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A studying by Bond graph of a chain pumping coupled to multi-sources

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***Abstract*— in this article, we're presenting a studying by Bond graph of a chain pumping coupled to multi-source. We're interested in two sum renewable sources; (photovoltaic source and wind source). The first part is dedicated to Bond graph modeling of various components of the pumping system. The second part presents the results of simulation, the induction machine coupled in each case: the PV generator and wind generator. We studied the complementarity of two generators (photovoltaic, wind). We're presenting the benefits of this application. All simulation results are discussed. With a party dedicated to the study of vector control with the direction of the rotor flux of induction pump.**

***Keywords*—Photovoltaic; Bond graph modelling; the wind generator; Vector control; hybrid system;**

I. Introduction

Electricity today is the easiest form of energy to operate, the production of this energy comes mainly from the processing of fossil fuels (oil, gas) or fissile (nuclear). These resources conduct a massive release of pollutants.

In the context of sustainable development and production of environmentally friendly, renewable energies are the solutions. Renewable energy is energy from the sun, wind, geothermal, waterfalls, tidal and biomass, and their operation does not generate waste and emissions: these are the energies of future.

In our country, one of the promising applications of this type of energy is the water pump, the search for solutions to the energy management applicable to the pump, it seems interesting to know a technique based on pumping two renewable energy sources (solar and wind) and know the benefits of complementarity of these two sources of this technique. The extent of the use of hybrid energy leads us to consider a system of wind-photovoltaic; water pumping consists of a coupled to an asynchronous motor hybrid permanent magnet generator which causes a centrifugal pump.

This article aims to study and simulate the pumping system hybrid (wind-PV).

To achieve this goal, we have developed in the first place, the necessary models to describe the operation of an asynchronous photovoltaic generator and turbine engine.

Second, we validated the system components in an open loop simulation. Then, we will discuss an application of hybrid power in a remote site system (water pump). This brings us to step, since it is clear that the open-loop operation does not give good performance, adopt the theory of vector control for controlling the induction motor fed by a three-phase inverter. Finally, confirm the validity of the pumping system with closed-loop simulations.

II. Bond graph modeling the PV generator

Generator applications are numerous, especially in remote locations (mountain huts, small telecommunication relays, measuring stations, road signs ...) or mobile homes (boats, caravans ...).

To introduce the association of electrical machinery to the PV generator, we treat first step an equivalent circuit of a standard PV source coupled to a load RL Figure 1. We model the diode by a non-linear resistor whose current-voltage relationship is designated by a nonlinear function $\psi_{RD.}$

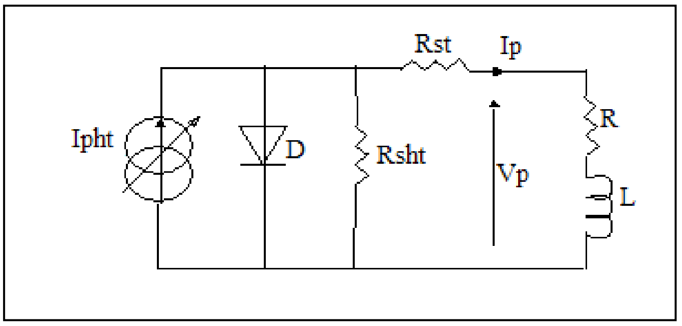

Fig.1. Equivalent circuit of a PV generator Coupled to a load R-L.

We are moving to phase simplification of the model is to neglect the effect of resistance Rsht and Rst (which is also justified the orders of magnitudes of resistance). Figures 2 and 3 represent the equivalent circuit reduces a PV source with cranking model and BG. [1]

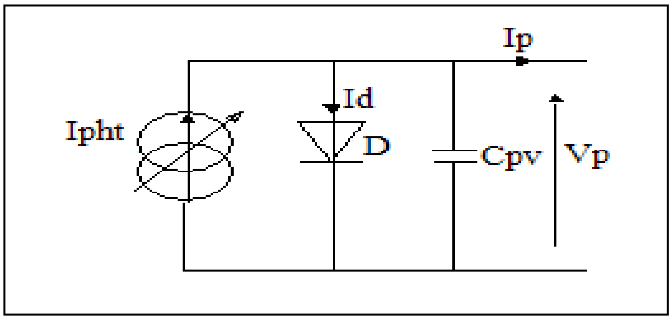

Fig.2. Electrical diagram with GPV start ability.

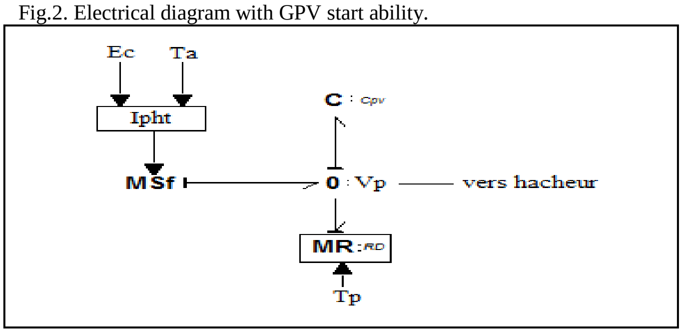

Fig.3. Bond graph model reduced by a PV generator.

III. BOND GRAPH MODEL OF THE WIND GENERATOR

A. *Modelling of wind speed*

Wind speed is the input system wind energy conversion. This is an important variable in modeling and simulation accuracy depends on the quality of the model.

The variation of the wind velocity is random, which leads to fluctuating characteristics. Thus, in order to reproduce these characteristics, those are two options that are experimental measurements and analytical modeling. The first is to carry out experimental measurements on a wind farm well defined.

This first solution is considerably more precise than the second, but only, it doesn't allow simulating different types of profiles of wind speed. This means that the profile of the wind speed obtained will be specific to a given site and can't be changed if you want to get a different operation, don't match the profile of the site in question.

B. *bond graph modeling of the wind turbine [2] [3]*

Figures 4 and 5 represent the equivalent circuit corresponds to the turbine model and Bond graph.

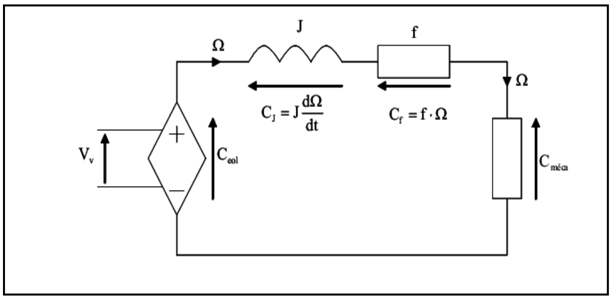

Fig.4. Diagram of the equivalent wind turbine.

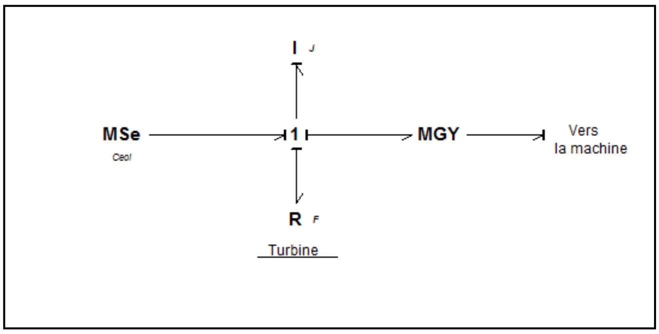

Fig.5. Bond graph model of the wind turbine.

C. *Modeling permanent magnet synchronous generator (GSAP)*

Systems are well adapted to the specific needs of this area. Small wind machines use small sizes. They represent a good solution for our pumping system. Most small wind turbines use permanent magnet generator and operates at variable speed. After mathematical modeling, we will model BG permanent magnet synchronous generator following Figure 6:

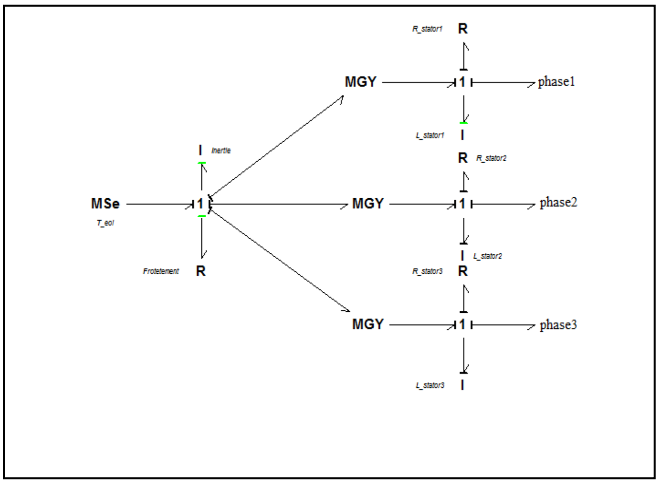

Fig.6. BG model of permanent magnet synchronous generator.

D. *Bond graph model of the wind generator*

To model all the elements that make up a wind generator, it will be a global model of a wind turbine shown in figure 7:

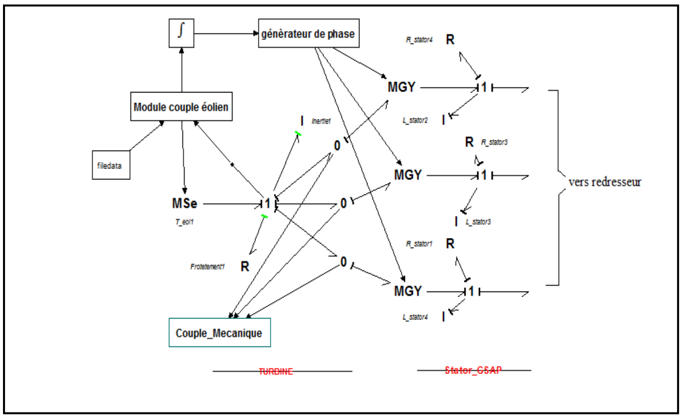

Fig.7. Bond graph model of a wind turbine.

IV. Vector Control

Vector control was introduced long ago [4]. However, the advent of microprocessors and their computational power has to apply vector control. Indeed, it requires calculations transformed Park, evaluation of trigonometric functions, integration, regulations ... which could not be done in analog. Control of induction machines requires control of torque, speed or even position.
Different structures of vector control of induction machines have been several publications [5] [6] [7] [8]
Figure 8, shows the structure of a direct control vector direction of flow of asynchronous motor pump with a flow sensor that was the object of our research [9] and [1].

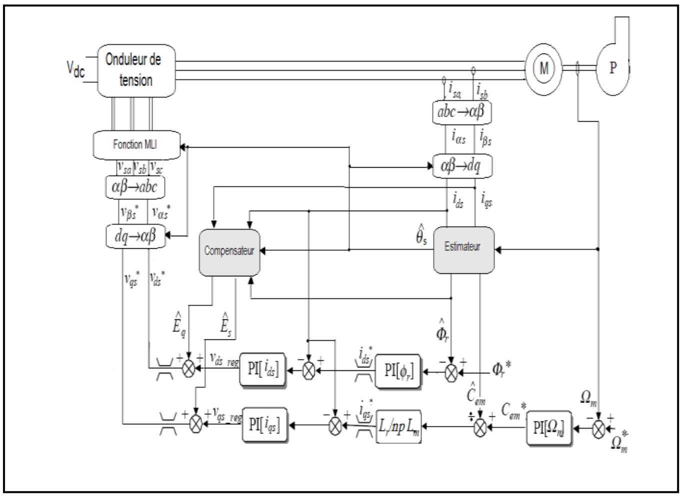

Fig.8. Diagram of vector control.

V. Application of the Hybrid System: Wind-PV

The hybrid system that is proposed in this article consists of two energy sources, solar and wind power for isolated system (water pumping system). This study focuses on the modeling and simulation of the coupling of the two channels in parallel.

A. *System description*

The general scheme of the direct coupling of a wind-photovoltaic pumping can be represented by the figure 9.
It consists mainly of:
- A hybrid generator (wind-PV), which powers the motor.
- A pump that contains two parts:
  - An electric motor is deposited above the water, alternating current.
  - A hydraulic pump generally centrifuged.

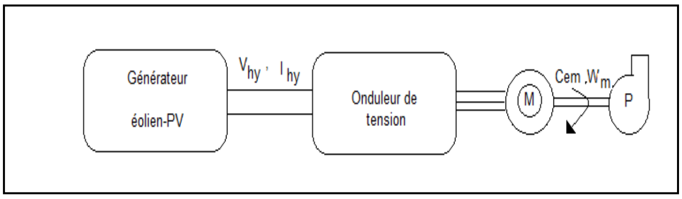

Fig.9. Hybrid system pumping water.

B. *Energy conversion system hybrid*

Once all the basic models validated, we performed the coupling of two chains, as shown in Figure 10. Dimensional aspects were empirical other points to be studied in this coupling:

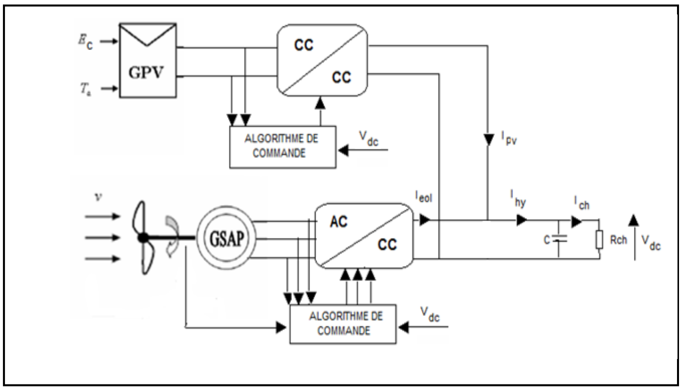

Fig.10. Diagram of the hybrid system.

The coupling of the two systems is done via a DC bus, as shown in figure 10.
It is necessary to have a mathematical model of this circuit. In Figure 11, is presented in detail the dc bus and you can see it is represented by the capacitor C connected to both systems.

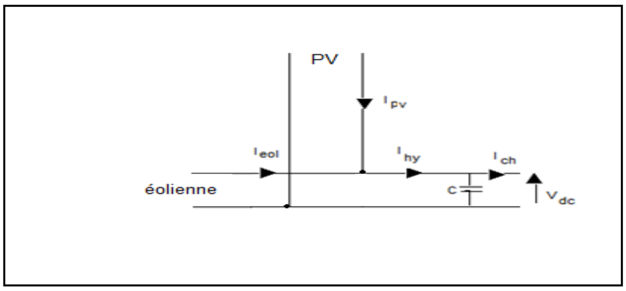

Fig.11. Model the DC bus.

From Figure 11, can be written in the following

Equation: $I_{hy} = I_{eol} + I_{pv} = I_c + I_{ch}$ (1)

With: $\begin{cases} I_c = c\dfrac{dV_{dc}}{dt} \\ I_{ch} = \dfrac{V_{dc}}{R_{ch}} \end{cases}$

Looking for a control algorithm the most efficient and easiest for our application, we are interested in the same order used for the chopper for the controlled rectifier (The principle of hysteresis current control).

The control algorithm used to control the voltage across the two systems is based on two control loops Figure 12 cascade: a current control by hysteresis and a hybrid control loop of voltage V_{dc}.

The transfer function is:

$$F(s) = \frac{V_{dc}^2(s)}{I_{hy}(s)} = \frac{V_{dc}}{C.s + \frac{1}{R_{dc}}} \quad R_{dc} \gg \Rightarrow F(s) = \frac{V_{dc}}{C.s} \qquad (2)$$

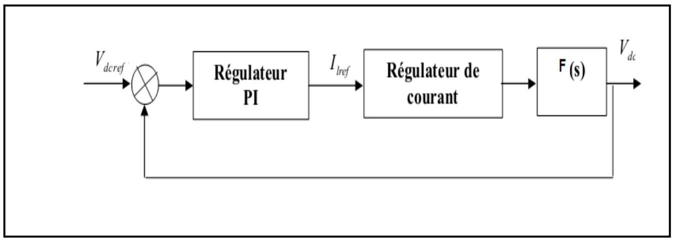

Fig.12. Regulating the bus voltage.

C. *Power system at a time by a wind turbine and a photovoltaic generator:*

The general schema of the direct coupling of a wind-photovoltaic pumping is represented in Figure 13.

This system consists of:

- A hybrid generator (wind-PV), which powers the motor.
- A pump that contains two parts:
  - An asynchronous motor.
  - A centrifugal pump.

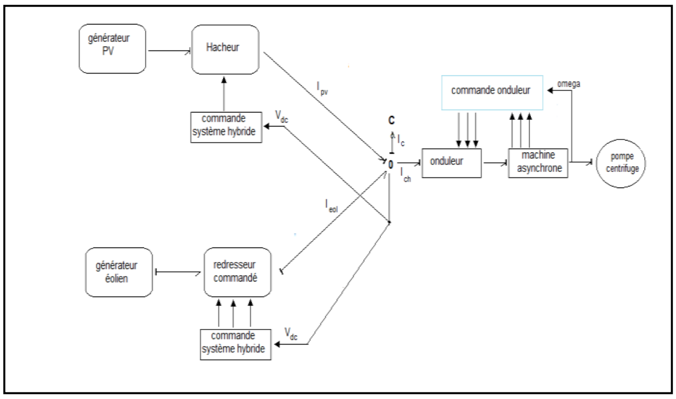

Fig.13. Bond graph model of the hybrid system in closed loop.

VI. Simulation result:

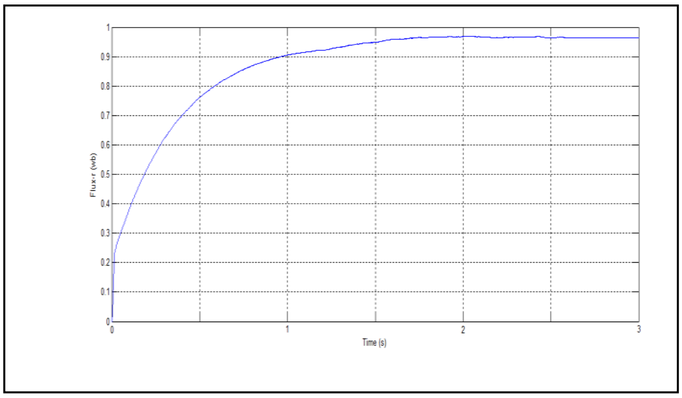

Fig. 14. Simulation response of flux

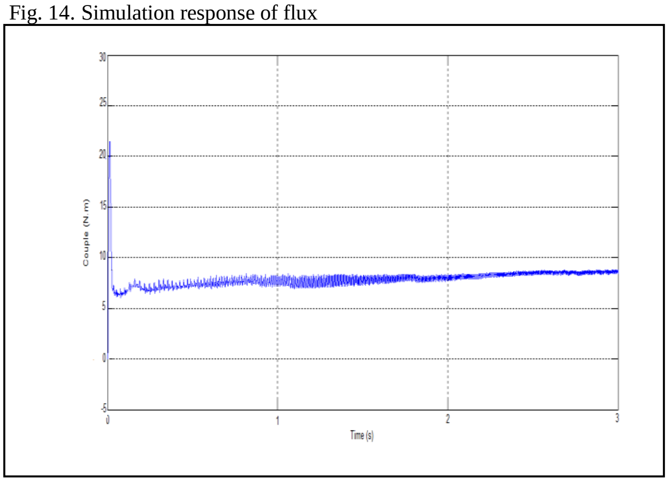

Fig. 15. Simulation response of Torque

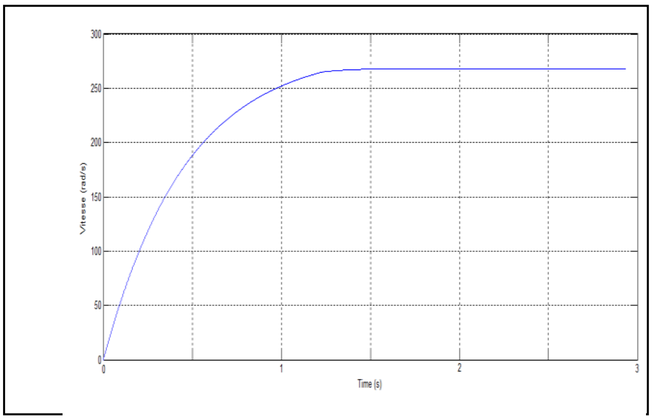

Fig. 16. Simulation response of speed

There, we have a good coupling with a closed-loop speed curve without influence or oscillation at system startup because the asynchronous machine is driven by the inverter.

The simulation of the pumping system using the wind-photovoltaic asynchronous motor with permanent magnets, with a direct coupling, respectively represent the variation of the flow rate of the pump depending on the engine speed (Figure 17) and the flow rate of the pump versus time (Figure 18):

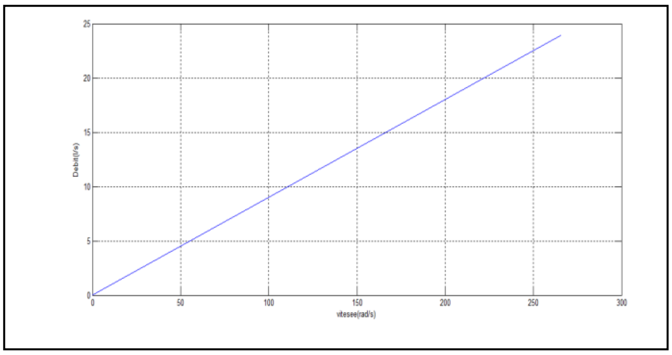

Fig.17. Pump flow variation function of the engine speed.

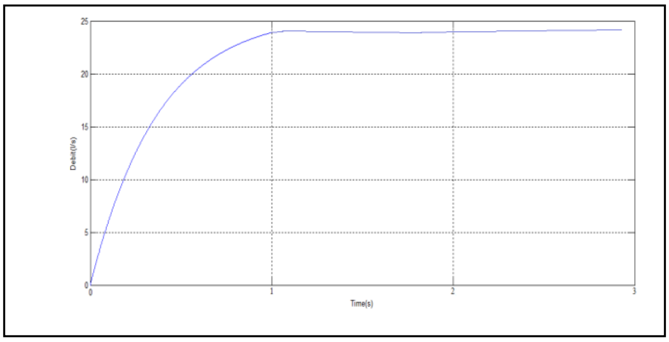

Fig.18. the pump flow rate versus time.

We studied the control of the induction machine closed loop using the principle of field-oriented: Theory of vector control, this command show that the transitional regime is moderate and lasts the shortest time possible.

And finally, we made a test for coupling the pumping system with two sources (wind turbine, photovoltaic generator). We note the effectiveness of this optimization on swing of the power around the maximum value of the reference power delivered by the two generators.

VII. Conclusion

The work presented in this article relate, in general, the studying, by bond graph modeling and simulation of closed-loop systems for electricity production from mixed renewable resources (wind and solar), for a pumping system.

In this context, we studied the complementarity of these two sources and the ability to adapt them and load. In addition we have studied the interconnection and control of each converter elements.

In the remainder of this work in the open loop simulation, it was shown that the study does not provide high performance for the asynchronous machine and the system does not respond quickly (this article does not contain this work) . So we proposed the control of the induction machine closed loop by exploiting the principle of stream-oriented: it is the theory of vector control.

Modeling and numerical simulation of the chain pump were performed using the Matlab software and the results are presented and discussed.

As perspectives, we can, for example, consider a practical implementation and implantation in isolated the proposed hybrid system

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