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Analysis and Control of a wind-diesel system twinning powering a local charge

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Abstract— **The production of electricity by means of a Hybrid Power System (HPS) combining several renewable energy sources is of great interest to developing countries, such as Algeria. This country has many areas, isolated and remote networks such as electricity distribution Adrar wilaya, knowing that the province is considered very windy area. All this leads us to think of hybrid systems in this site. We present in this paper a problem of proper management of a hybrid system (HPS)-based renewable energy to power an autonomous region, a wind turbine and a generator is used, this strategy to balance the exploitation of these sources. To adapt the production of renewable source necessary load, we integrate a storage system, such as battery whose purpose and to ensure continuity of service.**

The strategy of the energy sources is managed by a control unit providing the opening and closing of the electronic switches, depending on weather conditions (wind speed, temperature and pressure). It requires essential to adopt a research strategy of the maximum power point MPPT (Maximum Power Point Tracking) for the permanent transfer of energy between production and consumption.

Keywords— **Modeling, Hybrid network, Energy management ,Wind,Group diesel,(Ni-Cd) battery, inverter NPC multi level.**

I. INTRODUCTION

The electric power is an essential factor for the development and the evolution of the human societies that it is in the field of the improvement of the living conditions that on the development of the industrial activities. is-a-vis at the request of electricity, always increasing nowadays, and far from the use of polluting fossil energies like oil and the gas, several countries turned to the new form of energy known as “renewable energies”. Indeed, a true world challenge is taken with serious today, as well on the policy of reduction of the gas emissions for purpose of serre[1], while bringing back them to a tolerable level according to the convention of Kyoto.

The evolution of technologies of the components returns the conversion of these energies increasingly profitable and thus their uses economically become competitive compared to the traditional sources. These energies are exploited in mono source or hybrid and mode autonomous or connected to the network.

The power plant by several sources must meet connection architecture. Similarly, proper management of production sources vis-à-vis the consumer to cover the energy needs of the facility and ensure optimal use of the energy produced. In this context, we propose a study for a judicious choice of the network architecture composed by an autonomous wind diesel generator, a storage battery.

The first section you should:

-Choose the site of implantation of this system.

-Oversee the strategy adopted system.

-Describe the architecture of the hybrid network.

The second section is devoted to the modeling of different sources. And the equations for each generator block are assembled in simulation.

II. PROBLEMS OF THE PRODUCTION OF ELECTRICITY BY A DIESEL GROUP

Energy and economic operation of diesel generators supplying autonomous networks conditions are not optimal and should be improved.

A. Energy

The continued use of diesel consumption causes a considerable pollution caused by fossil fuel "Fig.1", knowing that when because of the lubricating oil viscosity insufficient due to lack of thermal energy released by engine combustion [2].

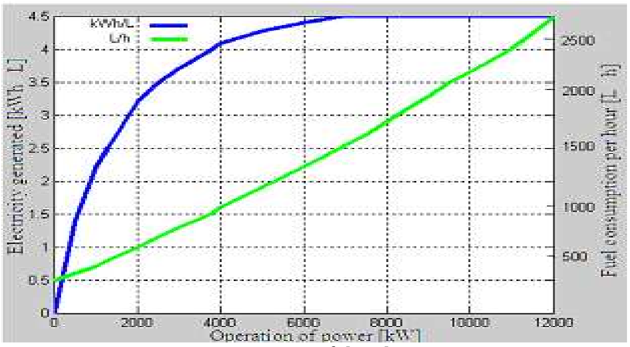


Figure 1. Energy curve of diesel consumption.

B. Economic

Diesel generators are relatively expensive and require a preventive and corrective maintenance. The average cost of kWh produced is high enough with important economic losses.

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".

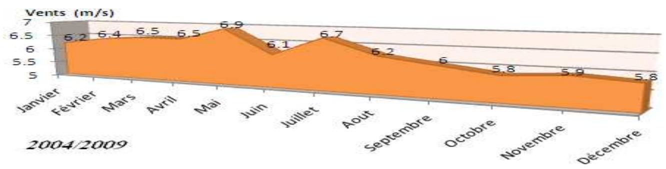


Figure 2. Monthly averages speed of wind of Adrar[3].

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.

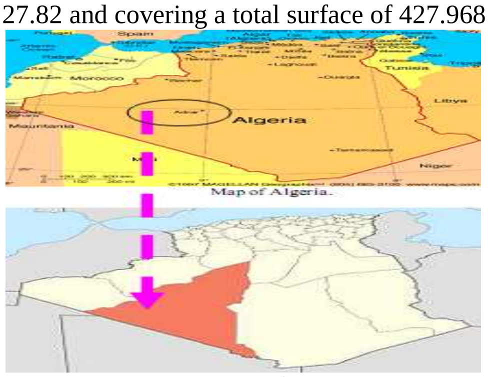


Figure 3. Map geography of wilaya Adrar [4].

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. The extremely difficult Climatic conditions are another parameter to be considered. All this leads us to think of hybrid systems for powering an area in this region .

IV. PRINCIPLE OF OPERATION HES

This system consists of a wind turbine with machine synchronous permanent magnet (GSAP), 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".

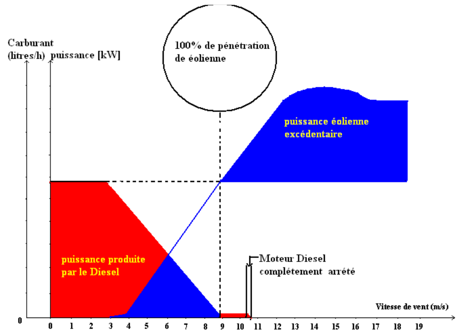


Figure 4. Variation of energy covered by a system Wind -Diesel and diesel consumption as a function of wind speed [5].

The conditions of the startup of the various sources are presented according to the following flow chart:

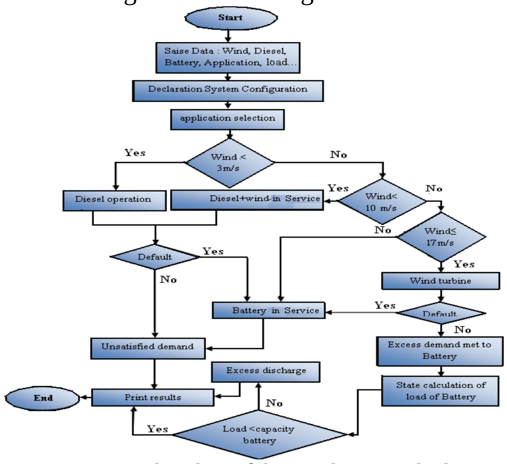


Figure 5. Flowchart of the simulation method.

The diagram of the hybrid global system powering an electric charge is shown in figure 6.

The connection of these elements is carried out at the level of a DC bus. This bus has the advantage of more easily interconnect the different elements of the hybrid system.

From the DC bus is connecting to the network through a DC/AC power converter that fits then the voltage and frequency before transforming it into energy to power alternative that will be passed to the loads.

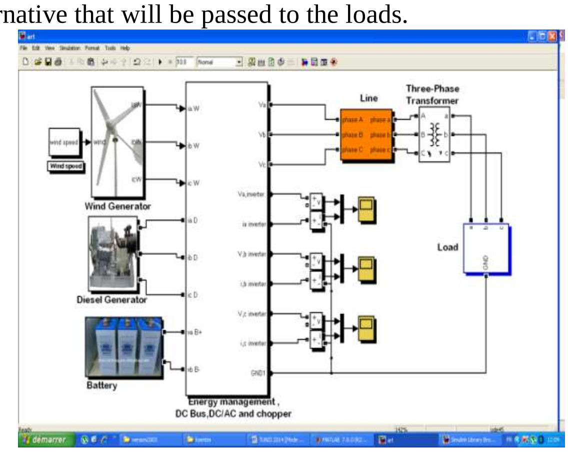


Figure 6. Overall system diagram.

V. MODELING OF SOURCES

A. *Modeling of the turbine of the wind*

Generator wind farm, consisting of a turbine at variable speed coupled with a synchronous generator with permanent magnets through a multiplier.

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 [6]:

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

2) Model of the turbine: Applying the theory of momentum and Bernoulli, we can determine the incident power (theoretical) due to wind [7-8]:

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

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 [9]:

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

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

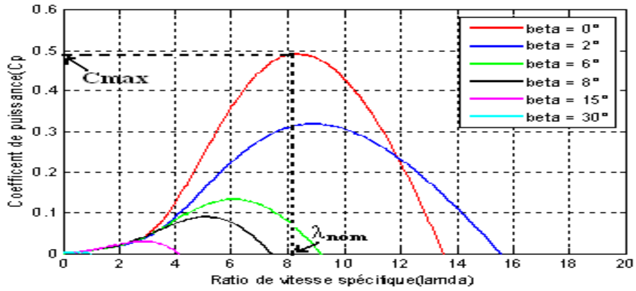


Figure 7. The characteristic of reactivity power coefficient according to λ and β.

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

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

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

3) *Model multiplier :* The multiplier adapts the (slow) speed of the turbine at the speed of the generator. This multiplier may is modeled by the equation:

$$C_{aer} = G * C_g \tag{10}$$

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 C_m:

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

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.8".

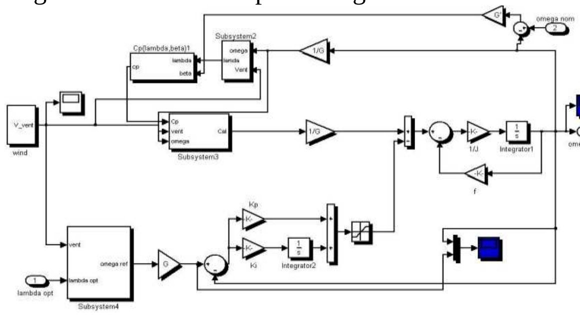


Figure 8. The wind turbine model block diagram

5) Modeling of permanent magnet synchronous machine

Current machines alternating are generally modeled by equations nonlinear (differential equations). The non linearity is due to the inductance and coefficients of the dynamical equations which depend on the rotor position and time. In this article based on simplifying assumptions the model of the MAS becomes relatively simple.

A three-phase transformation - two-phase is necessary to simplify the model.

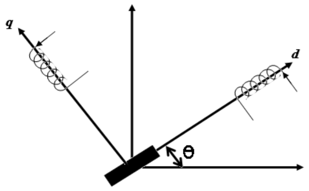


Figure 9. Machine in two-phase model

The three fixed stator windings and rotor with permanent magnets are represented on the figure.10.
After simplifications there :

$$V_d = R_s i_d + L_d \frac{di_d}{dt} - \psi_q . w_r$$
$$V_q = R_s i_q + L_q \frac{di_q}{dt} + \psi_d . w_r \qquad (13)$$

With

$$\psi_d = L_d . i_d + \psi_f$$
$$\psi_q = L_q . i_q \qquad (14)$$

Ψ: flow of permanent magnets.
The relationship (13) becomes

$$V_d = R_s i_d + L_d \frac{di_d}{dt} - L_q . i_q . w_r$$
$$V_q = R_s i_q + L_q \frac{di_q}{dt} + (L_d . i_d + \Phi_f). w_r \qquad (15)$$

The general expression of the electromagnetic torque and after simplification can be found:

$$Cem = P.(\phi_d i_q - \phi_q i_d) \qquad (16)$$

By replacing Φd and Φq with their values is:

$$Cem = P.((L_d - L_q). i_d + \phi_f). i_q \qquad (17)$$

The mechanical equation is written:

$$J \frac{d\Omega}{dt} + f\Omega = C_{em} - C_r \qquad (18)$$

$$\Omega = \frac{w_r}{P} \qquad (19)$$

With angular velocity Wr (electric pulse)

Magnet synchronous machine standing is used in most of the traditional methods of electricity generation. It uses a MSAP to convert the mechanical energy of the wind into electrical energy.

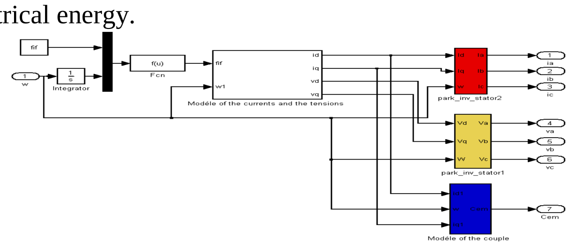


Figure 10. Magnet synchronous machine standing

B. *Diesel*

The generator consists of a diesel engine and a synchronous machine “Fig.11”. 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 [10].

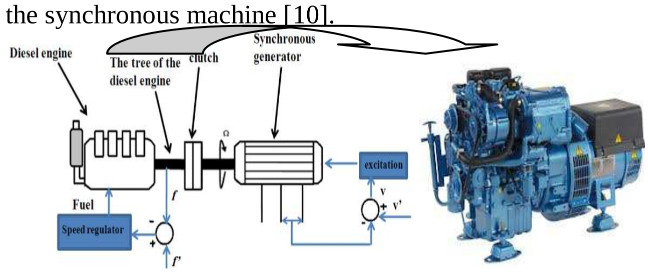


Figure 11. Configuring the diesel generator.

The torque developed by the diesel engine can be modeled in a simple way by a first-order time constant transfer function (τc) representing the constant combustion. Knowing that (τd) represents the delay on ignition there then this equation:

$$C_{diesel} = \frac{F}{1 + \tau_c p} e^{\tau_d p} \qquad (20)$$

Or F is a relative gain of the fuel level.

C. *Storage system modeling*

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 [11] is considered. This model assumes that the battery is composed of a controlled-voltage source and a series resistance, as shown in figure 12. This generic battery model considers the SOC as the only state variable [12].

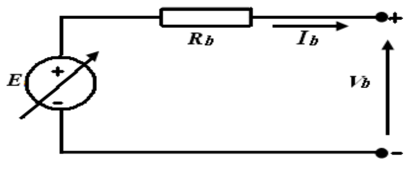


Figure 12. Generic battery model

The controlled voltage source is described by the following expression [11]:

$$E = E_0 - \frac{V_p Q_b}{Q_b - \int i_b dt} + \tilde{A} \exp\left(- B_t \cdot \int i_b dt\right) \quad (21)$$

When 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); $\tilde{A}$ is exponential zone amplitude (V), B_t is exponential zone time Fconstant inverse (AH^{-1}).

Under Matlab/*Simulink* environment, the battery block, used in this study, is of Nickel-Cadmium (Ni-Cd) type“Fig.13”.

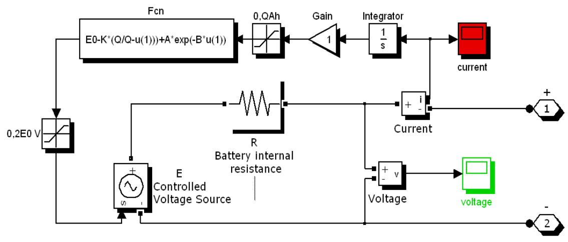


Figure 13. Ni–Cd Battery Simulink schematic.

D. *Model of the inverter PWM*

1. *Structure three levels inverter*

The inverter on three levels is composed of three arms and two sources of Continue tension each arm of the inverter consists of four pairs bidirectional diode-switch and two median diodes make it possible to have level zero of the output voltage of the inverter. The point medium of each arm is connected to a food continues la figure 14 gives a diagrammatic representation of this inverter.

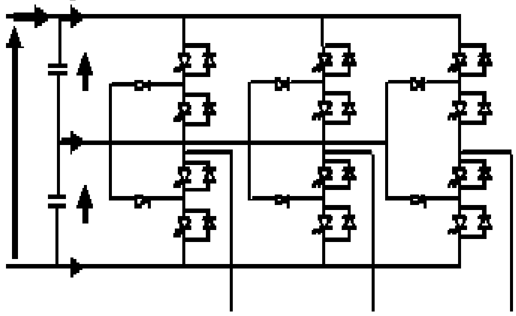


Figure 14. The inverter Structure three levels

2. *Control of static converters*

A converter is said to order mode if the transitions between its different configurations depend on only the external command and no longer the internal commands

a) *Additional order*

To prevent short circuits of the conduction voltage sources and to deliver the three desired voltage levels we must operate in its control mode.

Three additional commands can be applied on an arm of ups at three levels.

$$\begin{cases} G_{k3} = \overline{G_{k1}} ; \\ G_{k4} = \overline{G_{k2}} \end{cases} \quad \begin{cases} G_{k2} = \overline{G_{k1}} \\ G_{k4} = \overline{G_{k3}} \end{cases} ; \quad \begin{cases} G_{k4} = \overline{G_{k1}} \\ G_{k3} = \overline{G_{k2}} \end{cases}$$

With: G_{ks} control switch arm k Tks trigger.

TABLE 1. EXCITATION OF SWITCHES

G_{k1}	G_{k2}	G_{k3}	G_{k4}	V_{ko}
0	0	1	1	V_{c2}
0	1	0	1	unknown
1	0	1	0	0
1	1	0	0	V_{c1}

In order to have full control of the three levels inverter must eliminate the case which gives an unknown response.

By translating this additional order with the connection of the arm k switches functions, can be found:

$$\begin{cases} F_{k1} = 1 - F_{k4} \\ F_{k2} = 1 - F_{k3} \end{cases}$$

We define the function of connection of the semi-arm noted F_{km}^{b} with :

$$m = \begin{cases} 1 \text{ for the half arm top made up of } TD_{k1} and TD_{k2} \\ 0 \text{ for the half arm top made up of } TD_{k3} and TD_{k4} \end{cases}$$

Connection of the semi-arm functions are expressed using functions of the switches as follows:

$$\begin{cases} F_{k1}^{b} = F_{k1} F_{k2} \\ F_{k0}^{b} = F_{k3} F_{k4} \end{cases}$$

VI. RESULTS

To simulate the hybrid system (wind / diesel generator), we made the simulation scheme of Figure 6 in the Matlab-Simulink 7.8 software.

At ;t = 1.2s time coupling between two sources.

A. *Wind turbine*

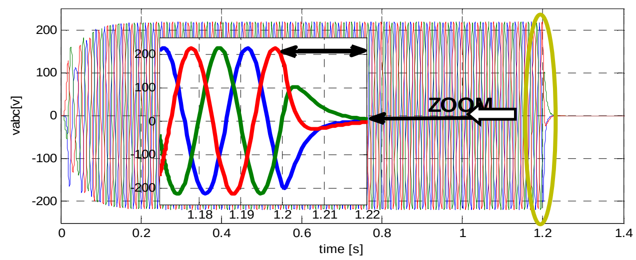


Figure 15. The evolution of the stator voltages.

B. *Diesel group*

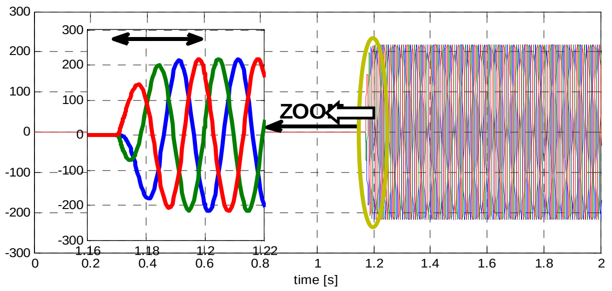


Figure 16. Voltages produced by Diesel Group.

C. *Diesel Group /Wind turbine*

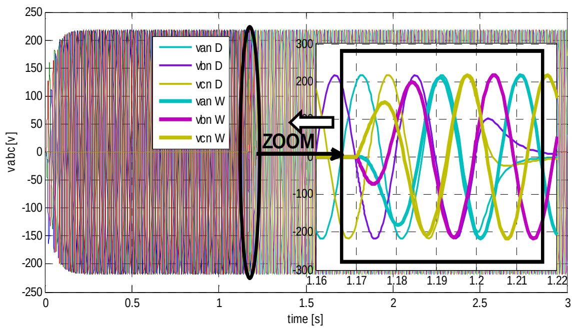


Figure 17. The evolution of the stator voltages.

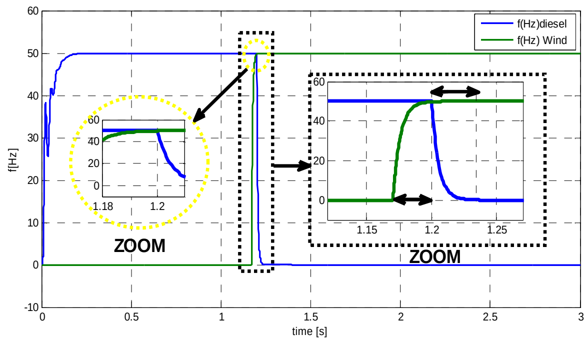
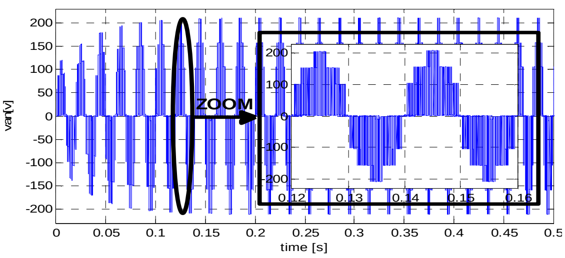


Figure 18. Overview of frequency.



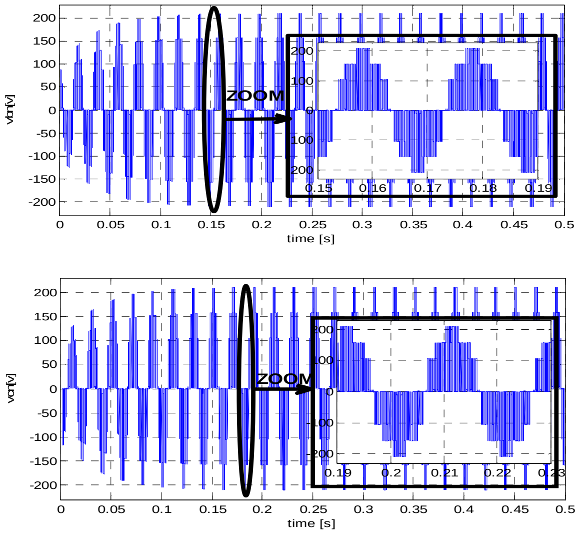


Figure .19 Simple tensions of phases "A,B,C" generated by inverter MLI

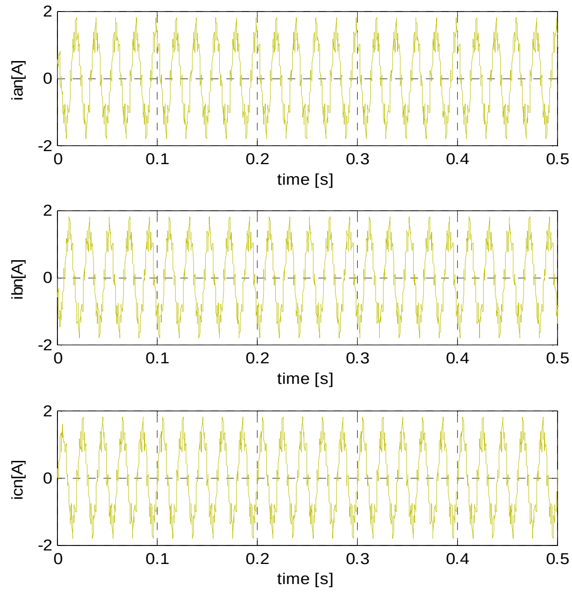


Figure.20 Simple currents generated by inverter MLI

VII. RESULTS

In this article we model a hybrid system in an isolated site.The hybrid system includes a variable speed wind turbine is which 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.

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