X SICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

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Transición energética en la 4ta revolución industrial

Reliability Assessment of Natural Gas Networks and their Impact on the Operation of Electric Power Distribution Systems

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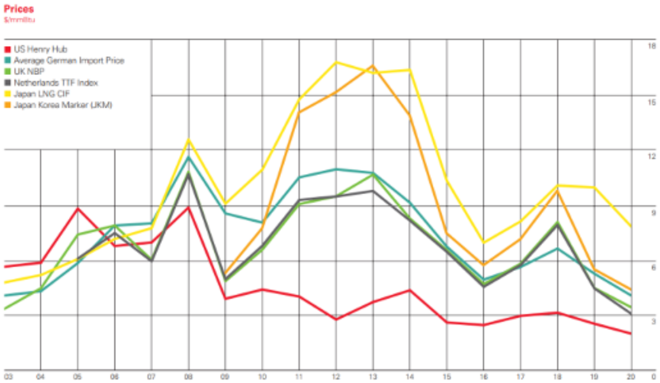
I. Introduction

In the last decade, the distributed generation based on natural gas (DG-NG) has been considered as a solution alternative to the operational difficulties associated with the continuous growth of the electricity demand, due to its multiple advantages such as low cost of natural gas, short implementation times and low emissions of greenhouse gases compared to other fuels.



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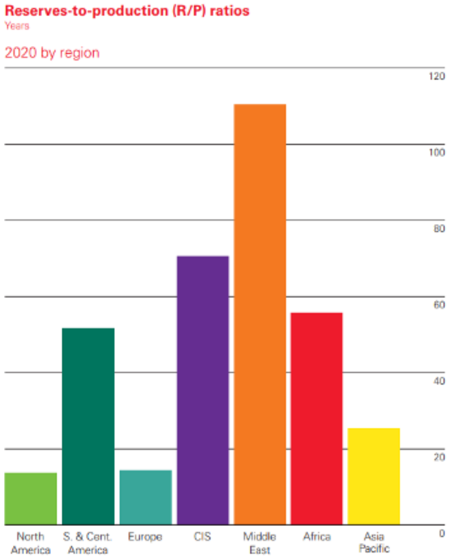
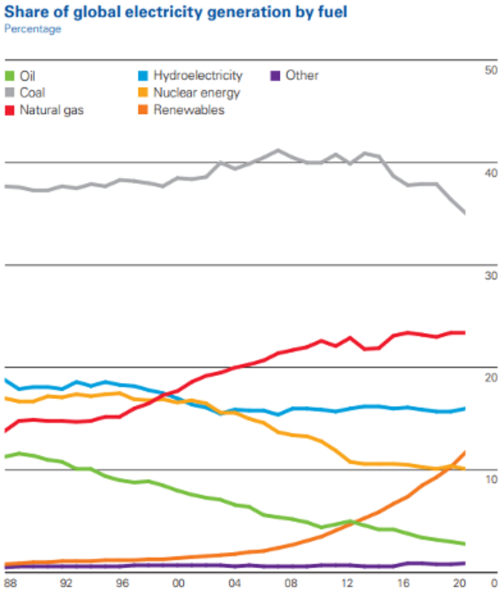
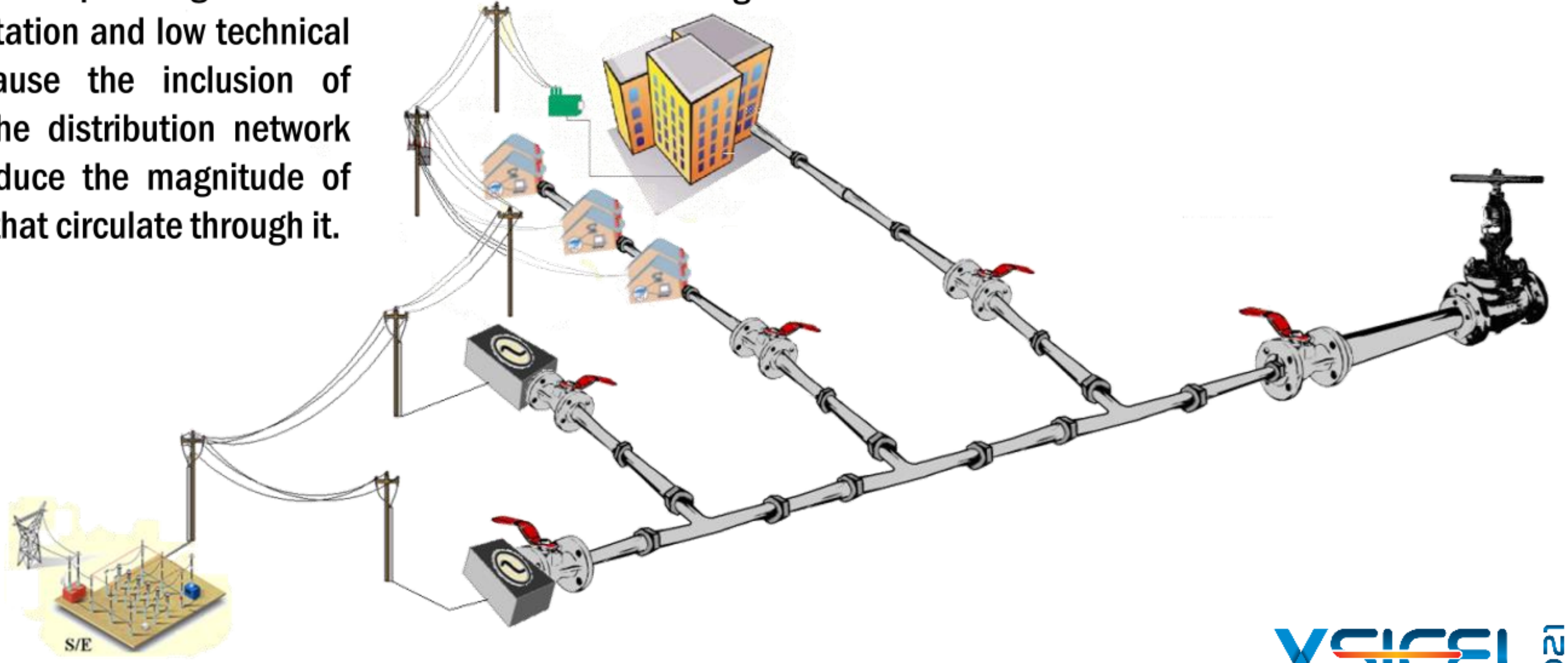




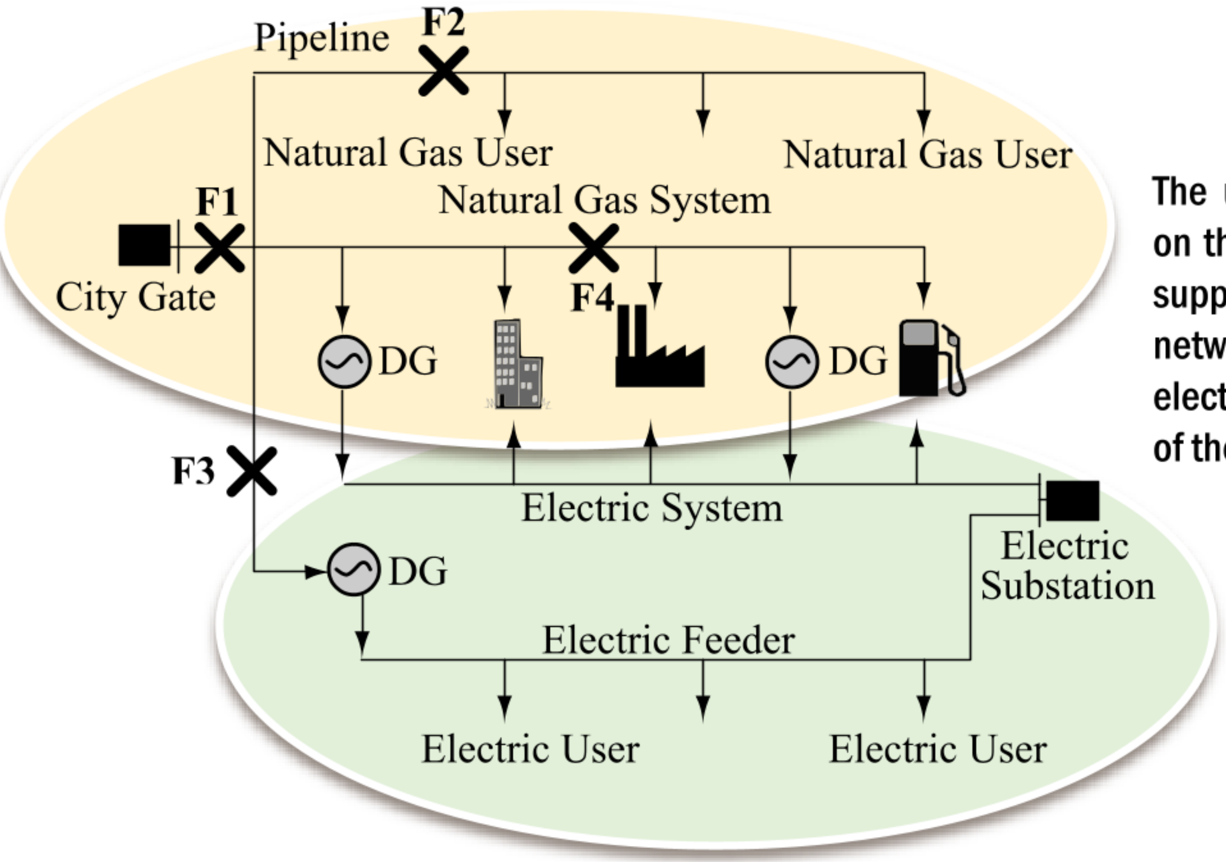
I. Introduction

The implementation of DG-NG allows to improve the reliability of the electrical system, since the occurrence of contingencies in the electrical distribution network generates islands, which could be supplied provisionally by the generators connected downstream of the failed element, reducing the number of unattended users

The implementation of DG-NG allows to obtain low cost planning solutions of implementation and low technical losses, because the inclusion of sources in the distribution network allows to reduce the magnitude of the currents that circulate through it.



II. Problem formulation

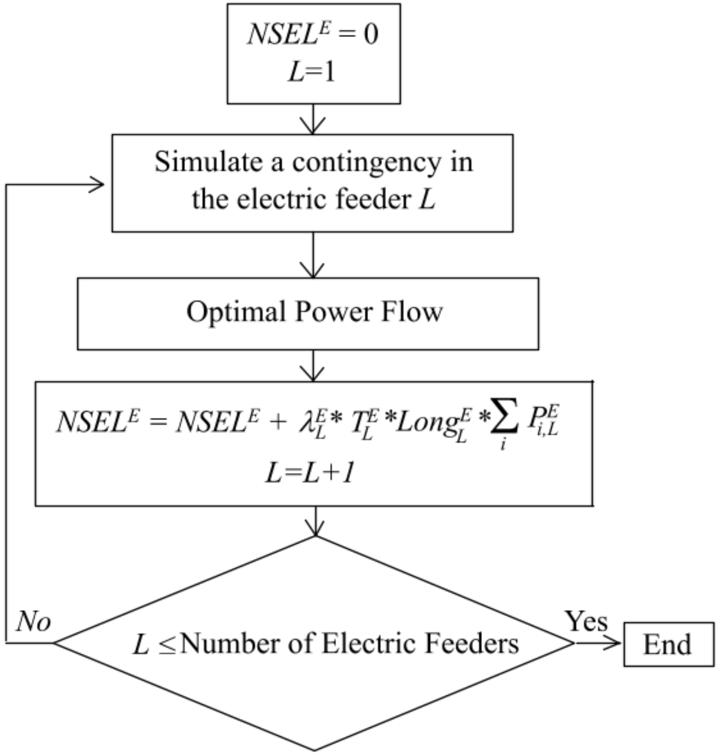


The use of DG-NG generates a dependence on the electricity distribution system with the supply of fuel through the natural gas network, which makes the reliability of the electric network be affected by the reliability of the said network.

III. Proposed methodology

$$NSEL^E = T * \sum_L \left| \lambda_L^E \times r_L^E \times Long_L^E \times \sum_i P_{i,L}^E \right| \qquad (1)$$

$NSEL^E$	Index of the non-supplied energy level by contingencies in the electrical network, without considering contingencies in the natural gas network.
L	Set of line sections of the electrical network.
T	Study period.
λ_L^E	Failure rate of the L section of the electrical network.
r_L^E	Repair time of the electric section L.
$Long_L^E$	Length of section L of the electrical network.
i	Set of loads of the electrical network.
$P_{i,L}^E$	Power not supplied to the load i due to a contingency in section L of the electrical network.



III. Proposed methodology

min $$OF = \sum_{i} real\{S_i^R\} \quad (2)$$

s.t. $$S_i^{ES} + S_i^{GD} - V_i \sum_{\forall l} a_{l,i}^E \, I_l^* = S_i^{LD} - S_i^R \quad (3)$$

$$\sum_{\forall i} a_{l,i}^E \, V_i = Z_l * I_l \quad (4)$$

$$0 \leq S_i^{SE} \leq S_i^{SE\_MAX} \quad (5)$$

$$0 \leq S_i^{GD} \leq S_i^{GD\_MAX} \quad (6)$$

$$V^{min} \leq V_i \leq V^{max} \quad (7)$$

$$|I_l| \leq I_l^{MAX} \quad (8)$$

$$0 \leq real\{S_i^R\} \leq real\{S_i^{LD}\} \quad (9)$$

$$imag\{S_i^R\} = imag\{S_i^{LD}\} * \frac{real\{S_i^R\}}{real\{S_i^{LD}\}} \quad (10)$$

V_i	Voltage in the node i (kV).
I_l	Current through the network section l (kA).
S_i^{ES}	Injected Power by a substation in the node i (MVA).
S_i^{GD}	Injected power by a DG in the node i (MVA).
S_i^{LD}	Power demand in the node i (MVA).
S_i^R	Power rationing in the node i (MVA).
Z_l	Impedance of the network section l (Ohm).
$a_{l,i}^E$	Element $l - i$ of the nodal incidence matrix.
$S_i^{SE\_MAX}$	Maximum capacity of a substation in the node i (MVA).
$S_i^{GD\_MAX}$	Maximum capacity of a DG in the node i (MVA).
V^{max}	Maximum voltage limit (kV).
V^{min}	Minimum voltage limit (kV).

III. Proposed methodology

$$NSEL^G = T * \sum_P \left| \lambda_P^G \times r_P^G \times Long_P^G \sum_i P_{i,P}^E \right| \qquad (11)$$

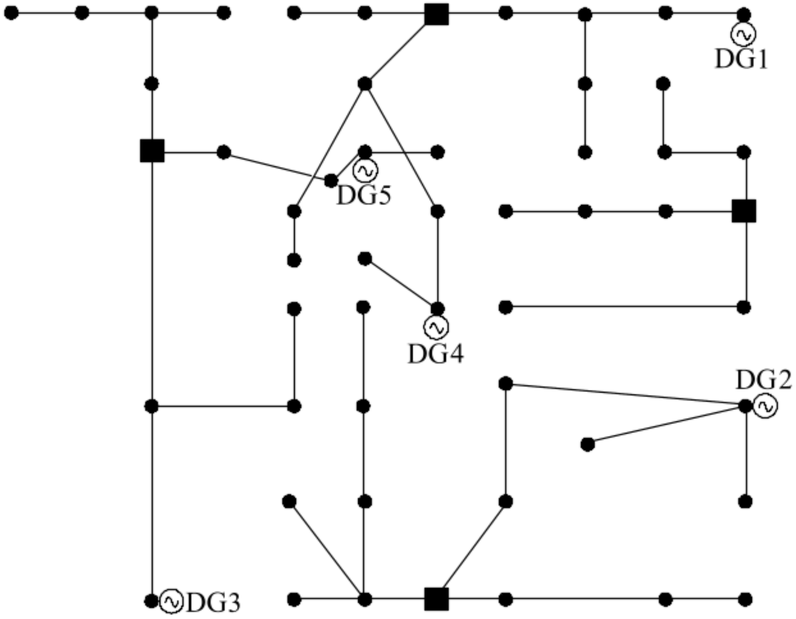
$NSEL^G$	Index of the non-supplied energy level by contingencies in the NG network.
P	Pipeline of the natural gas network.
T	Study period.
λ_P^G	Fault rate of pipeline P of the natural gas network.
r_P^G	Repair time of the P pipeline of the natural gas network.
$Long_P^G$	Length of the P pipeline of the natural gas network.
i	Set of loads of the electrical network.
$P_{i,P}^E$	Power not supplied to the load i due to a contingency in the P pipeline of the natural gas network.

Calculation of the impact percentage of the reliability of the natural gas network on the reliability of the electric network

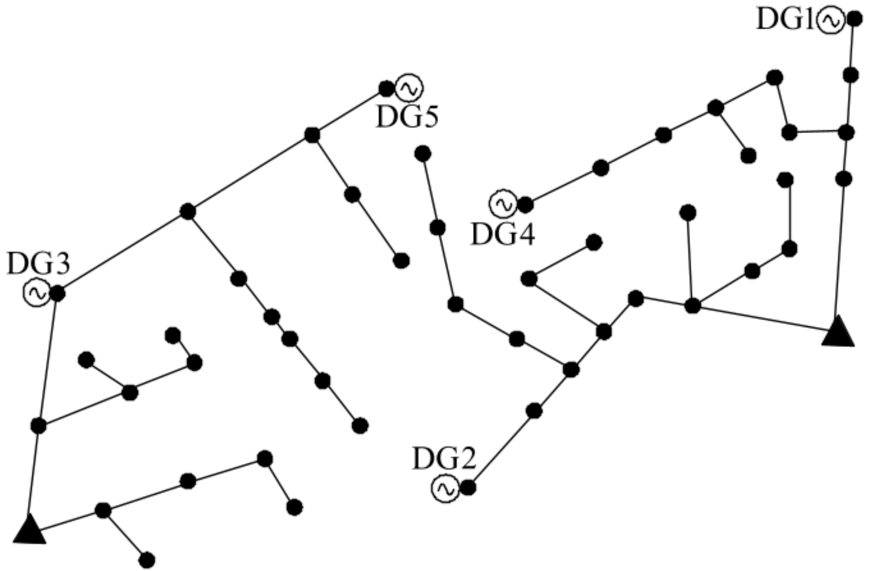
$$Impact = \frac{NSEL^G}{NSEL^E} \times 100\% \qquad (12)$$

If the contingencies in the natural gas network lead to lower *$NSEL^G$* values compared to the reference *$NSEL^E$* value, it is assumed that the effect of the natural gas network is not relevant for the operation of the electrical network. Otherwise, it evidences the existing dependence on the operation of both networks.

IV. Test and results



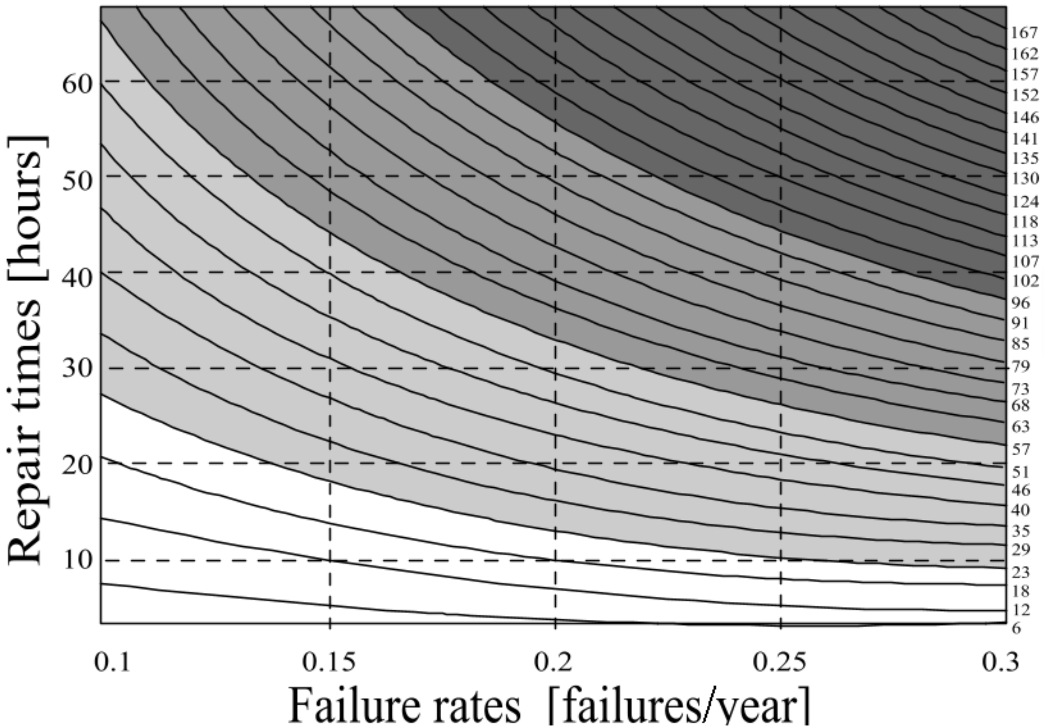
Electrical network



Natural gas network

IV. Test and results

Impact of the natural gas network on the electrical network



It is important to keep in mind that these formulations are highly dependent on failure rates and repair times in both systems. Therefore, the final evaluation requires real values and ranges of these parameters for both electrical and natural gas systems, in order to obtain results in accordance with reality.

V. Conclusions

With the purpose of guaranteeing the adequate operation of DG-NG in the electrical network, this paper develops a methodology that allows to quantify the impact of the reliability of the natural gas system on the reliability of the electrical system.

The results allow to affirm that the reliability of the electrical networks with important concentrations of DG-NG presents a high dependence on the natural gas network, when the latter presents a low reliability. This implies that planning methodologies for integrated electricity and natural gas distribution systems must consider the effect of the reliability of the gas network on the design of the infrastructure and on the location and sizing of DG-NG.

VI. Questions