advantage of more easily interconnect the different components of the hybrid system.

From the DC bus, the network connection is achieved thanks to a DC power / AC, which then adjusts the voltage and frequency of the front into AC power fed into the grid.

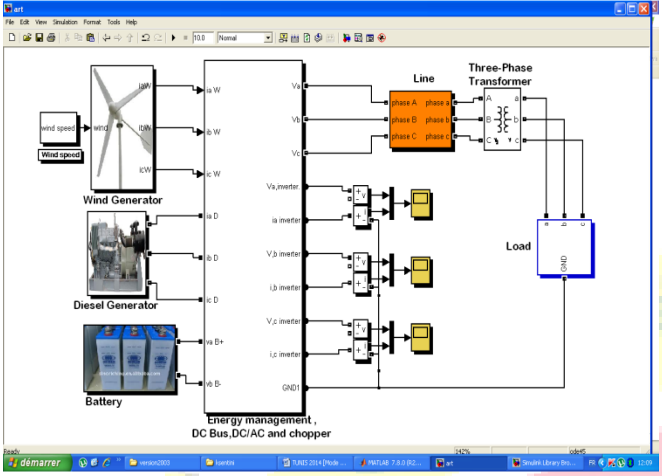


Fig.6 Overall system diagram.

V. MODELING OF SOURCES

A. *Modeling of the turbine of the wind and strategy of MPPT*

Generating for the selected conversion of kinetic energy of the wind is a double-fed induction generator [8-9]. In our case, we opted for a DFIG driven by the rotor with a limited range of speed variation (± 50%) of the nominal speed. This choice allows us to use one converter designed for a rated power of the order of 25 to 30% of rated power. [10] There will be less bulky, less expensive and require less bulky cooling system [11] “Fig. 7”.

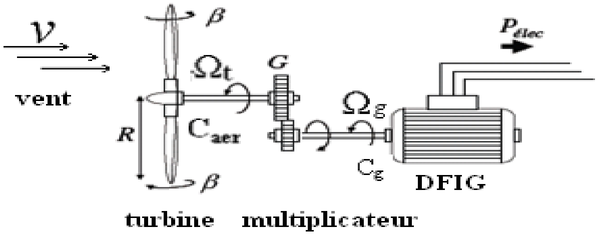


Fig.7 Components this wind.

1) *Model Wind:* The wind speed is usually represented by a scalar function that evolves over time.

$$V_v = f(t) \tag{1}$$

The wind speed will be modeled in this part, as deterministic as a sum of several harmonics [9]:

$$V_v = A + \sum_{n=1}^{i} a_n.\sin(b_n.W_v.t) \tag{2}$$

Fig.8 shows the speed of a simulated (2) random wind.

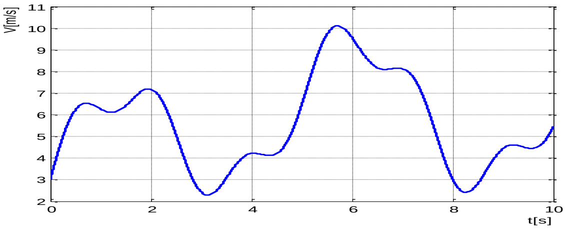


Fig. 8 Speed versus time.

2) *Model of the turbine:* Applying the theory of momentum and Bernoulli, we can determine the incident power (theoretical) due to wind [12-13]:

$$P_{incidente} = \frac{1}{2}.\rho.S.V^3 \tag{3}$$

S : The area swept by the blades of the turbine surface[m²].

ρ : the density of the air (ρ =1.225 (m ^{3}/ kg) at atmospheric pressure).

V: Wind speed [m / s].

In wind energy system due to various losses, provided on the power extracted from the turbine rotor is less than the forward power. The power extracted is expressed by equation (4).

$$P_{extraite} = \frac{1}{2}.\rho.S.Cp(\lambda,\beta).V^3 \tag{4}$$

Cp (λ/β): power coefficient, which expresses the aerodynamic efficiency of the turbine. It depends on the ratio λ, which represents the ratio between the speed at the tips of the blades and the wind speed, and the angle of orientation of the blades β.

The ratio λ expressed by (5):

$$\lambda = \frac{\Omega_t.R}{v} \tag{5}$$

The maximum power coefficient Cp was determined by Albert Betz as follows [14]:

$$Cp^{\max}(\lambda,\beta) = \frac{16}{27} \approx 0.593 \tag{6}$$

The power factor is the aerodynamic efficiency of the wind turbine. It depends on the shape of the turbine rotor and the angle of orientation of the blades β and the ratio of the speed λ. This coefficient can be written as follows:

$$Cp(\lambda,\beta) = 0.5176\left(\frac{116}{\lambda i} - 0.4\beta - 5\right)\ell^{\frac{21}{\lambda.i}} + 0.0068\lambda i \tag{7}$$

With:

$$\frac{1}{\lambda i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \tag{8}$$

Figure 9 shows the curves of the power coefficient as a function of λ for different values of *β*.

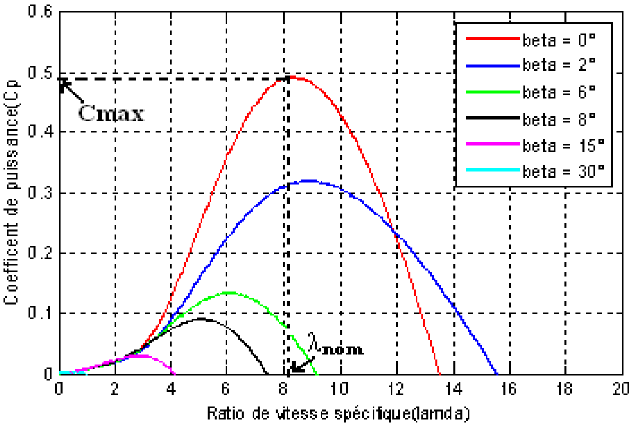


Fig.9 The characteristic of reactivity power coefficient according to λ and β.

One can notice on the ''Fig. 9'' that the reactivity power coefficient passes by a pure maximum an angle of the blade equal to 0° and a value particular of the speed ratio which one calls λnom (where λnom=8.1), and a reactivity power coefficient corresponding to lambda is Cpmax=0.48.

The aerodynamic torque on the output shaft can be expressed by (9):

$$C_{al} = \frac{P_{eol}}{\Omega_t} = \frac{1}{2}.\rho.S.Cp(\lambda,\beta).V^3.\frac{1}{\Omega_t} \tag{9}$$

Ωt : Rotational speed of the turbine.
C_{al}: Torque on the slow axis (turbine side).

Mechanical speed is related to the rotational speed of the turbine by the coefficient of the multiplier. The torque on the slow axis is connected to the torque on the fast axis (generator side) by the coefficient of the multiplier.

3) *Model multiplier* :The multiplier is characterized by its gain *G*. He adjusts the speed of rotation of the turbine Ω_t the speed of the generator Ω_g:

$$\Omega_g = G * \Omega_t \tag{10}$$

4) *Tree model:* The basic equation of dynamics applied to the shaft of the generator determines the evolution of the mechanical speed Ωm from the total mechanical torque Cm:

$$C_m = J\frac{d\Omega_m}{dt} \tag{11}$$

J : total inertia that appears on the rotor of the generator:

$$J = \left(\frac{J_t}{G^2}\right) + J_g \tag{12}$$

With:
J_g : the inertia of the generator.
J_t : the inertia of the turbine.

The above equations are used to establish the servo block diagram of the turbine speed ''Fig.10".

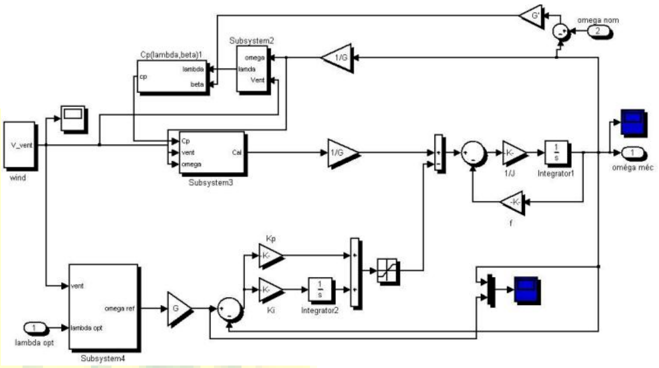


Fig.10 Block diagram of the Maximizing power with servo speed.

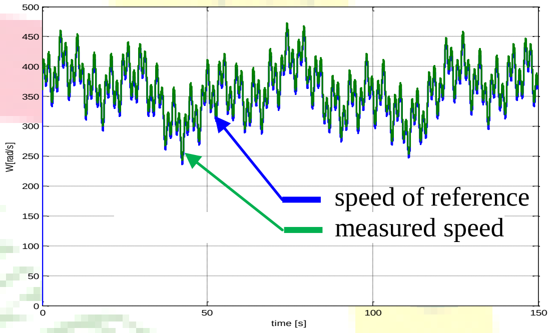


Fig. 11. Rotation and reference speed (rad/s).

Mechanical power that appears on the shaft of the generator (*Pm*) is expressed as the product of the mechanical torque (*Cm*) and the mechanical speed:

$$P_m = C_m * \Omega_m \tag{13}$$

B. Diesel

The generator consists of a diesel engine and a synchronous machine "Fig.12". The diesel engine produces mechanical energy by combustion of fuel. Synchronous generator converts mechanical energy into electrical energy. The frequency is regulated through regulation of the speed of the diesel engine, as the amplitude is controlled via the excitation of the synchronous machine. [15]

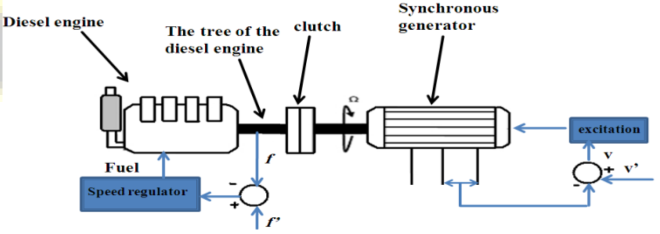


Fig.12 Configuring the diesel generator.

C. Storage system modelling

There are three types of battery models reported in the literature, specifically: experimental, electrochemical and electric circuit-based. Experimental and electrochemical models are not well suited to represent cell dynamics for the purpose of state-of-charge (SOC) estimations of battery packs.

However, electric circuit-based models can be useful to represent electrical characteristics of batteries. The simplest electric model consists of an ideal voltage source in series with an internal resistance.

In this work, a generic battery model suitable for dynamic simulation presented in [2] is considered. This model assumes that the battery is composed of a controlled-voltage source and a series resistance, as shown in figure 13. This generic battery model considers the SOC as the only state variable [3].

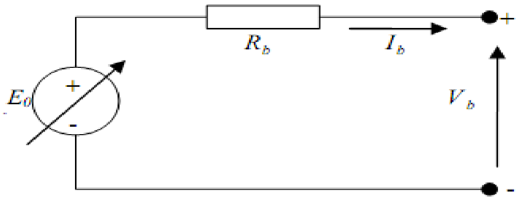


Fig.13 Generic battery model

The controlled voltage source is described by the following expression [2]:

$$E = E_0 - \frac{V_p Q_b}{Q_b - \int i_b dt} + \tilde{A}\exp\left(-B_t \cdot \int i_b dt\right)$$

Where E is the battery constant voltage (V), E_0 is battery constant voltage (V); V_p is the polarization voltage (V), Q_b is the battery capacity (AH), i_b is the battery current (A); Ã is exponential zone amplitude (V), B_t is exponential zone time constant inverse (AH^{-1}).

Where Ī is the algebraic value of the current (in case of positive and negative load for discharge).

Under Matlab/*Simulink* environment, the battery block, used in this study, is of Nickel-Cadmium (NiCd) type. It implements a generic dynamic model parameterized to represent most popular types of rechargeable batteries.

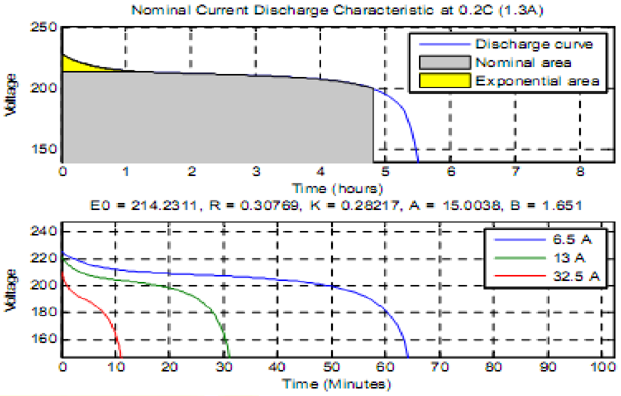


Fig.14 Typical discharge characteristics.

D. Model of the inverter PWM

Figure 15 represents the Simulink model of the sinus triangle PWM control and figure 18 shows the simulation of the inverter switches states S_a, S_b, S_c as well as the output voltages v_{an}, v_{bn}, v_{cn}, when the input are three-phase sinusoidal voltages with a frequency of 50 Hz and an amplitude of 220V.

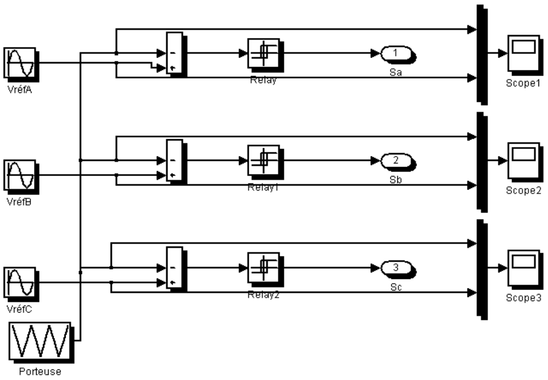


Fig. 15 Model under SIMULINK of the sinus-triangle PWM control

VI. SIMULATION RESULTS

To simulate the hybrid system (wind / diesel), we made the simulation scheme of Figure 6 in the Matlab-*Simulink* software, at **t = 1.2s** time coupling between two sources.
The shape of the current phase of two sources for the coupling is shown in fig.15. It is sinusoidal with an amplitude of ± 4.9

A, with a 20 ms period (50 Hz).

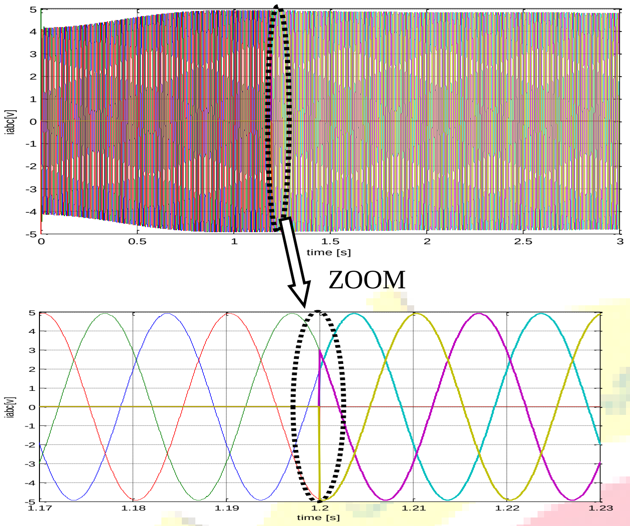


Fig. 16 Simple currents produced by (Wind/Diesel) with regulation of the phases.

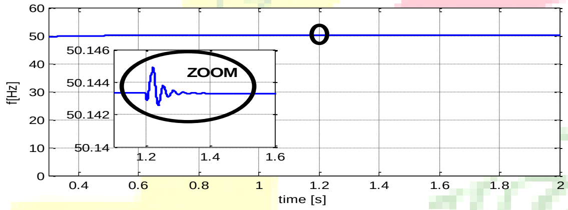
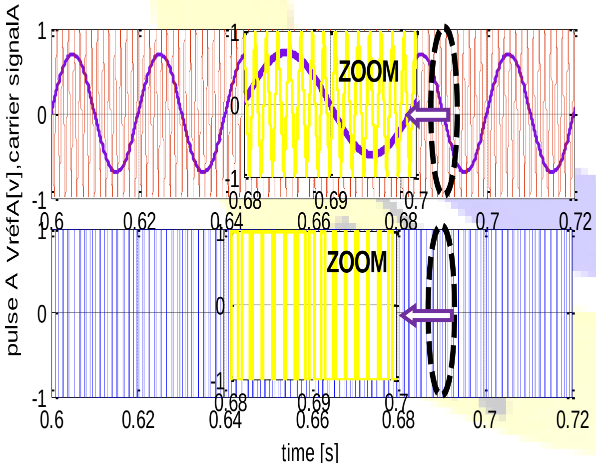


Fig.17 Overview of frequency.



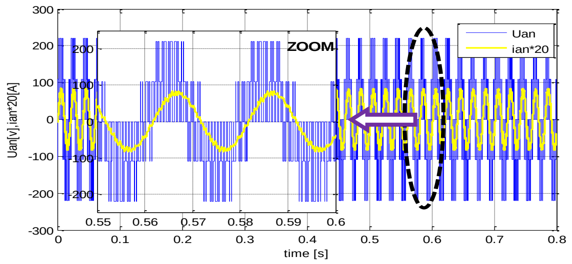
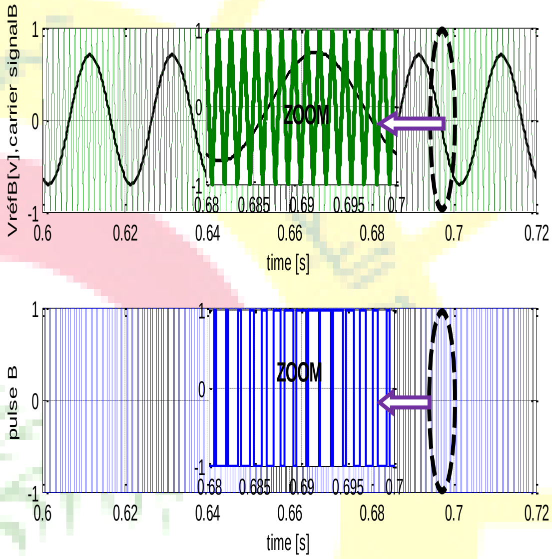


Fig. 18 Voltage and simple current of phase "A" generated by inverter PWM.



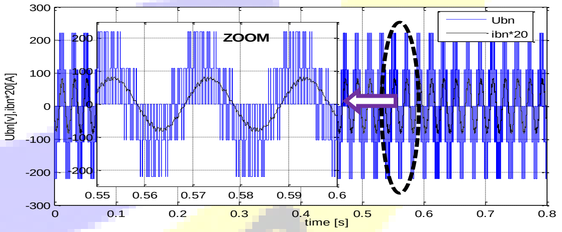


Fig. 19 Voltage and simple current of phase "B" generated by inverter PWM.

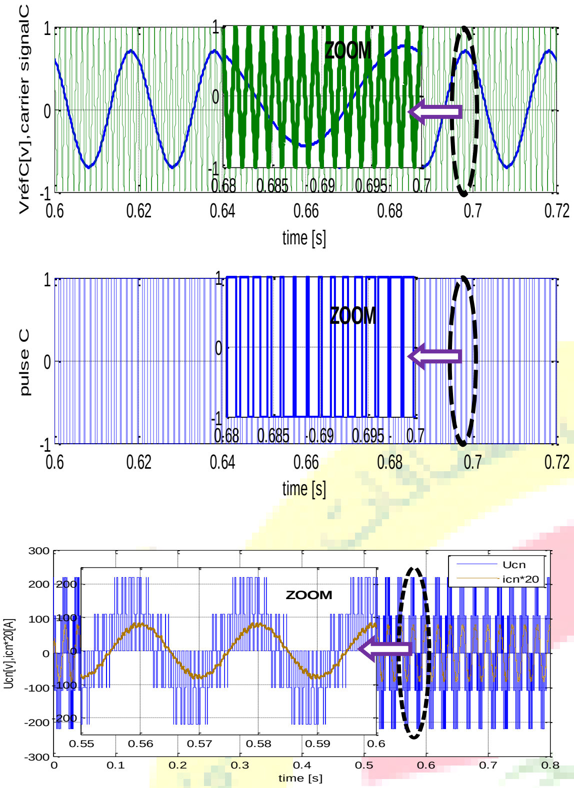


Fig. 20 Voltage and simple current of phase "C" generated by inverter PWM.

VII. CONCLUSIONS

In this article we model a hybrid system in an isolated site. The hybrid system includes a variable speed wind turbine is controlled by the MPPT (Maximum Power Point trancking) command, a diesel generator and battery as an electrochemical storage system. Simulation management system has been applied to Adrar site where meteorological data (wind speed, temperature, relief) are available. According to the results, management has enabled us to obtain a technical and economic gain fuel, longevity of the generator, an assurance of service continuity and removing a portion of greenhouse gas emissions during operation in wind.

VIII. REFERENCES

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