X SICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

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Optimal Sizing of a Grid-Connected Microgrid and Operation Validation Using HOMER pro and DIgSILENT

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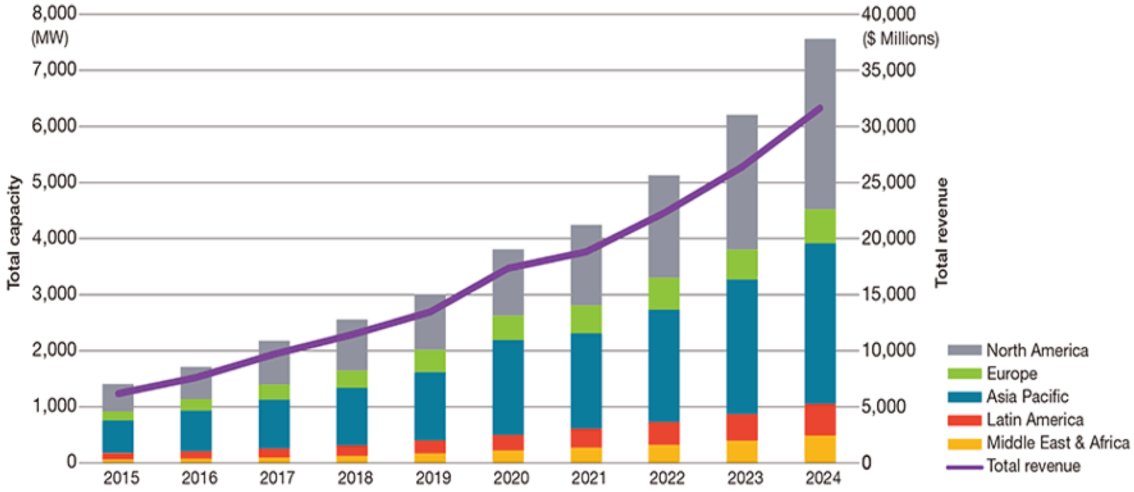
Motivation

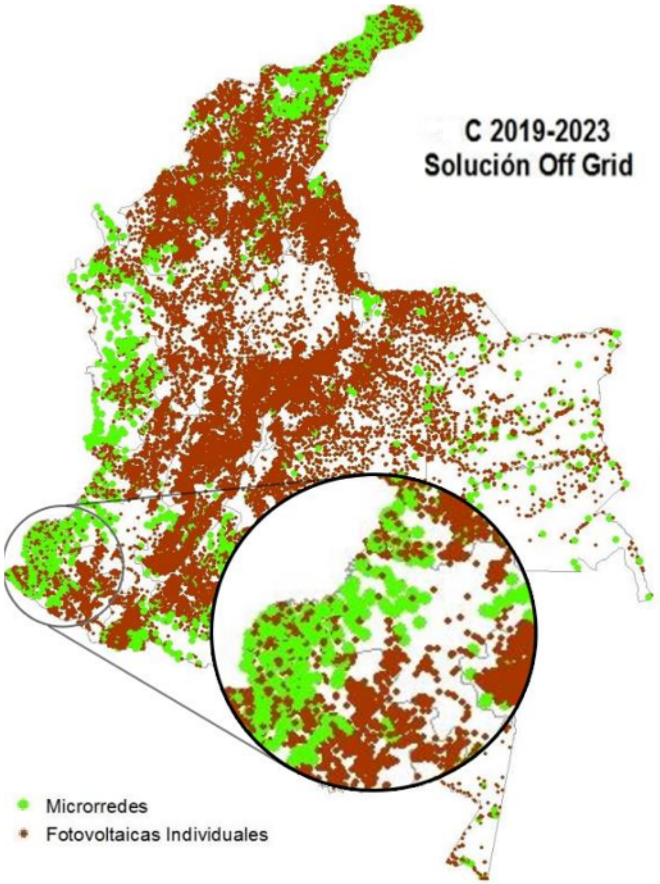
Microgrids installed capacity has been duplicated to 3000 MW from 2015 to 2019 in the U.S. It is projected to install **7500 MW by 2024**. The overview is similar for **Latin America**, it is expected to install **1000 MW by 2024** [1].



Source: Navigant Research

Motivation

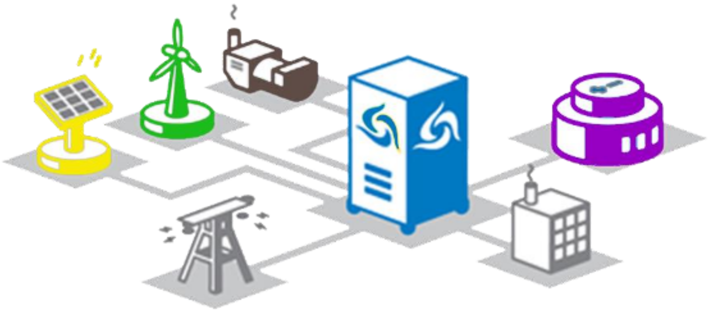
Colombia supports the adoption of renewable energy by UPME through Indicative Plan Coverage Expansion Energy (PIEC 2019 - 2023), which based on economic and technical studies, recommends installing more than **1000 PV systems and 257 autonomous microgrids** to enable energy access in rural zones



Electrification solutions based on microgrids and PV systems [2].

Motivation

Methodology to size the components of a **connected microgrid** using HOMER Pro.



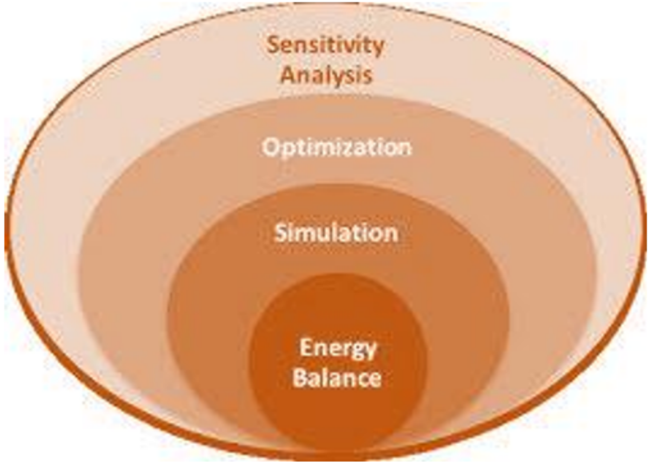
Case of study is presented with all **economic, technical details, and regulatory issues.**

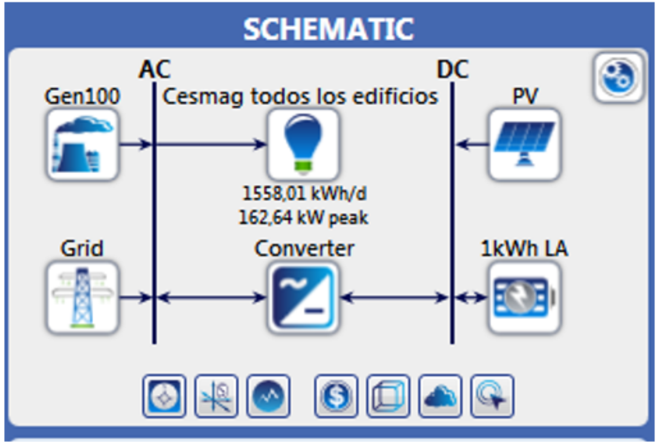
Methodology to validate the operation of the microgrid using DIgSILENT.

Optimal sizing using HOMER Pro

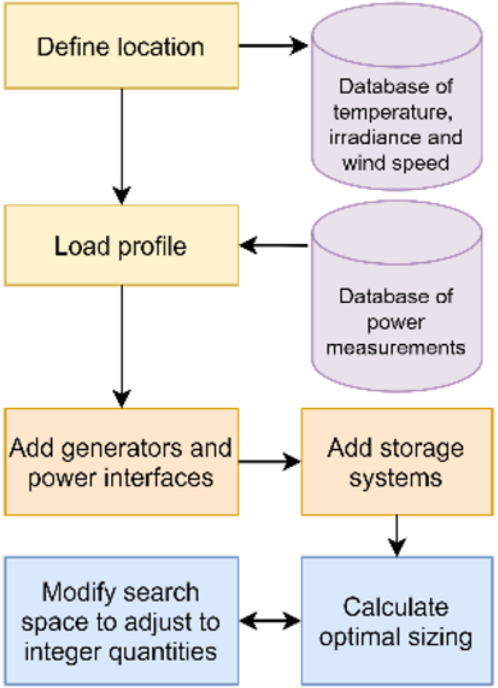
HOMER Pro is the optimization tool for evaluating designs, which allows us to calculate an optimal number of components to minimize the net present cost.

HOMER Pro





Optimal sizing using HOMER Pro



Sizing methodology description

Costs and economical parameters

The total Net Present Cost (NPC)

$$NPC = \frac{C_{T,A}}{CRF(d,l)}$$

The Capital Recovery Factor (CRF)

$$CRF(d,n) = \frac{d(1+d)^n}{\left((1+d)^n - 1\right)}$$

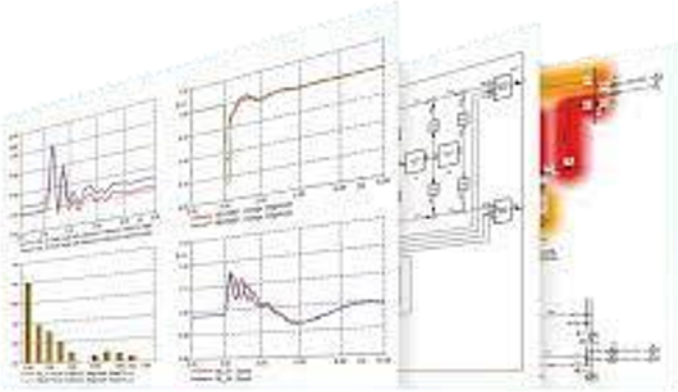
The Cost of Energy (CoE)

$$COE = \frac{C_{T,A}}{E}$$

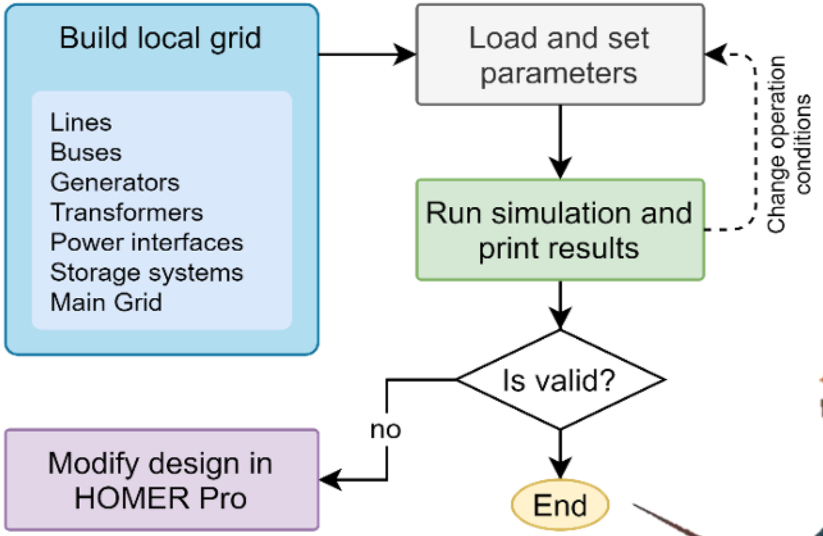
Operation validation using DIgSILENT

Simulating power systems to have a better analysis, this allows us to easily test microgrid designs and better evaluate their performance.

1. Power flows
2. Voltage profiles
3. Currents through lines
4. The load factor of components
5. Power losses



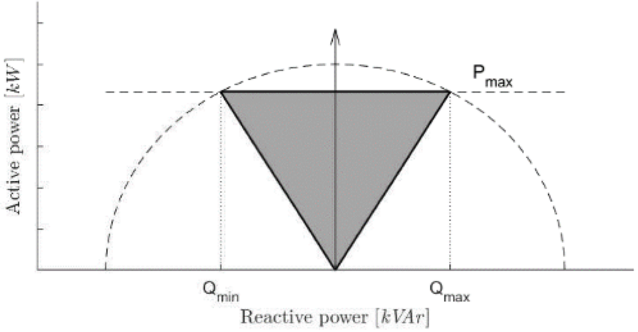
Operation validation using DIgSILENT



1. **A local grid** corresponding to the microgrid has to be built.

2. All parameters have to be loaded into DIgSILENT **microgrid model**.

3. Running and printing of results are performed to drawn off **numerical indicators** under different simulation scenarios.

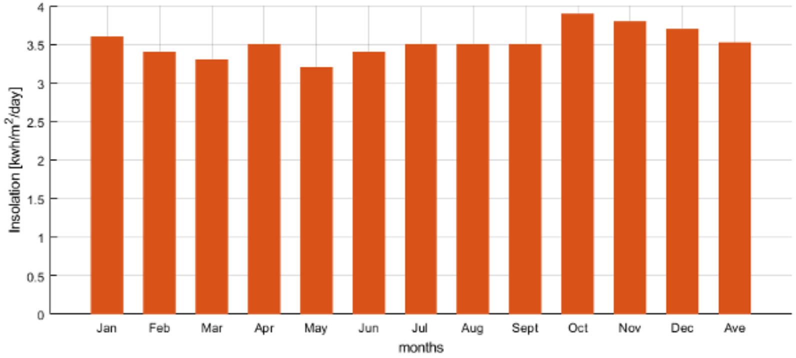


Inverter capability curve

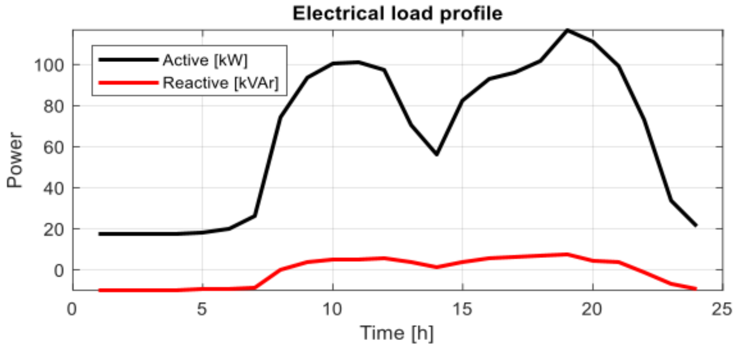
Description of the case of study

Location and data recopilation

CESMAG University is located in with coordinates 1°12'32" North latitude and 77°16'42" West longitude. Insolation data were taken from 2013 to 2020.



Insolation data



Electrical load profile

Available areas for solar panels

Description of the case of study

Costs

The University **buys energy** at a price of **0.152 USD/kWh**, and according to CREG (law 1715 in 2014 and resolution 030 in 2018) the University is able to **sell energy** to the electricity company at a price of **0.043 USD/kWh.**

Component	Capacity	Capital [$]	Replacement [$]	O&M [$/year]
Solar Panel	530 W	322.93	322.93	3.23
Converter	10 kW	4984.4	4984.34	49.84
Battery	83.4 Ah	324.93	324.93	3.24
Gen Diesel	180 kW	0	51902.28	0.06

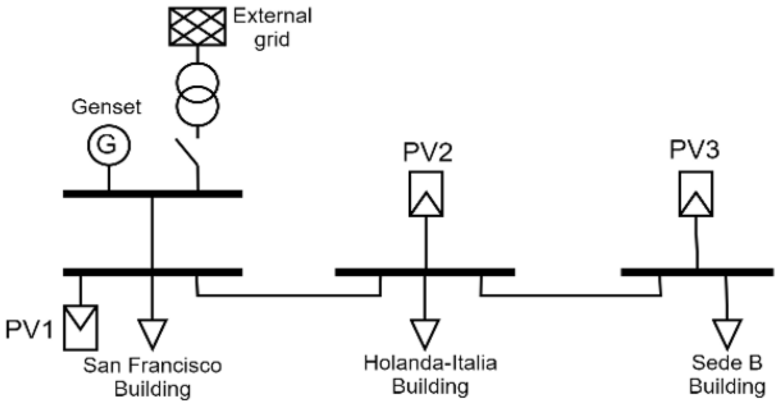
Operational constraints

Maximum peak power is calculated from **availability area** in each Building

$$P_{TA} = \frac{A_{TA}}{A_P} P_P$$

Campus Buildings	Area [m²]	Nº Panels	Peak power [kW]
Sede B	1413.19	553	293
Holanda-Italia	645.37	253	134
San Francisco	1138.16	445	236
		TOTAL	663

Results and discussions



Component	Size
PVs total peak power	552 kW
Power Inverter	285 kW
Batteries [1kWh]	0
Genset	180 kW

Optimal design according HOMER Pro

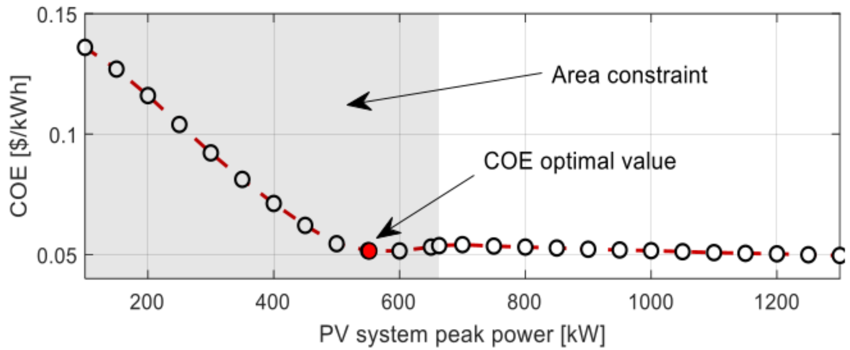
The best option is to get energy from **three PV systems**, while **batteries and other diesel generators are discarded** by high operational and capital costs

G is the existing genset, which works as emergency power backup.

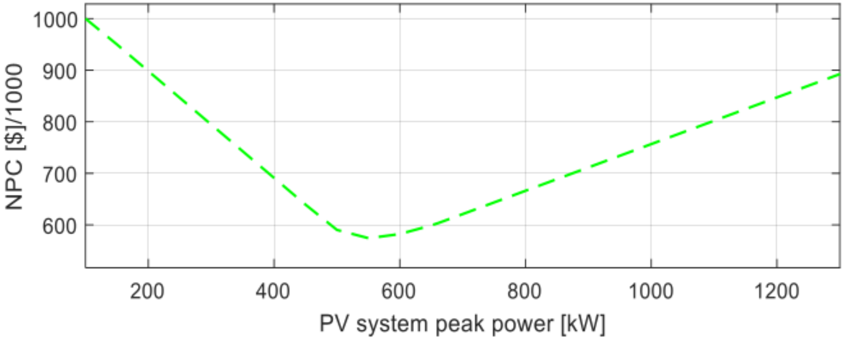
PV1, PV2 and PV3 are the optimal photovoltaic systems with sizes of **196.55 kW, 111.45 kW and 244.01 kW** respectively.

Results and discussions

The **COE is higher for small PV system sizes** and as the maximum power increases it reaches its minimum value just like the NPC.

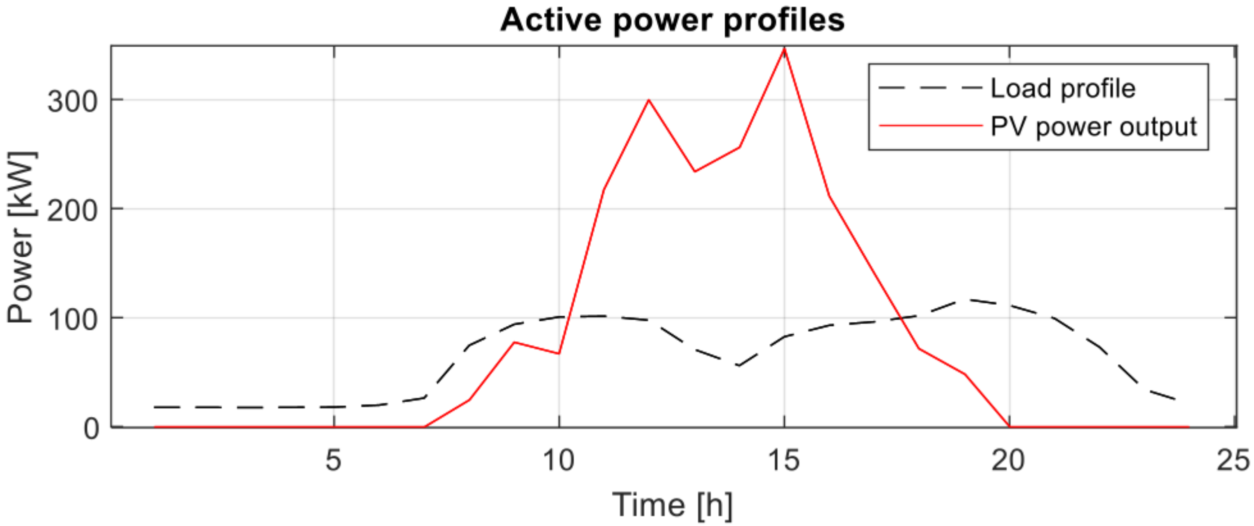


If we ignore the area restrictions, the **COE decreases slightly after the optimum value** of maximum power of the PV system, while the **NPC increases rapidly**.



Results and discussions

Validation results with DIgSILENT



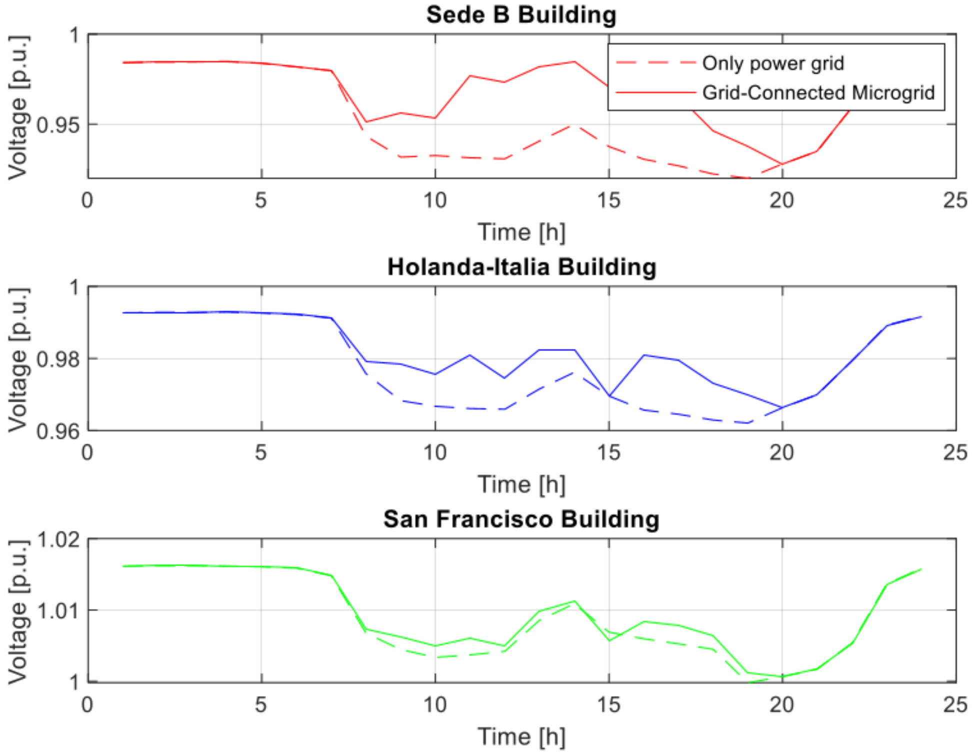
Active power profiles of the load profile and photovoltaics as of July 1, 2007, when generation exceeds electricity demand.

Results and discussions

Voltage profiles

The buildings B and Holland-Italy buildings **improve their voltage profiles with the addition of distributed generation**, while the San Francisco voltage profile does not change significantly.

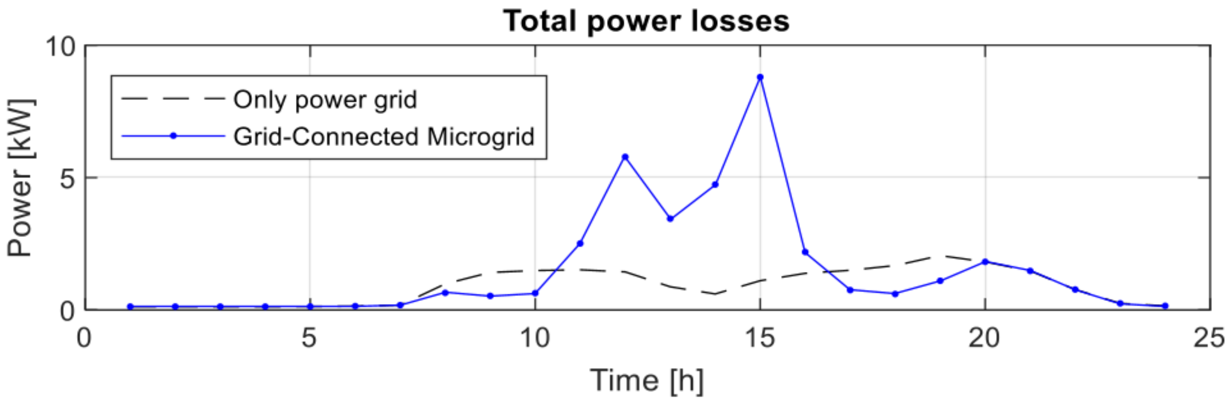
In any case, the effect of the DGs is positive, **keeping the voltage profiles in the allowed range [0.9, 1.1] p.u.**



Results and discussions

Power losses

Energy losses are reduced by the location of DGs at non-peak hours **(8 a.m. to 10 a.m. and 5 p.m. to 8 p.m.)**, but **increase significantly at peak times between 10 a.m. and 5 p.m. M.** When the production of the photovoltaic system exceeds the electrical load and the energy flows into the external electrical grid.



Conclusions

- **This work presents a simplification for planning and validating a microgrid using HOMER Pro and DIgSILENT Power Factory.** Planning and validating of the grid-connected microgrid using HOMER Pro and DIgSILENT allows finding an optimal **COE value using a lower area in comparison with available area.** This is because a bigger area implies higher capital and operational costs. This raises COE despite incomes for energy excess which are sold to lower price according to CREG 121-2017 of Colombia.

- NPC optimal confirms COE optimal value. NPC decreases rapidly as peak power installed increases but if the peak power overpass the optimal value then incomes are smaller in comparison with operational costs, therefore economic benefits are not substantial. In this way, **producer/consumer users must evaluate the available areas according to with this planning methodology to make an intelligent decision, reconsidering whether to use more or less area.**

Conclusions

- According to Colombian regulatory aspects in RETIE (Reglamento Técnico de Instalaciones Eléctricas Colombiano), distribution power losses should not exceed 3%. According to power losses figure, **the maximum percentage of power losses is in the proportion of 8.8kW to 346.29kW, that is to say 2.54%, thus the system and the design are is in compliance with the regulations**.

- According to the Colombian regulation given CREG 024-2005, there is a power quality problem in the voltage level when it is lower than 0.9 p.u. or higher than 1.1 p.u., **according to voltage profiles in none of the buildings is violating regulation.**

References

[1] A. Aram, «Microgrid Market in the USA», *Hitachi Rev.*, vol. 66, n.º 5, pp. 454-455, 2017.

[2] UPME, «Plan Indicativo de Expansión de Cobertura de Energía Eléctrica PIEC 2019-2023», *UPME, Colombia*, *Technical Report*, no. 69, p. 141, 2019.

[3] Institute of Electrical and Electronics Engineers, *IEEE Std 1159 - IEEE Recommended Practice for Monitoring Electric Power Quality.*, vol. 2009, n.º June. 2009.

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[5] J. D. Garzón-Hidalgo y A. J. Saavedra-Montes, «Una metodología de diseño de microredes para zonas no interconectadas de Colombia», *TecnoLógicas*, vol. 20, no. 39, pp. 39-53, 2017.

[6] R. Rodríguez, G. Osma, y G. Ordóñez, «Retos de la planificación energética de micro-redes en regiones rurales remotas con cargas dispersas », *IX Simposio Internacinal sobre Calidad de la Energía*

Thank you!

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