X SICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

XSICEL 2021
Transición energética en la 4ta revolución industrial

Penetration of Renewable Energy Sources Analysis using the Dispa-Set Model in Colombian Power System Projected at 2024

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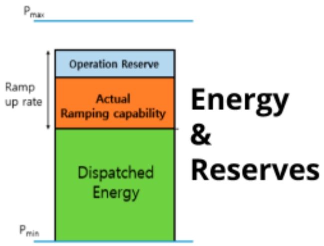
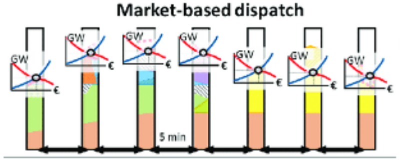
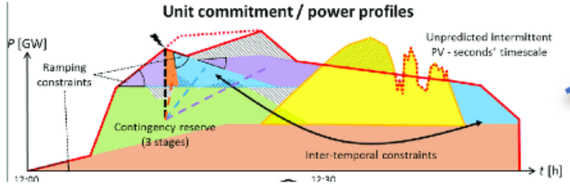
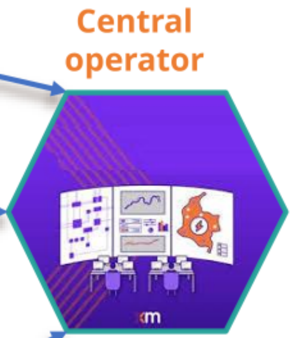








The unit commitment problem

Consists of two parts:

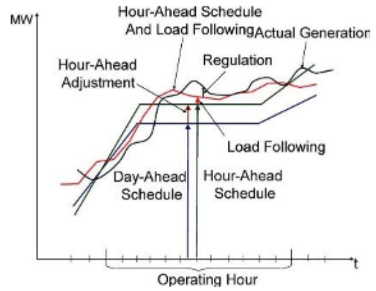
i) **scheduling** the start-up, operation, and shut down of **the available generation units**

ii) **allocating the total power** demand among the available generation units.

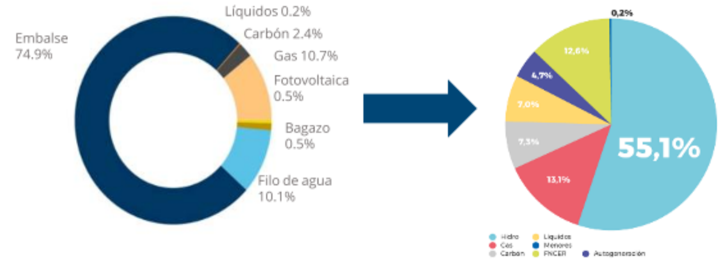
Full information on the technical and economic data of the generation units, the demands in each node, and the transmission network.

I. Introduction

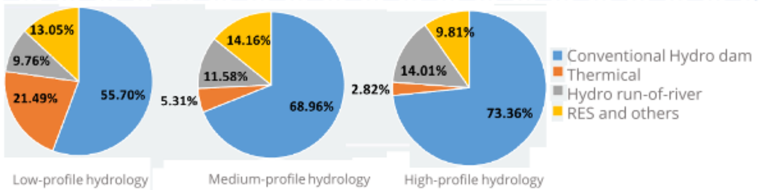
Projected Colombian power system – Changes in the power grid



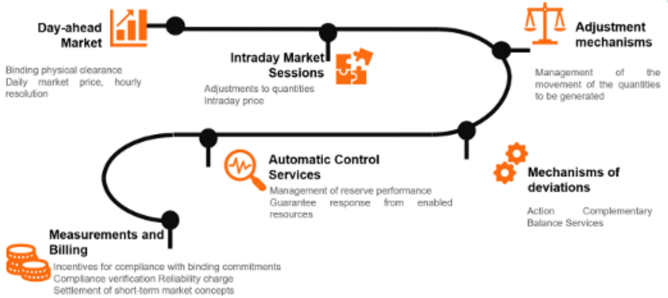
Intraday-Real-Time
Unit Commitment /Dispatch



Future energy matrix



Weather profiles dependency



Adaptation of the energy market

III. Theoretical aspects

Dispa-Set Model [1]

Represent with a high level of detail the short-term operation of large-scale power systems solving the so-called unit commitment problem

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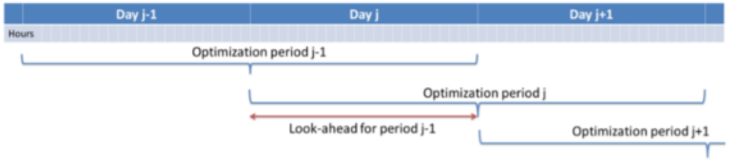
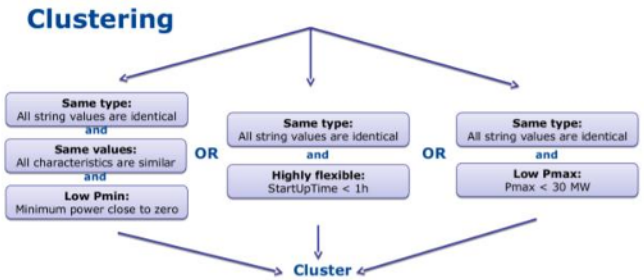
Technologies





Optimisation model

Objective function

Minimize the total power system costs.

The sum of different cost items: start-up and shut-down, fixed, variable, ramping, transmission-related and load shedding (voluntary and involuntary) costs.

Constraints

- Day-ahead energy balance
- Reserve constraints (Upward/Downward)
- Power output bounds
- Ramping Constraints
- Minimum up and down times
- Storage-related constraints
- Emission limits
- Network-related constraints
- Load shedding

[1] Quoilin, S., Hidalgo Gonzalez, I. and Zucker, A., Modelling Future EU Power Systems Under High Shares of Renewables: The Dispa-SET 2.1 open-source model, EUR 28427 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-67952-0 (print),978-92-79-65265-3 (PDF), doi:10.2760/25400 (online),10.2760/914770 (print), JRC105452.

III. Proposed methodology

DispaSet Model

- Use modification to the original formulation to accomplish with the Colombian power system operational and network constraints, and to include the system net transfer capabilities (NTC) among its areas.

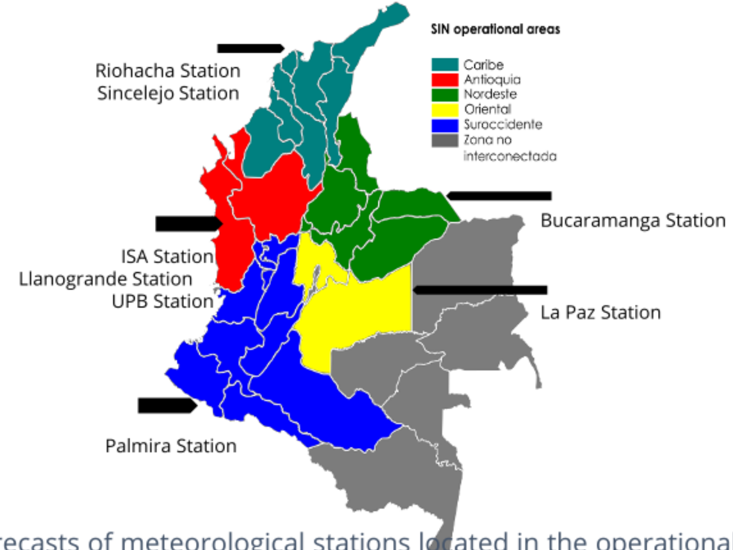
Application of the Dispa-Set model

- Assess the impact of the RES and BESS integration
- system net transfer capabilities (NTC) among its areas
- Taking into consideration low, medium, and high hydrology profiles
- predicted renewable energy shares
- Analyses considered the projected Colombian power system to the year 2024

Compare and assess the impact in the Colombian Power System

- The energy shares of each type of energy source
- Displacement of conventional energy sources.
- System operational costs

Analysis in Colombian Power System



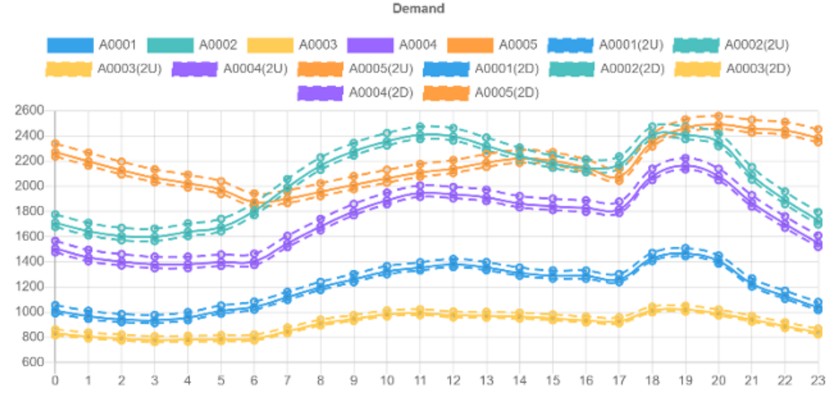
Forecasts of meteorological stations located in the operational areas of the National Interconnected System (SIN)

Average Day Load by Areas for date Saturday

Area	Actual System Load [MW]	2024 Stage projection Load [MW]	%Total Load
A1 Antioquia	1196.39	1399.61	15 %
A2 Oriental	2050.57	2398.88	26 %
A3 Nordeste	903.39	1056.83	11 %
A4 Suroccidente	1725.81	2018.95	21 %
A5 Caribe	2173.26	2542.40	27 %
Total Load	8049.11	9416.30	100 %

System actual capacity and projected installed capacity for the year 2024

Area	Resources	
	Actual System	*2024 Stage projection*
A1 Antioquia	58	76
A2 Oriental	27	33
A3 Nordeste	30	33
A4 Suroccidente	96	107
A5 Caribe	27	50
Total Resources	238	299
Total Installed Capacity [MW]	17704.95	22658.28

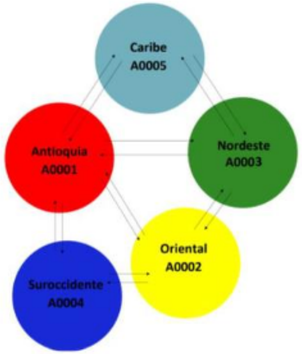


Load Forecast, Up and Down reserves by system areas for date Saturday.

Analysis in Colombian Power System

Installed Generation Capacity per Areas

Area	Fuel Type	*Actual System*	*2024 Stage projection*
		Installed Capacity [MW, %]	
A1 Antioquia	WAT	4609.69	6526.77
	GAS/HRD/OIL	354	354
	BIO	19.9	28.9
A2 Oriental	WAT	1119.8	1119.8
	GAS/HRD/OIL	693.34	693.34
	BIO	23.2	33.08
	SUN	19.9	117.4
A3 Nordeste	WAT	2963.47	2963.47
	GAS/HRD/OIL	835.3	1165.3
A4 Suroccidente	WAT	2892.03	3080.4
	GAS/HRD/OIL	547.55	547.55
	BIO	153.3	190.1
	SUN		19.7
A5 Caribe	WAT	420	420
	GAS/HRD/OIL	3004.9	3664.9
	BIO		2.25
	SUN	8.06	430.72
	WIN	18.42	1300.42



Net Transfer Capacity (NTC) network model.

Antioquia and **Nordeste** have the lowest demand, and its demand/capacity ratio is 25% and 36%.
More significant resources with operational flexibility.

Oriental is a critical area, its limit installed capacity, in a demand/capacity ratio of 96.

Suroccidente presents a demand/capacity relationship of 65%, with a mainly hydro generation.

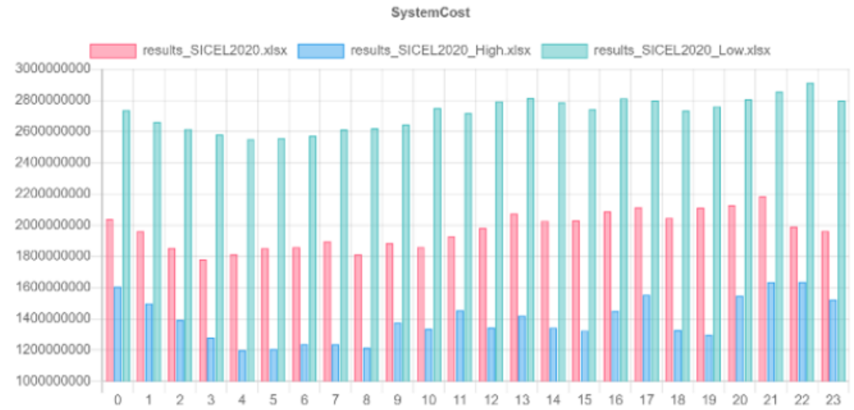
Caribe presents the highest demand, with a 28% percentage, under the scenario without new resources renewable, it was 70% of its installed capacity composed mainly of thermal units.

With the 2024 projection including BESS plants, this relationship Load / Low generation capacity at a value of 36%.

The expansion of the network in this area is vital for the proposed analysis, since it is one of the areas that will have the most integration of renewable generation and is currently the area with the most network problems.

IV. Results

System operational costs



Hourly cost of dispatch for each hydrology profile for 2020 scenario

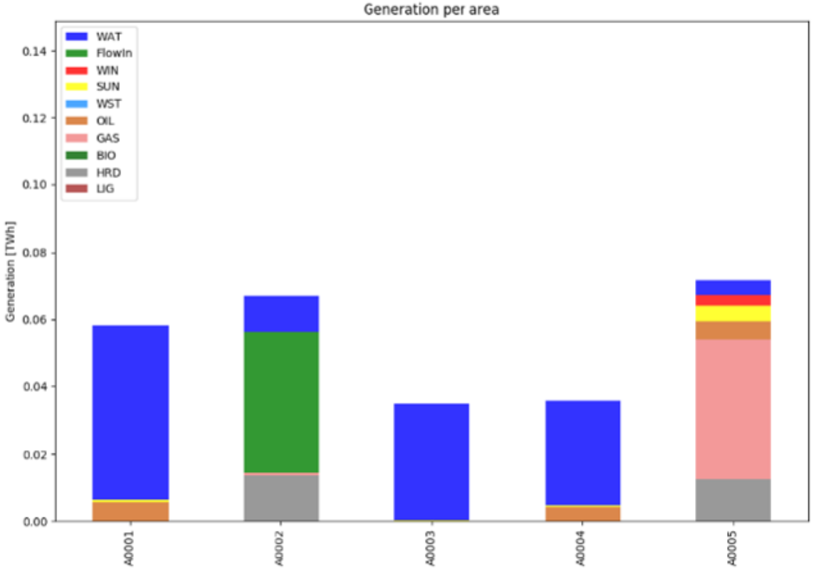
Total cost and variation for each hydrology profile for 2020 scenario.

Profile % Reservoir Level	Total Cost [$]	Variation [%]	Cost [%/kWh]
Low 30%	39.420'194.738	9.49 %	201.33
Medium 50%	36.004'884.204	0 %	185.87
High 80%	34.306'292.926	-4.72 %	177.56

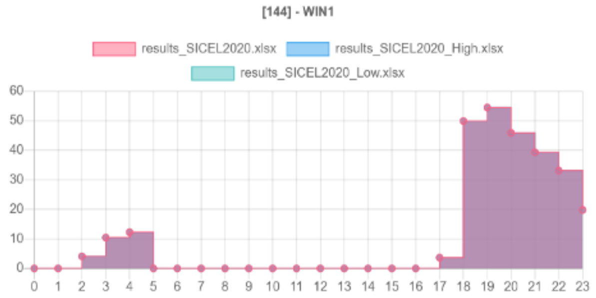
Total cost and variation for each hydrology profile for 2024 scenario.

Profile % Reservoir Level	Total Cost [$]	Variation [%]	Cost [%/kWh]
Low 30%	33.457'224.024	4.05 %	182.17
Medium 50%	32.154'335.628	0 %	174.18
High 80%	30.906'950.899	-3.88 %	169.73

Energy shares of each type of energy source

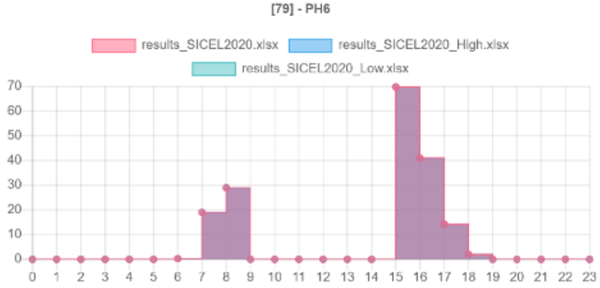


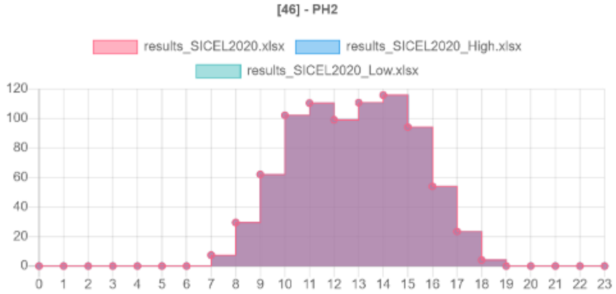
Generation per area: Contribution for each technology



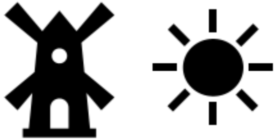
Variation Wind Plant WIN1 placed in the Caribe Area

Variation photovoltaic Plant 6 placed in the Nordeste Area.





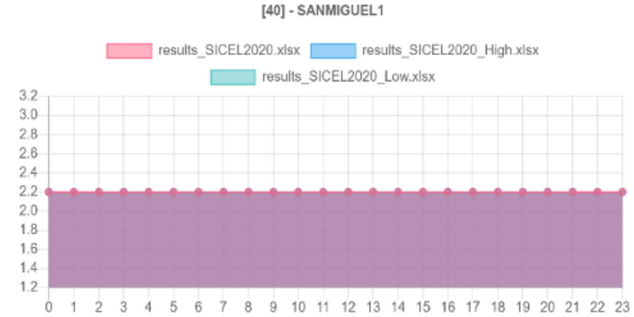
Variation photovoltaic Plant 2 placed in the Antioquia Area



Renewable generation is dispatched according to the availability of the profile, which varies according to the region where the plants are located.

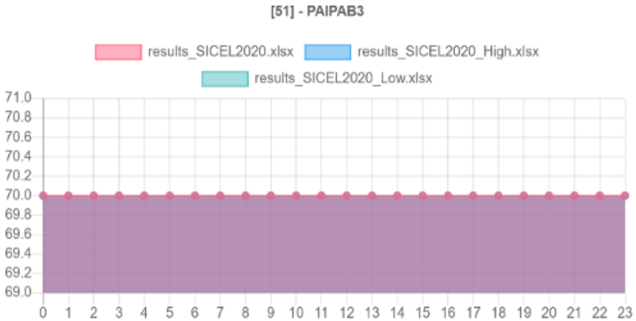
Low-profile hydrology scenario (30%)
Medium-profile hydrology scenario (50%)
High-profile hydrology scenario (80%)

Some hydropower and Thermical plants provide support to the areas and are not affected by variations between profiles.



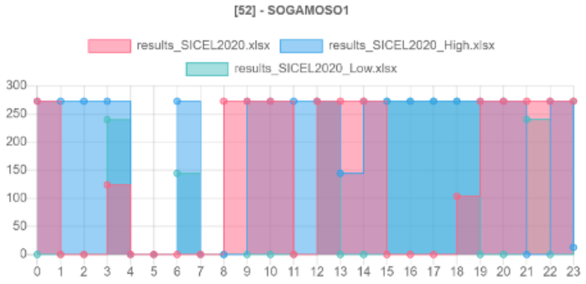
Variation hydro plant SANMIGUEL1 placed in the Antioquia Area

Variation thermical plant PAIPAB3 placed in the Oriental Area

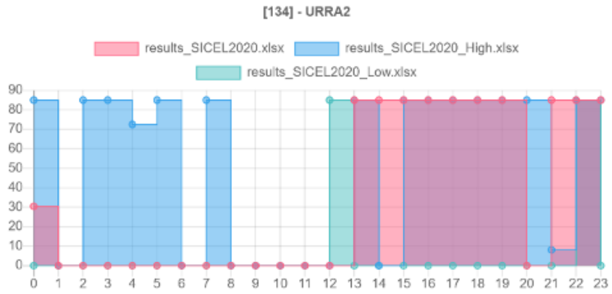


Antioquia area (A1) :	San Miguel and Troneras;
Oriental area (A2) :	Paipa, Tasajera, and Yopal
Nordeste area (A3):	La Guaca and Salto II
Suroccidente area (A4):	Calima, Esmeralda, Salvajina, and San Francisco
Caribe area (A5) :	Flores, Guajira, Proelec, Termonorte, Zipa

Low-profile hydrology scenario (30%)
Medium-profile hydrology scenario (50%)
High-profile hydrology scenario (80%)

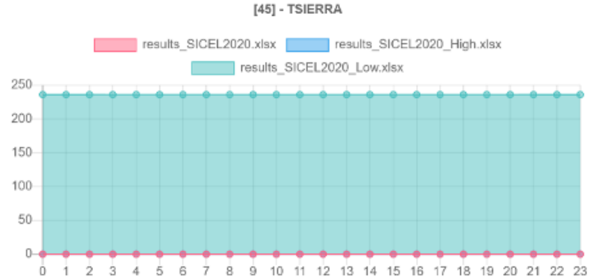


Variation hydro plant SOGAMOSO1 placed in the Oriental Area.

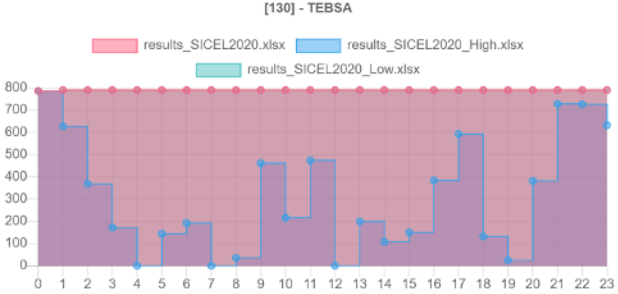


Variation hydro plant URRA2 placed in Caribe Area.

Some hydro plants varying your power output depending on hydrology profile.



Variation thermical plant TERMOSIERRA placed in the Antioquia Area.



Variation thermical plant TEBSA placed in the Caribe Area.

Some thermal plants with higher associated costs are required if the hydrology profiles do not have the required availability.

Low-profile hydrology scenario (30%)
Medium-profile hydrology scenario (50%)
High-profile hydrology scenario (80%)

V. Conclusions

- An approach to the prototype of economic dispatch was carried out with the inclusion of new types of generation sources (Wind and Solar renewable resources, batteries, vehicles electricity), other types of unconventional distributed generation could also be considered in future works (thermal storage, gas storage, among others).
- The case analyzed, due to its simplicity, could be used to perform calculations in granularity of five minutes, to reach real-time powerflow.
- The calculation of emissions could be made according to a dispatched generation, including penalties in the cost function.
- Despite considering information on real resources, the system does not represent the Colombian case totally due to the lack of some representative restrictions such as block models of resources.

V. Conclusions

- The worst-case scenario is found when the hydrology profile is low, the cost of dispatch increases considerably. This energy must be supplied with the resources available, in this case, the renewable and thermal plants according to the network's forecast are used.
- The displacement of conventional sources is mainly related to the offer prices and composition of the dispatch model and restrictions.
- More extensive analysis is required to determine the sensitivities of each resource to include renewable resources by area, in addition to the impact it will have added by its forecasts.

THANK YOU

Questions

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