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Presentan: Nicolás Costa y Gerardo Ahrtz

GIICEP

Grupo de Investigación en Instrumentación, Control y Electrónica de Potencia

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Principales líneas de investigación

- Sistemas de control
- Instrumentación y electrónica de potencia
- Aplicaciones a energías renovables
- Aplicaciones a procesos

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Linear and non-linear control of wind farms. Contribution to the grid stability

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ABSTRACT

This paper deals with linear and non-linear control of wind farms equipped with doubly-fed induction generators (DFIG). Both, active and reactive wind farm powers are employed in two independent control laws in order to increase the damping of the oscillation modes of a power system. In this way, it presented a general strategy where two correction terms are added, one by each independent control, to the normal operating condition of a wind farm. The proposed control laws are derived from the Lyapunov approach. Meanwhile for the reactive power a non-linear correction is presented, for the wind farm active power it is demonstrated that the classical proportional and inertial laws can be considered via the Lyapunov approach if wind farms are considered as real power plants, i.e. equivalent to conventional synchronous generation. Finally, some simulations are presented in order to support the theoretical considerations demonstrating the potential contributions of both control laws.

1. Introduction

Since two decades ago, many countries have been modifying their laws in order to promote the development of renewable energy. Under this environment, wind energy has emerged as the most promising energy source. However, as the size of wind farms increases, the interaction between them and electrical networks becomes more important. Thus, regarding the total power grid, wind power creates problems related to the fluctuating nature of wind giving place to power fluctuations that degrade the quality of power networks. These unfavorable circumstances, which limit the wind farm penetration, are enhanced in weak grids. In this way, it is well known that modern grid codes are considering wind farms behaviors equivalent to that ones of the named "conventional (synchronous) generation" taking into account the wind power plants concept [1,2] by considering power and voltage controls. At the same time, the distributed nature of wind farms over a geographical region and the rather different energy conversion systems, when compared with conventional generation, are opening new and different ways in which wind farms can contribute to the network stability. Therefore, the wind farms contribution to the electrical network stability is an important subject of study.

This paper proposes control laws based on Energy Functions [3,4]. The control laws are independent of operating points and linearization techniques assuring the contribution of wind farms over a wide range of (different) working conditions.

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Linear and non-linear control of wind farms. Contribution to the grid stability

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The structure of this paper is as follows. In Section 2, a wind farm model is presented and the generating unit, doubly-fed induction machine, is described. In Section 3, the wind farm control strategy plus the added laws are presented. From the Energy Function approach the proposed control laws are obtained. In Section 4, the impact of the proposed laws is evaluated through simulation results. Finally, in Section 5 conclusions are presented.

2. Wind farm model

A complete model of a wind farm with a high number of windmills, may lead to compute an excessive and impractical number of equations. The size of the wind farm model may be reduced by aggregating several wind turbines with similar incoming wind into a bigger turbine called aggregated turbine [5]. Therefore, this work will consider an aggregated wind turbine representing a wind farm.

2.1. Wind turbine

The torque and the mechanical power developed by a wind turbine are given by: [6]

$$T_t = \frac{\pi \rho r^2}{2} \upsilon^3 C_p(\lambda)/\Omega_t, \tag{1}$$

$$P_t = \frac{\pi \rho r^2}{2} \upsilon^3 C_p(\lambda), \tag{2}$$

where ρ is the air density, r is the radius of the turbine, υ is the wind speed, $C_p(\lambda)$ is the power coefficient, $\lambda = \Omega_t r/\upsilon$ is the tip speed ratio and Ω_t is the turbine speed. Because of the maximum $C_p(\lambda)$ is obtained at a nominal tip speed ratio $\lambda = \lambda_o$, looking for taking the maximum power available at any wind speed, the control system must adjust the turbine speed to operate at λ_o.

2.2. Electric generator

The wind farm considered in this work is equipped with doubly-fed asynchronous generators (DFIG). In such machines, the rotor winding is fed by back-to-back voltage source converters. The operation of an induction machine can be analyzed using the classical theory of rotating fields and the well-known d–q model [3,7]. The electromagnetic torque (T_e) and the stator active (P_e) and reactive (Q_e) powers of a double fed induction generator are:

$$T_e = -\frac{3}{2} P L_m \left(i_{sx} i_{ry} - i_{sy} i_{rx} \right), \tag{3}$$

$$P_e = \frac{3}{2} \left(u_{sx} i_{sx} + u_{sy} i_{sy} \right), \tag{4}$$

$$Q_e = \frac{3}{2} \left(u_{sy} i_{sx} - u_{sx} i_{sy} \right), \tag{5}$$

with P is the number of poles, L_m is the magnetizing inductance, u_{sx} and u_{sy} are stator voltages and i_{sx}, i_{sy} are the stator and rotor currents in a general reference frame [7].

Because of vector control, it is possible to control active and reactive powers independently [7,8].

2.3. Wind farm aggregated model

As was aforementioned, the wind farm is represented by an aggregated wind turbine. Then, in this work a single lumped mass mathematical model of the wind farm is considered [9,10]:

$$\left(J_g + \frac{J_t}{N^2} \right) N \dot{\Omega}_t = \left(J_g + \frac{J_t}{N^2} \right) \dot{\Omega}_r = \frac{T_t}{N} - T_e, \tag{6}$$

which is referred to generator shaft trough the gearbox transmission N, being J_t and J_g the inertias of the wind turbine and the generator plus the gearbox one.

This dominant pole approximation is particularly justified in the DFIG wind farm case in which the time constant of the current controls is about 20 ms, which is really fast compared with the time scale of the phenomena (grid stability) analyzed in this work [5].

Also, because of the transient behaviors studied in this work involve a reduced time scale in comparison with the average wind speed change, it is considered that wind speed remains constant in the analysis.

3. Wind farm control

Power system stability has been defined as that property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance [3].

In order to contribute to the network stability, both active and reactive wind farm power controls of a wind farm are considered. Then, steady state controls (normal operating conditions) plus corrections looking for contributing to the grid stability are proposed:

$$\begin{aligned} Q_{wf} &= K_{QV} \Delta V + \Delta Q_{ext}, \\ P_{wf} &= P_{SC} + \Delta P_{ext}. \end{aligned} \tag{7}$$

Meanwhile the reactive power is controlled by considering the voltage profile with K_{QV} the voltage gain and ΔQ_{ext} the correction, P_{wf} is the total active power of the wind farm with P_{SC} the power reference given by a Supervisory Control [11,12] and ΔP_{ext} the wind farm correction which contributes to the network stability.

3.1. Reactive power control

As presented in ref. [13], maintaining the voltage at the connection point by regulating the reactive power is not a necessary and sufficient condition in order to contribute to the network stability. Thus, besides the contribution to the quality of energy with the voltage profile at the connection point, it is possible collaborating with the damping of a power system by changing the reactive power in order to damp the names 'electromechanical oscillations'.

In this way, it is well known that the Energy Function ν of a power system, where it is considered the classical model of the synchronous generators, is [4,14]:

$$\nu = \sum_{k=1}^{N_G} \left(0.5 M_k \tilde{\omega}_k^2 - P_{Mk} \tilde{\delta}_k \right) + \sum_{k=1}^{N_L} \left(P_{Lk} \tilde{\theta}_k + \int \frac{Q_{Lk}}{V_k} dV_k \right), \tag{8}$$

with

$$\tilde{\omega}_k = \omega_k - \omega_{COI}, \quad \omega_{COI} \doteq \frac{1}{M_T} \sum_{k=1}^{m} M_k \omega_k,$$

$$\tilde{\delta}_k = \delta_k - \delta_{COI}, \quad \delta_{COI} \doteq \frac{1}{M_T} \sum_{k=1}^{m} M_k \delta_k,$$

$$\tilde{\theta}_k = \theta_k - \delta_{COI}, \quad M_T \doteq \sum_{k=1}^{m} M_k,$$

with N_L and N_G the number of loads and generators, M_k the machine inertia constant, ω_k the machine speed, δ_k the angle of the voltage behind the transient reactance, θ_k the angle at each bus, P_{Mk} the mechanical power of the generators, P_{Lk} and Q_{Lk} the active and reactive load powers and V_k the voltage at the connection point. The angles and speeds are measured with respect to the center of inertia (COI) reference frame (δ_{COI} and ω_{COI}).

To damp the electromechanical oscillations, the incremental Energy Function of the power system must decrease. The time derivative of this Energy Function considering the wind farm acting through its reactive power yields:

$$\dot{\nu} = \sum_{k=1}^{N_G} \left(M_k \dot{\tilde{\omega}}_k + P_{Gk} - P_{Mk} \right) \dot{\tilde{\delta}}_k + \sum_{k=1}^{N_L} P_{Lk} \dot{\tilde{\theta}}_{Lk} + \sum_{k=1}^{N_L - 1} \frac{\dot{V}_k}{V_k} Q_{Lk} - \frac{\dot{V}_{wf}}{V_{wf}} \Delta Q_{ext}. \tag{9}$$

The key consideration in the last expression is that meanwhile the Energy Function of the uncontrolled system remains the same with the uncontrolled or controlled wind farm (expression (8)), the time derivative changes with the control. Indeed, by considering the uncontrolled system, all of the nodes present the next derivative function:

$$\dot{\nu}_Q = \sum_{k=1}^{N_L} \frac{\dot{V}_n}{V_n} Q_n = 0. \tag{10}$$

However, by considering the control action the last expression becomes:

$$\dot{\nu}_Q = \sum_{k=1}^{N_L - 1} \frac{\dot{V}_k}{V_k} Q_{Lk} - \frac{\dot{V}_{wf}}{V_{wf}} \Delta Q_{ext}, \qquad \dot{\nu}_Q = -\frac{\dot{V}_{wf}}{V_{wf}} \Delta Q_{ext}. \tag{11}$$

Then, the reactive power ΔQ_{ext} must be chosen in order to allow the sufficient condition of the derivative of the Energy Function.

Note that, in equation (9), the expression in between parenthesis is zero because of the generators power balance (or it is negative when considering some internal friction). The next two terms correspond to the power balance equations at the nodes and are zero. Then, looking for damping the electromechanical oscillations, the last expression must be less than zero. In this way, a non-linear control strategy of the wind farm through the reactive power (ΔQ_{ext}) can be derived from expression (9) by considering that the wind farm emulates the behavior of a static var compensator [12,14]:

$$\Delta Q_{ext} = b_u V_{wf}^2 \quad \Rightarrow \tag{12}$$

$$-\frac{\dot{V}_{wf}}{V_{wf}} \Delta Q_{ext} = -b_u V_{wf} \dot{V}_{wf} = -\frac{1}{2} b_u \frac{d}{dt} V_{wf}^2. \tag{13}$$

In order to keep the sufficient condition:

$$b_u = K_r \frac{dV_{wf}^2}{dt}; \quad \text{with} \quad K_r > 0 \tag{14}$$

where b_u is the (equivalent) wind farm susceptance.

3.2. Active power control

Even when there are works which derived the active power control wind farm control action from the Energy Function [12], in that works wind farms are considered as negative loads [15,16]. However, it has not been found yet for the knowledge of the authors, that the named inertial behavior of the wind farms [9,17], i.e. a control law that takes into account the derivative of the frequency, contributes to the stability by using the Lyapunov Theory. Thus, if it is expected that wind farms act as real power plants [1], it is necessary to employ the Lyapunov expressions by considering that wind farms are behaving as their equivalent synchronous generators (the conventional power plants) with proportional and derivative frequency control laws. The equations representing the dynamic behavior of synchronous generators for the reduced model, are [3]:

$$\dot{\tilde{\delta}}_k = \tilde{\omega}_k, \tag{15}$$

$$\dot{\tilde{\omega}}_k = \frac{1}{M_k} \left(P_{mk} - D_k \omega_k - P_{Gk} \right), \tag{16}$$

where M_k is the inertia of the whole machine (synchronous generator plus prime mover), P_{mk} is the mechanical power produced by the prime mover, D_k is the component of internal friction of the generator and P_{Gk} is the electrical power injected in the network. Because of variables are in per unit, powers and torques are equal [3]. Mimicking the analysis for a wind farm with frequency control and inertial contribution yields:

$$\dot{\alpha}_k = \Omega_{gk}, \tag{17}$$

$$\dot{\Omega}_{gk} = \frac{1}{M_{gk}} \left(P_t - P_{wf} \right), \tag{18}$$

with the control as:

$$P_{wf} = P_{SC} + \Delta P_{ext}, \tag{19}$$

$$\Delta P_{ext} = K_p \left(\tilde{\omega}_{ref} - \tilde{\omega} \right) + K_d \left(\dot{\tilde{\omega}}_{ref} - \dot{\tilde{\omega}} \right) = K_p \breve{\omega} + K_d \dot{\breve{\omega}}, \tag{20}$$

then:

$$\dot{\breve{\omega}} = \frac{1}{K_d} \left(P_t - \left(K_p \breve{\omega} + M \dot{\Omega}_{gk} \right) - P_{SC} \right). \tag{21}$$

Note the similarity of this expression with (16) for synchronous generation. Then, the analysis focuses on addressing the control of the wind farm as in ν_1 which considers the derivative of the Energy Function of asynchronous generator in (9):

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$$e_1 = \sum_{k=1}^{N_G}\left(0.5\,M_k\breve{\omega}_k^2 + P_{Gk}\breve{\theta}_k - P_{Mk}\breve{\theta}_k\right) \tag{22}$$

The equivalent expression for a wind farm is:

$$e_{1wf} = 0.5\,\breve{\omega}_k^2 + \frac{P_{SC}}{K_d}\breve{\theta}_{wf} - \frac{P_t}{K_d}\breve{\theta}_{wf} \quad \Rightarrow \tag{23}$$

$$\dot{e}_{1wf} = \breve{\omega}_k\dot{\omega}_k + \frac{P_{SC}-P_t}{K_d}\dot{\theta}_{wf} = \left(\dot{\omega}_k + \frac{P_{SC}-P_t}{K_d}\right)\dot{\theta}_{wf}, \tag{24}$$

$$\dot{e}_{1wf} = \left(-\frac{M_{wf}}{K_d}\dot{\Omega}_g - \frac{K_p}{K_d}\breve{\omega}\right)\dot{\theta}_{wf} = -\frac{M_{wf}}{K_d}\dot{\Omega}_g\dot{\theta}_{wf} - \frac{K_p}{K_d}\dot{\theta}_{wf}^2, \tag{25}$$

being $K_p > 0$ and $K_d > 0$ it is verified the negative sign of the second term in the last expression. On the other side, in order to verify the negative sign of $-(M_{wf}/K_d)\dot{\Omega}_g\dot{\theta}_{wf}$ it is necessary analyzing the wind farm convergence to an equilibrium point (e.p.), knowing that $M_{wf} > 0$ and considering that the wind farm (the aggregated turbine) is outside the equilibrium point.

Fig. 1 presents the torque – speed curves of the aggregated wind turbine with the wind velocity as a parameter. The e.p., considering constant wind velocity, corresponds to nominal frequency at the wind farm connection point with constant shaft speed $\Omega_{e.p.}$ of the aggregated turbine.

In order to verify the convergence to the equilibrium, two conditions outside the e.p., which are consequence of electrical disturbances, will be analyzed. Firstly, because of a disturbance action, the aggregated wind turbine is operating at point A (Fig. 1) with $\Omega_A < \Omega_{e.p.}$, being the frequency $\breve{\theta}_A < \breve{\theta}_{e.p.}$. At that point, the wind farm generated power is bigger than the nominal one by considering the wind farm contribution to restore the frequency at the connection point. When the disturbance disappears, the network returns to its normal configuration and the wind farm power is bigger than that which maintains the power balance in the system. As the deviation of the frequency decreases, so does the wind farm generated power. As a consequence, the wind turbine torque decreases and the turbine speed experiences an increment until the speed reaches $\Omega_{p.e.}$. Thus, while the frequency reaches their nominal value, the wind turbine increasing its speed. Then, the (negative) sign of (25) is verified by considering:

$$\dot{\theta}_{wf} = \dot{\theta}_{ref} - \dot{\theta}_A > 0 \quad \text{and} \tag{26}$$

$$\dot{\Omega}_g = \frac{\Omega_{e.p.} - \Omega_A}{\Delta t} > 0. \tag{27}$$

Secondly, if as a consequence of another disturbance the aggregated turbine is operating at point B (Fig. 1), when the disturbance is removed the sign of (25) yields:

$$\dot{\theta}_{wf} = \dot{\theta}_{ref} - \dot{\theta}_A < 0 \quad \text{and} \tag{28}$$

$$\dot{\Omega}_g = \frac{\Omega_{e.p.} - \Omega_B}{\Delta t} < 0. \tag{29}$$

Expressions (27) and (29) verify the negative sign of (25).

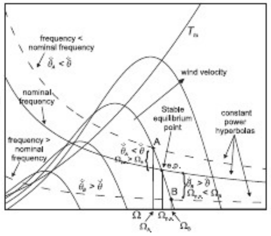

Fig. 1 – Torque – speed characteristics. Convergent behavior to the e.p.

4. Impact of the control laws

This section evaluates how the proposed control laws can contribute to the stability of a power grid. Fig. 2 shows the system under test, where it is produced a three phase short circuit to ground for 80 ms. The system is formed by two areas connected by a weak tie.

The symmetrical network topology considered (without the wind farm) is usually employed in the literature for showing intra and inter-area oscillations [3,14] and for getting understanding in the subject in order to solve more complex networks. Meanwhile, local or intra oscillations are calculated as the difference between the shaft speeds of generators G1–G2 in Area 1 and G3–G4 in Area 2, inter-area oscillations are calculated as the difference between the shaft speeds of generators G1–G3 (Fig. 2).

The data of the network, except the wind farm power production of 40 MW and the added 187 MVAR in order to improve the voltage profile in each area, is given in [3]. All of the synchronous generators are operating with an MB PSS with simplified setting (IEEE type PSS4B according to IEEE std. 421.5). A power flow analysis indicates that in Area 1, G_1 and G_2 are delivering 521.08 MW and 700 MW, respectively, meanwhile in Area 2, G_3 delivers 719 MW and G_4 delivers 700 MW. Then, Area 1 is exporting 268 MW to Area 2. It is important to note the difference between the generated power of each area when they are compared with the delivered power of the wind farm (40 MW).

Looking for analyzing the proposed controls, simulation results are presented for the next cases:

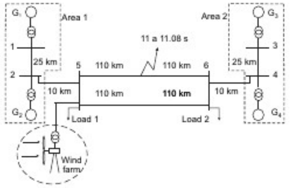

Fig. 2 – System under test.

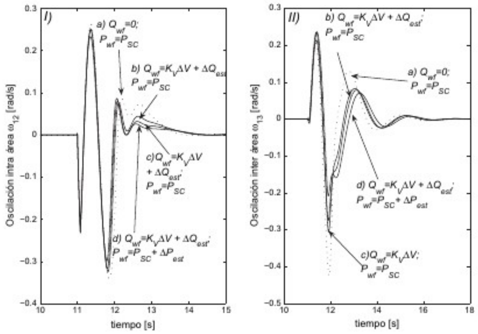

Fig. 3 – Intra (I) and inter (II) area oscillations.

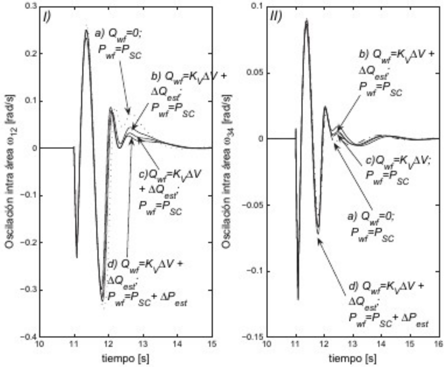

Fig. 4 – Intra area oscillations (I) generators 1 versus 2 (II) generators 3 versus 4.

- a) $Q_{wf} = 0$; $P_{wf} = P_{SC}$
- b) $Q_{wf} = K_{QV}\Delta V$; $P_{wf} = P_{SC}$
- c) $Q_{wf} = K_{QV}\Delta V + \Delta Q_{est}+$; $P_{wf} = P_{SC}$
- d) $Q_{wf} = K_{QV}\Delta V + \Delta Q_{est}+$; $P_{wf} = P_{SC}\Delta P_{est}$.

Fig. 3 shows both oscillations intra area (I) in Area 1 and inter-area (II). Fig. 3 shows the improvement due to the wind farm control. It is noted the positive effect that the voltage control has in reducing both kinds of oscillations at the same time, this improvement is increased with the addition of the proposed controls.

Fig. 4 presents both local modes calculated as the difference between the shaft speeds of the generators 1 and 2 in Area 1 and 3 and 4 in Area 2. In Area 2, oscillations w_{34} are (slightly) deteriorated with the contribution of the wind farm which is attributed to its local influence. Note, however that w_{34} is lower than its equivalent w_{12}.

5. Conclusions

This paper proposes control laws derived from energy functions considering an independent control of active and reactive powers of a wind farm.

As a consequence of the Energy approach, the obtained control laws are not based on the linearization of the system. This assures a bigger domain of attraction of the wind farm contribution indicating than, even under severe disturbances, the proposed control laws will contribute to the network stability.

Meanwhile, for the non-linear control law of the reactive power, the wind farm emulated the behavior of a static compensator, for the active power it was demonstrated that it is possible to justify the linear (proportional and derivative) control from a Lyapunov approach. Indeed, after considering wind farms as power plants could be shown that proportional and derivative (inertial effect) laws of the wind farms contributed to the stability of the network.

It is important to note the local nature of the signals used for control laws. This characteristic of the chosen signals with the Energy Function employed avoid any coordination with the rest of the system. Additionally, the damping is not dependent on the type of load, nor the power flow direction and neither the kind of failures.

Finally, simulation results agreed with the theoretical ones.

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Appendix. Data

Wind turbine: $P = 700$ kw at $\upsilon = 11.75$ m/s; $r = 22$ m; $\rho = 1.224$; $C_p(\lambda) = 1.206 \times 10^{-5}\lambda^7 - 2.71 \times 10^{-4}\lambda^6 + 2.0399 \times 10^{-3}\lambda^5 - 6.519 \times 10^{-3}\lambda^4 + 1.257 \times 10^{-2}\lambda^3 - 1.54 \times 10^{-2}\lambda^2 + 2.85 \times 10^{-2}\lambda - 4.05 \times 10^{-2}$.

DFIG: $V = 690$ V; $Rs = 0.0067\ \Omega$; $P = 4$; $Ls = 0.0075$ Hy; $Lm = 0.0061$ Hy; $Lr = 0.0084$ Hy; $Rr = 0.187$ Hy; $a = 0.3806$ turns ratio; $J_{t+mi} = 536\,096.59$ kg m^2.

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Esquema de una red eléctrica moderna

European Smart Grids. Vision and Strategy for Europe’s electricity Networks of the future

Esquema de una red eléctrica moderna

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Sistema de generación grande

Esquema de una red eléctrica moderna

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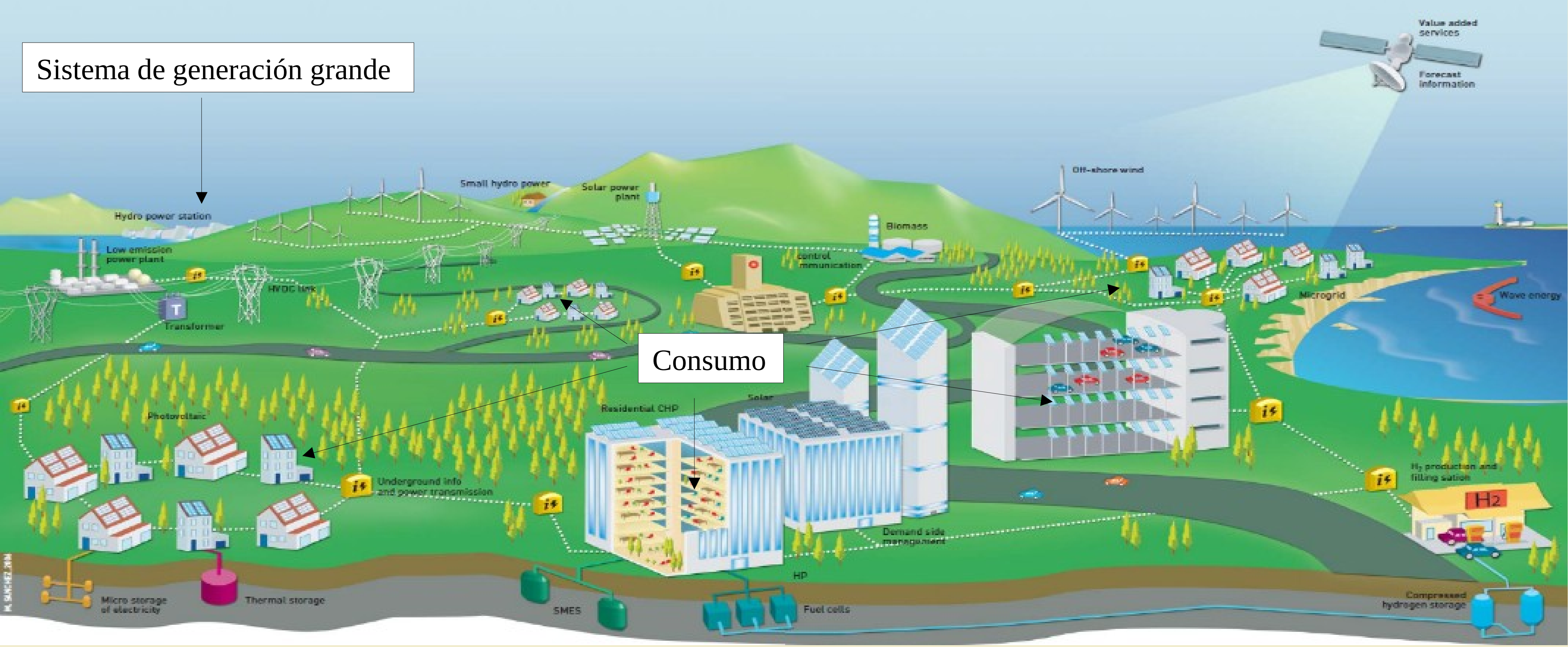

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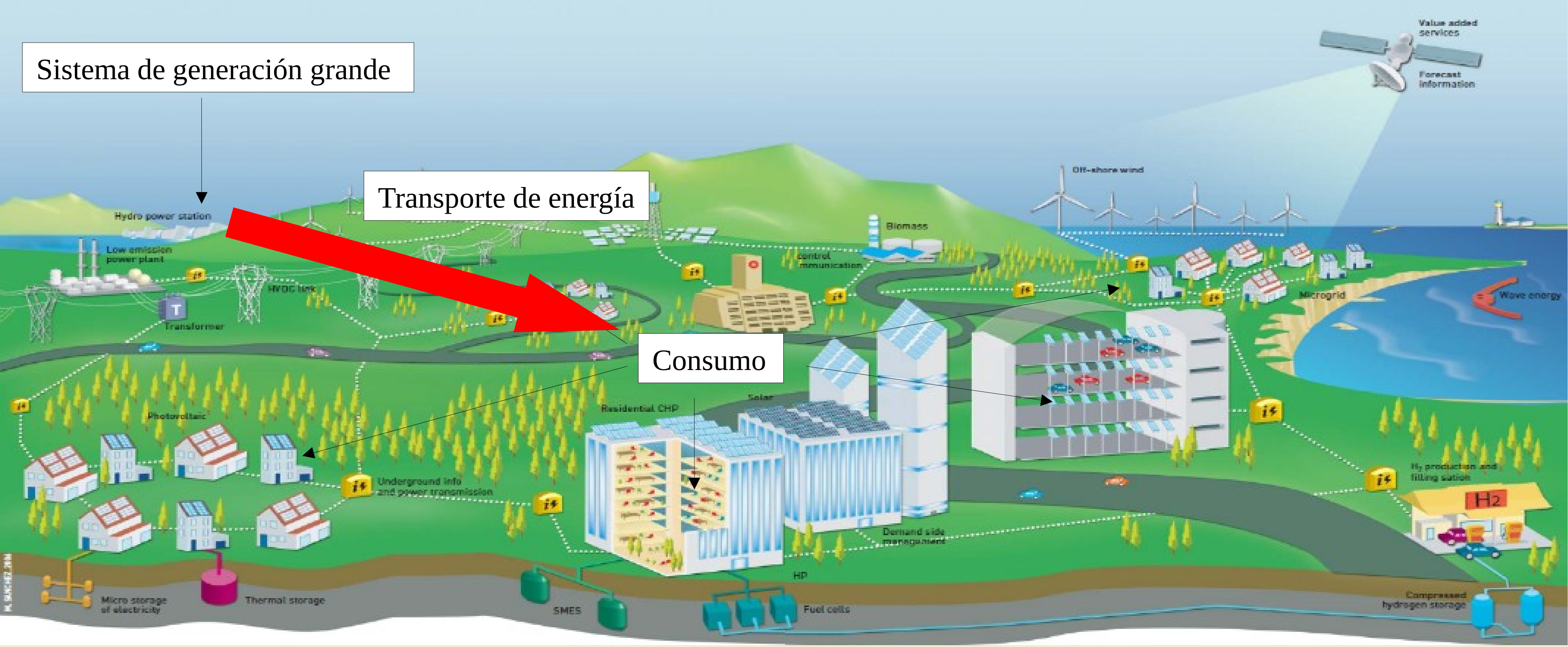

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Sistema de generación grande junto a varios sistemas (más chicos) dispersos

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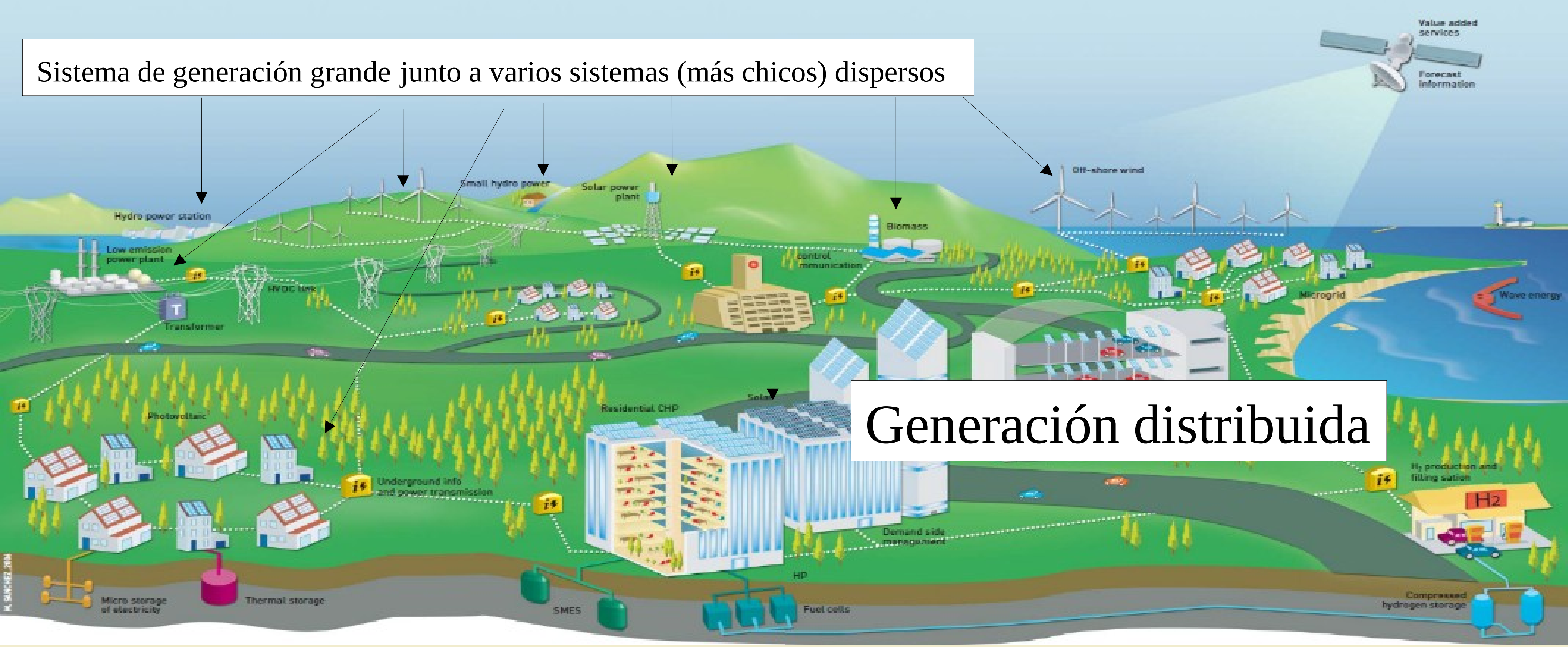

Generación distribuida

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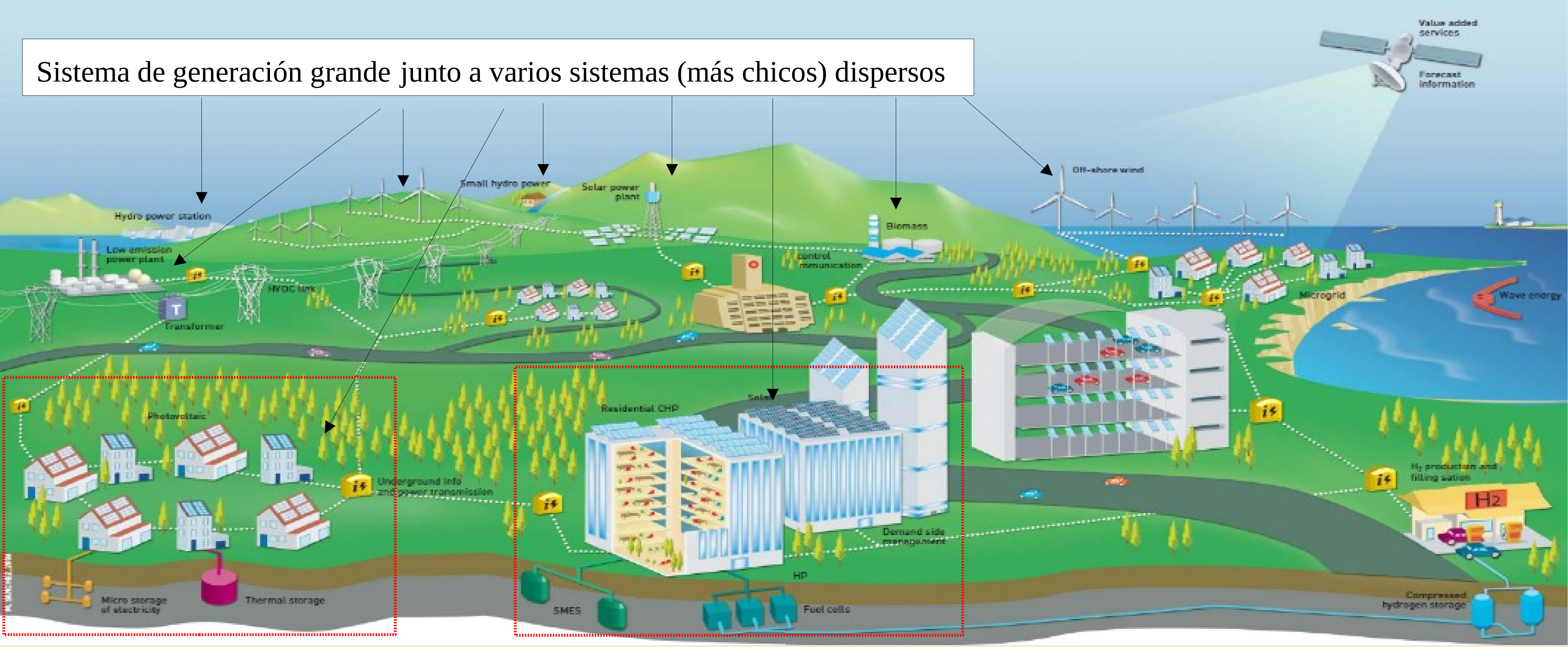
European Smart Grids. Vision and Strategy for Europe’s electricity Networks of the future

Sistema de generación grande junto a varios sistemas (más chicos) dispersos



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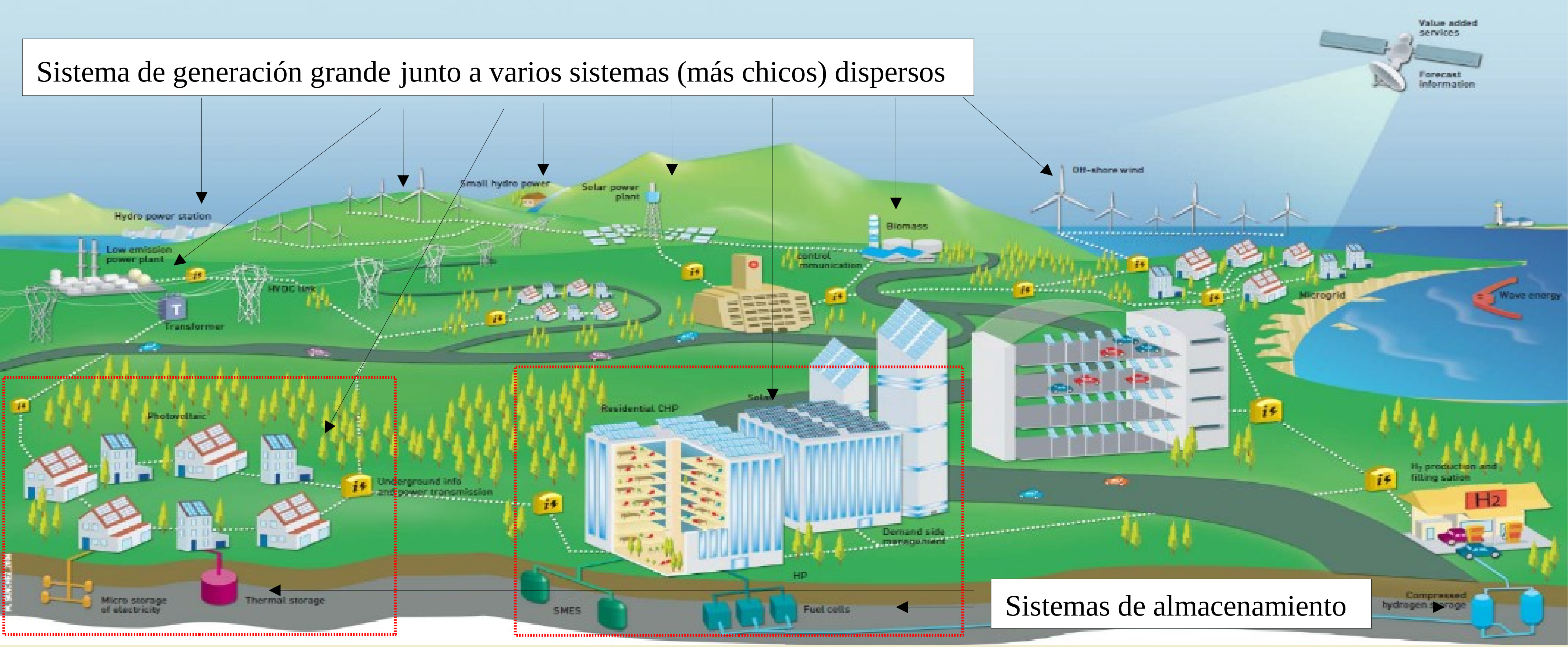

Sistemas de almacenamiento

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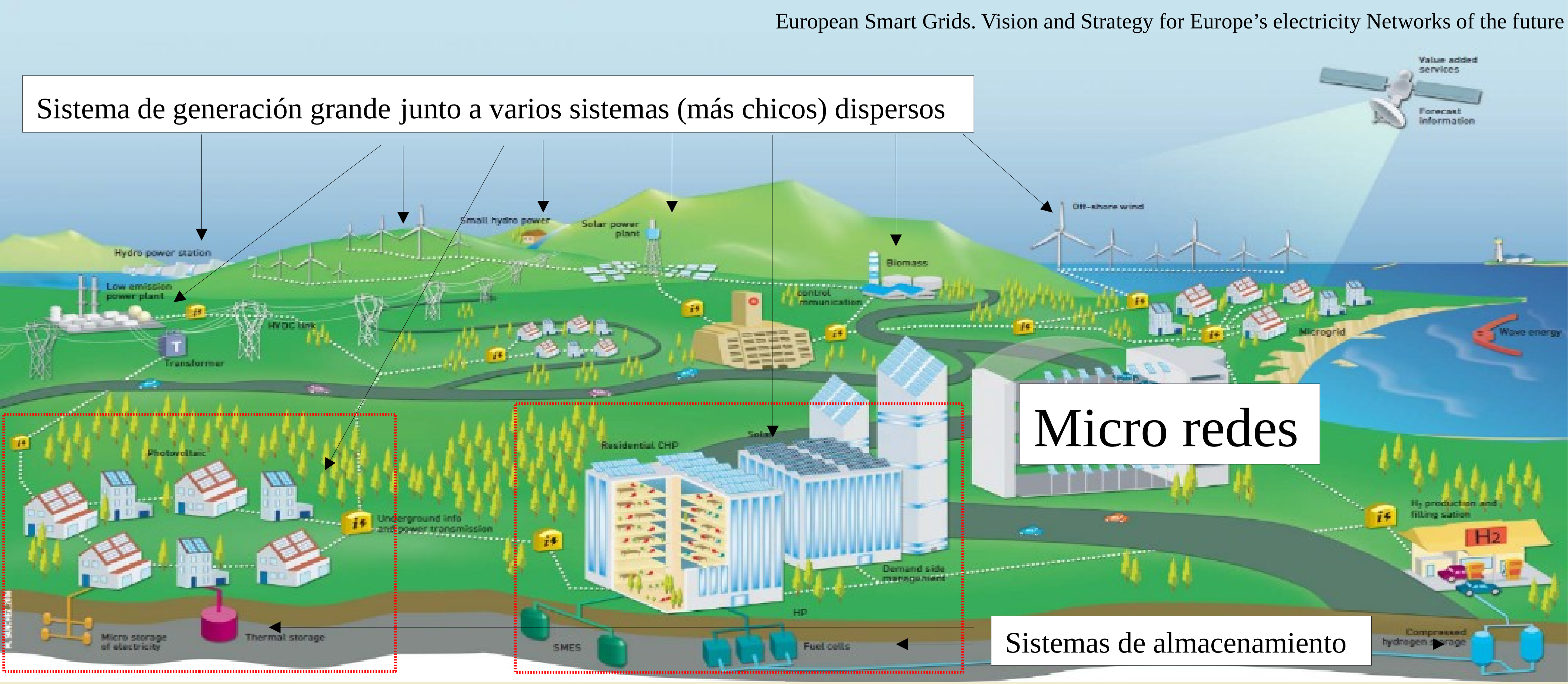

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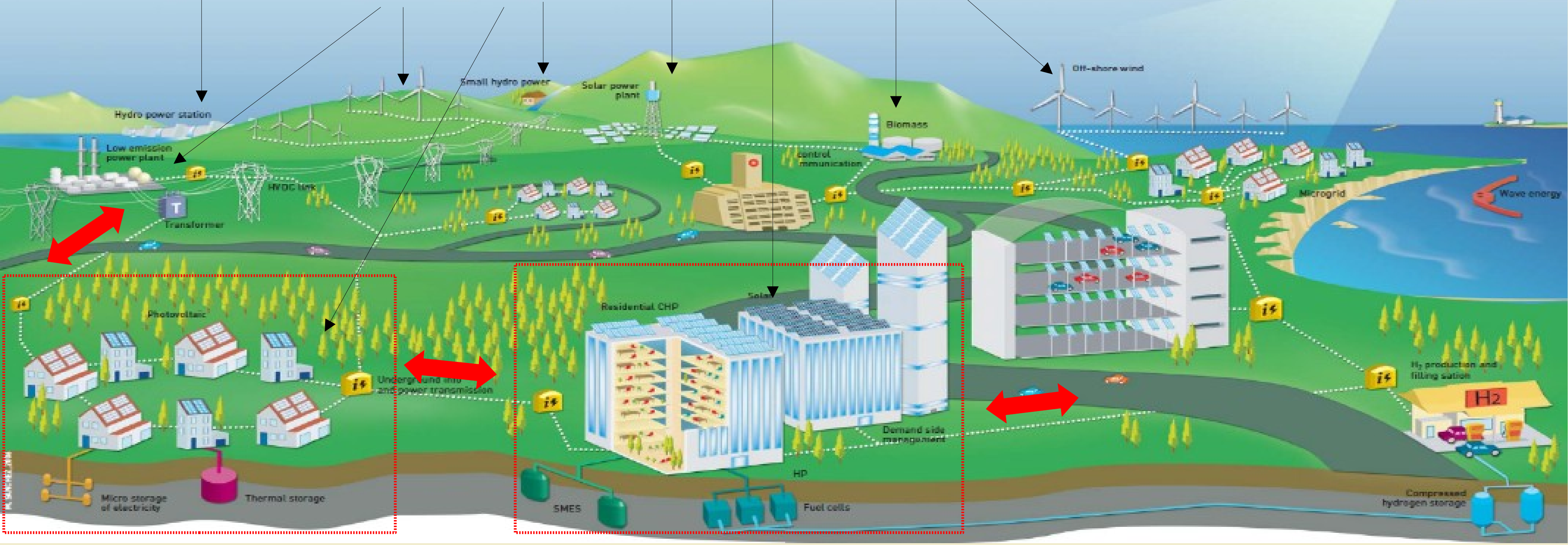

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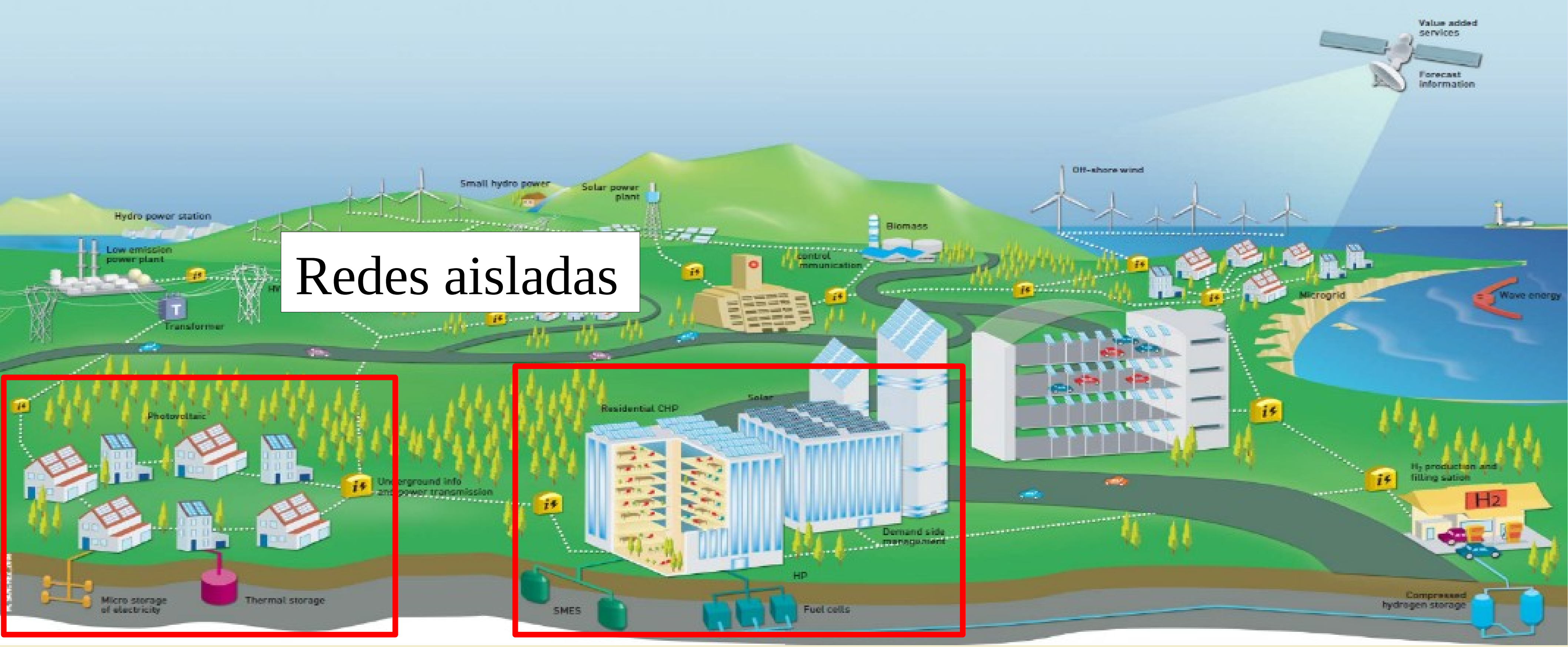
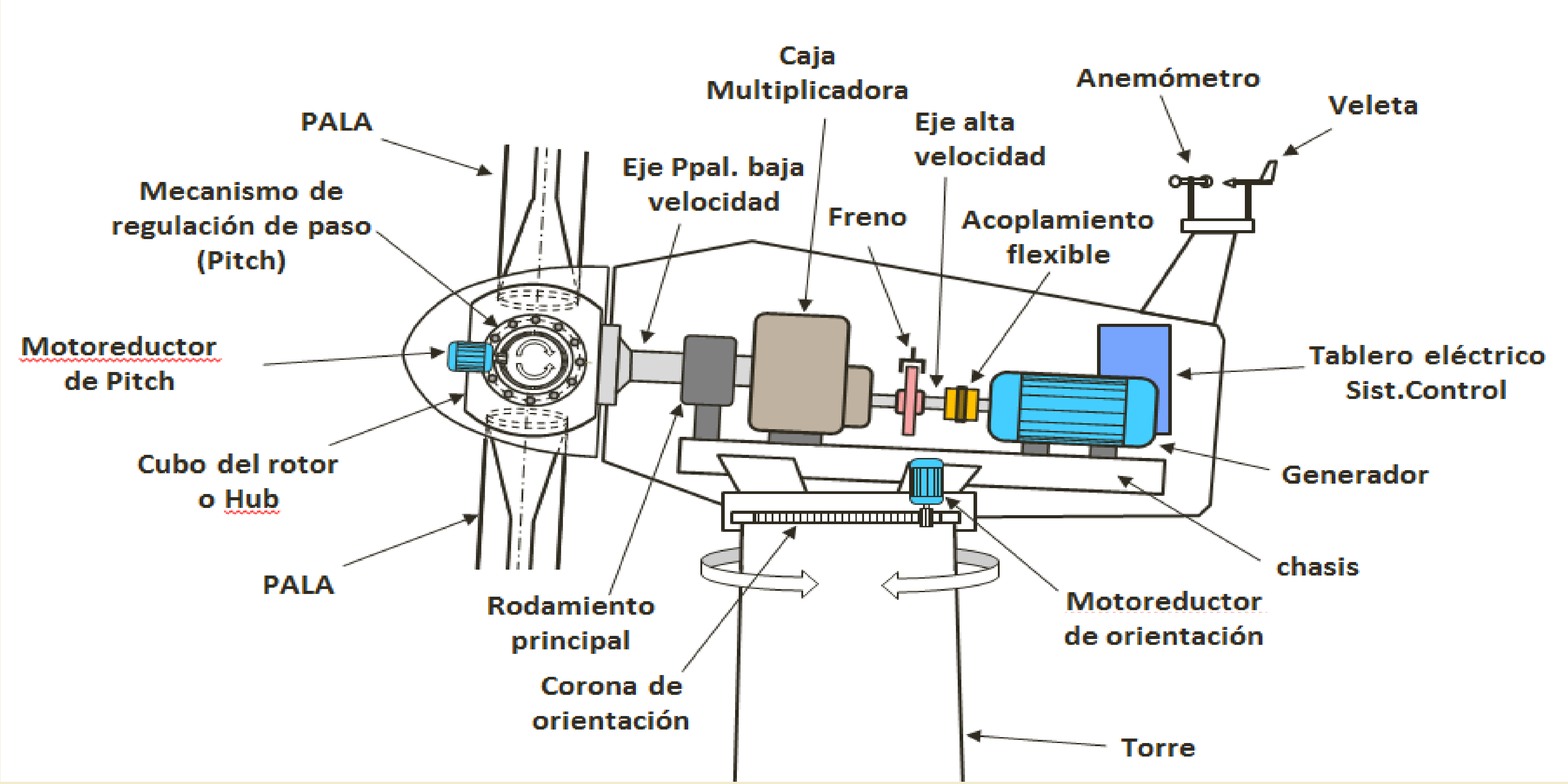


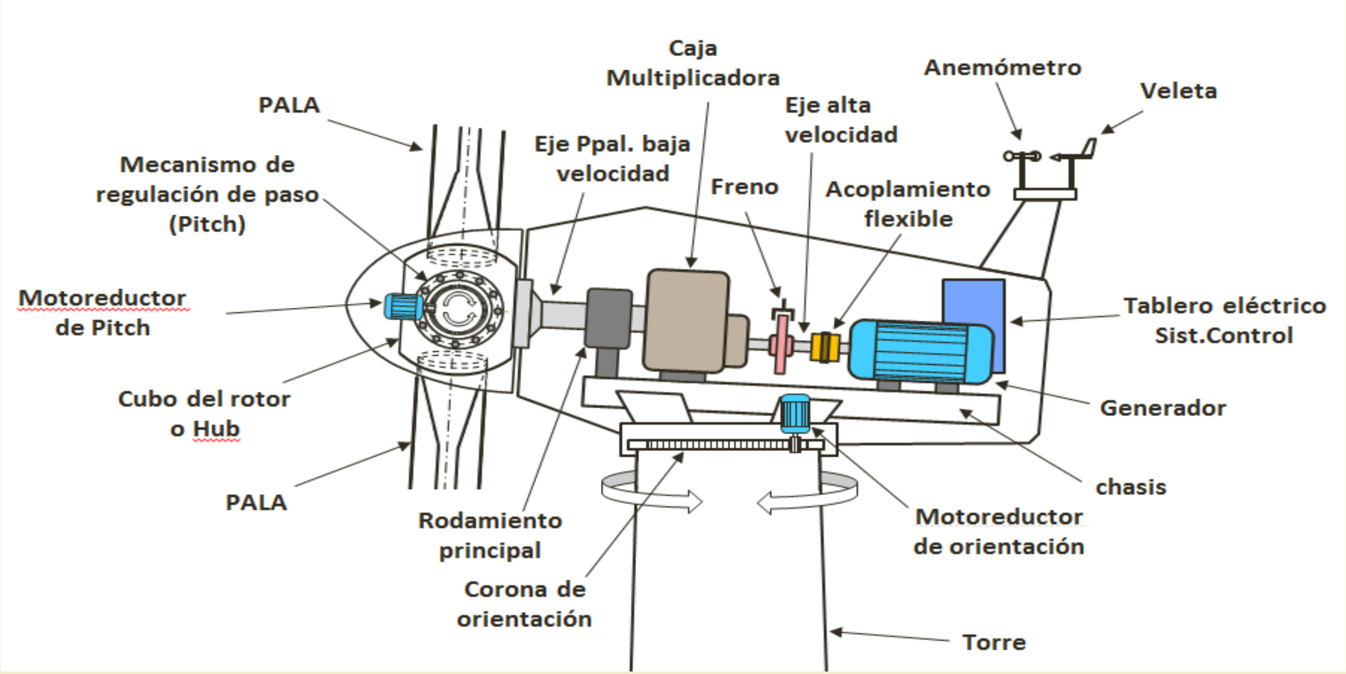
Actividades de investigación

→ Control de aerogeneradores



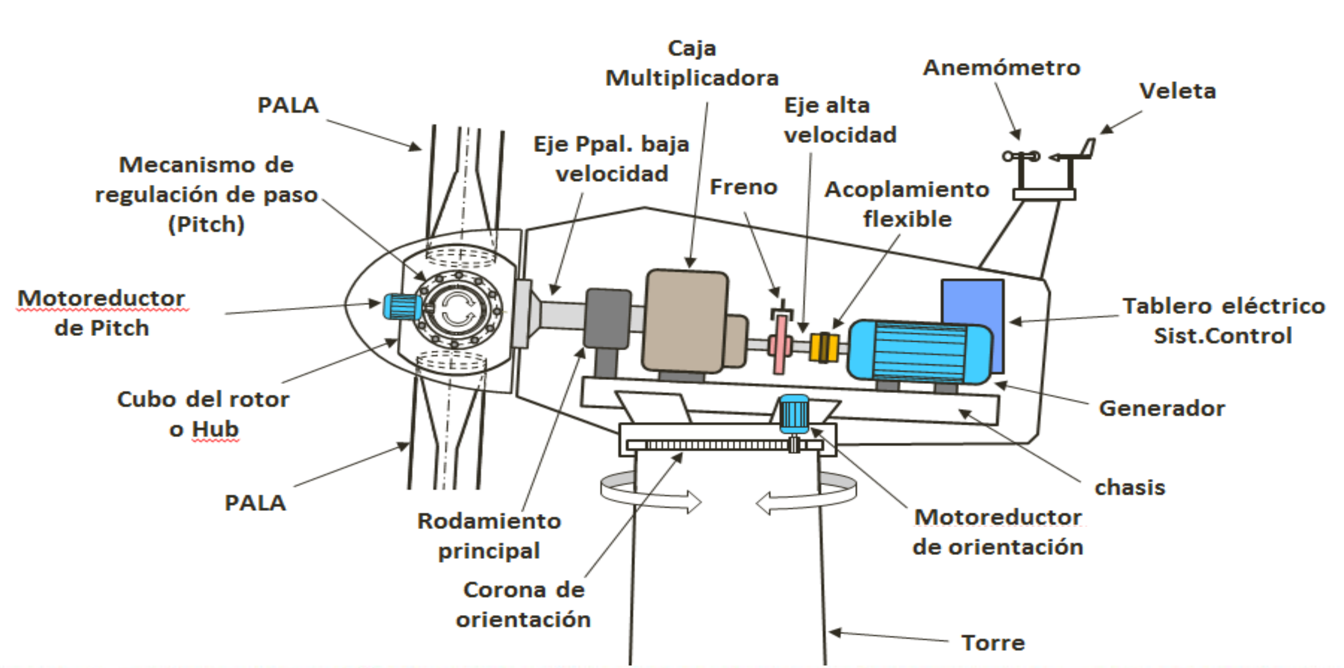
Actividades de investigación

→ Control de aerogeneradores



Actividades de investigación

→ Control de aerogeneradores



DISEÑO DE UNA TURBINA EÓLICA DE BAJA POTENCIA ADECUADA A LA AGRESIVIDAD DEL CLIMA PATAGÓNICO

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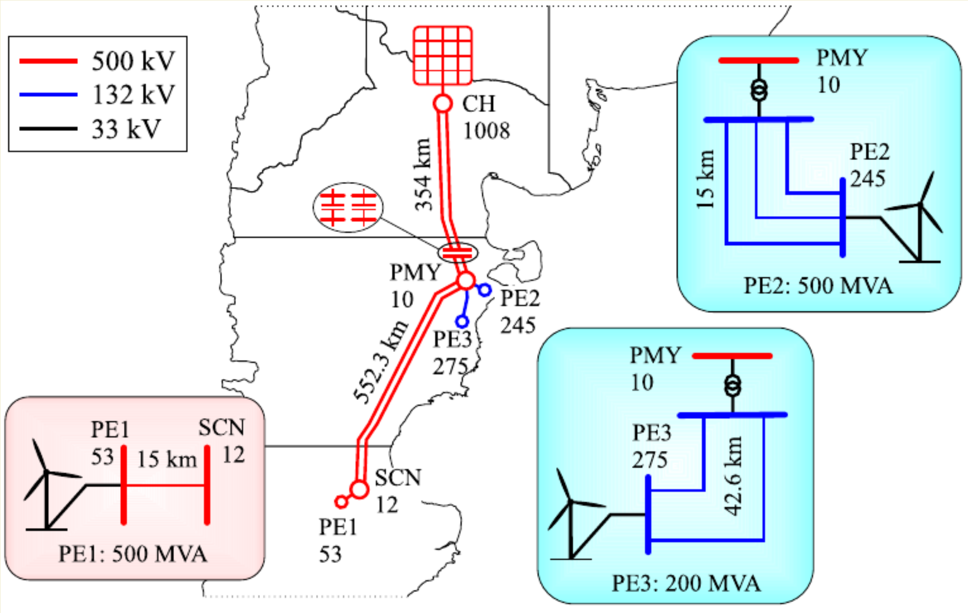
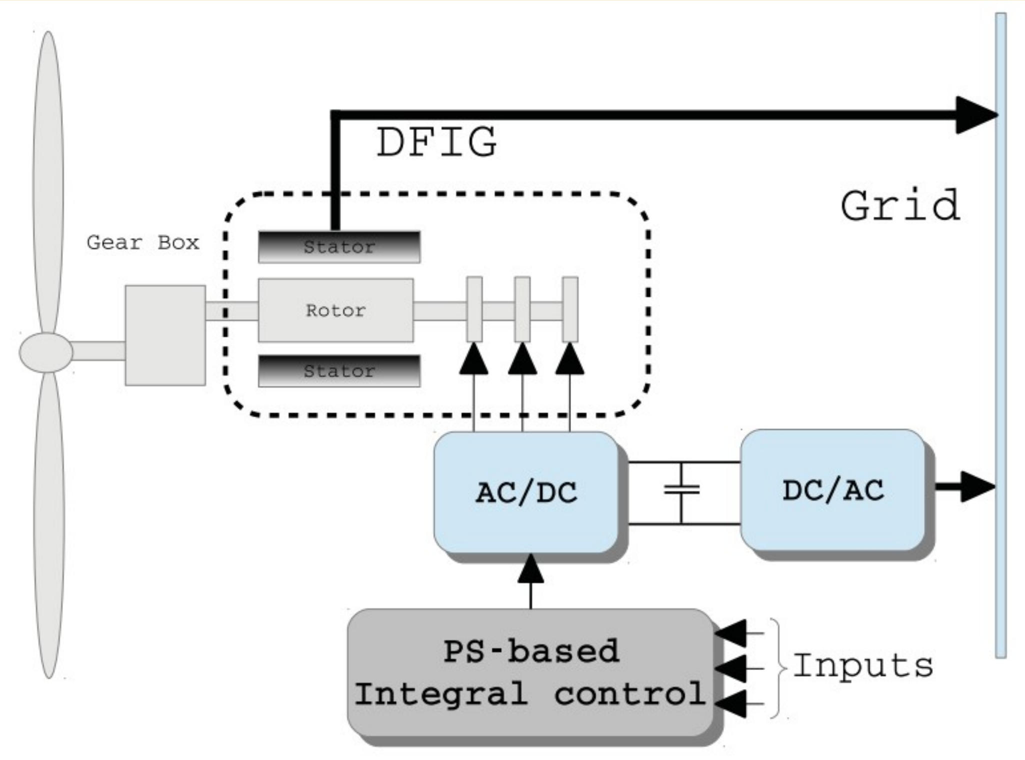
[(1)] Universidad Nacional de la Patagonia San Juan Bosco, Ruta Prov. N°1 s/n, Ciudad Universitaria Km4, (CP 9000), Comodoro Rivadavia, Argentina

Actividades de investigación

→ Control de aerogeneradores





Passivity and Lyapunov based controls of a Wind Energy Conversion System

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Power-based control with integral action for wind turbines connected to the grid

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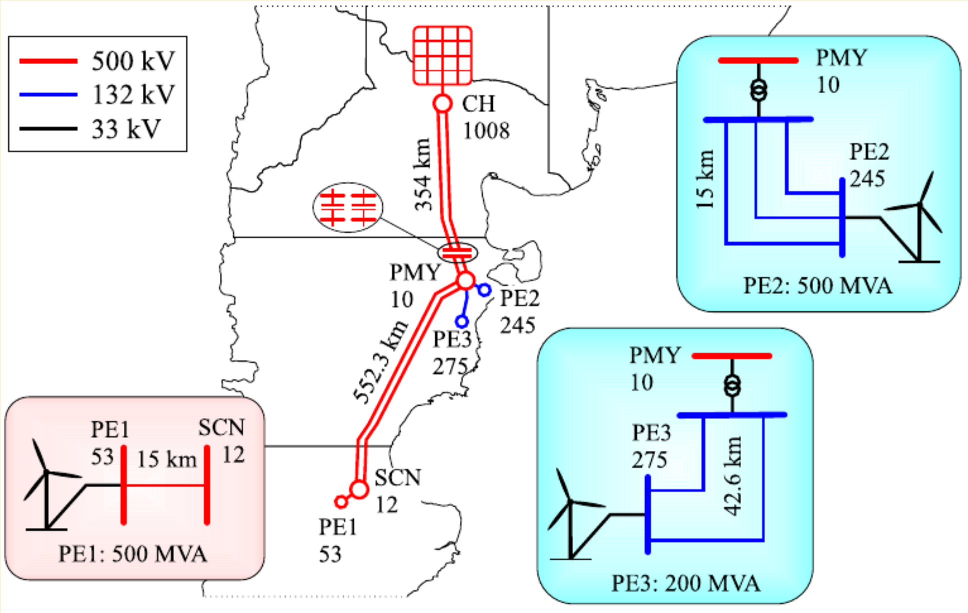
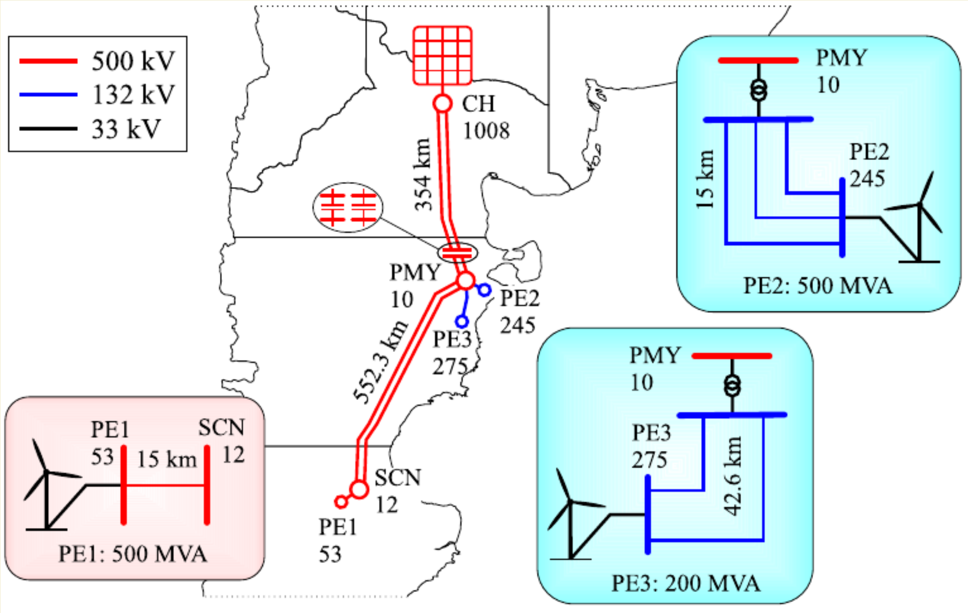
Actividades de investigación

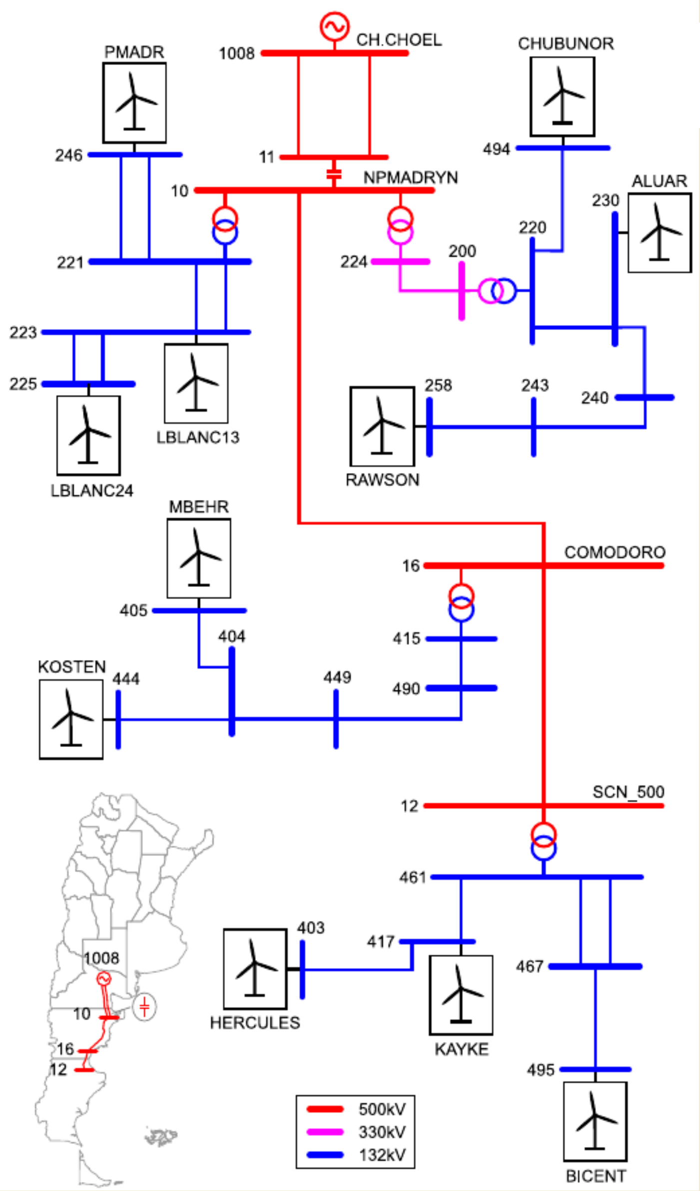
→ Interacciones subsincrónicas



Actividades de investigación

→ Interacciones subsincrónicas





Subsynchronous control interaction studies in DFIG-based wind farms using selective modal analysis

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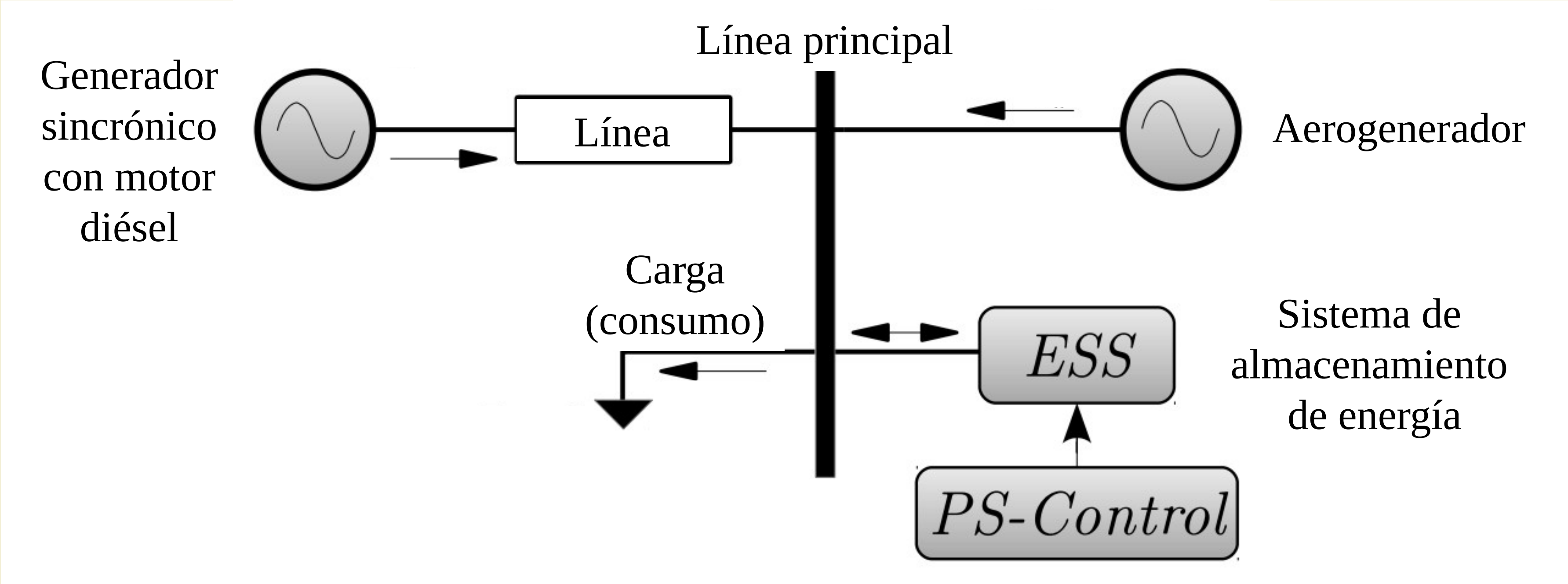
Actividades de investigación

→ Micro Redes



Passivity-based control of energy storage units in Distributed Generation Systems

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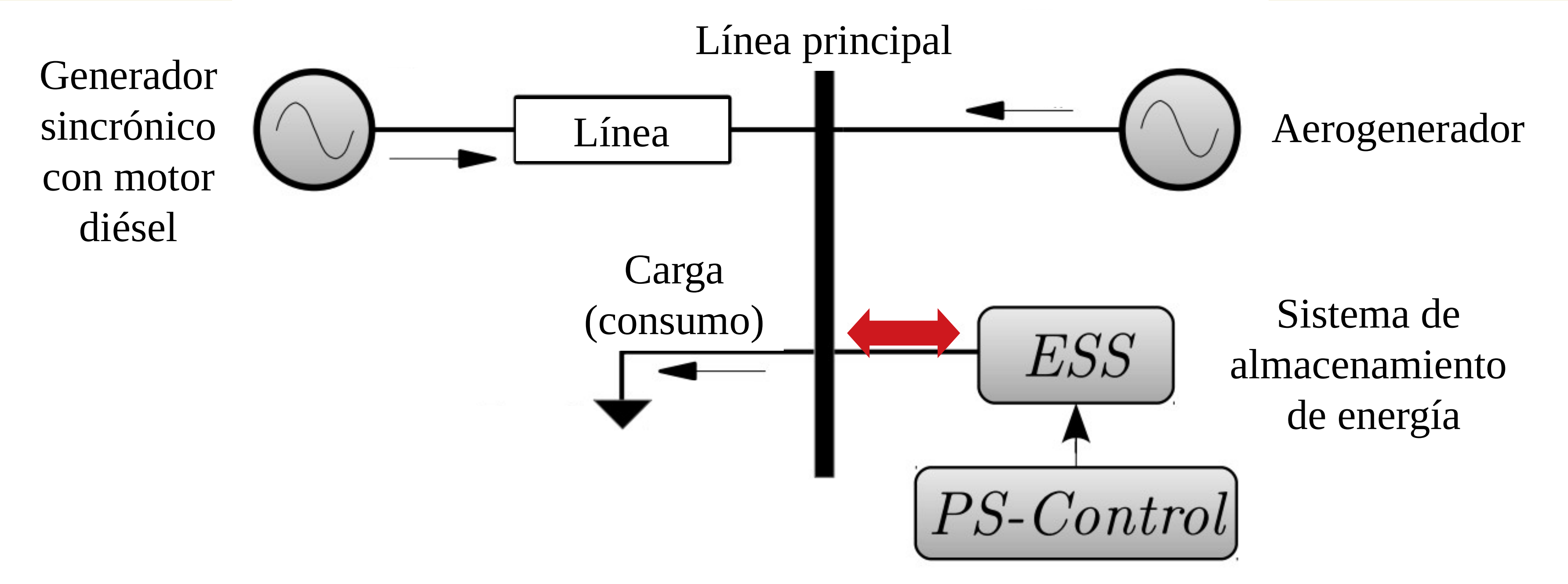
§Comisión de Investigaciones Científicas de la Provincia de Buenos Aires, Argentina.

Actividades de investigación

→ Micro Redes



Passivity-based control of energy storage units in Distributed Generation Systems

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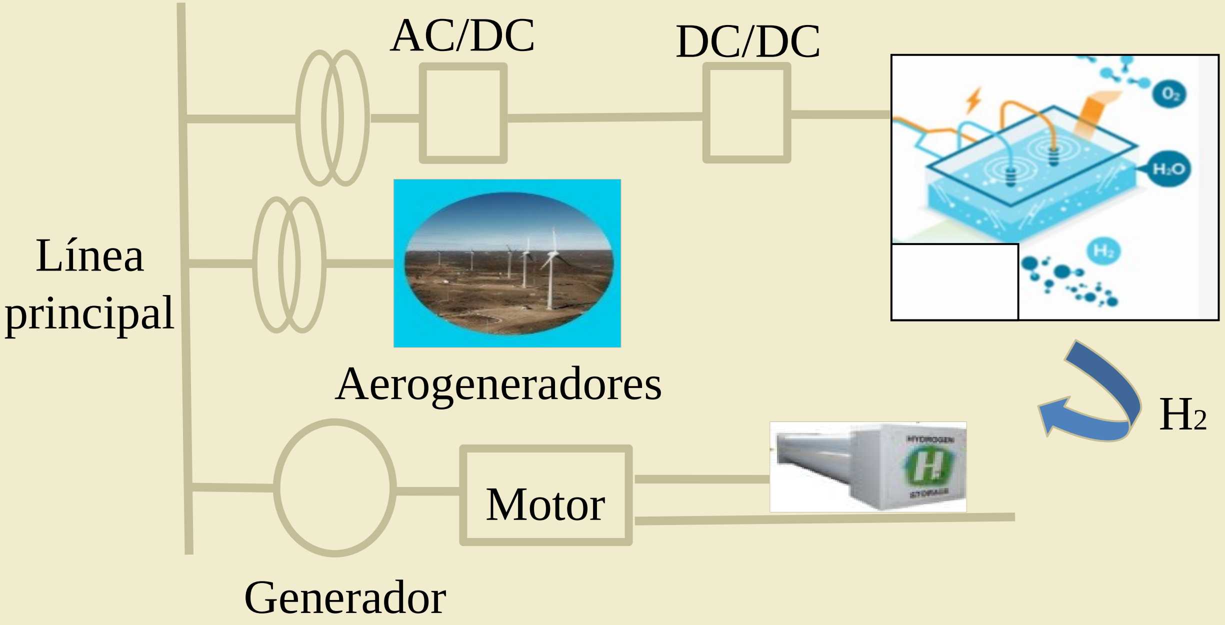
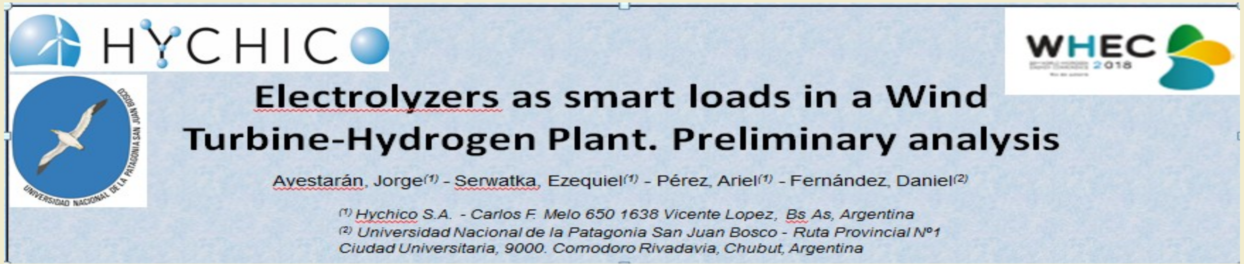
§Comisión de Investigaciones Científicas de la Provincia de Buenos Aires, Argentina.

Actividades de investigación

→ Control de electrolizadores para micro redes





HYCHICO

WHEC 2018

Electrolyzers as smart loads in a Wind Turbine-Hydrogen Plant. Preliminary analysis

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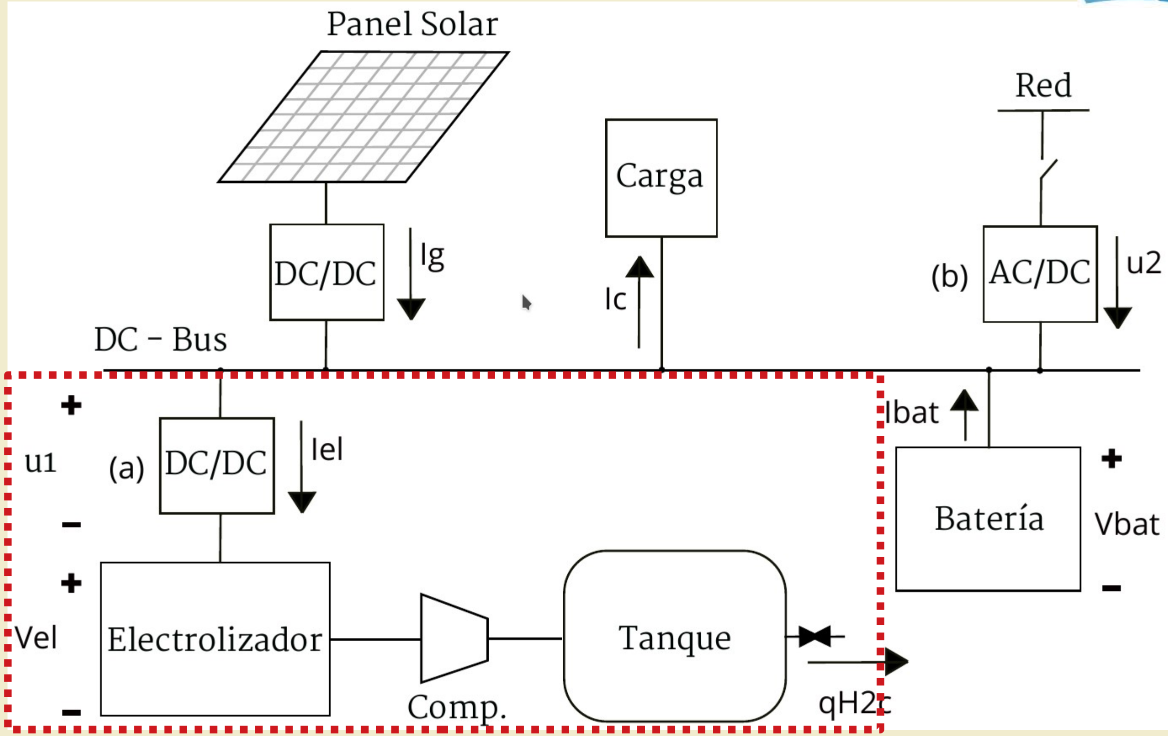
(2) Universidad Nacional de la Patagonia San Juan Bosco - Ruta Provincial Nº1 Ciudad Universitaria, 9000. Comodoro Rivadavia, Chubut, Argentina

Actividades de investigación

→ Control de electrolizadores para micro redes



Control Predictivo con Restricciones Débiles para Micro-Red de Producción y Despacho de Hidrógeno

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La Plata, Argentina.

Daniel Fernández
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Comodoro Rivadavia, Argentina.

Ricardo Mantz
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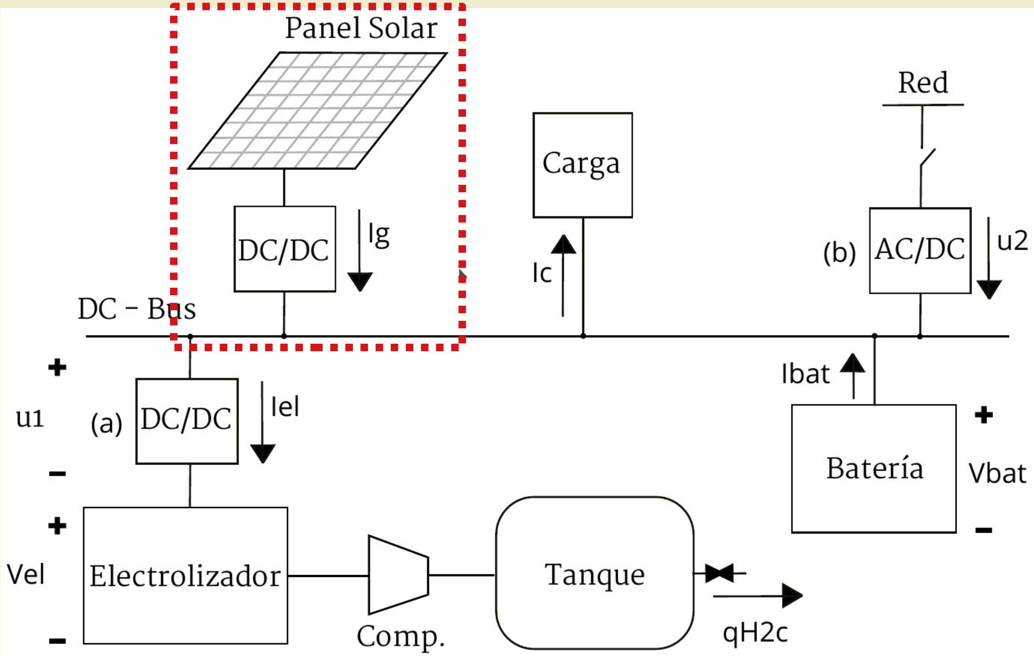
La Plata, Argentina.

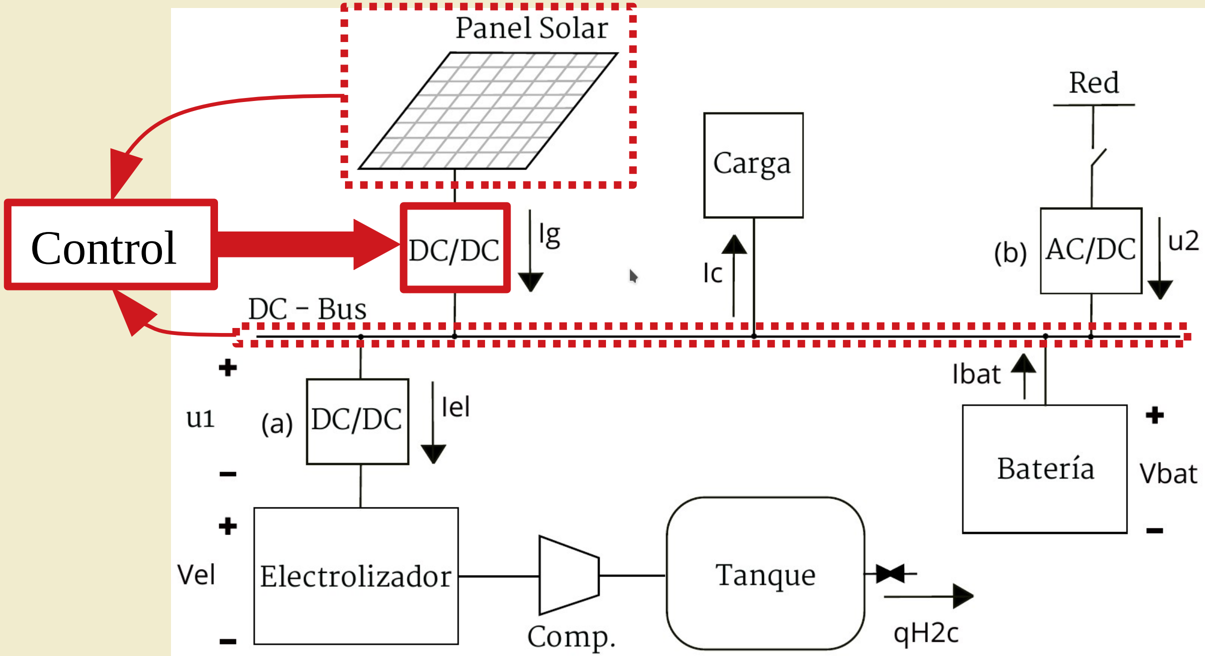
Actividades de investigación

→ Seguimiento de máximo de potencia en paneles solares



Actividades de investigación

→ Seguimiento de máximo de potencia en paneles solares



MPPT for a photovoltaic system under partial shaded conditions

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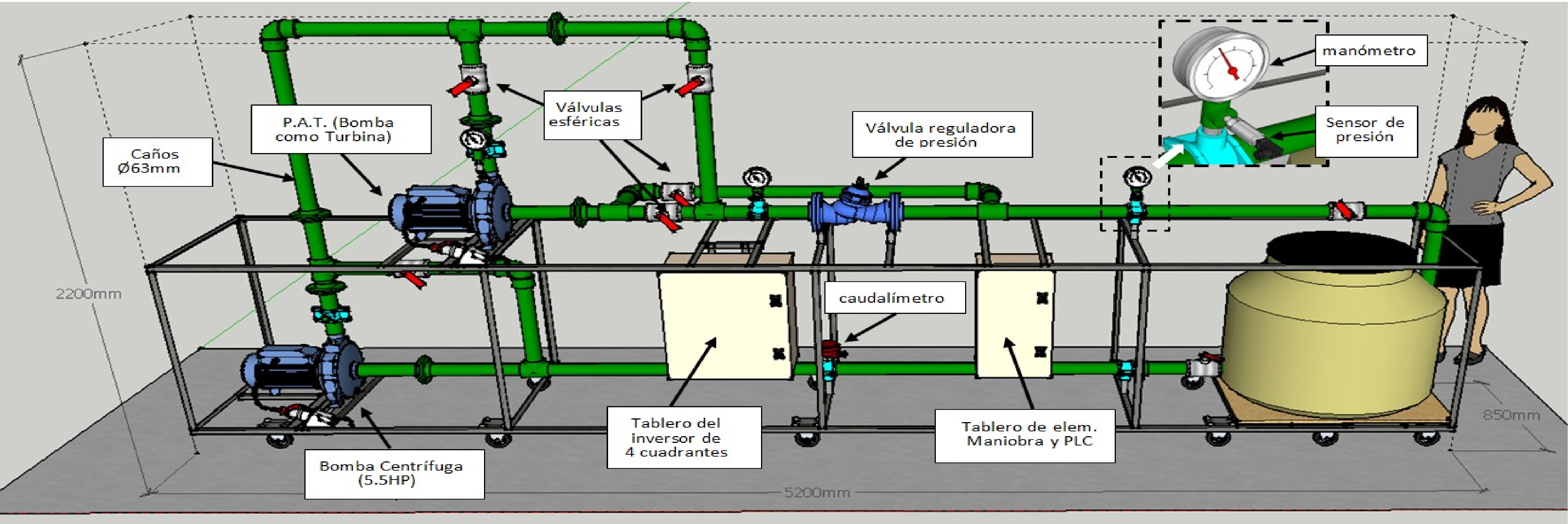
Actividades de investigación

→ Control de presión y recuperación de energía



A Modbus client for the identification of an energy recovery system for a water distribution network

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Control and modeling of a centrifugal pump used as a turbine in an energy recovery system

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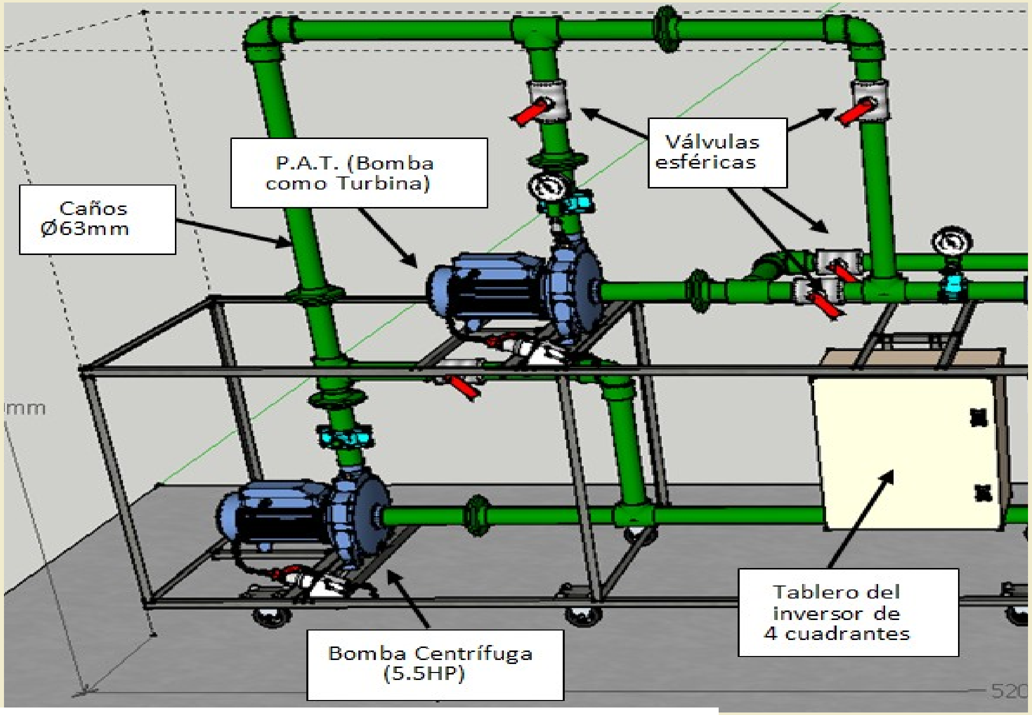
Actividades de investigación

→ Control de presión y recuperación de energía



Control of a centrifugal pump as a turbine in an energy recovery system

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Producción científica (2018 en adelante)

- NICOLÁS E. COSTA, GUSTAVO REVEL, DIEGO M. ALONSO, ROBERTO D. FERNÁNDEZ. Subsynchronous Control Interaction studies in DFIG-based wind farms using Selective Modal Analysis. Journal of Electrical Power and Energy Systems. Volumen 123. Diciembre 2020.

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- MARTÍNEZ LEANDRO; ROBERTO DANIEL FERNANDEZ; RICARDO MANTZ; PEDRO BATTAIOTTO. Evaluación y control de sistemas de producción de hidrógeno como cargas inteligentes en micro redes con alta penetración de generación renovable. V Jornadas de Investigación, Transferencia y Extensión de la Facultad de Ingeniería de la Universidad Nacional de La Plata.

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Producción científica (2018 en adelante)

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Producción científica pendiente de revisión (hasta agosto 2020)

- ROBERTO DANIEL FERNÁNDEZ; FERNANDO VALENCIAGA; RAMIRO PEÑA. Wind Energy Conversion System under asymmetrical voltage failures. Analysis and nonlinear control. Asian Journal of Control.

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