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V/F Control for Induction Motor Drive Fed by Photovoltaic Generator

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ABSTRACT: This Article studies the V/f control configuration of a Photovoltaic pumping system. The solar generator delivers a direct continuous voltage, that is been inverted into an alternative one by mean of a PWM implemented strategy on the converter. The V/f strategy is studied into two phases, an open loop control and a closed loop one. The paper highlights the technique of keeping constant the V/f ratio, while the machine's speed is in variation. Thus, insuring to keep constant the maximum torque and the flux of the induction motor.

KEYWORDS: PV Generator, DC/AC converter, induction motor, PWM approach, V/f control.

I.INTRODUCTION

Because of many environmental and economic reasons, there is an increasing interest in the deployment of renewable energy sources. In addition, the power system needs to be expanded [1].
One of the most promising renewable energy sources is the photovoltaic (PV) energy source. The increasing interest in PV-based sources is attributable to their many advantages such as ease of installation, less maintenance, and long lifetime [2].
Also, solar energy is not only an answer to today's energy crisis but is an environmental friendly form of energy. Photovoltaic (PV) generation is an efficient approach for using the solar energy. Solar panels (an array of photovoltaic cells) are now extensively used for running street lights, for powering water heaters and to meet domestic loads. The cost of solar panels has been constantly decreasing which encourages its usage in various sectors. One of the applications of this technology is used in irrigation systems for farming. This is green way for energy production which provides free energy once an initial investment is made [3].
Solar power depends upon the availability and intensity of solar radiation reaching the solar panels and provides power output that is converted to AC power by appropriately rated DC/AC inverters [4].
What we dispose in this article is a Simuation of the whole photovoltaic pumping system. All the parts are represented on Matlab Simulink and the results are recovered at the end.
As for the control approach applied, we have chosen to implement the V/f control method. In fact, there are various methods for the speed control of an Induction Motor [5]. They are: Pole Changing, Variable Supply Frequency Control, Variable Supply Voltage Control , Variable Rotor Resistance Control , V/f Control , Slip Recovery, Vector Control . Of the above mentioned methods, V/f Control is the most popular and has found widespread use in industrial and domestic applications because of its ease-of-implementation.
The main purpose of this work is to develop a model to implement V/f control of an induction motor. The whole system being fed by solar panels. Before that, the step of programming a PWM Inverter that drives the induction motor is necessary. In this sense, PWM signal generation, and Inverter topologies are also presented and simulated.
In this article, we present the design and simulation of a Photovoltaic system, implementing a V/f control technique (scalar control). The approach is adopted permitting an operating with maximum power provided by the PV Generator in any weather conditions. The PV system elements are: the PV generator, the three-phase PWM (Pulse Width Modulation) voltage inverter, and the induction motor coupled to a centrifugal pump. The induction motor based PV pumping systems offers an Alternative for a more reliable free system [6].
In section II, we give the whole model of the Photovoltaic system, presenting in details each part of it. The section III presents the scalar control using V/f constant value, applied in order to carry out speed, torque in addition to stator currents and flux regulation. Both open loop and closed loop schemes are achieved. At the end, we simulate the different configurations in order to show the efficiency of the adopted approach in maintaining constant the maximum

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torque and the flux while keeping constant the ratio V/f. Also, we highlight the improvement brought by closed loop control compared to open loop one, this, in fastening the system's response and the stability state reaching.

II.SYSTEM MODEL AND ASSUMPTIONS

The studied system is composed of three principle blocks: the photovoltaic generator, the DC/AC converter, and the induction machine. For each block, we enhance the general modeling and the different characteristics we dispose in our system. The global model is given in Fig.1.

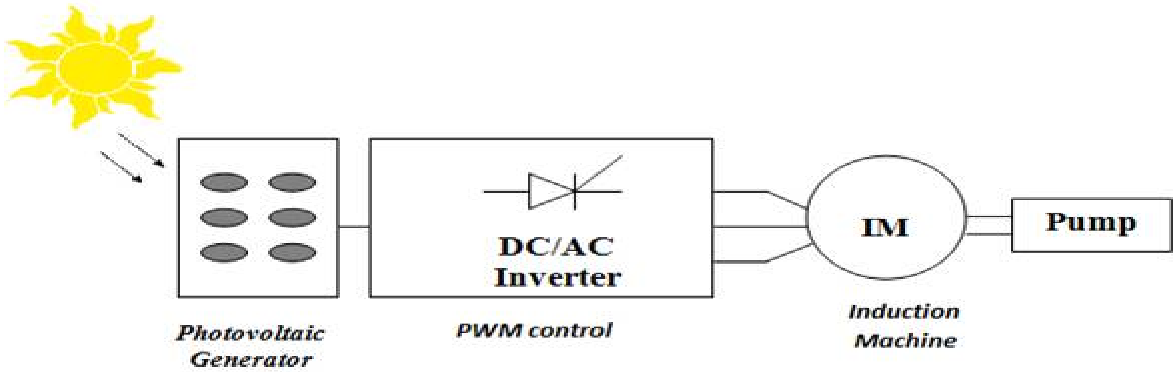

Fig .1 Configuration of the Photovoltaic System.

II.1. PHOTOVOLTAIC GENERATOR MODEL

A Photovoltaic Generator is composed as given in Fig. 2: N_{bp} branches in Parallel. Each branch includes N_{ms} panels in serial. In each panel, there are N_{cs} cells in serial [7].

i_p is the current delivered by one cell and v_p the voltage at its terminal.

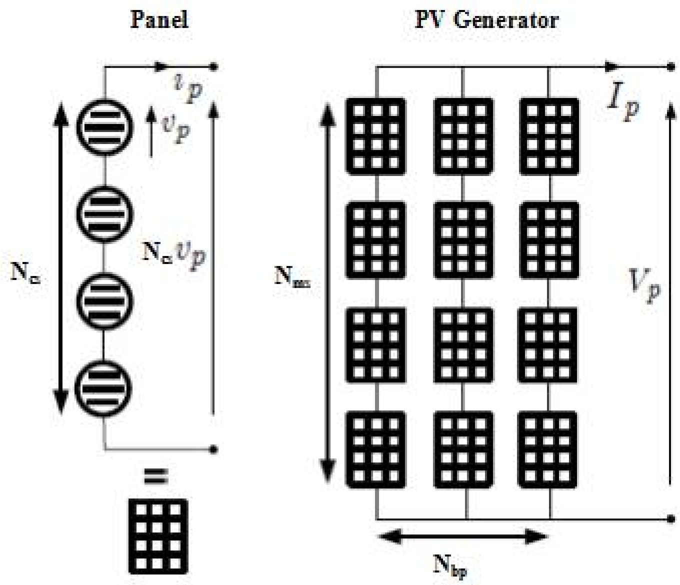

Fig. 2: Assembly of Solar pannels.

In order to compare the generation of a single cell towards a whole photovoltaic generator, we can write:

$$I_p = i_p \times N_{bp} \;; \quad V_p = v_p \times N_{cs} \times N_{ms} \quad (1)$$

Then, the photovoltaic Current I_p in the Photovoltaic Generator is given by:

$$I_p = N_{bp}[I_{ph} - I_s(\exp(\frac{V_p}{V_T}\frac{1}{N_{cs}N_{ms}}) - 1)] \tag{2}$$

Where:

I_{ph} : is the given current under a given illumination.

I_s : is the current of opposite saturation of the diode.

V_p : is the output voltage of a photovoltaic generator.

N_{bp} : is the number of parallel branches in the Photovoltaic Generator.

N_{cs} : is the number of cells in serial.

N_{ms} : is the number of panels in serial.

V_T : is the thermal potential, it is given by:

$$V_T = \frac{nK_BT_j}{q} \tag{3}$$

q : is the charge of an electron $(1,6.10^{-13}C)$.

K_B : is the constant of BOLTZMAN $(J/°K)$.

T_j : is the Temperature of Diode Junction $(°K)$.

n : is the Ideality factor of the solar cell; factor between 1 and 5 in the practice.

The optimal operating point of the PV generator is characterized by an optimal power value that is calculated such that:

$$P_{p\_opt} = I_{p\_opt} \times V_{p\_opt} \tag{4}$$

Where

V_{p_opt} is the optimal output voltage of the generator:

$$V_{p\_opt} = 0.76V_{co} \tag{5}$$

V_{co} is the open circuit voltage.

I_{p_opt} is the optimal current,

$$I_{p\_opt} = 0.9I_{cc} \tag{6}$$

I_{cc} is the short circuit current.

II.2. THREE PHASE PWM INVERTER

An inverter is a circuit that converts DC (Direct current) sources to AC (Alternating current) sources. Inverters are used in a wide range of applications from small switched power supplies for a computer to large electric utility applications to transport bulk power [8].

It is a circuit which converts a DC power input into an AC power output at a desired output voltage and frequency. This conversion is achieved by controlled turn-on and turn-off devices like IGBT's. Ideally, the output voltage of an Inverter should be strictly sinusoidal. However the outputs are usually rich in harmonics and are almost always non-sinusoidal. Square-wave and quasi-square-wave voltages are acceptable. The DC power input to the inverter may be a battery, a fuel cell, solar cell or any other DC source [5].

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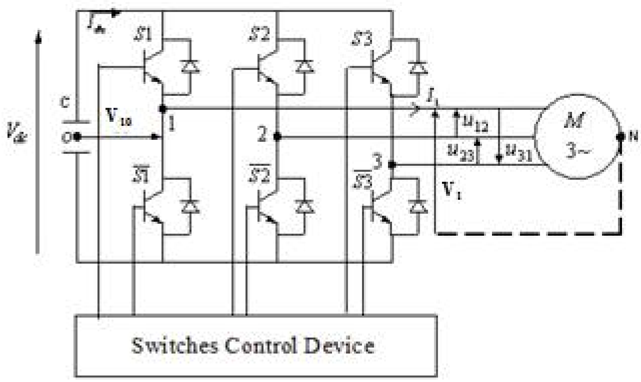

Fig .3 DC-AC Converter Diagram.

As shown in Fig.3, the inverter is powered by a DC voltage source V_{dc}. It is composed of three arms, each arm represents a single-phase bridge circuit.
Every bridge contains two switches, each one realized through a transistor (or a thyristor) in antiparallel with a diode called the return current or feedback diode. The switches of a same arm of the DC-AC converter are complementary in order to avoid causing short-circuit in the power source. This is also the case for the logic signals associated to the control. If we design by Si the control associated to the switch i, we could write the following relation:

$$\overline{S1}=1-S1;\ \overline{S2}=1-S2;\ \overline{S3}=1-S3 \quad (7)$$

In a general way; we note:

- V_1, V_2, V_3 : The simple voltages of the machine.
- U_{12}, U_{23}, U_{31} : The composed voltages of the machine.

We introduce then a fictive point O ; center of the continuous source , in order to establish the necessary equations.

According to the structure given by the figure Fig.3, the voltage on V_{10} equals $\frac{V_{dc}}{2}$ when $S1=1$ and $\overline{S1}=0$; it becomes $(-\frac{V_{dc}}{2})$ when $S1=0$ and $\overline{S1}=1$. The same analysis is valid for V_{20} if we use the controls $S2$ and $\overline{S2}$, and for V_{30}, if we use $S3$ and $\overline{S3}$. The voltages V_{10}, V_{20}, V_{30}, are given by the following relations :

$$\begin{cases} V_{10} = (S1-\overline{S1})\frac{V_{dc}}{2} = (2S1-1)\frac{V_{dc}}{2} \\ V_{20} = (S2-\overline{S2})\frac{V_{dc}}{2} = (2S2-1)\frac{V_{dc}}{2} \\ V_{30} = (S3-\overline{S3})\frac{V_{dc}}{2} = (2S3-1)\frac{V_{dc}}{2} \end{cases} \quad (8)$$

The composed voltages are given by:

$$\begin{cases} U_{12} = V_{10} - V_{20} = (S1-S2)V_{dc} \\ U_{23} = V_{20} - V_{30} = (S2-S3)V_{dc} \\ U_{31} = V_{30} - V_{10} = (S3-S1)V_{dc} \end{cases} \quad (9)$$

The system of simple voltages V_1, V_2, V_3, is balanced ; thus we can write:

$$\begin{cases} V_1 = \dfrac{U_{12} - U_{31}}{3} \\ V_2 = V_1 - U_{12} = \dfrac{-2U_{12} - U_{31}}{3} \\ V_3 = V_1 + U_{31} = \dfrac{U_{12} + 2U_{31}}{3} \end{cases} \quad (10)$$

If we replace U_{12}, U_{23}, U_{31} , in (9) by (10), we get:

$$\begin{cases} V_1 = (2S1 - S2 - S3)\dfrac{V_{dc}}{3} \\ V_2 = (2S2 - S1 - S3)\dfrac{V_{dc}}{3} \\ V_3 = (2S3 - S1 - S2)\dfrac{V_{dc}}{3} \end{cases} \quad (11)$$

The system (11) can be written as a matrix notation by:

$$\begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \frac{V_{dc}}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} S1 \\ S2 \\ S3 \end{bmatrix} \quad (12)$$

We note that the current I_{dc} provided by the supply V_{dc} (Fig. 3) to the DC/AC converter is expressed considering the currents I_1, I_2, I_3 , by:

$$I_{dc} = S_1 I_1 + S_2 I_2 + S_3 I_3 \quad (13)$$

The power delivered by the continuous source is such that:

$$P = V_{dc} I_{dc} \quad (14)$$

The expression (14) shows how the converter transmits fully to the load, the power delivered by the continuous source.

II.3. MODELING OF THE INDUCTION MOTOR

Induction Motors are often termed the “Workhorse of the Industry”. This is because it is one of the most widely used motors in the world. It is used in transportation and industries, and also in household appliances, and laboratories [5]. The major reasons behind the popularity of the Induction Motors are: They are cheap compared to DC and Synchronous Motors , Induction Motors are very rugged in construction. Their robustness enables them to be used in all kinds of environments and for long durations of time. Induction Motors have high efficiency of energy conversion. Also they are very reliable [5].

We give below the induction machine’s equation, in order to integrate them after, in the photovoltaic system’s Simulink model.

A. Electric Equations

The electric equations of the Induction Machine are given by:

$$V_{ds} = R_s I_{ds} + \frac{d}{dt}\varphi_{ds} - \omega_s \varphi_{qs} \quad (15)$$

$$V_{qs} = R_s I_{qs} + \frac{d}{dt}\varphi_{qs} + \omega_s \varphi_{ds} \quad (16)$$

$$V_{dr} = R_r I_{dr} + \frac{d}{dt}\varphi_{dr} - (\omega_s - \omega_r)\varphi_{qr} \quad (17)$$

$$V_{qr} = R_r I_{qr} + \frac{d}{dt}\varphi_{qr} + (\omega_s - \omega_r)\varphi_{dr} \quad (18)$$

$$\varphi_{ds} = L_s I_{ds} + M_{sr} I_{dr} \quad (19)$$

$$\varphi_{qs} = L_s I_{qs} + M_{sr} I_{qr} \quad (20)$$

$$\varphi_{dr} = L_r I_{dr} + M_{sr} I_{ds} \quad (21)$$

$$\varphi_{qr} = L_r I_{qr} + M_{sr} I_{qs} \quad (22)$$

V_{dr}, V_{qr} are the Direct and Inverse components of the rotor voltage.

V_{ds}, V_{qs} are the Direct and Inverse component of the stator voltage.

ϕ_{dr}, ϕ_{qr} are Direct and Inverse components of the rotor flux.

ϕ_{ds}, ϕ_{qs} are Direct and Inverse component of the stator flux.

I_{dr}, I_{qr} are Direct and Inverse components of the rotor current.

I_{ds}, I_{qs} are Direct and Inverse components of the stator

R_s, R_r are Stator and Rotor resistances.

L_s, L_r are Stator and Rotor inductances.

ω_r is the Electric speed of the rotor (rotational speed).

ω_s is the Synchronism speed (Stator pulsation).

B.Mechanical equations

Fundamental dynamic relationship applied to the rotating part of the induction machine, adopting the motor convention is given by:

$$J\frac{d\Omega_r}{dt} + f\Omega_r = C_{em} - C_r \quad (23)$$

Where C_{em} and C_r design respectively the electromagnetic and the resistant torques.

Ω_r is the mechanical speed. We hence have the relation:

$$\omega_r = p\Omega_r \quad (24)$$

Where p is the number of pair poles.

We get then the following equation representing the induction motor:

$$J\frac{d\omega_r}{dt} + f\omega_r = p(C_{em} - C_r) \quad (25)$$

III. CONTROL STRATEGY

The choice adopted for the strategy control of the PV system, was made based on V/f approach. This technique is based on maintaining constant the $\frac{V}{f}$ ratio. Besides, in order to control the DC/AC inverter, a Pulse Width Modulation Strategy is implemented, since it is one of the basic requirements of the V/f approach scheme. Interpretations and simulation results are carried out in the next part of this paper.

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III.1. THE PWM CONTROL

PWM voltage source static frequency inverters presently comprehend the most used equipments to feed low voltage industrial motors in applications that involve speed variation. They work as an interface between the energy source (DC power line) and the induction motor [9].
The simplest way to generate a PWM signal is the intersective method, which requires only a sawtooth or a triangle waveform (easily generated using a simple oscillator) and a comparator.
PWM is often used to control the supply of electrical power to another device such as in speed control of electric motors.

Let's consider f_t and f_s the frequencies of respectively the triangle waveform and the sinusoidal one. If f_t is choosen big comapred to f_s, then the harmonic frequencies are rejected so far and then can be eliminated by filtering.
In the simulation and results part, we present the PWM Generator where the pulses are generated by comparing a triangular carrier waveform to a reference signal. The parameters are also given.

III.2. THE V/f CONTROL STRATEGY

The scalar control is based on the original concept of a frequency inverter: a signal of certain voltage/frequency ratio is imposed onto the motor terminals and this ratio is kept constant throughout a frequency range, in order to keep the magnetizing flux of the motor practically unchanged [9].
Conjointly, there are various advantages for V/f Control, such as [5]:

- It provides good range of speed.
- It gives good running and transient performance.
- It has low starting current requirement.
- It has a wider stable operating region.
- Voltage and frequencies reach rated values at base speed.
- The acceleration can be controlled by controlling the rate of change of supply frequency.
- It is cheap and easy to implement

Elements of the control

The V/f control scheme, for asynchronous machine, is given by the following equation [10]:

$$V_s = F_s w_s \sqrt{1 + (\frac{1}{t_s w_s})^2} \qquad (26)$$

V_s is the effective voltage of the sine wave,

w_s is the stator pulsation,

$t_s = \frac{L_s}{R_s}$ is the stator constant time,

f_s is the stator flux.

If we consider negligible the voltage fall due to the resistance R_s, we have:

$$V_s = f_s w_s \qquad (27)$$

What characterizes a law:

$$\frac{V_s}{f_s} = K, \text{ K constant} \qquad (28)$$

This law will be implemented into the control loop of the Photovoltaic system.
Both open loop and closed loop control schemes are tested for the considered system.

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A. Open Loop V/f Control

In this part, we aim to apply a $\frac{V}{f}$ control strategy by maintaining constant the fraction $\frac{V_s}{f_s}$ (28).

In this method, the stator voltage is kept constant, and the supply frequency is also static (50 Hz), what keeps the V/f ratio constant.

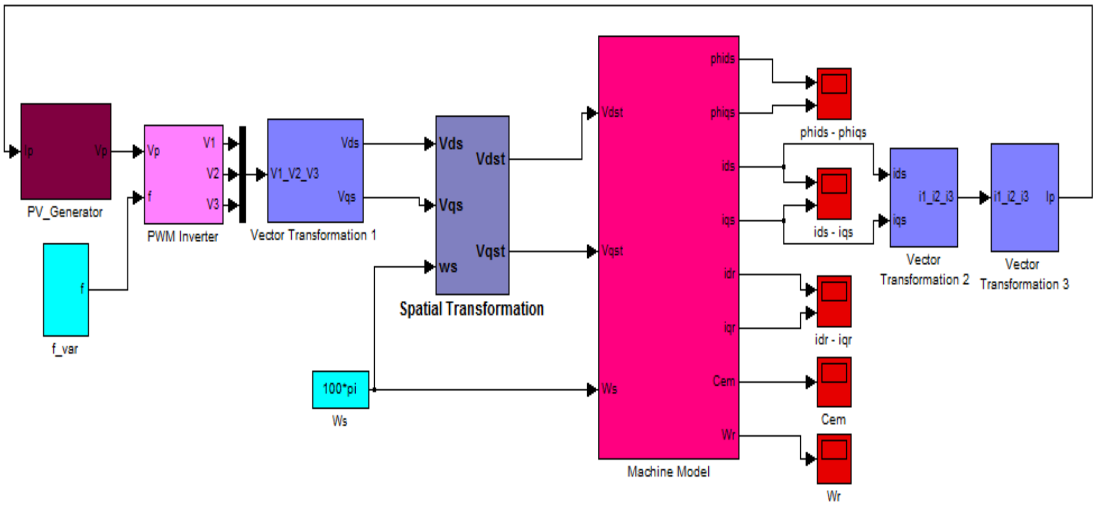

Fig.4 Simulink model of the V/f Open Loop Control, applied to the photovoltaic pumping system.

The Figure Fig. 4 shows the MATLAB code of the different parts of the PV system (PV Generator - PWM inverter-Induction Machine). The simulation and results of this part are shown next in the part IV.

B.Closed Loop V/f Control

As for the closed loop system, the diagram is given by Fig.5.

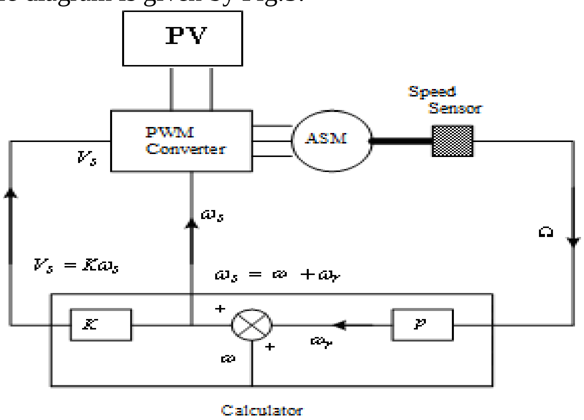

Fig. 5: Diagram of the closed loop V/f Control applied to the photovoltaic pumping system.

The closed loop V/f control applied to the PV system differs from the open loop V/f one. The frequency f_s injected to the PWM inverter, is at this time, deduced from the stator pulsation w_s relative to the induction machine. w_s is in fact generated by a calculator, such that the slip pulsation is equal to $w = \frac{w_s}{10} = \frac{314.15}{10} rad/s$ [10].

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IV. RESULTS AND DISCUSSION

The proposed methods are designed and tested on MATLAB / Simulink software.
In this part, we intend to implement the control approach to the whole system (Photovoltaic Generator – PWM inverter-Induction generator) given in Fig.1. The overall control procedure consists of two stages: one, in generating the adequate signals from the DC/AC converter, that is the PWM technique. In the second stage; we aim to implement the V/f technique, both in open and closed loop schemes. A comparison between the two schemes will be made.
The main result is that, by varying the magnitudes of V and f while keeping the V/f ratio constant, the flux and hence the torque can be kept constant throughout the speed range. Another result, is, the closed loop control makes faster the system's response.
The related specific parameters of the PV array are carried out in the Table Tab.1.

Parameter	***Value***
Number of parallel branches In the Photovoltaic Generator N_{bp}	1
Number of modules in serial N_{ms}	15
Number of cells in serial N_{cs}	36
Short circuit current I_{cc} for one cell	$3.85A$
Open circuit voltage V_{co} for one cell	$21V$
Standard condition of Temperature T	$300°K$
Standard condition of Illumination E	$1000W/m^2$

Tab.1 Main Data for Phtovoltaic Generator.

The optimal operating point characteristics of the available generator, according to equations (4), (5) and (6), are given by: $V_{p\_opt} = 239.4V$; , $I_{p\_opt} = 3.46A$; $P_{p\_opt} = 830watt$.
The related specific parameters of the induction machine are carried out in the Table Tab.2.

Electrical Parameter	***Value***
Stator Resistance R_s	23.7W
Rotor Resistance R_r	16.1W
Stator Cyclical Inductance L_s	$1.5808H$
Rotor Cyclical Inductance L_r	$1.5808H$
Magnetizing Cyclical Inductance $M_{sr} = 1.46H$	$1.46H$
Nominal Power P_n	$0.37Kw$
Moment of Inertia J	$35.e^{-3} Kg.m^2$
Number of pair of poles p	1
Nominal Voltage V_s (Delta)	220V
Nominal Voltage V_s (Star)	380V
Load torque $C_r = K\omega_r^2$	$K = 7.5248e^{-6}$

Tab.2 Main Data For Induction Machine.

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The algorithm integration is the Runge-Kutta (ODE4) one, fixed step equal to 0.0001 s.

IV. 1. PWM CONTROL

In order to feed the PWM inverter, the voltage V_{dc} mentioned in Fig.3, should satisfy the following condition [10] ;

$$V_{dc} \geq \sqrt{2}\mathrm{V_s} \tag{29}$$

Where $\mathrm{V_s}$ is the effective Simple voltage of the induction motor.

V_{dc} is itself the output voltage V_p of the photovoltaic generator (Fig.2). It is equal to: $V_p = 15 \times 21 = 315V$.

For an input DC voltage of $315V$, the circuit produces Three-phase AC voltage output. The load is delta-connected $V_s = 220V$, and then it satisfies (29).

We are interested in simulating the behavior of the PWM inverter. The purpose is to generate three voltages $V_1;V_2;V_3$ (as given in equation (12)), that the fundamentals are with phase shift $\frac{2p}{3}$.

The considered DC-AC converter have the following characteristics for its supply: $f_t = 1050Hz$, $f_s = 50Hz$, $a = 1$ and $V_{dc} = 315\mathrm{V}$.

The modulation depth ratio a is given by:

$$a = \frac{V_{sn}}{V_t} \tag{30}$$

V_{sn} is the effective voltage of the sinusoidal waveform.

V_t is the effective voltage of the triangle waveform.

We illustrate in Fig.6 one of the output voltages of the three phases inverter, V_1.

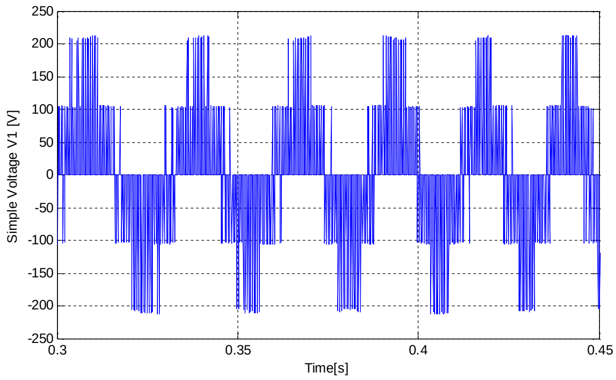

Fig. 6: Simple Voltage (in one phase) at the output of DC-AC converter for a PWM control strategy with $f_t = 1050Hz$, $f_s = 50Hz$ $a = 1$ and $V_{dc} = 315\mathrm{V}$.

IV.2. V/f CONTROL

In this part, the outputs of the three-phase inverter (Fig.6 is for one phase) are connected to the induction machine. We do simulate the V/f control for both open and closed loop schemes.

The PV generator is the one that parameters are given in Tab.1, the induction machine's data is given in Tab.2.

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A. Open Loop V/f Control

We intend to maintain constant the ratio $\frac{V_s}{f_s}$. The adopted diagram is the one given in Fig. 4.

$V_s = 220V$ and $f_s = 50Hz$, thus $\frac{V_s}{f_s} = 4.5$.

The sinusoidal waveform generated to the PWM converter is based on a frequency signal , as given in Fig.7. It is hence a ramp where $f_s = 50Hz$ stabilizes at $t = 0.1s$.

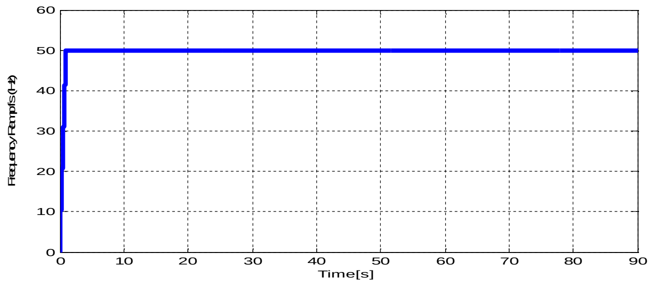

Fig. 7. Frequency Ramp f_s, generated to PWM inverter.

The following figures show us the behavior of the induction motor variables while applying the V/f open loop control.

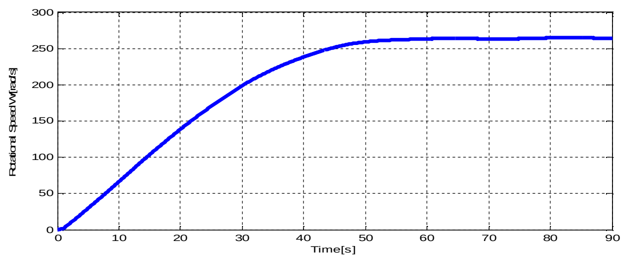

Fig.8 Rotational Speed Wr during V/f Open Loop Control.

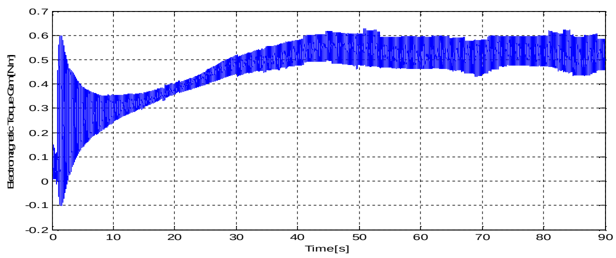

Fig.9 Electromagnetic Torque during V/f Open Loop Control.

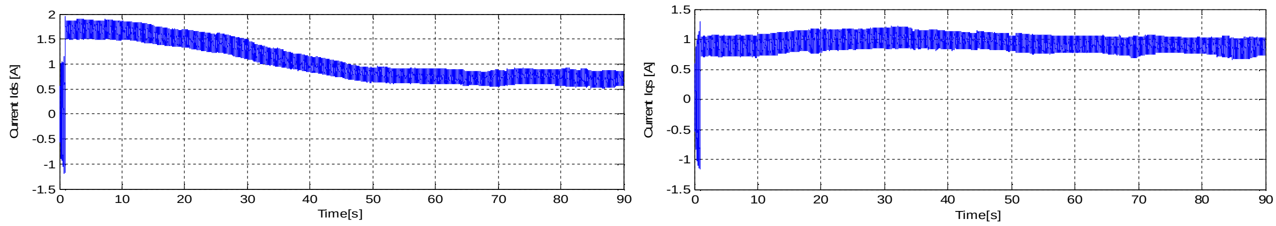

Fig. 10. Stator Currents during V/f Open Loop Control.

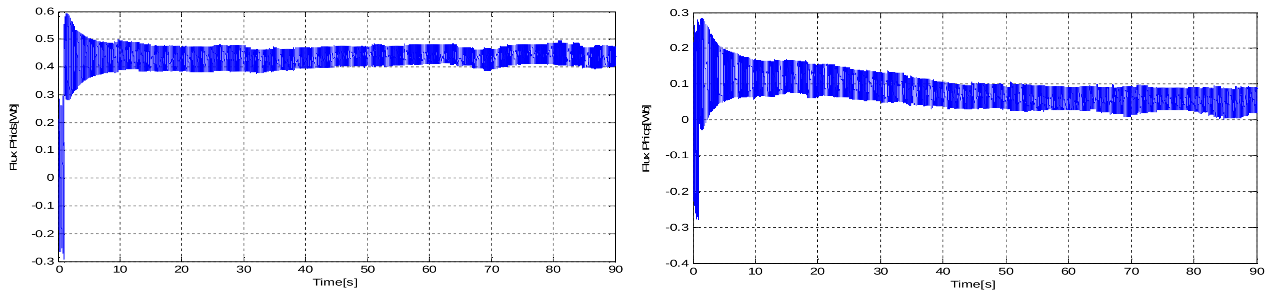

Fig. 11 Stator Flux during V/f Open Loop Control.

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Figures Fig.8-11, show the responses of the Photovoltaic system, while a V/f open loop control, they especially highlight the behavior of the induction machine. It is clear that the rotational speed (Fig.8) attends the stability without any oscillation, it depends on the frequency $f_s = 50Hz$ and this one is maintained constant from $t = 0.1s$. The electromagnetic torque given in Fig. 9, also reaches the stability , altough there are some fluctuations due to the relatively high value stator resistance. As to currents and flux (Fig 10 and 11) , they also attend the steady state as the rotational speed of the motor evolves to reach the final value of $260 rad/s$ at steady state.

B. Closed Loop V/f control

The structure of the closed loop control of the Photovoltaic system is given in Fig. 5.
The different variables of the system's response are depicted in Figures Fig.12-15.

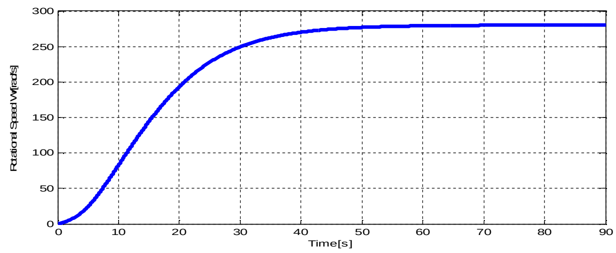

Fig. 12. Rotational speed during V/f Closed Loop Control.

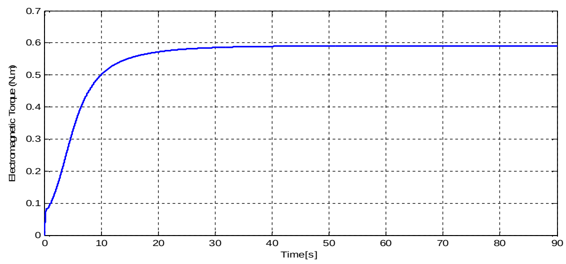

Fig. 13. Electromagnetic torque during V/f Closed Loop Control.

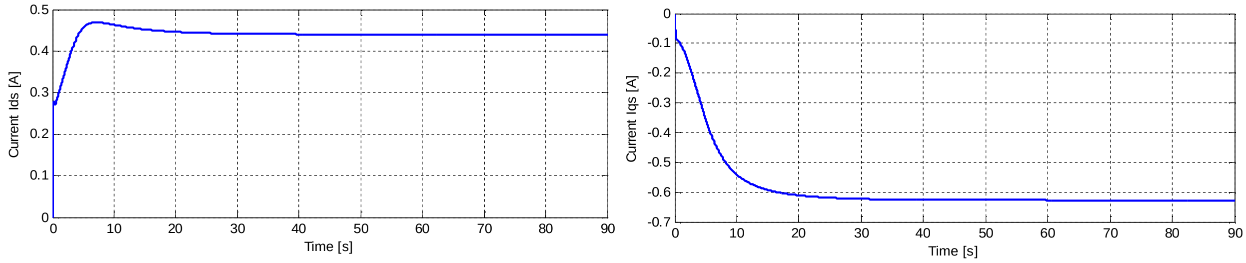

Fig.14 : Stator Currents during the closed loop V/f Control.

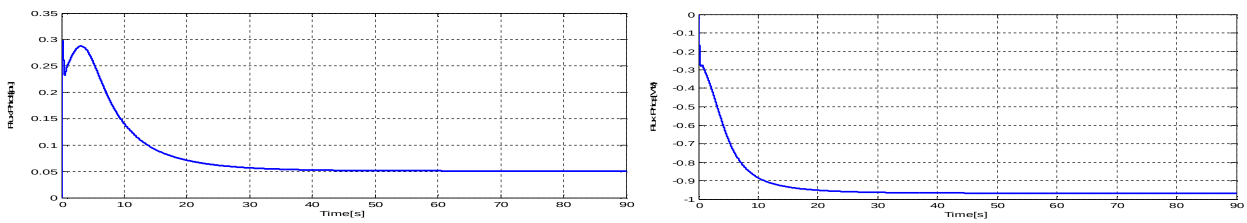

Fig.15 : Stator Flux during the closed loop V/f Control.

One first conclusion we can reach from the curves allures, is that some variables are made to respond faster by the V/f closed loop control. We take for example, the rotational speed of the induction machine. It is shown on Fig.12 that it reaches the value of $w_r = 200 rad/s$ at $t = 20s$, while it takes more time to reach the same value in open loop V/f control ($t = 30s$ in Fig.8).
We observe the same behavior for the electromagnetic torque C_{em}. The value of $C_{em} = 0.5 N.m$ is reached at $t = 40s$ for Open loop control (Fig.9), whereas in closed loop control, $C_{em} = 0.5 N.m$ at $t = 10s$.
Another important remark is, at $t = 30s$, the torque (Fig.13) becomes constant ($C_{em} = 0.59 N.m$) for a changing value of Rotor speed. This, as shown in Fig.5, whenever frequency is varied, the terminal voltage is also varied in order to maintain the V/f ratio constant. Hence Speed control is achieved in the Induction motor.

Finally, as can be observed on Fig.14 and Fig.15 , both the stator currents and flux, exhibit high transients during the starting of the motor. They then settle down to constant values in the steady state.

V. CONCLUSION

We have utilized in this paper a group of solar pannels feeding a pumping device. The DC supply voltage taken from it, is adapted in order to feed a three phase PWM inverter. The PWM signals are generated by comparing triangular waveform with a sinusoidal one.

Besides, a V/f control is implemented on the induction motor. Both open loop and closed loop strategies aimed to keep the V/f ratio constant. Especially in the closed loop scheme, the voltage source Inverter varied the magnitude of the terminal voltage in a way that V/f ratio remains the same. The adopted approach contributed in keeping the maximum torque whereas the rotor speed of the machine is in expansion. The electric variables of the motor present some fluctuations during the motor's boot but tend to stabilize whenever the scalar control is applied.

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