OPTIMIZATION SYSTEM OF PHOTOVOLTAIC RENEWABLE ENERGY MANAGEMENT WITH HYBRID STORAGE

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ABSTRACT

The management of electrical energy brings several advantages in production as well as in financial terms. This structure gives several advantages in the management of the electrical energy produced. The objective is to minimize the energy wasted. Each energy surplus will be directly used for pumping the water stored in the basin of the STEP system (Station of Energy Transfer by Pumping) to the upper reservoir and which will then be used to produce energy for consumption (normal or in case of unforeseen need). The optimization of energy production will be obtained above all by managing the complementarity of each system, so that the battery is only used as a last resort and that the STEP system compensates for each lack of energy. The two renewable energy production systems will both be used to charge the accumulator (battery) as well as to pump water to the STEP tank. The advantage of this system is the existence of a closed cycle of energy production which generates production.

This management of energy flows is realized by a system using Fuzzy Logic.

Keywords: Renewable energy, Photovoltaics, Wind turbines, STEP, Energy management, Battery.

INTRODUCTION

In this work, a regulator system model which aims to manage electrical energy through interconnected electrical energy parks is conceived. The energy is managed and optimized through fuzzy logic system in the controller.

1. Problematic

The system includes a hybrid production system (Photovoltaic and hydraulic), in normal operation. The main grid is directly connected to the hybrid renewable energy source.

The battery can receive energy from the production systems and the STEP station depending on the circumstances and the weather condition in order to maintain its state of charge.

In the event of a power cut in the main network (weather condition, switch between production system and STEP), the main network is powered directly by the batteries until production is restored.

During the normal operation of the production system (energy supplied is enough to satisfy energy umping the excess of energy is used to charge the reservoirs of the STEP station and/or the batteries. The state of charge of the battery is controlled by the inverter thanks to the regulator of the battery voltage level.

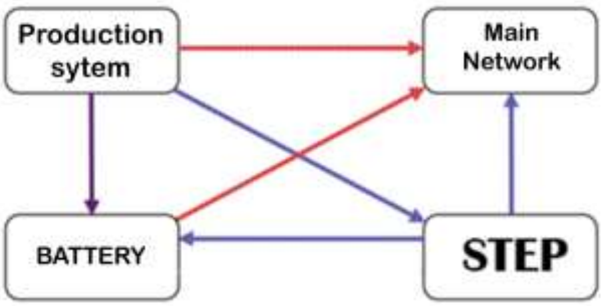
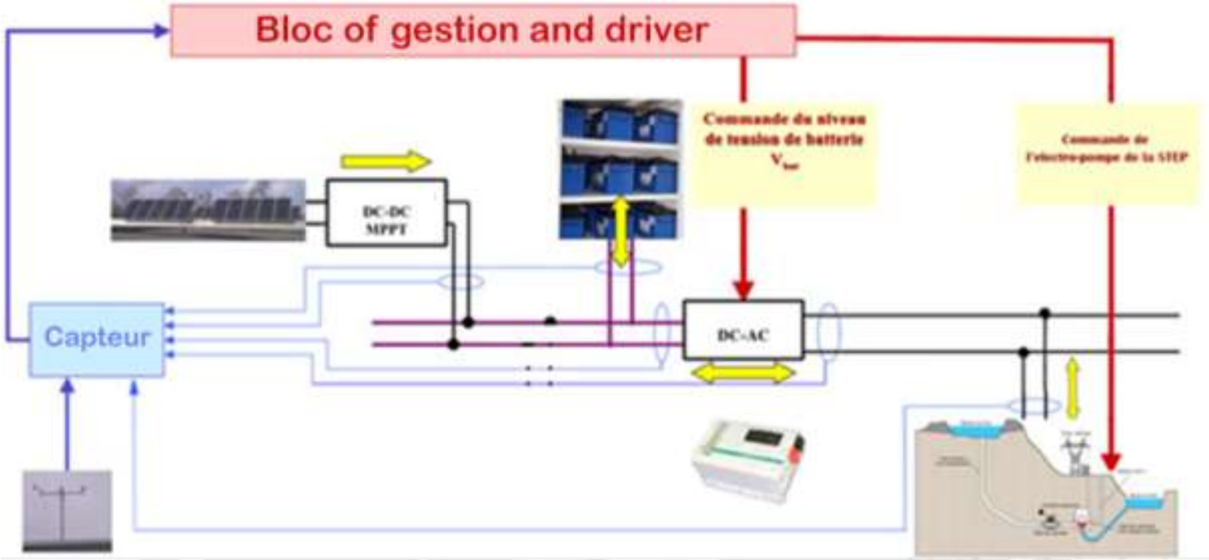


Figure 1: System management

In normal operation, the Production system is kept constant, therefore is no need to take precautions. On the other hand, in an unfavorable weather situation, if the Production system becomes too weak, the connection between the battery and the main network is cut for safety for the accumulator, the energy management with the STEP station is activated to avoid the power cut in the main network.

1.1. Bloc diagram of the overall system

The bloc diagram of this system is show in this picture.



there are some faulty production systems, and a securized energy supply whatever the weather condition.

In short, it has the double advantage of minimizing environmental disturbances thanks to consumption at the production site of renewable natural resources and maximum security of supply.

The presence of two types of energy storage system promotes the continuity of energy production without any interruption.

The production system that is proposed here is called hybrid hydraulic and photovoltaic production system equipped with a hybrid accumulator and STEP storage system.

The system design here (Fig.2) is for individual home.

1.2. Adopted architecture

The two-bus configuration, DC and AC, is shown in Fig.3 and has superior performance compared to the earlier configuration. In this configuration, renewable energy sources can supply part of the AC load directly, which increases the efficiency of the system and reduces the nominal power of the WWTP Turbine and the inverter.

The STEP Turbine and the inverter can operate independently or in parallel by synchronizing their output voltage.

When there is a surplus of energy from the photovoltaic panels or the STEP turbine, the battery can be charged.

The bi-directional inverter can supply load peaks when the STEP Turbine is overloaded.

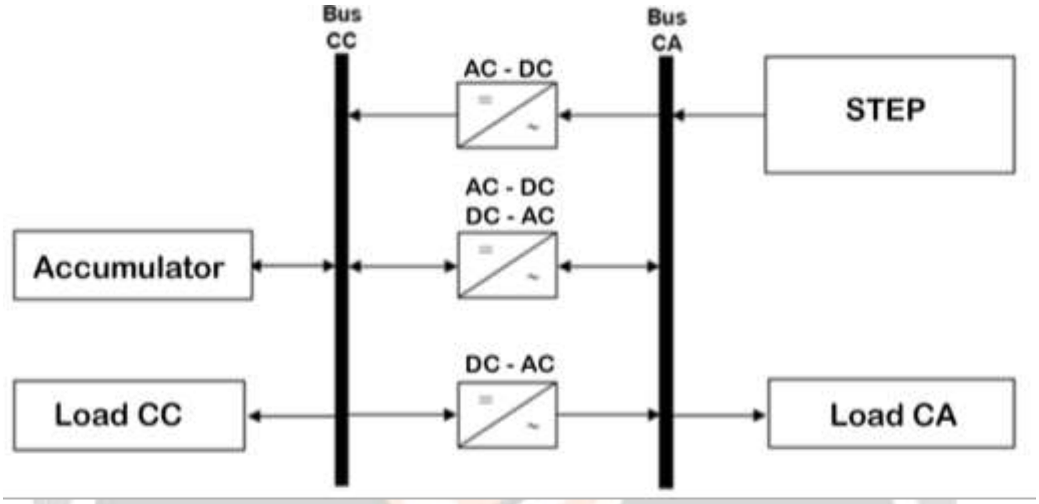


Figure 3: Configuration of PHS system in two-bus at CC and at CA

The advantages and disadvantages of such a system are presented below.

The advantages are :

(i). That the STEP Turbine and the inverter can operate independently or in parallel. When the charge level is low, one or the other can generate the necessary energy. However, the two sources (Batteries and Turbine) can operate in parallel during load consumption peaks.

(ii). That there is a possibility of reducing the nominal power of the Turbine of the STEP and the inverter without affecting the capacity of the system when suppling the load peaks.

The disadvantage is that:

- The realization of this system is relatively complicated because of parallel operation (the inverter must be able to operate autonomously and non-autonomously by synchronizing the output voltages with the output voltages of the STEP Turbine).

2. Optimisation of the production

General information on fuzzy logic

The design of a “fuzzy controller” requires going through the stages of choosing fuzzy variables, membership functions, inference methods and the fuzzification strategy.

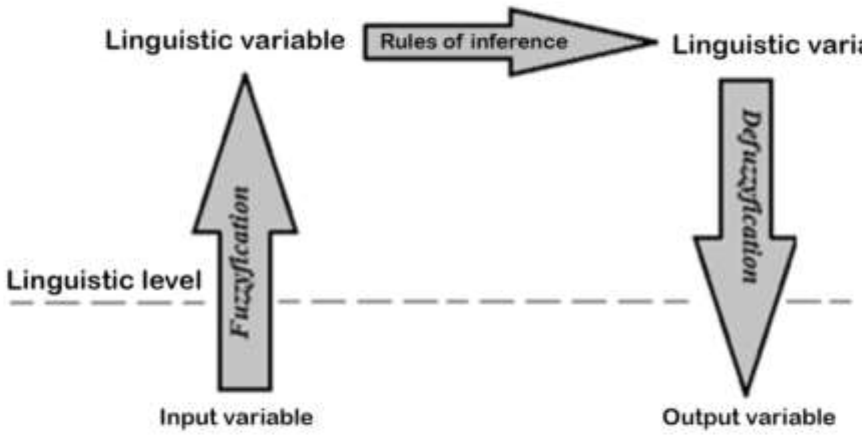


Figure 4: Design steps of a fuzzy regulator

- Fuzzification

At this stage we transform the physical variables into linguistic variables. Each physical variable corresponds to a degree of belonging to a linguistic variable.

- Rules of inference :

These rules make it possible to determine the output signal of the controller according to the input signals; they are expressed in the form “IF THEN”. In the fuzzy rules intervene the operators "AND" and "OR". The "AND" operator applies to the variables inside a rule, while the "OR" operator links the different rules. There are several possibilities to interpret these two operators. The max-min inference method realizes, at the level of the condition, the "AND" operator by formulating the minimum. The conclusion in each rule, introduced by “THEN”, links the membership factor of the premise with the membership function of the output variable, realized by the formation of the minimum. Finally, the "OR" operator, which links the different rules, is achieved by forming the maximum.

- Defuzzification :

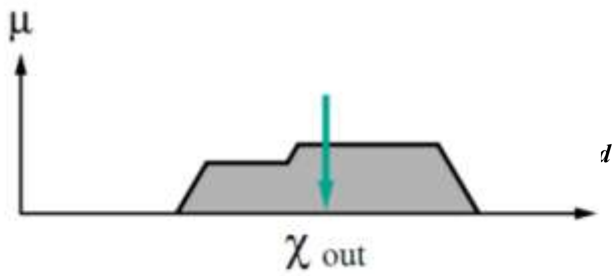
Defuzzification converts output fuzzy sets into physical variables suitable for such a process. Several DEFUZZIFICATION strategies exist. In this work method of the “center of gravity” is chosen.

It is given Equation:

$$x_{out} = \frac{\int x\mu(x)dx}{\int \mu(x)dx}$$

x_{out} : output value

μ : degree of membership



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2.1. Optimization of th

- Fuzzification

In this part, we will try to design a corrector based on the principle of disturbance and observation. The input variables of the fuzzy corrector will be Ev(k) and Ep(k) defined by the following equations:

$$E_v(k) = V_p(k) - V_p(k-1)$$
$$E_p(k) = P_p(k) - P_p(k-1)$$

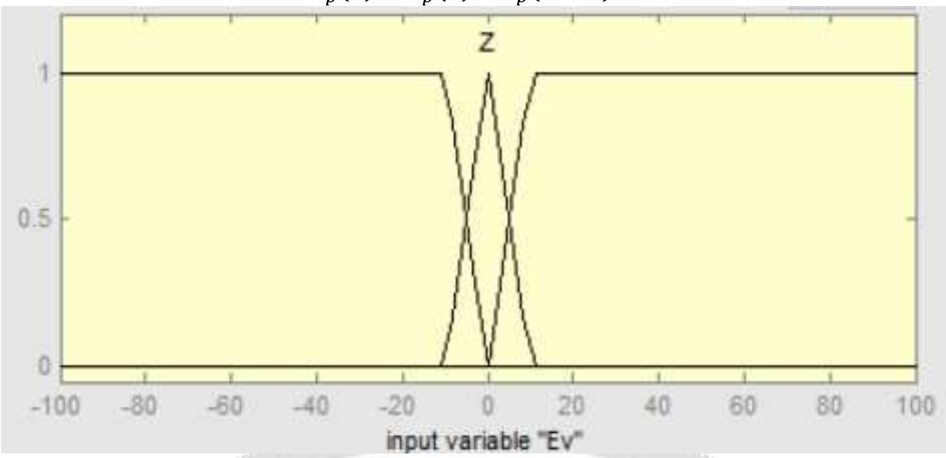


Figure 6: Linguistic variable Ev(k)

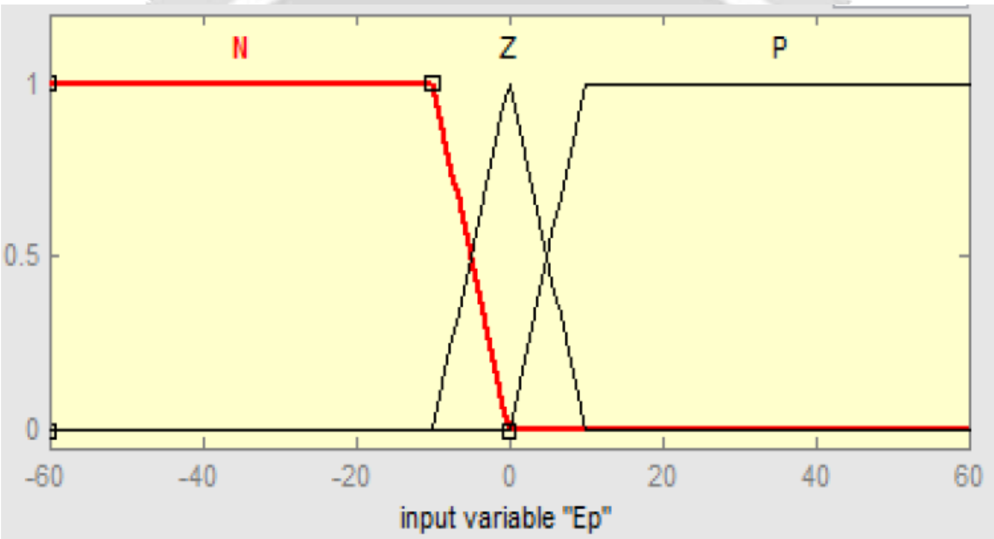


Figure 7: Linguistic variable Ep(k)

- Rules of inference

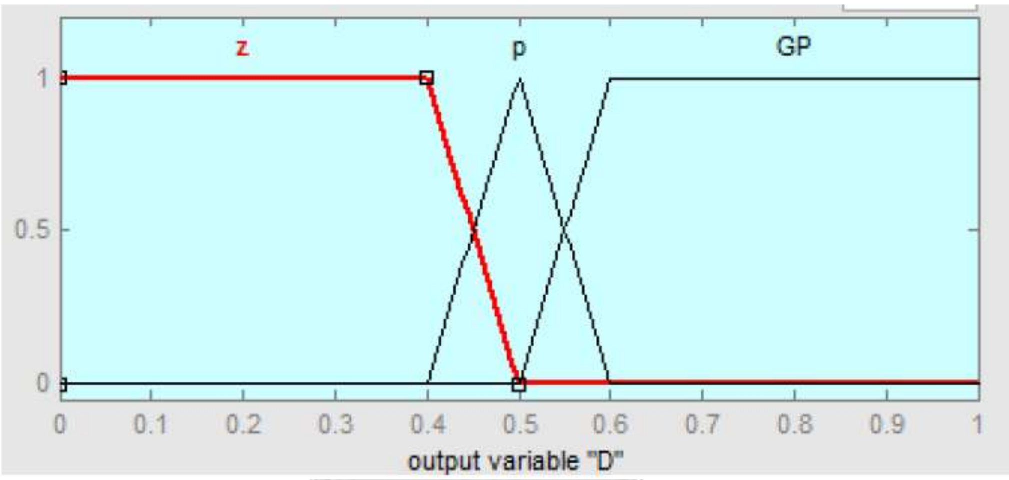
The inference rules for these corrections are presented in the following table:

Tab 1: Inference rules

Règle N°	**Ep**	**Ev**	**D**
1	P	P	Z
2	N	P	GP
3	Z	P	P
4	Z	Z	P
5	N	Z	P
6	P	Z	P
7	P	N	GP
8	N	N	Z
9	Z	N	P

- Defuzzification

For Defuzzification, we have chosen the “Center of Gravity” method. We have only one output variable which is the duty cycle D.



3. Simulation of the battery charge-discharge manager

Introduction

To be able to optimize the energy management of the hybrid Photovoltaic – Hydraulic system with storage, a dimensional study is necessary, as well as a simulation of the battery charge management system.

3.1. Storage sizing

The calculation of the capacity (C_{bat}) of the batteries depends on several data, it can be calculated as follows:

$$C_{bat} = \frac{E_{ele.N_j}}{U_{Bat.\eta_{Bat}.PDD}}$$

The number of batteries that are used can be calculated as follows:

$$N_b \geq \frac{C_{Bat}}{C_{Bat,u}}$$

With :

E_{ele} : Electrical energy required for pumping
N_j : Number of days of autonomy
PDD : Battery depth of discharge
η_{Bat} : Battery performance
N_b : Batterie number
$C_{Batt,u}$: Unit capacity

The calculation of the different powers, the number of panels and the number of batteries to be used is presented in the table below:

Tab 2: Calculation of the different powers

The daily energy required	704 Wh/j
Photovoltaic generator power	400 W
Number of panels needed N_{pv}	5
Battery capacity	149 Ah
Number of batteries Nbat	2

The overall scheme of the system is represented by the Fig 9:

Control box

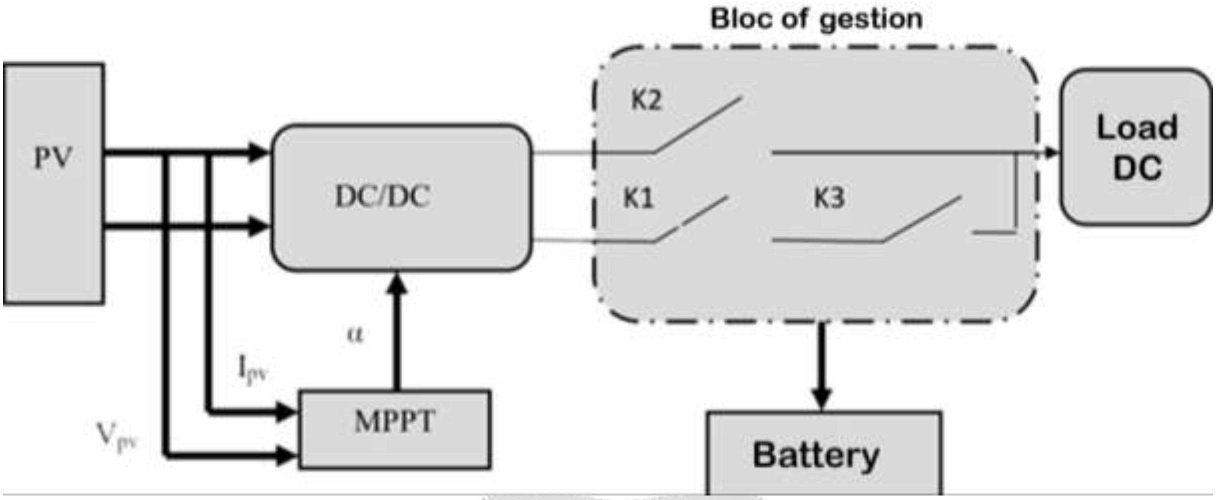


Figure 9: Overall scheme of the system

- Photovoltaic modules
- DC/DC converter
- Three switches (K1, K2, K3)

4. *Energy management mode between the different components of the system*

In order to operate the system in a perfectly autonomous way, it is essential to optimally manage the flow of energy between the various components of the system. It is therefore necessary to introduce a management system. To supervise the entire photovoltaic installation, it is assumed that the batteries are initially charged. The management system is mainly responsible for supplying the load and protecting the batteries (we take a minimum state of charge SOC_{min} = 30% and a maximum state of charge SOC_{max} = 95%). The different modes that govern the operation of the proposed system and which are the different modes listed below:

MODE 1 : The batteries are charged SOC_{max} 95%
The photovoltaic generator is sufficient to satisfy the load P_{pv} P_{ch}

MODE 2 : P_{pv} is insufficient to supply the load P_{pv} P_{ch}
The battery adds its power to satisfy the load $P_{ch} = P_{pv+Pbatt}$
$SOC_{min} \geq SOC$

MODE 3 : Only the battery supplying the load $P_{batt} = P_{ch}$ $SOC \geq SOC_{min}$

MODE 4 : The P_{vp} sufficient to power the load $P_{pv} = P_{ch}$

MODE 5 : Batteries fully discharged $SOC < SOC_{min}$
No photovoltaic production $P_{pv} = 0$

4.1. Energy management strategy

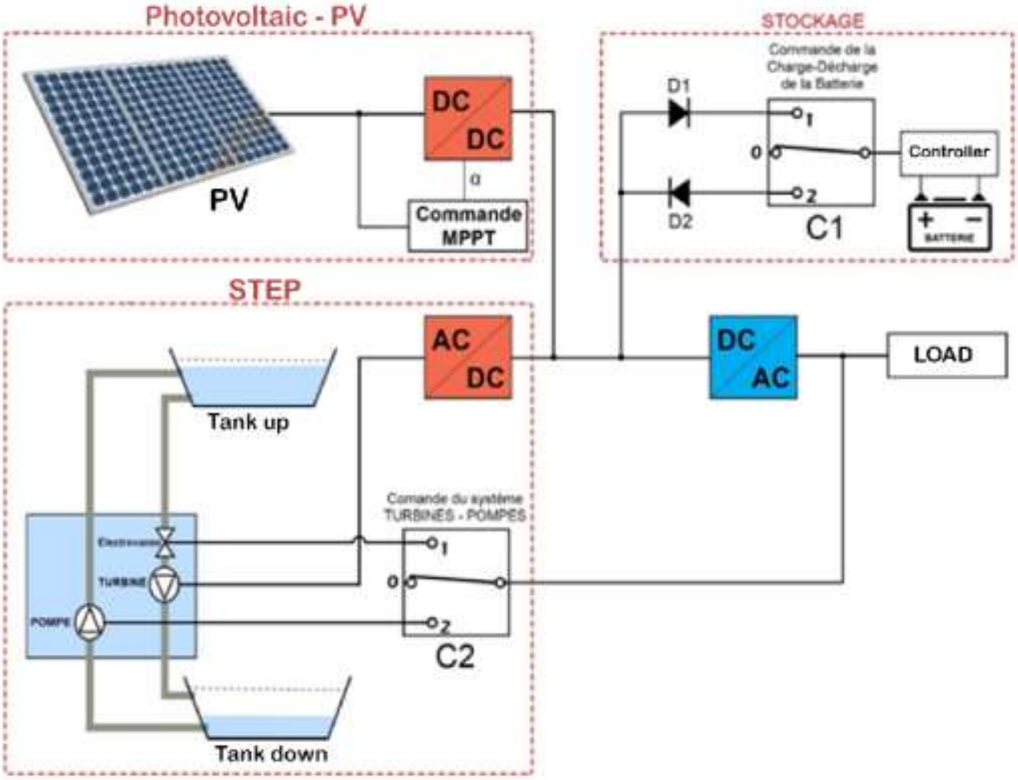


Figure 10 : Management system block diagram

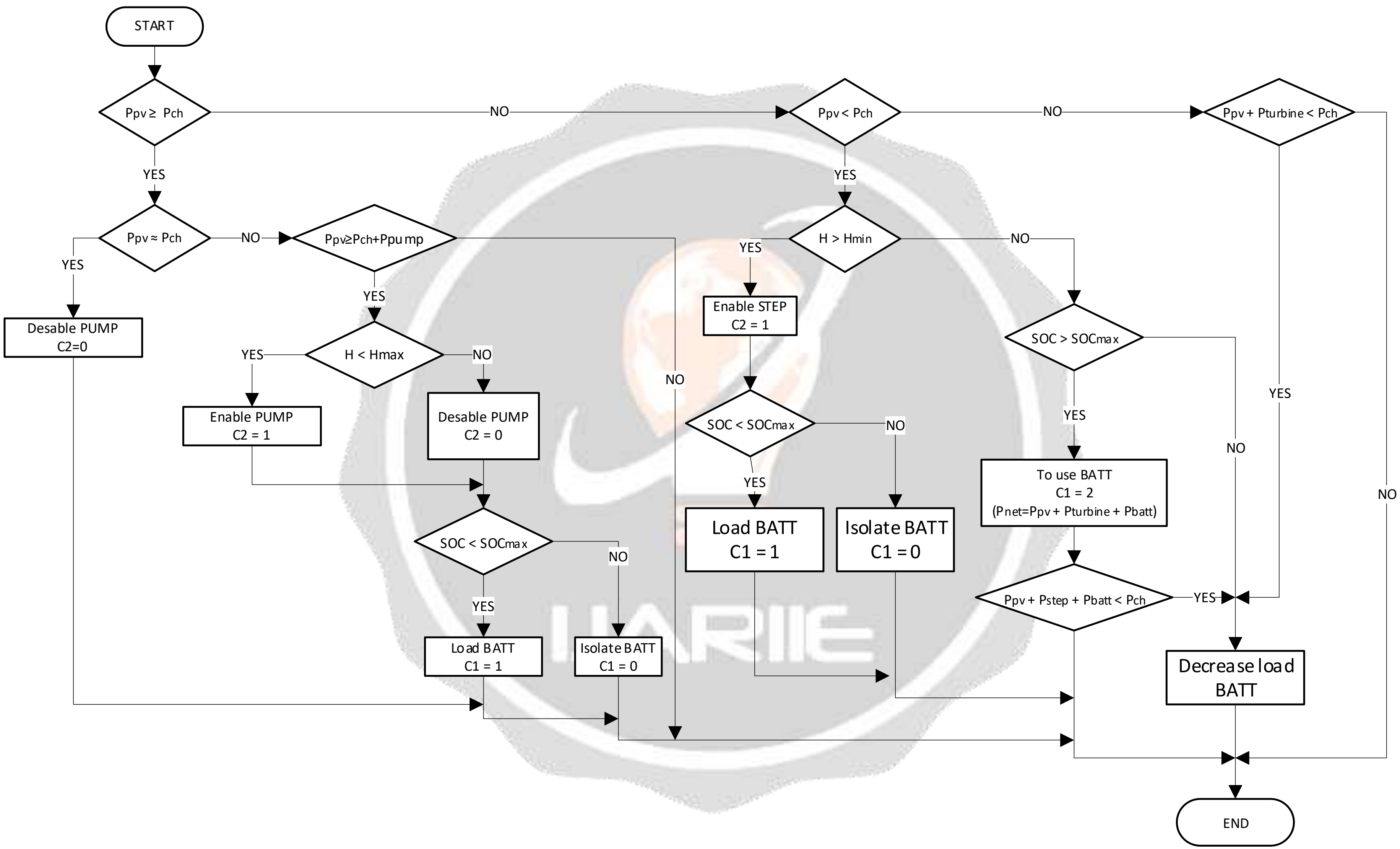


Figure 11 : System block diagram

Several scenarios are considered in order to achieve better energy management of the autonomous hybrid system, such as the scenario listed below:

- **Scénario 1 :** The energy produced by the photovoltaic panels is sufficient to power the total load.
  - *(i)* *Condition 1 :* $P_{PV} \cong P_{ch}$
    Disable the system STEP (Switch C2 position 0)
  - *(ii)* *Condition 2 :* $P_{PV} \geq P_{ch} + P_{Pompe}$

  - If the level of the upper tank H of the STEP is lower than the maximum level H_max, then supply the pump of the STEP system.

  - If the upper tank of the STEP system is full, then deactivate the Pump.

  - If the state of charge of the SOC batteries is lower than the maximum state of charge 〖SOC〗_max, then the excess energy is stored in the battery (Switch C1 position 1).

  - If the battery is charged, isolate the battery from the charging circuit (switch C1 position 0).

- **Scénario 2 :** The energy produced by the photovoltaic panels is lower than the demand ($P_{PV} < P_{ch}$).
  - (i) *Condition 1 :* the level of the upper tank H of the STEP is higher than the minimum level H>H_min, then activate the solenoid valve of the Turbine.
    - ➢ If the state of charge of the SOC batteries is lower than the maximum state of charge 〖SOC〗_max, then the excess energy is stored in the battery (Switch C1 position 1).
    - ➢ If the battery is charged, isolate the battery from the charging circuit (Switch C1 position 0).
  - (ii) *Condition 2 :* the level of the upper reservoir H of the STEP is less than or equal to the minimum level H≤H_min, then deactivate the solenoid valve of the Turbine and the Pump.
    - ➢ If the state of charge of the SOC batteries is greater than the minimum state of charge 〖SOC〗_min, then the battery adds the power source: $P_{net} = P_{PV} + P_{Turbine} + P_{Batt}$ (Switch C1 position 2).
      - ❖ Si $P_{PV} + P_{Turbine} + P_{Batt} < P_{ch}$, then decrease the power of the load.
    - ➢ If the batteries are discharged (SOC≤ 〖SOC〗_min), then decrease the load power.
- **Scénario 3 :** The energy produced by all the photovoltaic panels P_{PV} and the turbine $P_{Turbine}$ is insufficient ($P_{PV} + P_{Turbine} < P_{ch}$).
  - (iii) Condition 1 : If the state of charge of the SOC batteries is greater than the minimum state of charge 〖SOC〗_min, then activate the battery source (Switch C1 position 2).
  - (iv) Condition 2 : If the batteries are discharged ($SOC \leq SOC_{min}$), then decrease the power of the load.

Management of the autonomous photovoltaic-hydraulic hybrid system with storage

For the management of the hybrid system, the objective is to minimize as much as possible the waste as well as the losses of energy during production in order to be able to optimize the autonomy of the system as much as possible.

The main source of energy in this system is the photovoltaic panel which simultaneously charges the battery through a regulator that manages the charge of the latter.

Surplus electrical energy will then be used to pump the STEP station to fill the upper reservoir, which will then be used to compensate for energy shortages.

In this system, three distinct parameters must be considered:

• The energy production power of the photovoltaic panel

• The level of the reservoirs of the STEP system

• Battery charge and discharge level

For energy management, the net power of the entire hybrid system is first calculated. This net power (Pnet) is equal to the sum of the power produced by the photovoltaic panels (PPV) and the power of the STEP turbine ($P_{Turbine}$).

$$P_{net} = P_{PV} + P_{Turbine}$$

The P_GEN power is zero when the energy produced by the photovoltaic panels is sufficient to supply the power to the loads (P_{ch})

Then we have :

$$P_{net} = P_{PV} > P_{ch\,Total}$$

The total load power is equal to the Load power (Pch) and the STEP pump power (P_{pompe}).

$$P_{ch\,Total} = P_{ch} + P_{pompe}$$

The power of the pump is zero if the upper reservoir of the STEP system is full.

4.2. Energy management

In this strategy, apart from the main load, the PHS hybrid system will also supply auxiliary loads (the turbine, optional load). The main load is supplied without interruption, while the auxiliary loads are supplied when there is an excess of energy. Auxiliary loads are connected and disconnected in order of priority (Figure IV-30). Indeed, if there is a surplus of energy, the batteries will be charged first, then the rest will be used to supply the deferred loads and then the optional loads. Water pumps and desalination units are examples of low priority deferred loads in normal operation. Optional loads are all loads that have utility and can be used during the period of excess energy that would otherwise be dissipated.

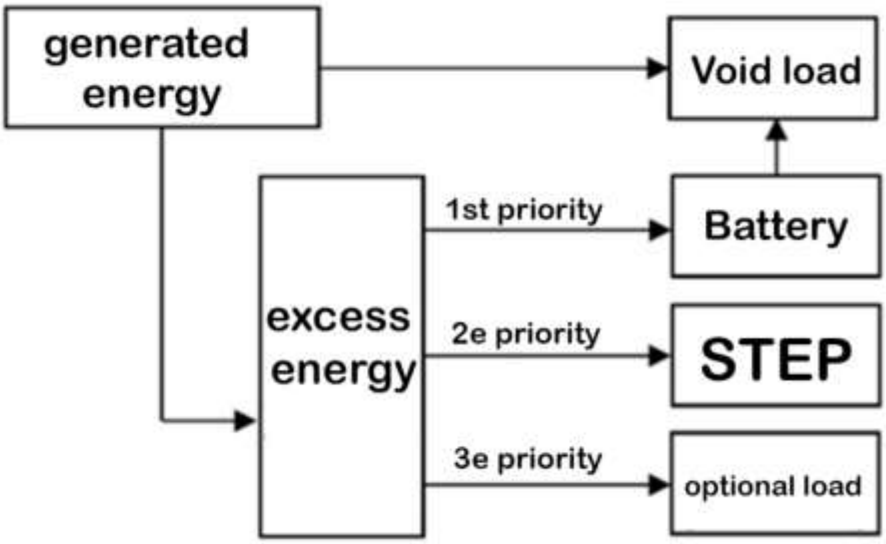


Figure 12 : Load priority diagram

CONCLUSION

During our research, we can see that the management of the energy produced minimizes the waste of electricity production.

The advantage of this system is the use of a third-party mechanism so as not to lose excess energy and to use it in the event of insufficient energy, which is a very effective technique.

Fuzzy logic has helped us in adapting the system to various situations.