Computational Tool for Optimal Expansion of Transmission Networks

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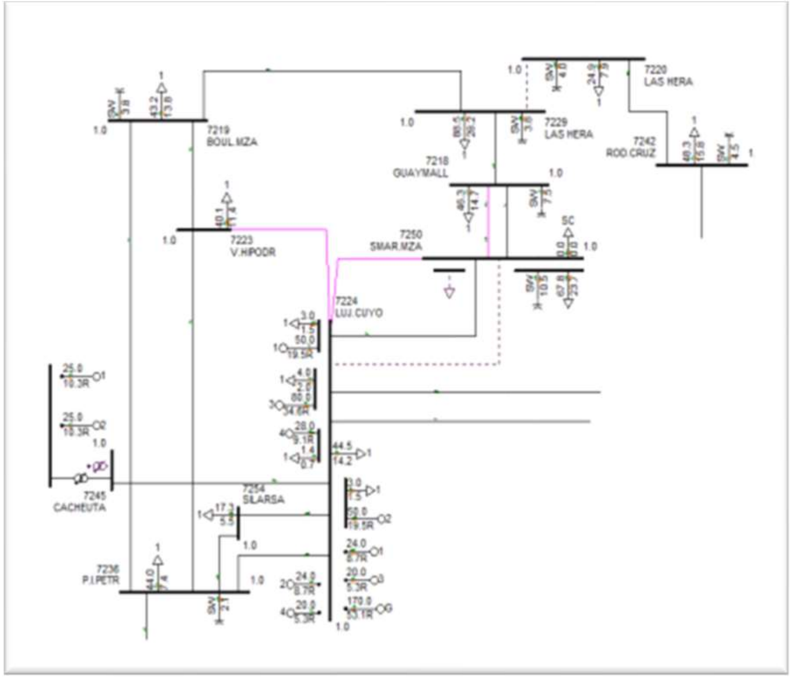

About us

Investigation group since 2004

Universidad Tecnológica Nacional, Fac. Buenos Aires

Methodologies and tools for transmission expansion planning

The organizing committee certifies that **Mariano Tomás Anello, Alberto Del Rosso and Sergio Pascual** attended the conference IEEE Power & Energy Society T&D – Latin America 2020 and presented the paper titled: **Potential Benefits of Implementing Ambient Adjusted Rating in the Argentinean Transmission System**

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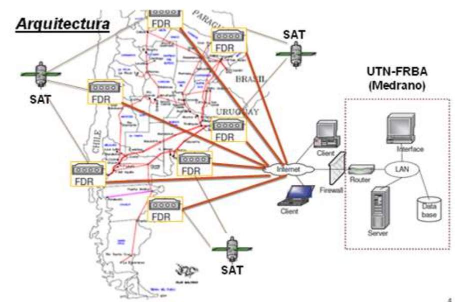

Motivation: TNEP.py

Computational tool for transmission system expansion

Requirements:

- Easy to use
- Handles multiples load scenarios
- Integration with other tools

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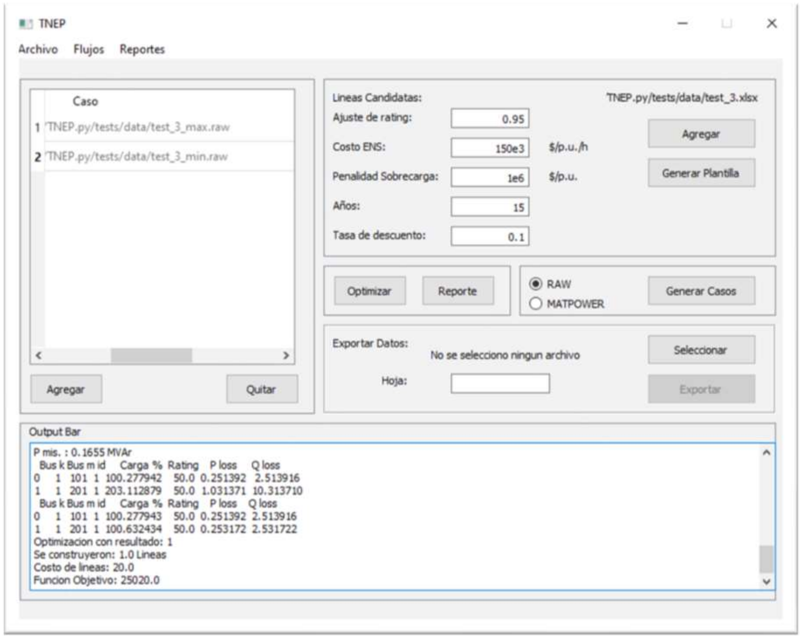
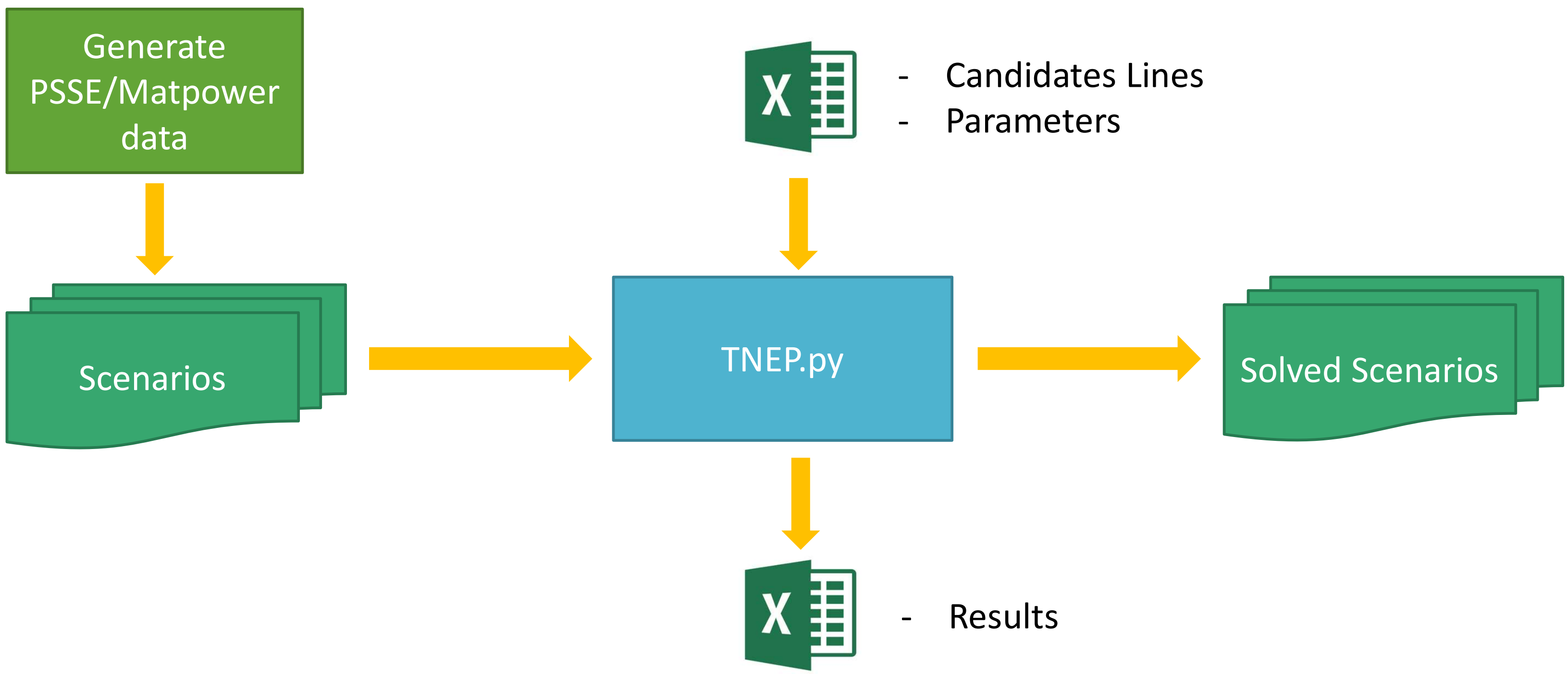


Description: Workflow



Problem description: Transmission Network Expansion Planning

$$\min \sum_{(i,j)\in\Omega_c} \zeta_{ij}\cdot D_{ij} + B\sum_{k\in S}\sum_{(i,j)\in\Omega} \overline{f_{ij}}_k + \sum_{k\in S} C_k \sum_{i\in B_L} r_{ik}$$

ζ_{ij}: Decision of construction of line
D_{ij}: Cost of line $[U\$D]$

$\overline{f_{ij}}_k$: Overloads $[MW]$
B: Penalty $\left[\frac{U\$D}{MW}\right]$

r_{ik}: Load Shed$[MW]$
C_k: Cost of load shed $\left[\frac{U\$D}{MW}\right]$

$$C_k = C\cdot F_k\cdot R_k\cdot\frac{T_k}{T}\cdot\left[\frac{(1+r)^n-1}{r\,(1+r)^n}\right]$$

- C: Cost of load shed
- F_k: Failure time
- R_k: Failure Rate
- $\frac{T_k}{T}$: Relative time of scenario
- $\left[\frac{(1+r)^n-1}{r\,(1+r)^n}\right]$: CRF

Problem description: Transmission Network Expansion Planning

$$\min \sum_{(i,j)\in\Omega_c} \zeta_{ij}\cdot D_{ij} + B\sum_{k\in S}\sum_{(i,j)\in\Omega} \overline{f_{ij_k}} + \sum_{k\in S} C_k \sum_{i\in B_L} r_{i_k}$$

$subject\ to$:

$$\left.\begin{array}{ll}
p_{i_k} - d_{i_k} + r_{i_k} - \sum_{(i,j)\in\Omega_i} f_{ij_k} = 0, & i\in B \\
f_{ij_k} = -b_{ij}(\theta_{i_k} - \theta_{j_k}), & (i,j)\in\Omega\backslash\Omega_c \\
\left|f_{ij_k} + b_{ij}(\theta_{i_k} - \theta_{j_k})\right| \le (1-\zeta_{ij})M, & (i,j)\in\Omega_c
\end{array}\right\} \text{Physical Constraints}$$

$$\left.\begin{array}{ll}
\left|f_{ij_k}\right| \le f_{ij}^{max} + \overline{f_{ij_k}}, & (i,j)\in\Omega_m,\quad k\in S \\
\left|f_{ij_k}\right| \le \zeta_{ij} f_{ij}^{max} + \varphi_{ij_k}, & (i,j)\in\Omega_c \\
\left|\varphi_{ij_k} - \overline{f_{ij_k}}\right| \le (1-\zeta_{ij})M, & (i,j)\in\Omega_c \\
\left|\varphi_{ij_k}\right| \le \zeta_{ij}M, & (i,j)\in\Omega_c
\end{array}\right\} \text{Engineering Constraints}$$

Problem description: Transmission Network Expansion Planning

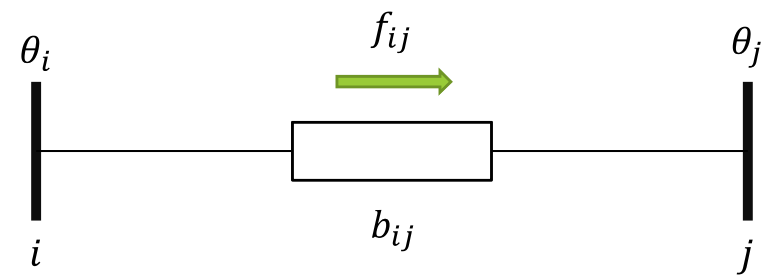
How to handle build decision variables

$\zeta_{ij} = 1 \;\Rightarrow$ Build Line

$\left|f_{ij_k} + b_{ij}(\theta_{i_k} - \theta_{j_k})\right| \leq \cancel{(1 - \zeta_{ij})M}$

$\left|f_{ij_k} + b_{ij}(\theta_{i_k} - \theta_{j_k})\right| \leq 0$

$f_{ij_k} = b_{ij}(\theta_{i_k} - \theta_{j_k})$

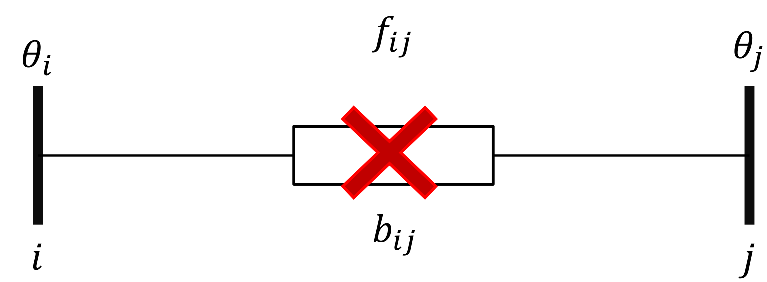


$\zeta_{ij} = 0 \;\Rightarrow$ Not build

$\left|\varphi_{ij_k}\right| \leq \cancel{\zeta_{ij}M}$

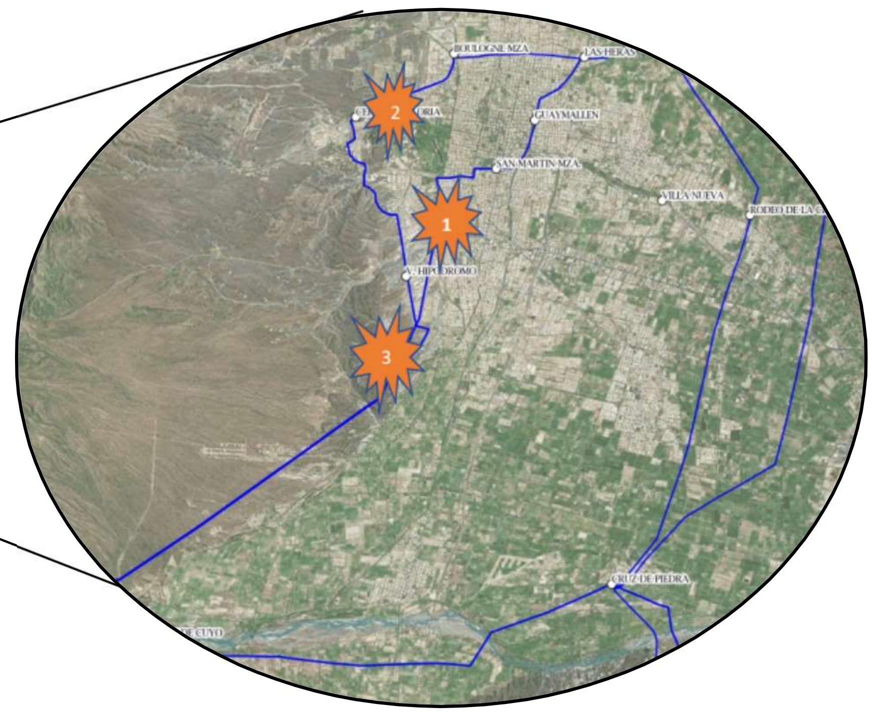
$\left|f_{ij_k}\right| \leq \cancel{\zeta_{ij} f_{ij}^{max} + \varphi_{ij_k}}$

$f_{ij_k} = 0$

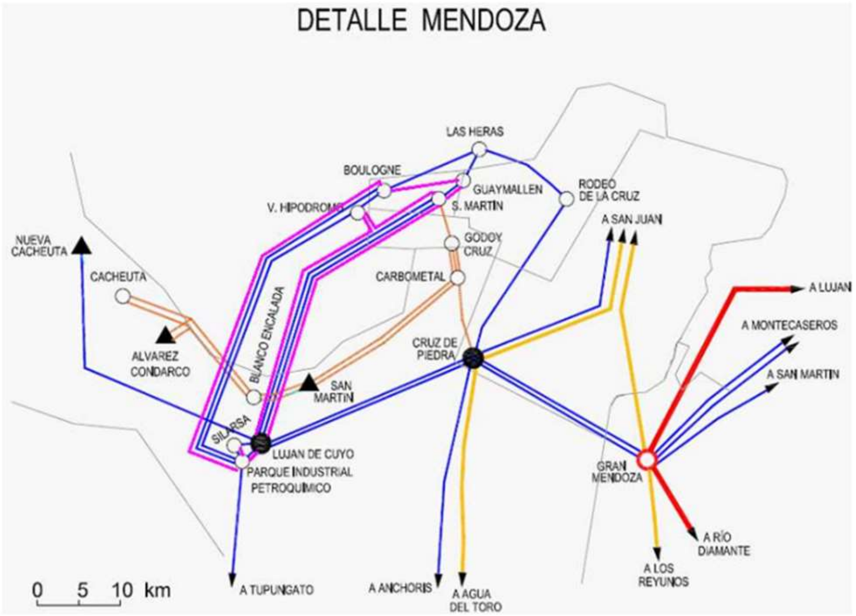


Study case: Power System Scenarios

- Argentinean electric power system (SADI)
- 3 scenarios with different line contingency
- Avoid overloads in Cuyo area



Study Case: Line Projects

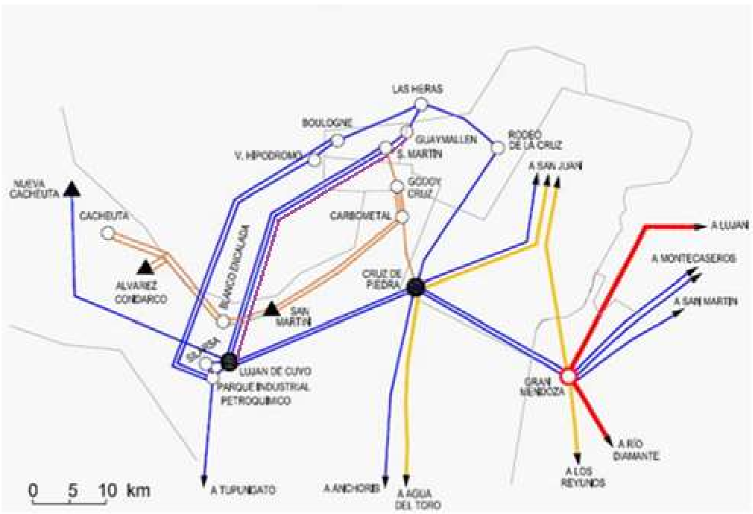


- Eight 132kV lines projects
- Six buses with possibility of load shed (20%)

Bus i	Bus j	id	r	x	b	Rating	Cost
7224	7250	NL	0.02066	0.05715	0.01449	100	$ 12,000,000,000
7224	7236	NL	0.00159	0.00576	0.00133	150	$ 600,000,000
7236	7254	NL	0.000182	0.000643	0.00016	150	$ 200,000,000
7223	7224	NL	0.01308	0.047534	0.01099	100	$ 9,000,000,000
7223	7250	NL	0.007652	0.021167	0.005367	100	$ 12,000,000,000
7218	7250	NL	0.00072	0.00172	0.06146	85	$ 1,000,000,000
7218	7219	NL	0.00083	0.00197	0.07024	100	$ 5,000,000,000
7219	7236	NL	0.01308	0.047534	0.01099	150	$ 12,000,000,000

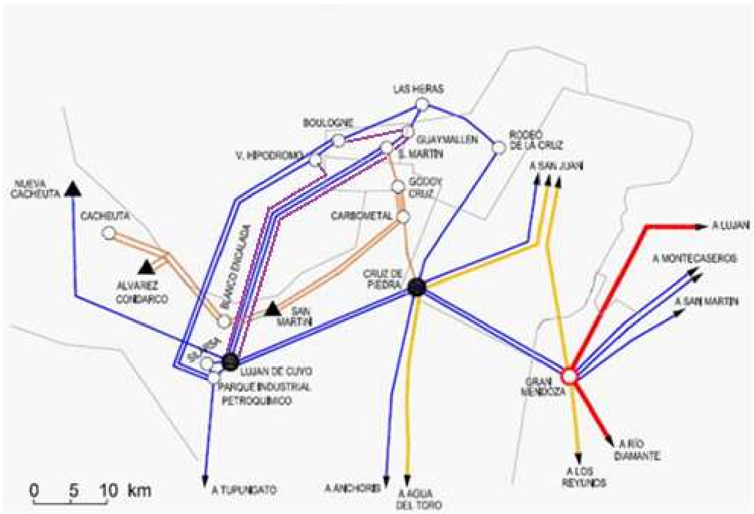
Study Case: Results

With load shed



- Lines build: 3
- Cost: U$D 20.6M

Without load shed



- Lines build: 4
- Cost: U$D 27M

23.7 % of difference

Conclusions

TNEP.py incorporates control policies (load shed) to achieve a lower inversion cost

The computational tool can handle country sized power systems

The results can be used with another power systems analysis tools