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Centrifugal pump based on asynchronous machine powered by wind system in a small farm

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Abstract – This document present, the use of wind energy with storage using artificial intelligence in isolated sites for different applications, such as water pumping, is of primary interest to the population of developing countries who do not have safe access to drinking water. The objective of this dissertation is to calculate the parameters of a centrifugal pump according to the number of a small village to satisfy the need for water. Therefore, we use vector control associated with a submerged asynchronous motor pump set. The configuration of this system includes a wind turbine, an MSAP, a rectifier, a bus and a voltage inverter supplying an asynchronous machine coupled to a centrifugal pump. Moreover, an MPPT block which ensures operation at maximum power of the wind system.

Keywords- Asynchronous Machine, MPPT Control, Wind Energy, Energy Storage, Agriculture Irrigation.

I. INTRODUCTION

Wind pumping with storage system is one of the applications of renewable energy in isolated sites. This technology is in development and characterized by a gradually decreasing cost. The first generation of wind pumping systems uses permanent magnet DC motors, especially for low and medium height applications. In recent years, the asynchronous motor is increasingly used for solar pumping applications because of its simplicity, robustness and low price. The pumping chain studied in our case, equipped with an MPPT control, uses an asynchronous motor, driving a centrifugal pump, which is equipped with a speed control system in order to have the possibility of adjusting the flow rate water [1,2, 3].

This work will have focused on the sizing of the overall system and the representation of the simulation results of the system studied with the application of intelligent control to the pump set.

Validation of the pump model

We used an asynchronous machine powered by a three-phases two-level inverter controlled by PWM strategy, This machine is controlled by a PI regulator in a field oriented control and FLC controller [4-5].

Model of an asynchronous machine and its control

Content the two-phase stator and rotor voltages in the d-q are writing as follows:

$$V_{dqs} = \left(R_S i_{dqs} - \omega_s \Phi_{qds} + \frac{d}{dt}\Phi_{dqs}\right) \quad (1)$$

$$V_{dqr} = 0 = \left(R_S i_{dqr} - \omega_s \Phi_{qdr} + \frac{d}{dt}\Phi_{dqr}\right) \quad (2)$$

The electromagnetic torque developed by the machine is express according to rotor flow and of the stator current by:

$$C_{em} = p * M\left(I_{dr}I_{qs} - I_{qr}I_{ds}\right) \quad (3)$$

However, the electromagnetic torque formula is complex, it does not resemble that of a direct current machine where the natural decoupling between the adjustment of the flux and that of the torque makes it easy to control. We are faced with an additional difficulty in controlling this torque, so vector control comes to solve this problem of decoupling the flow adjustments inside the machine from that of the torque. Therefore, we approach indirect vector control by orientation of the rotor flux [1].

In order to maintain the decoupling characteristics of an asynchronous motor, given by the following equations thus [6,7, 8] : $\varphi_{qr} = \varphi_r$, $\varphi_{qr} = 0$

The mechanical load is a centrifugal pump; its resistive torque imposed applies a load torque proportional to the

Speed-square of the motor:

$$C_r = K.\Omega^2 \quad (4)$$

With: K Constant, which depends on pump nominal data.

We can add an external loop to control the speed, to increase the speed, a positive torque must be imposed, to decrease it, a negative torque is necessary. It then appears that the output of the speed regulator must be the torque reference. This reference torque must be impose by the application of currents; this is the role of current regulators.

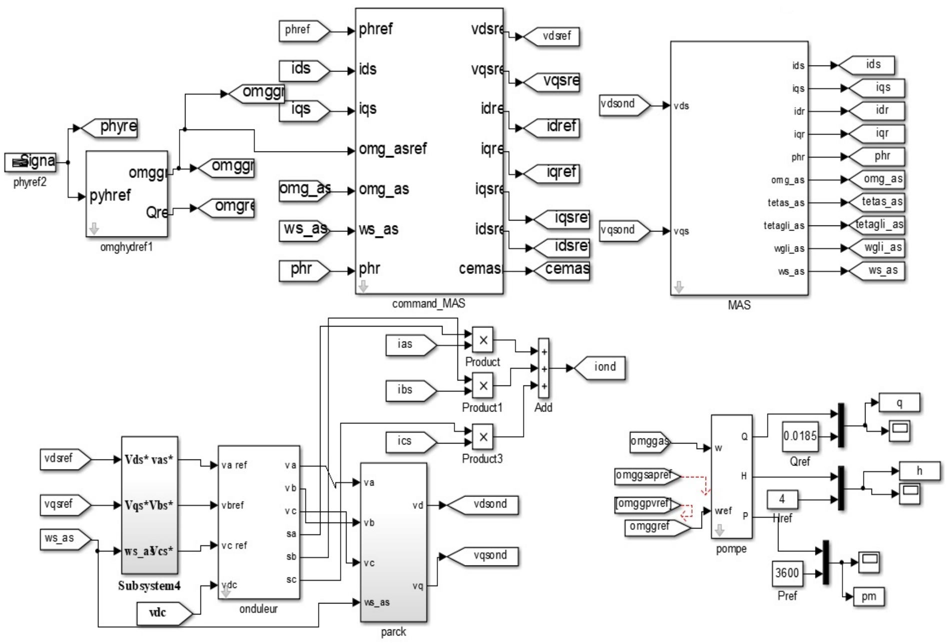

Figure 1. The block diagram of a field-oriented control of a field- oriented asynchronous machine coupled to a centrifugal pump, powered by wind turbine through an inverter

Pump system modelization

Pump system must be chosen according to the actual characteristics of the installation in which it is to be installed. The following data will be necessary to size the pump: water flow (Q) and total head (HMT).

Table 1. Daily water needs of the pumping installation.

Watering			
Type of a farm	Area (hectare) 5	m^3/days/hectare 50	overall 180m^3/day
Water inhabitants			
N_P 7	N_F 8	Q_P Litters/person 50 liters/day/person	overall 2.8m^3/day
Water animals			10m^3/day
overall			192.8m^3/day

Table 2. HMT

Geometric height at suction	Geometric height at discharge	Pipe losses	HMT
H_{ga}	H_{gr}	PC%	$(H_{ga}+H_{gr})(1+PC)$
7	7	10	15.4

We measure the consumed power. All data quite simply measured, the water flow rate measured by flow meter, the consumed power was measured by wattmeter and the pressure measured by pressure meter. Then, we calculate the hydraulic power. It is given by the relation

$$P_H = \Lambda . Q . HMT \quad \text{with:} \quad \Lambda = \rho . g \qquad (5)$$

$$\rho = 1000 kg/m^3, g = 9.81\ m/s^2$$

$$P_{méc} = \frac{P_H}{\eta} = 4\ KW\ ,\ Q=0{,}185\ m^3/s \qquad (6)$$

$$\frac{Q}{Q_{ref}} = \frac{\Omega}{\Omega_{ref}}\ ,\ \frac{H}{H_{ref}} = \left(\frac{\Omega}{\Omega_{ref}}\right)^2,\qquad \frac{P}{P_{ref}} = \left(\frac{\Omega}{\Omega_{ref}}\right)^3 \qquad (7)$$

II. RESULTS

System responses using the PI _FLOU controller obtained by simulation are presented in the following figures.

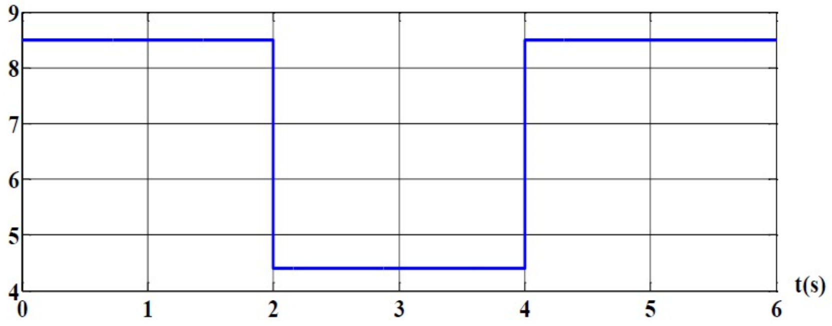

Figure 2. Wind speed (m/s).

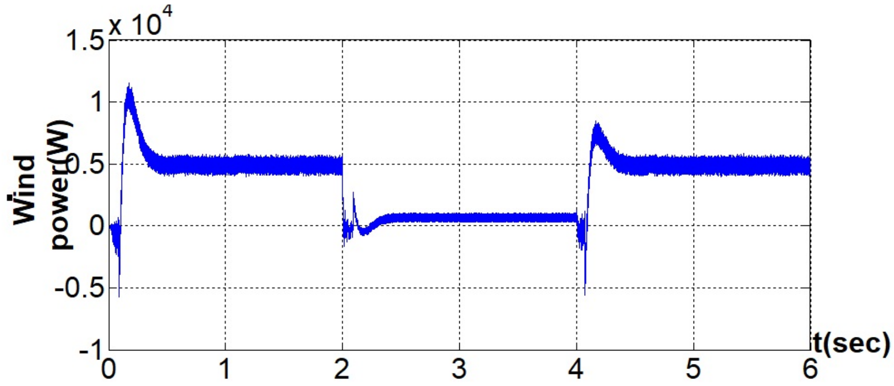

Figure 3. Wind power.

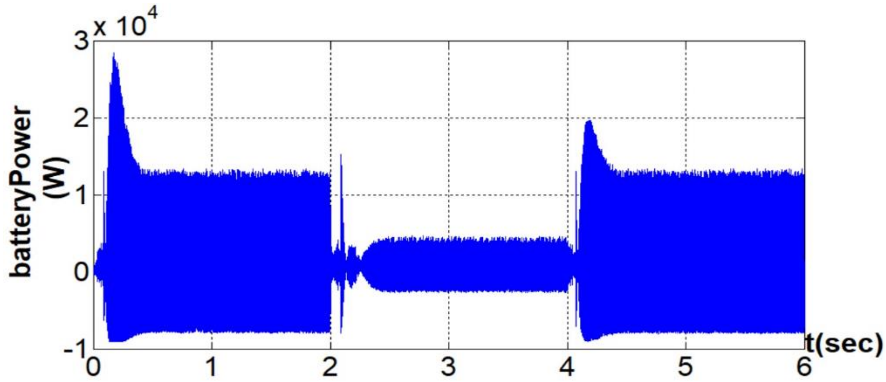

Figure 4. Battery power.

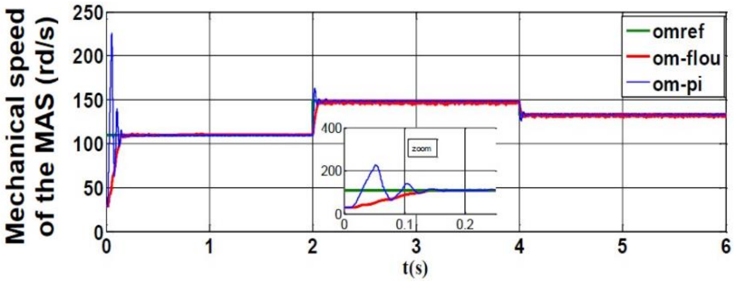

Figure 5. Mechanical speed.

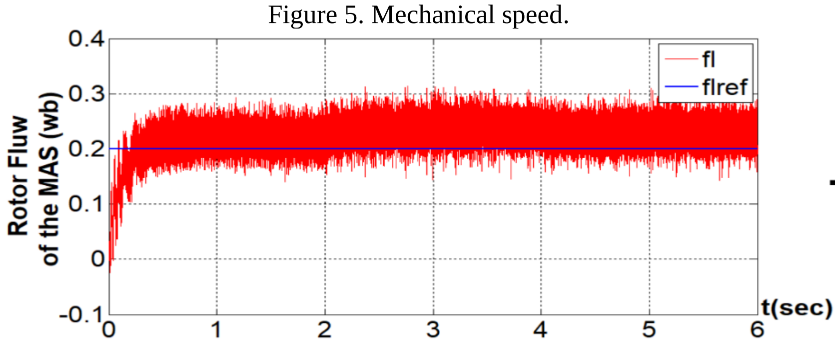

Figure 6. Rotor flow of the MAS.

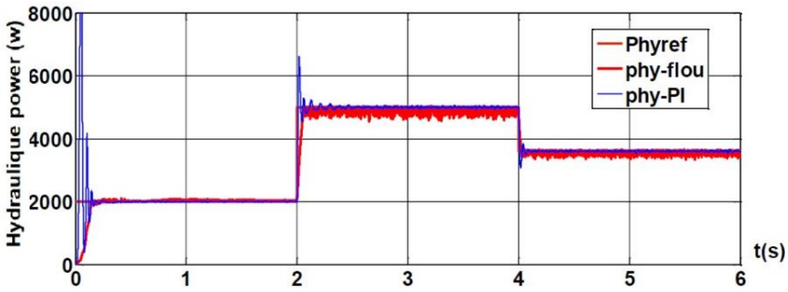

Figure 7. Hydraulic power.

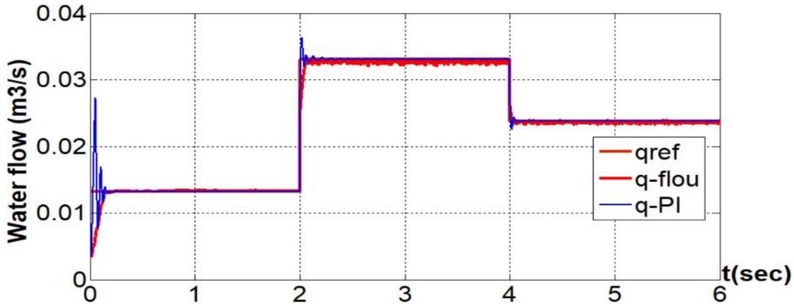

Figure 8. Water flow.

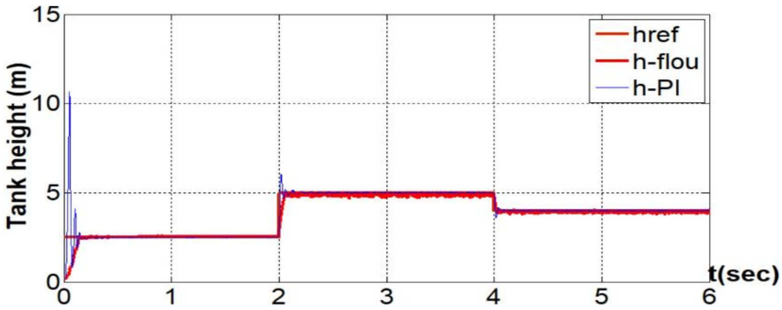

Figure 9. Tank height (m).

III. RESULTS AND DISCUSSION

The simulation results illustrated by the figures above concern the motor pump unit, we chosed variable wind speed as shown “Figure 2” if wind speed at the instant lower than t=2s, the wind is superior, the power produced by the wind generator powers the pump, at time t between 2s and 4s the available wind energy is insufficient so the batteries provide energy to the pump, and at the moment greater than 6s, the wind is superior, the power produced by the wind generator powers the pump. The hydraulic power tends to follow the wind power so that the battery power is equal to the optimal as “Figure 7”. The mechanical speed of the asynchronous machine is the same shape wind speed and follows its reference, the rotor electromagnetic torque, hydraulic power, the currents, water flow and tank height follow their desired references, this signifying the robustness of the PI-Fuzzy controller “Figure 6-9”. Also, note that the fuzzy controller is faster than the PI one because the response time is better.

IV. CONCLUSION

In this article, we have dimensioned the wind pumping system and studied a control structure using both the concept of the oriented flow method for the asynchronous machine and MPPT operation for the power adapter. The vector control strategy by rotor flow orientation served here as a solution to control the flow rate and the total head of the pumping station.

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