X SICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

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Modeling and simulation of the integration of a Power-to-Gas plant in a power system network

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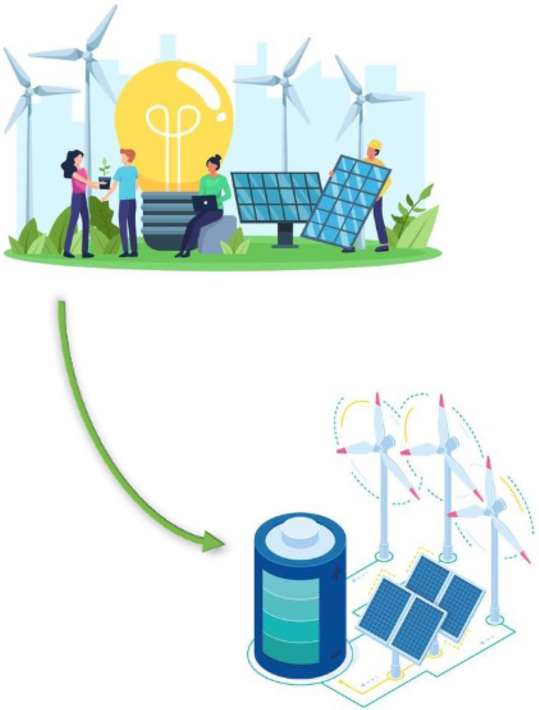
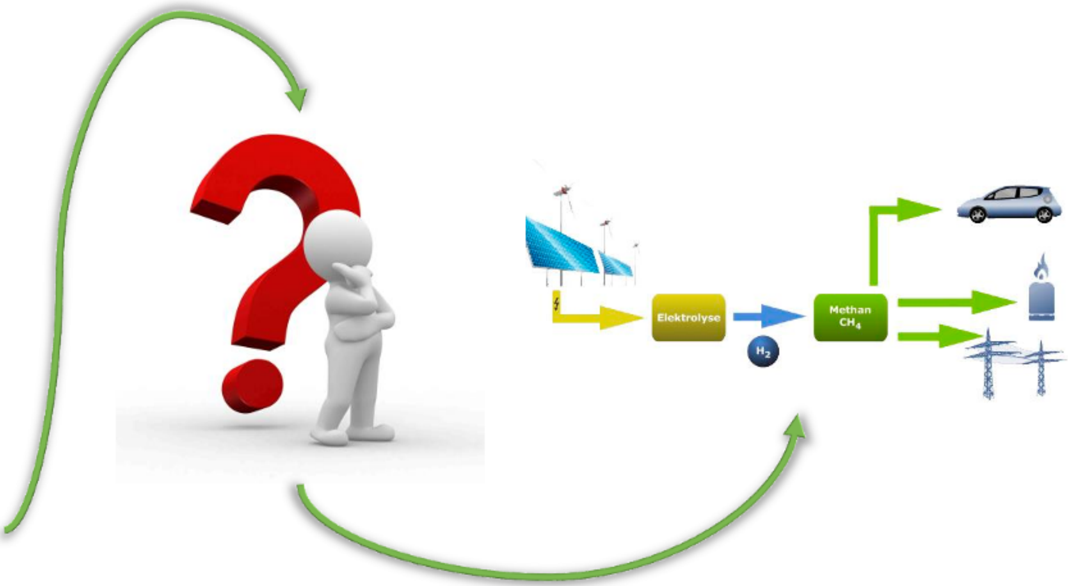
I. Introduction





Reference

- https://image.freepik.com/vector-gratis/concepto-energia-limpia-energia-renovable-futuro-mejor-personas-energia-ecologica-panel-solar-aerogenerador-estilo-plano_7737-2028.jpg
- https://www.elespectador.com/economia/almacenar-energia-en-baterias-nueva-opcion-para-renovables-article/
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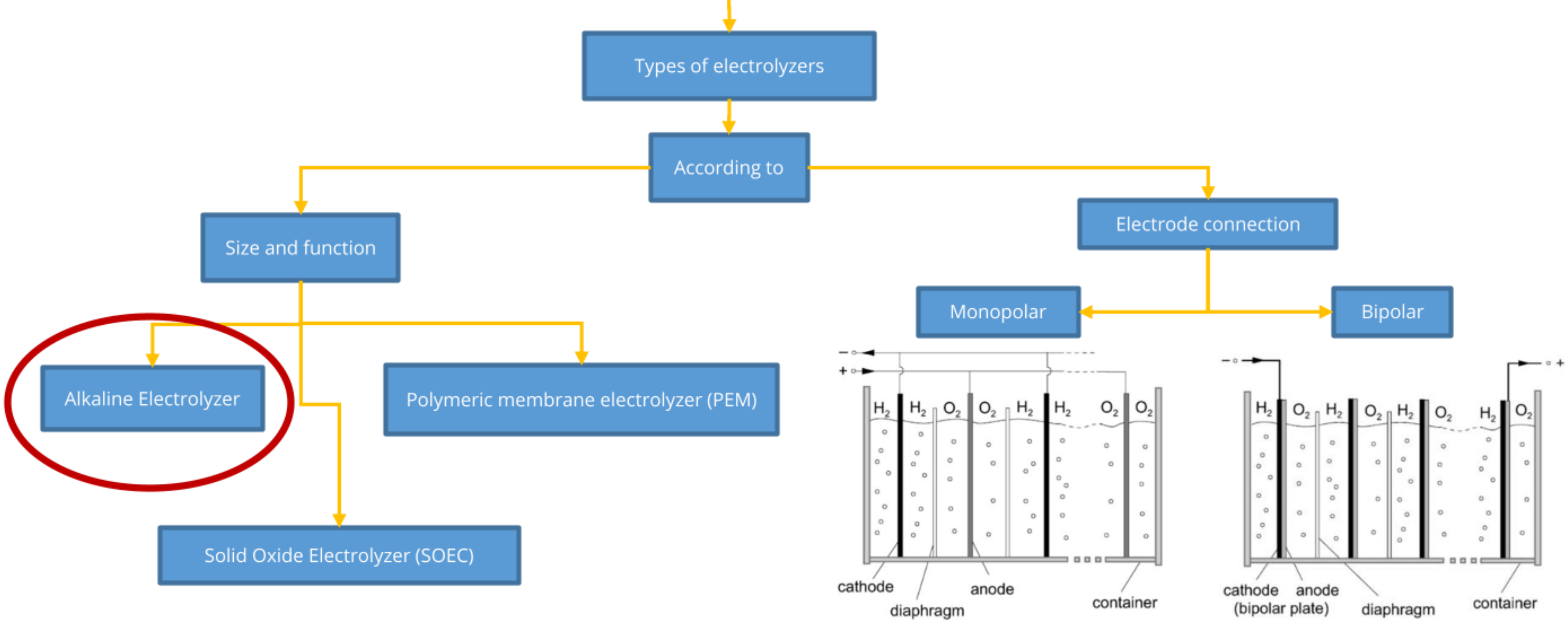
- https://greenbuildingelements.com/wp-content/uploads/2015/04/Methansynthese.jpg

II. Theoretical aspects

An electrolyzer is a device capable of separating water molecules into their constituent oxygen and hydrogen atoms.



Reference
Ø. Ulleberg, “Modeling of advanced alkaline electrolyzers: a system simulation approach,” Int. J. Hydrogen Energy, vol. 28, no. 1, pp. 21–33, Jan 2003.

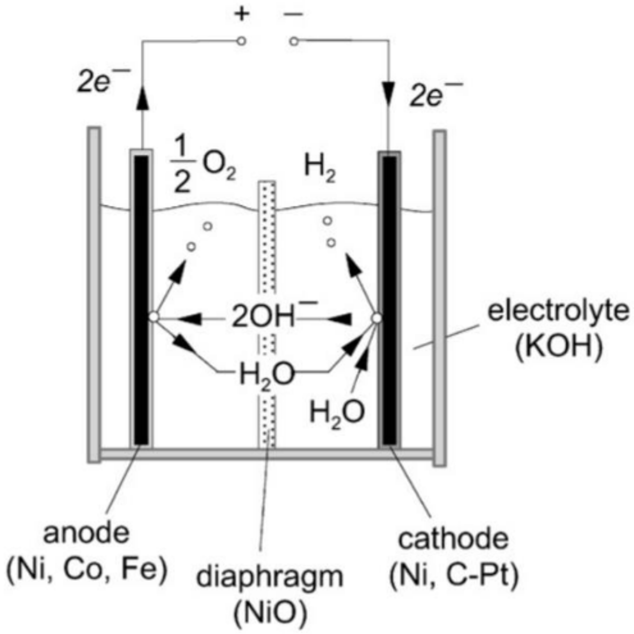
III. Proposed methodology

General equation of water electrolysis

$$H_2O + Electrical\ energy \rightarrow H_2(g) + \frac{1}{2}O_2(g)$$

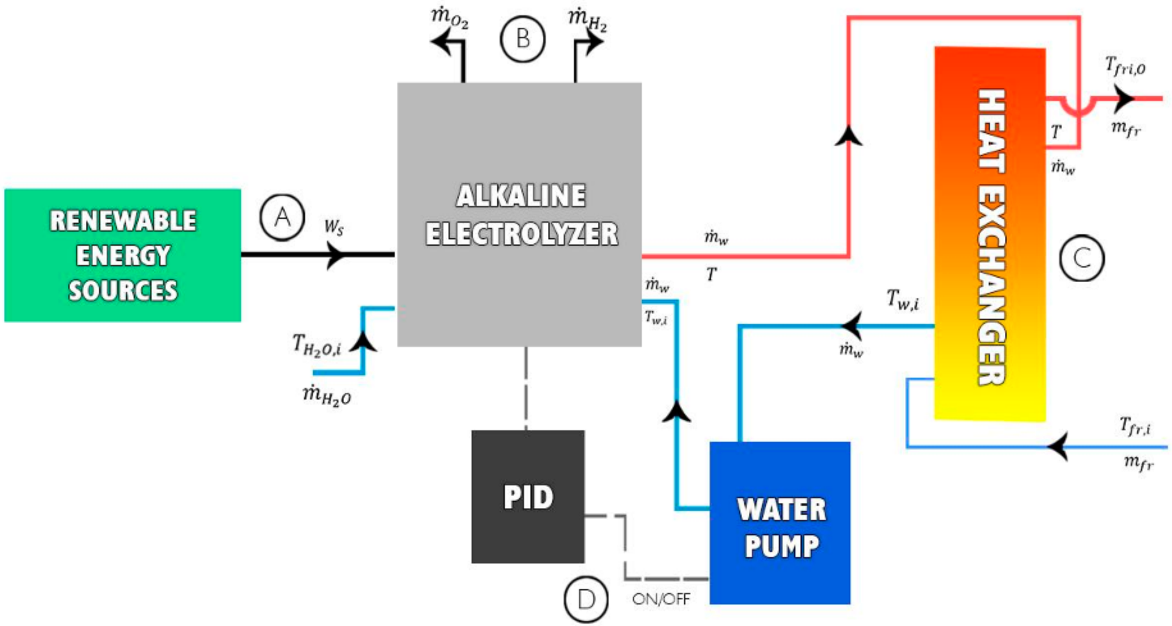
Anode: $2OH^-(aq) \rightarrow \frac{1}{2}O_2(g) + H_2O + 2e^-$

Cathode: $2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$



Reference
Ø. Ulleberg, "Modeling of advanced alkaline electrolyzers: a system simulation approach," Int. J. Hydrogen Energy, vol. 28, no. 1, pp. 21–33, Jan 2003.

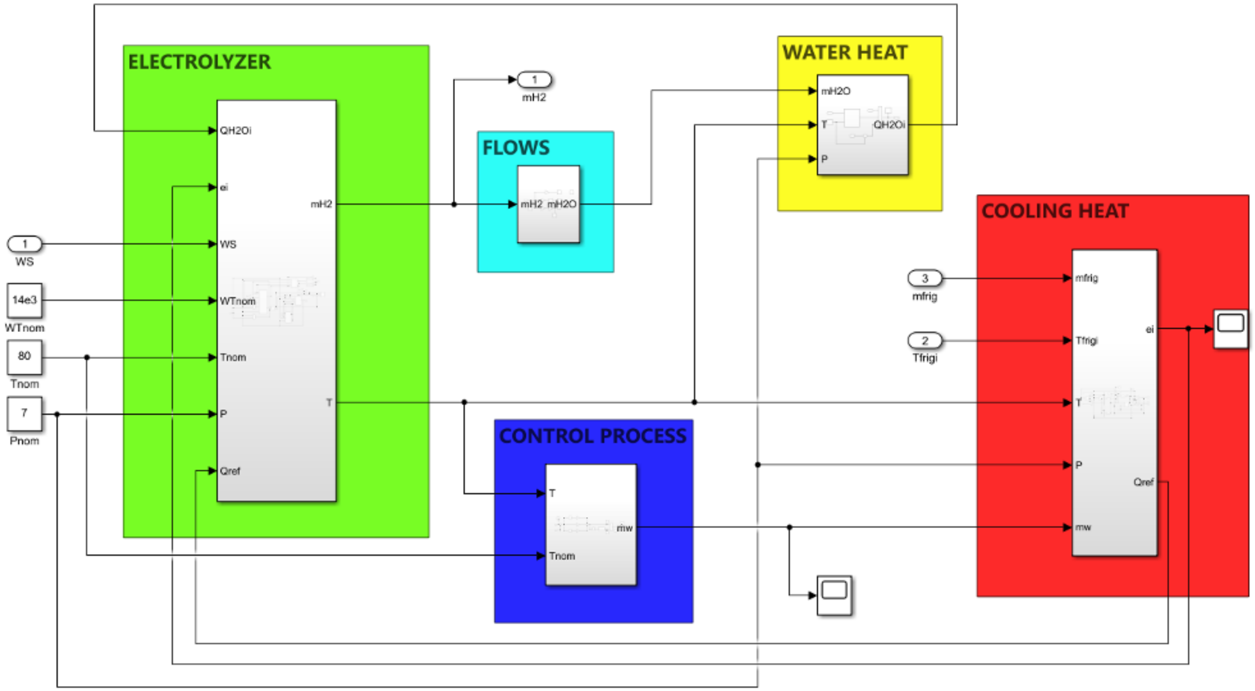
III.I. Power to Gas plant



Power-to-Gas plant.

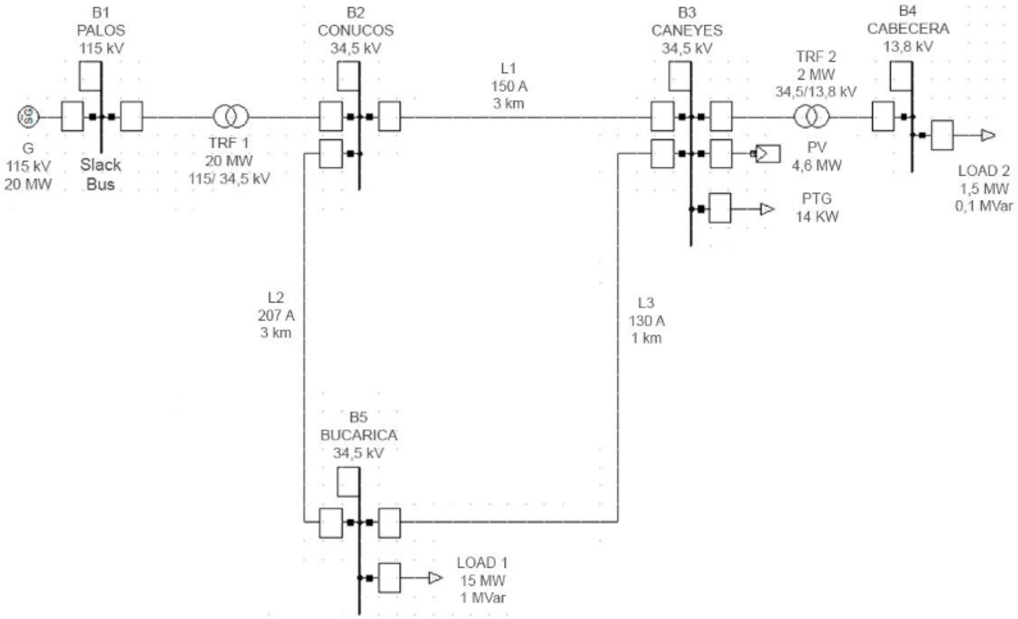
Parameter	Value
Electrode area	0,25 m^2
Number of cells (series)	21
Number of cells (parallel)	1
Thermal capacity	625000 J/°C
Thermal resistance	0,167 °C/W
Maximum power	26 kW
Nominal power	14 kW
Nominal e. current	350 A
Nominal temperature	80°C
Nominal pressure	7 bar
Water flow rate	0,2 kg/s
Water temperature	10 °C
Heat exchanger UA	100 W/°C

III.II. Power to Gas plant implemented in Simulink



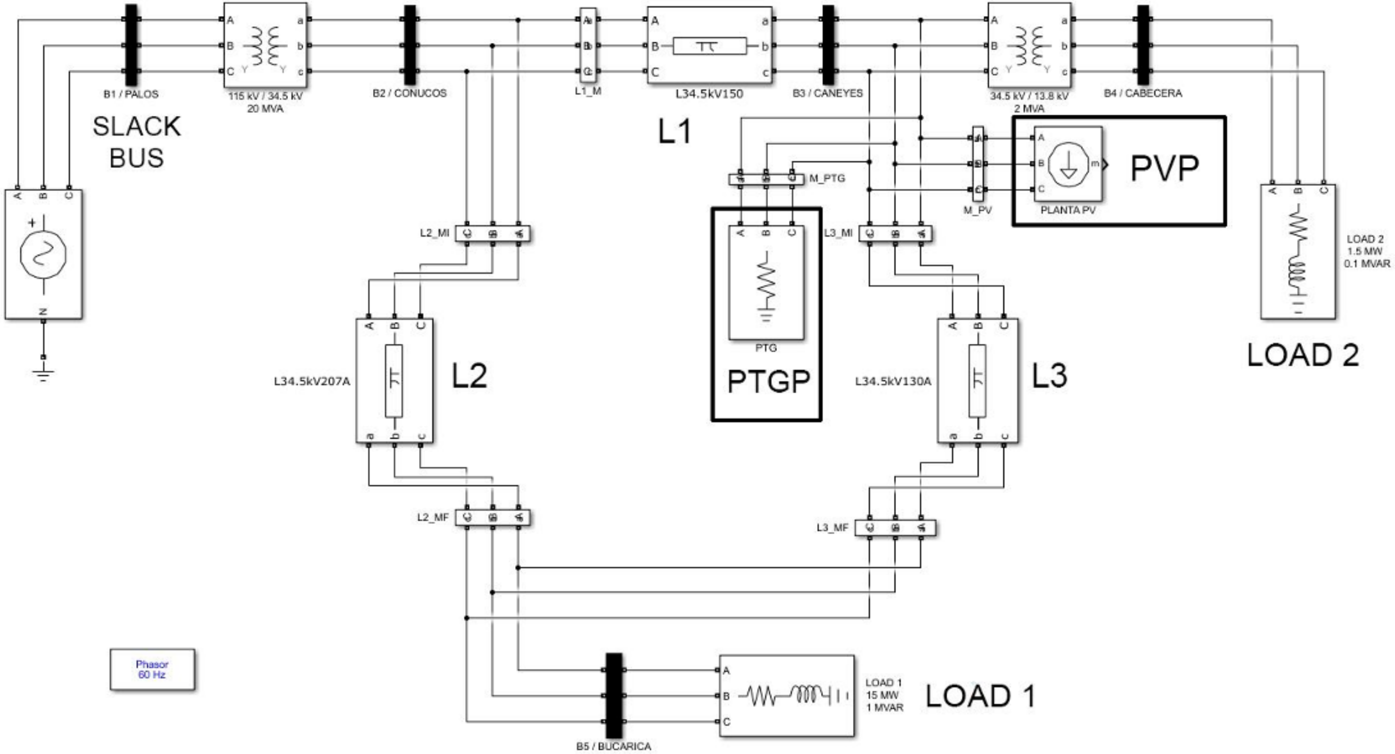
Power to Gas plant model implemented in Matlab Simulink.

III.II. One-line diagram of the power system



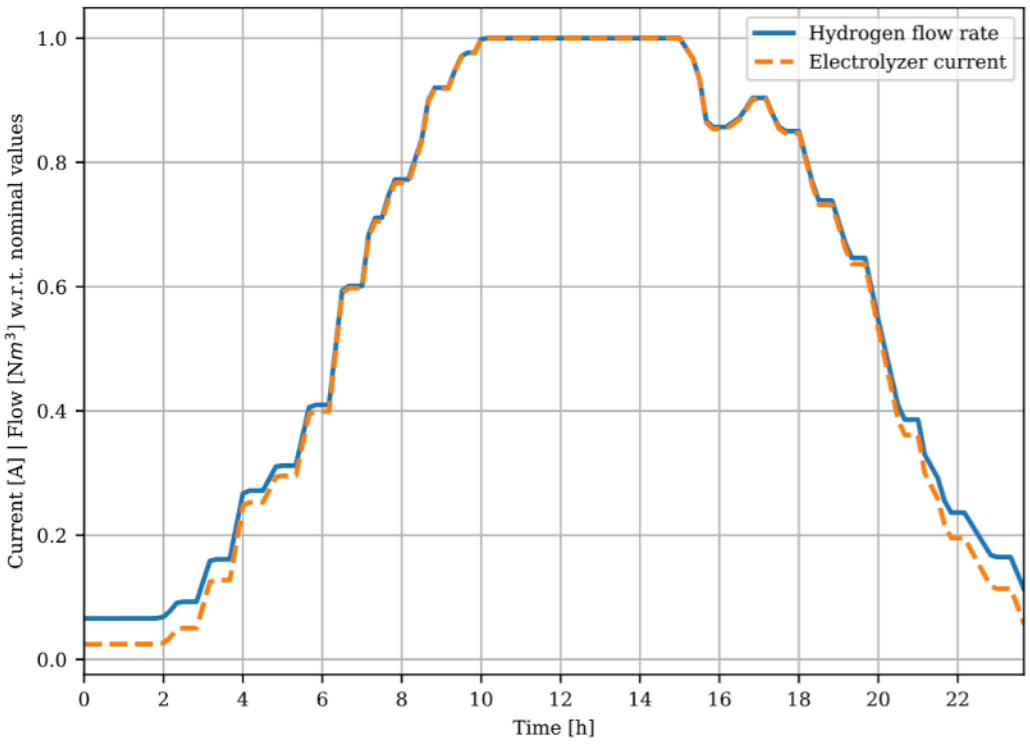
Bus	B1 PALOS 115 kV	
	B2 CONUCOS 34.5 kV	
	B3 CANEYES 34.5 kV	
	B4 CABECERA 13.8 kV	
	B5 BUCARICA 34.5 kV	
Transmission lines	L1 34.5 kV / 150 A / 3 km	R: 0.23 Ω/km
	L2 34.5 kV / 207 A / 3 km	L: 1.33 mΩ/km
	L3 34.5 kV / 130 A / 1 km	C: 9.78 nF/km
Power transformer	T1 115/34.5 kV / 20 MVA	$L_{1,2} = 0.3$p.u.
	T2 34.5 kV/13.8 kV / 2 MVA	
Load	D1 15 MW / 1 MVAr	
	D2 1.5 MW / 0.1 MVAr	
Generation	115 kV / 20 MW	

III.III Power system implemented in Simulink



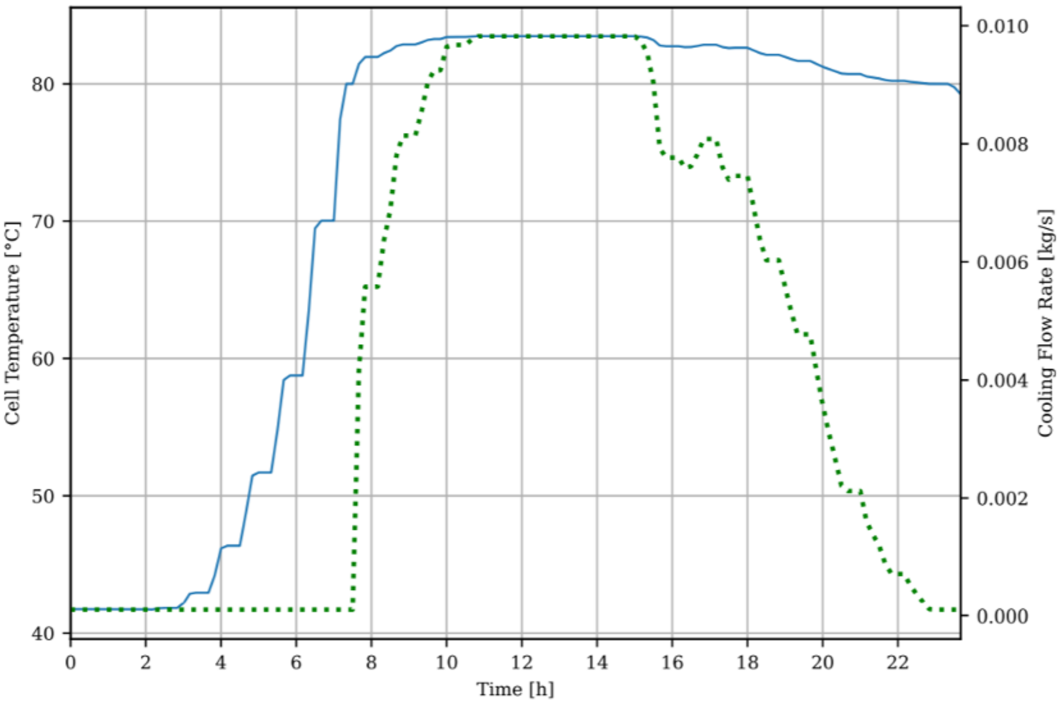
Power system used to test the integration of the Power To Gas (PTG) plant and the photovoltaic (PV) plant.

IV. Results



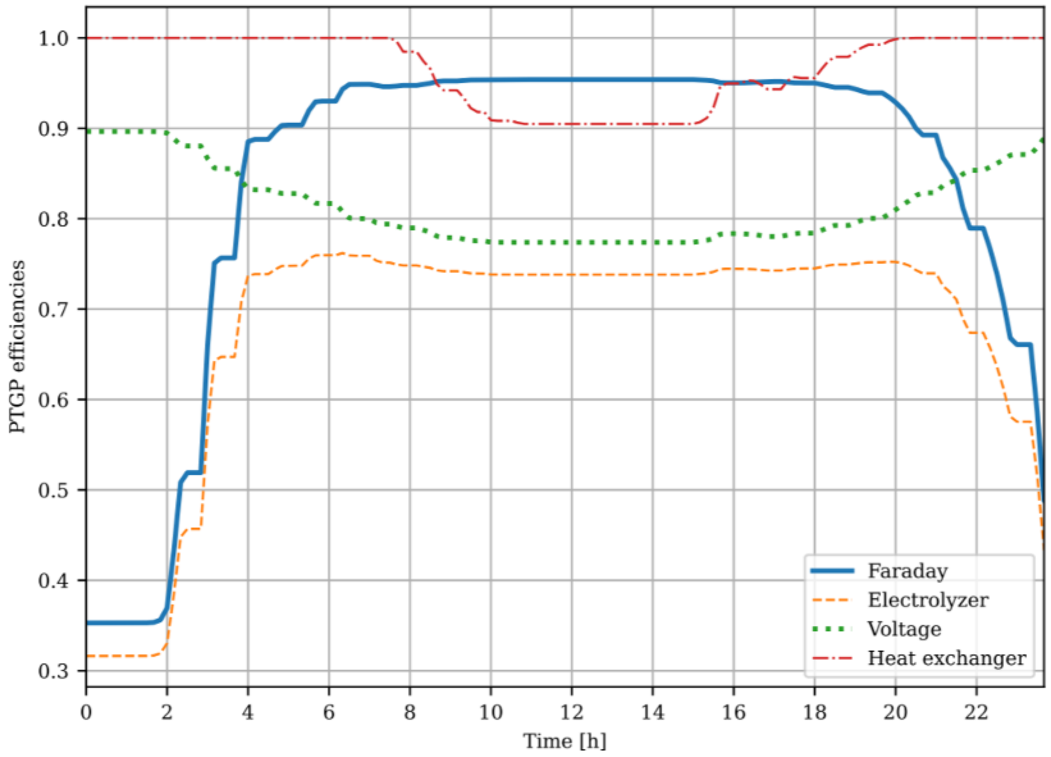
Current and hydrogen flow as a fraction of its nominal values. When both curves are equal current and hydrogen production are proportional.

IV. Results



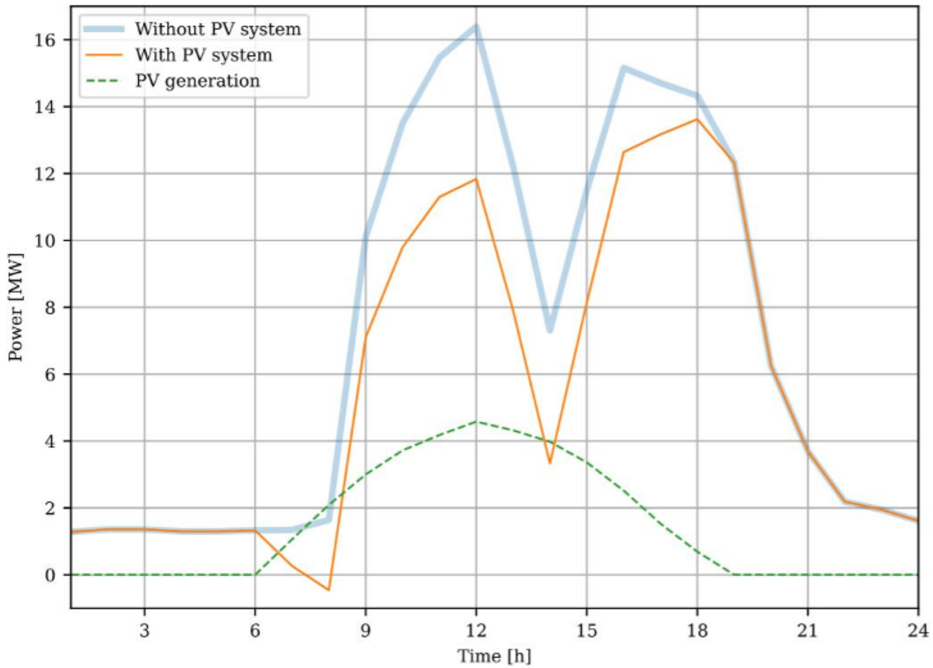
Cell temperature (continuous line) and cooling system water flow rate (dotted line) operation profile of the PTGP.

IV. Results



PTGP Faraday, Electrolyzer, Voltage and Heat exchanger efficiencies for the operation profile.

IV. Results



Active power profile at slack bus and PVP generation.

Line	Loading [%]		
	without PVP	with PVP	with PVP and PTG
L1 (150 A)	81.36	65.54	65.63
L2 (207 A)	74.54	63.27	63.32
L3 (130 A)	76.50	100.06	99.99

V. Conclusions

- A simulation tool based in Matlab/Simulink and EES to quantify the power and hydrogen outputs for a PTGP connected to the power transmission system was succesfully implemented and tested. A case study to show the impact on the network secure operation of PVP was presented, as well as a solution based on the integration of a PTGP.
- From the simulations it is clear the importance of the electrolyzer temperature and current to maintain maximum efficiency. Besides, MatLab/Simulink has been presented as a capable framework to predict the behavior of this kind of energy systems.
- The current model handle the changes in input power with a quasidynamic approach, however, experimental studies are needed to understand the errors and limitation of this kind of modeling when predicting the electrolyzer dynamics.
- Also, as a future work, it is important to study the power electronic interface controls and architectures to improve PTGP efficiency and increase the device life-time even under a variable input power profile.

VI. Acknowlegments

This work was financed by “Universidad Industrial de Santander” (Santander, Colombia), under the research project “"Despacho óptimo coordinado de sistemas de transporte de energía eléctrica y gas en presencia de altas penetraciones de energía renovable" with code VIE-UIS-2695.