Long Term Planning Method Comparison Considering DG Interconnection

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Introduction

Opening of
the energy market

New technologies for embedded
generators and storage devices

Overload of
transmission systems

European and
Kyoto accord

Ecological
constraints

Rising amount of distributed generator in distribution systems
(not planned for)

New Management methods of
DGs

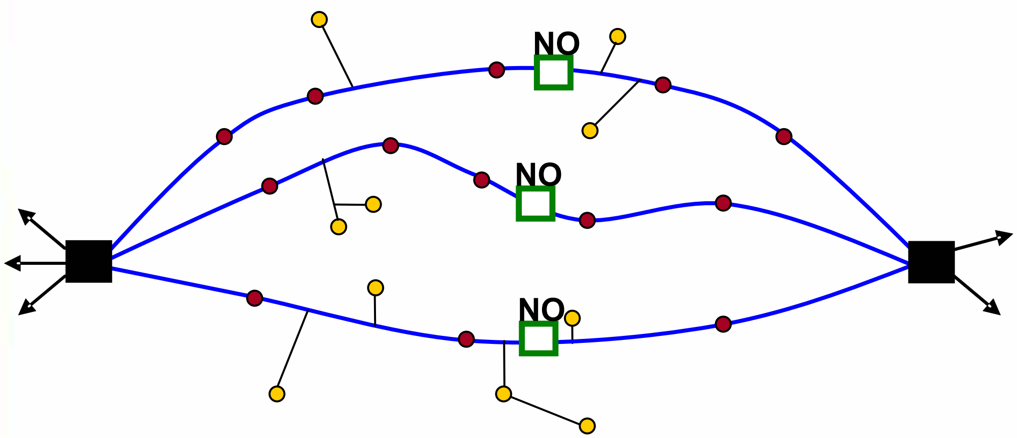
New architectures paradigms

Contents

Contents

- The different architectures
  - Loopable radially operated
  - Secured feeder and its derivatives
- DGs impacts and solutions
  - Definition
  - Evolutions due to a massive penetration and possible solutions
  - Impact studies for wind mill insertion
- Research algorithms for optimal structures design
  - Implementation of the studied network and evaluation criteria
  - Secured feeder
  - Grid structure
  - Elliptic structure
  - Synthesis
- Conclusion and further works

Secured feeder



- HV/MV substation
- Normally open switch
- Primary feeder
- Secondary feeder
- MV load with normally closed switches
- MV load

Description

- Two ways to provide electricity
- Radial operations
- Secured feeders between two substations

Advantages

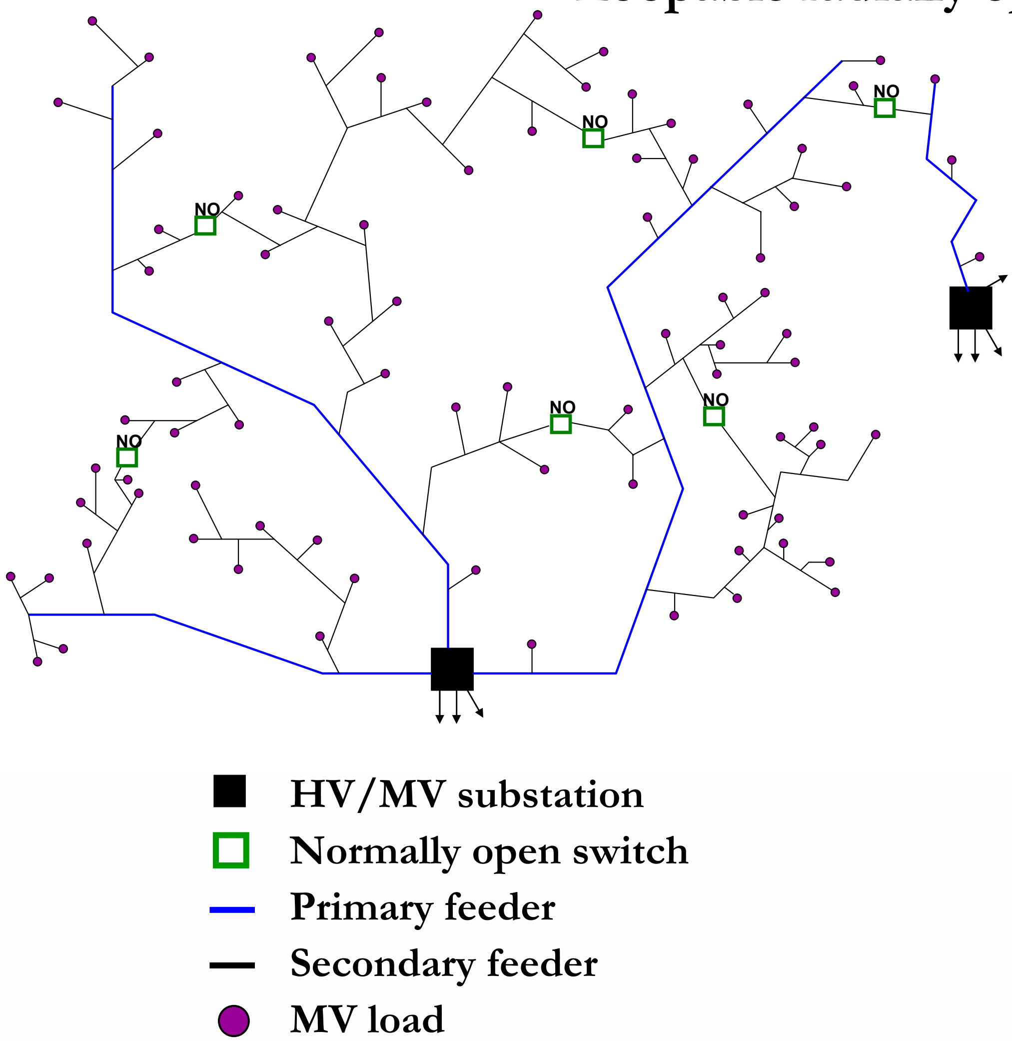
- Cheap
- Easy way to operate
- Good quality of service

Drawback

- Feeder power limited

The different architectures

Loopable radially operated



Description

- One way to provide electricity
- Secured feeder :
  - from another substation
  - from the same substation

Advantages

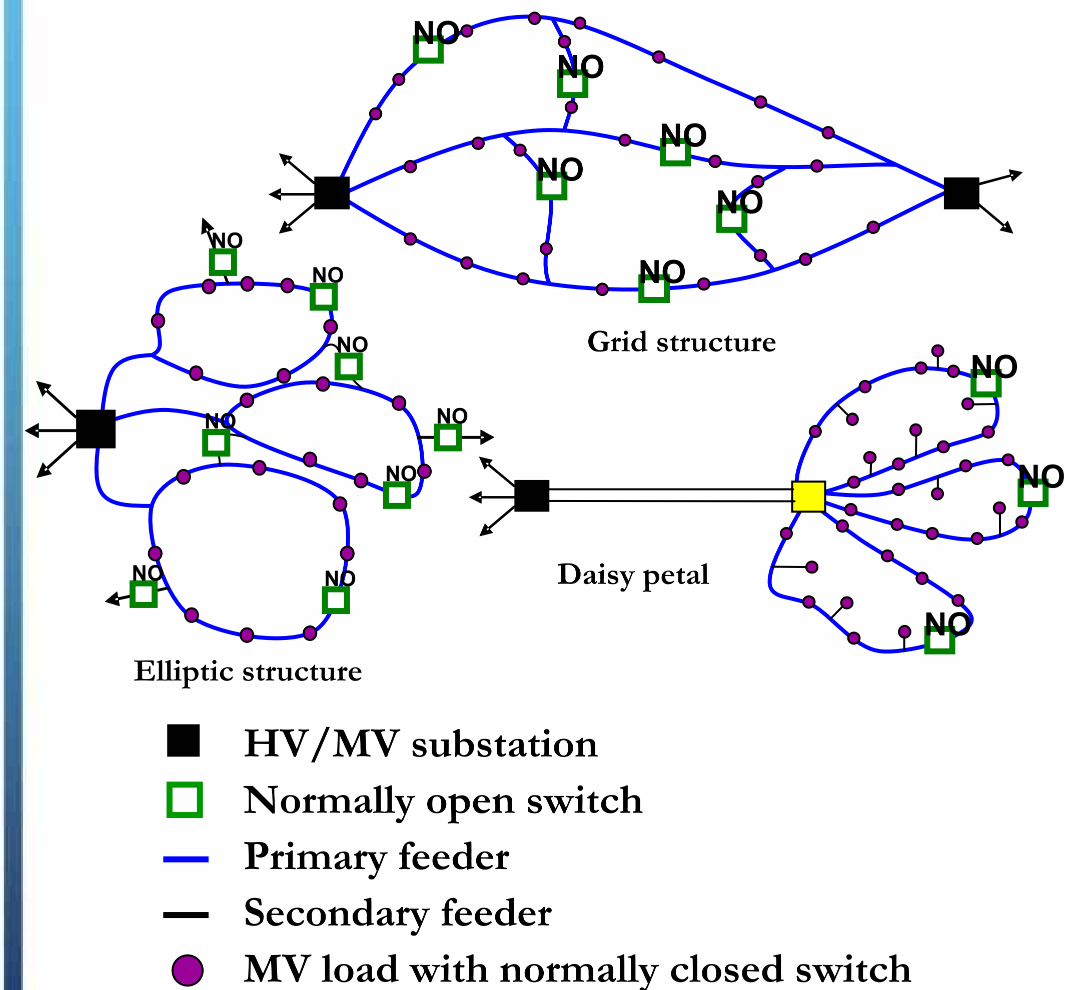
- Cheap
- Easy to operate
- Acceptable quality of service

Drawback

- Feeder power limited

The different architectures

Secured feeder derivatives



Grid

- Quality of service excellent
- Very expensive structure
- Feeder power less limited

Daisy Petal

- Useful for locally concentrated load
- Enable a future creation of a substation

Elliptic structure

- Complicated operation
- Hardly reliable because hardly automated

Contents

DGs impacts and solutions

Definition

- Interconnected with the distribution network
- Pn ≤ 12 MW (France for MV level)

Evolutions due to a massive penetration

- Distribution network → power sent back to transport level
- Reduction of centralized primary plants (in proportion)
- Participation to Ancillary Services (frequency support/voltage adjustment)
- Protection relays behavior disturbed

Possible solutions

- *Reinforcement* (conductors mutation that are congestioned) or dedicated feeder
- Looping/meshing of distribution networks

DGs impacts and solutions

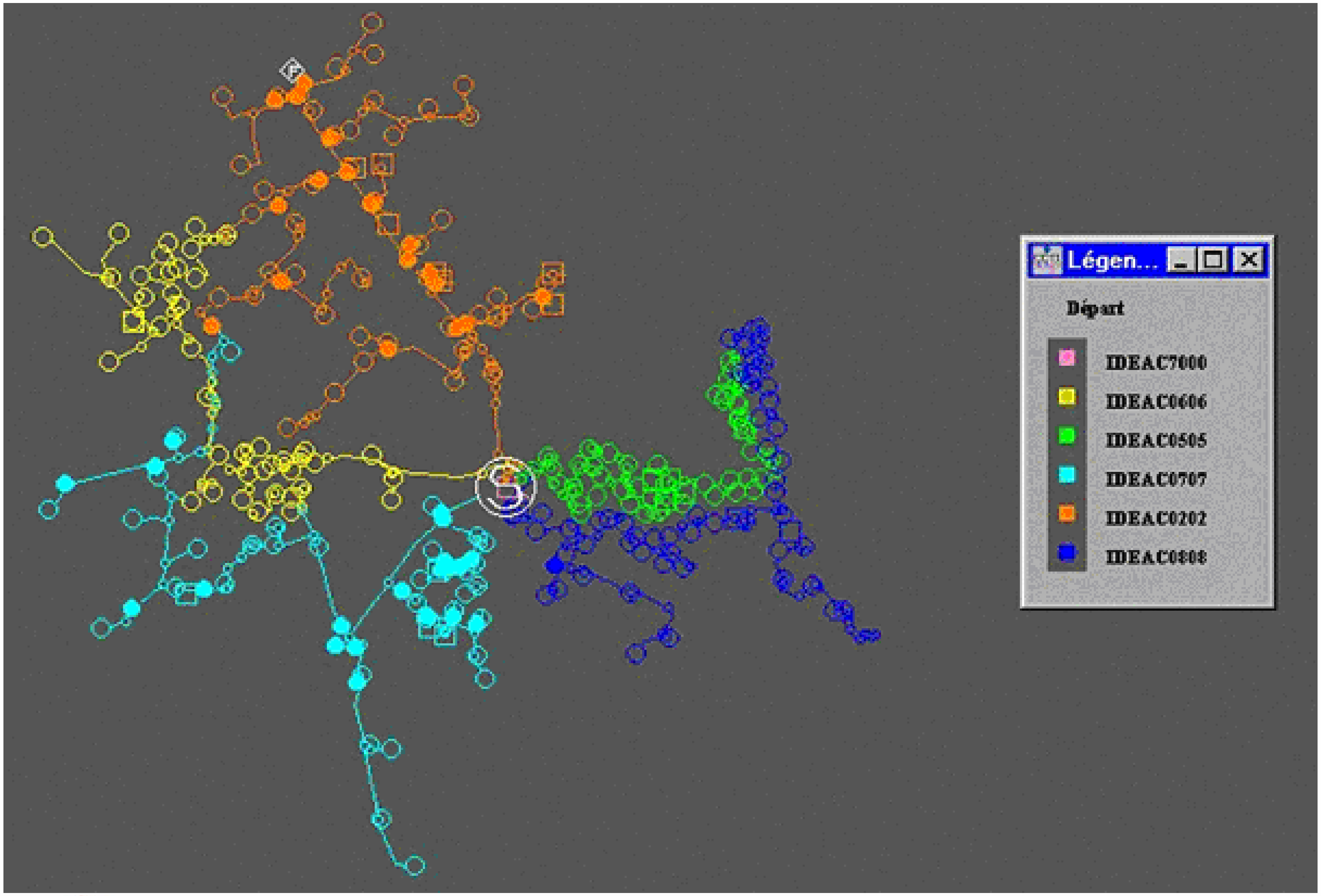
Impact studies of wind mill insertion

- Study on a part of a real network (EDF)

Characteristics

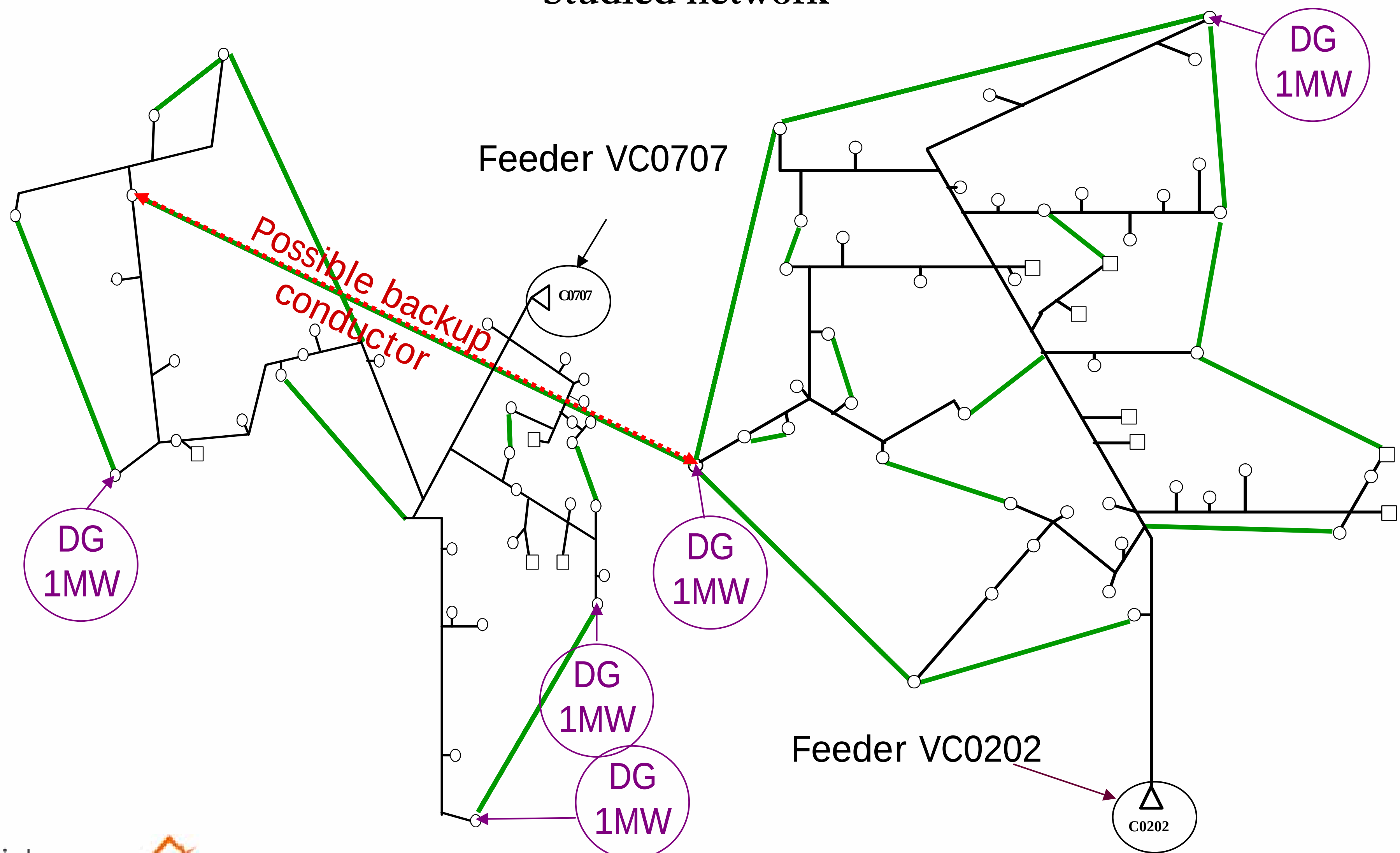
- Substation : 63 kV
- Transformer : 36 MVA, 63 kV/20 kV
- Two rural feeders that can be rescued
- Use of a program (impact of wind mills on the voltage profile)

Real EDF network

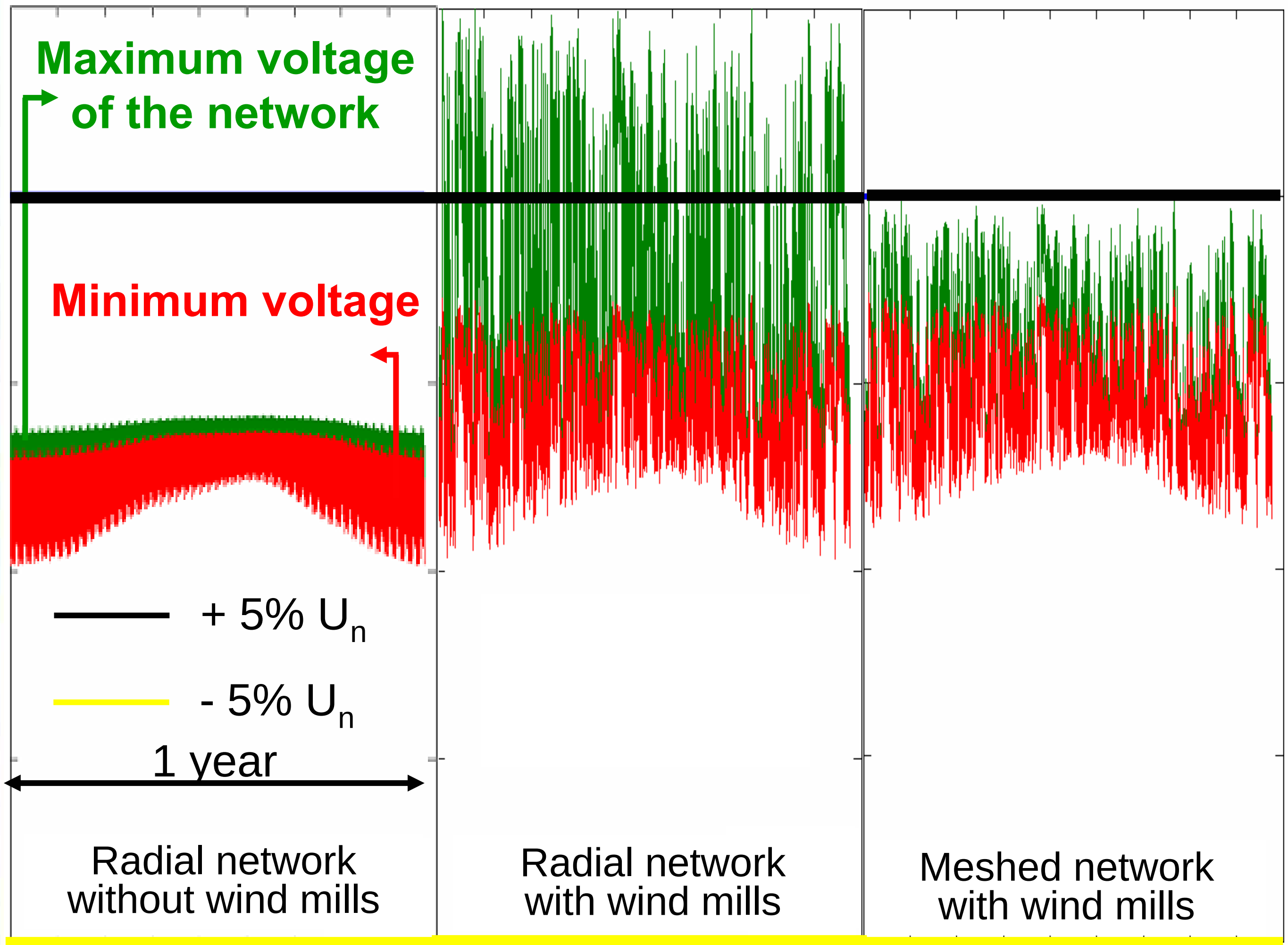


DGs impacts and solutions

Studied network



Voltage profile



Radial network: increase of voltage over 8 % x U_n

Highly meshed network: voltage lower than 5 % x U_n

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Implementation of the studied network and evaluation criteria

→ The existing conductors are erased
→ Only substation and load locations were considered
→ Objective: to find an optimal pattern among
- secured feeder
- grid structure
- elliptic structure

→ Why? Meshable structures help reducing some DGs impacts

Research algorithms for optimal structures design

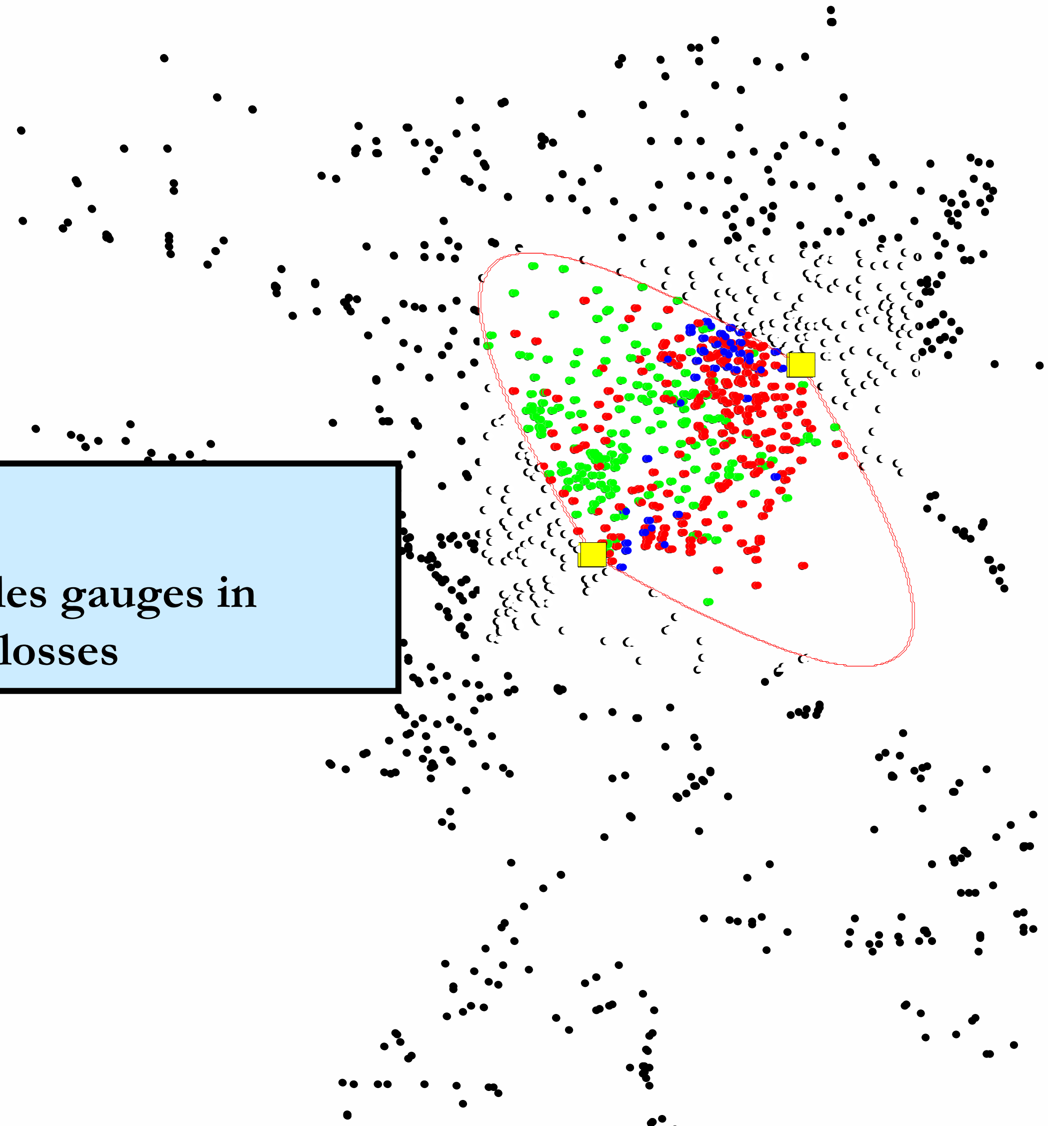
Problem reduction:

→ Two parabolas as limits

→ Rotation

Qualification index:

→ Determination of cables gauges in order to optimize power losses



Conductor gauges to optimize power losses

$$\mathrm{Cact} = \mathrm{I} + \sum_{n=0}^{N} \frac{\mathrm{Cp}_n}{(1+\mathrm{i})^n}$$

With :
- Cact = actualized cost (k€)
- I = Investment (k€)
- C = Cost of 1 kW of pick power losses (k€)
- p_n = pick power losses at year n in kW
- i = actualized cost (8%)
- N = 40 years

$$p_n = \frac{\mathrm{RS_0}^2 (1+l)^{2n}}{U^2}$$

With :
- l = load evolution (2%/an)
- S_0 = load at year 0
- R = resistance of conductors

Considering $X = \frac{(1+t)^2}{1+i}$

$$\Rightarrow$$

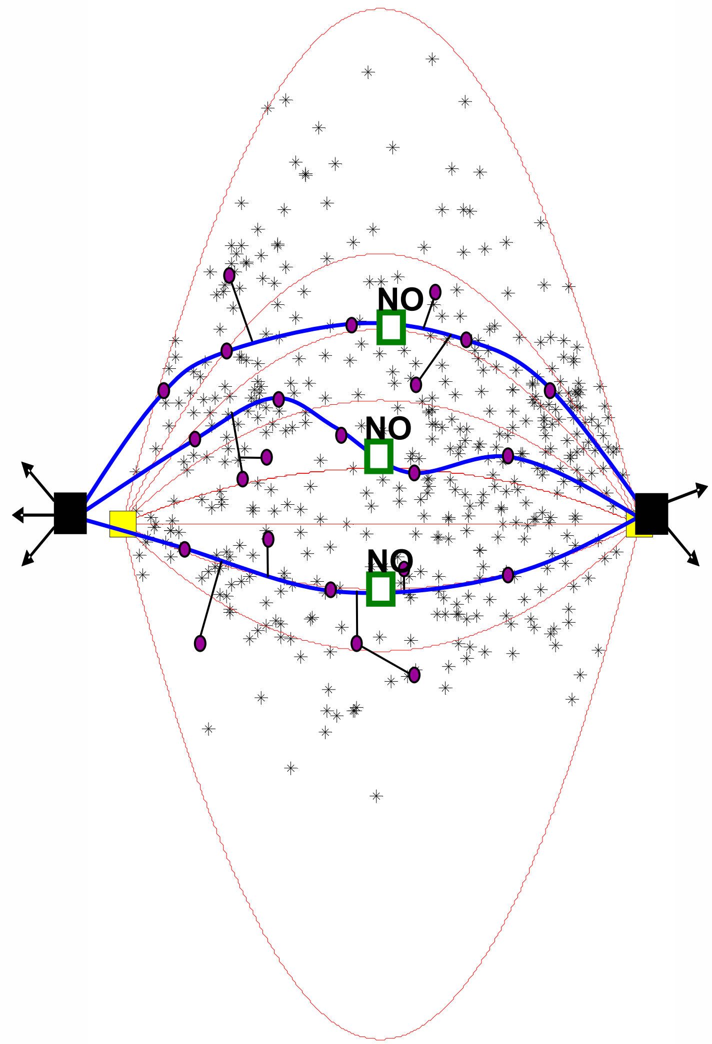
$$Cact = I + C \times \frac{RS_0{}^2}{U^2} \times \frac{1 - X^{N+1}}{1 - X}$$

Research algorithms for optimal structures design

Secured feeder

Steps :

- Find the number of primary feeders
- Allocate secondary loads to those feeders
- Find the gauge of metal conductors

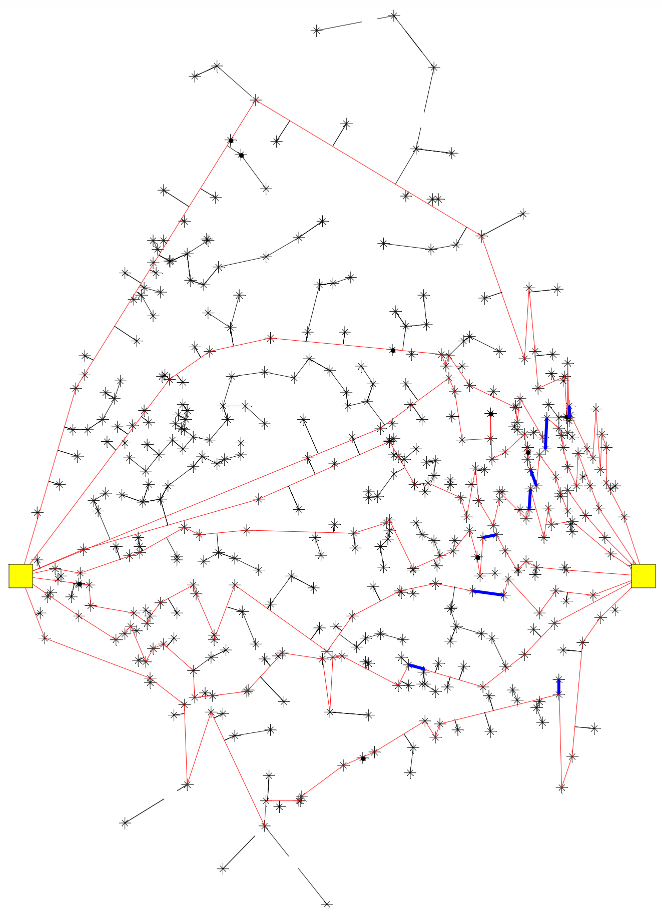


Example: maximal rate = 20 %

→ Equation of the parabola joining the two substations and symmetrical : $y = ax^2 - ax$

Creation of areas ↔ minimize the square error between the parabola and the loads of the considered area.

Research algorithms for optimal structures design



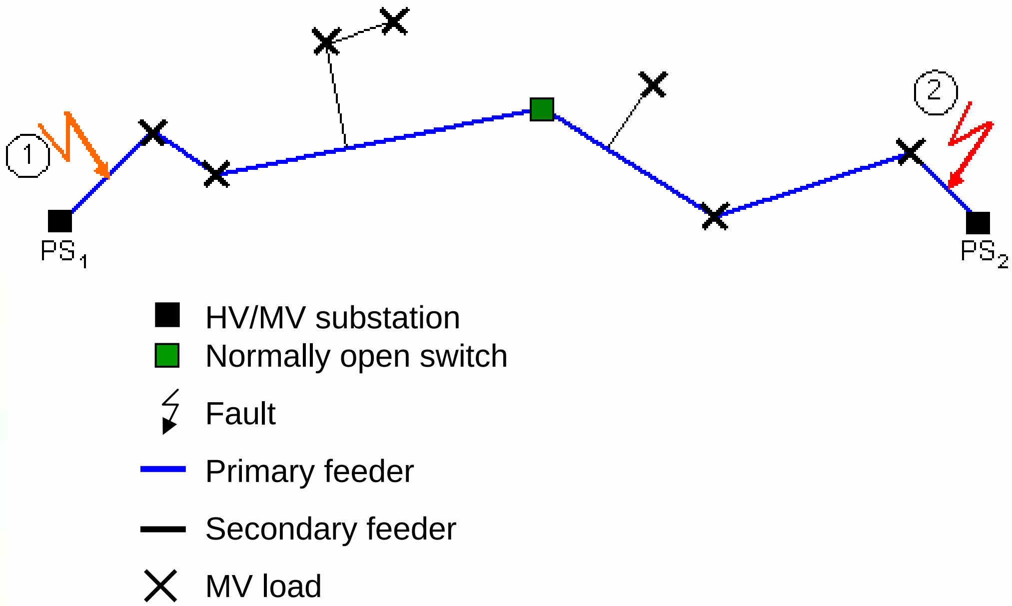
<u>Criteria to choose the primary feeders</u>

Joining large consumers

<u>Criteria to choose the secondary feeders</u>

Shortest way to primary feeders

Research algorithms for optimal structures design



Fault 1 → PS2 have to supply all the loads

↓

Sizing up cables to satisfy this constraint

↓

Section (mm²)	Resistance (Ω/km)	Impa (A)
95² Alu	0,32	337
150² Alu	0,206	447
240² Alu	0,125	598
240² Cu	0,075	748

← Actualized cost

Grid structure

Meshed structure (economically not reasonable)

⇩

Good architecture → power losses optimization

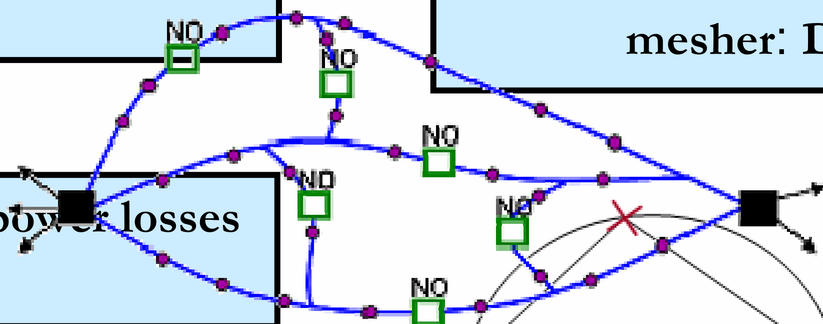
⇩

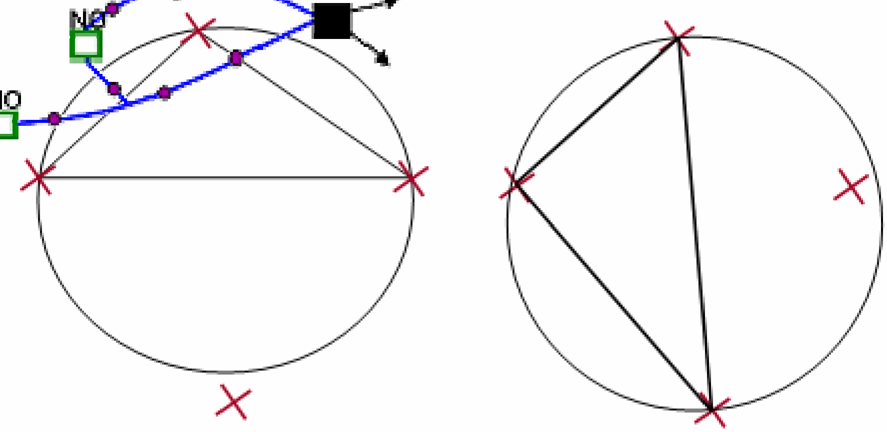
Choice of inter-substation secured feeders

⇩

Choice of intra-substations secured feeders

Choice of meshing → automatic mesher: Delaunay

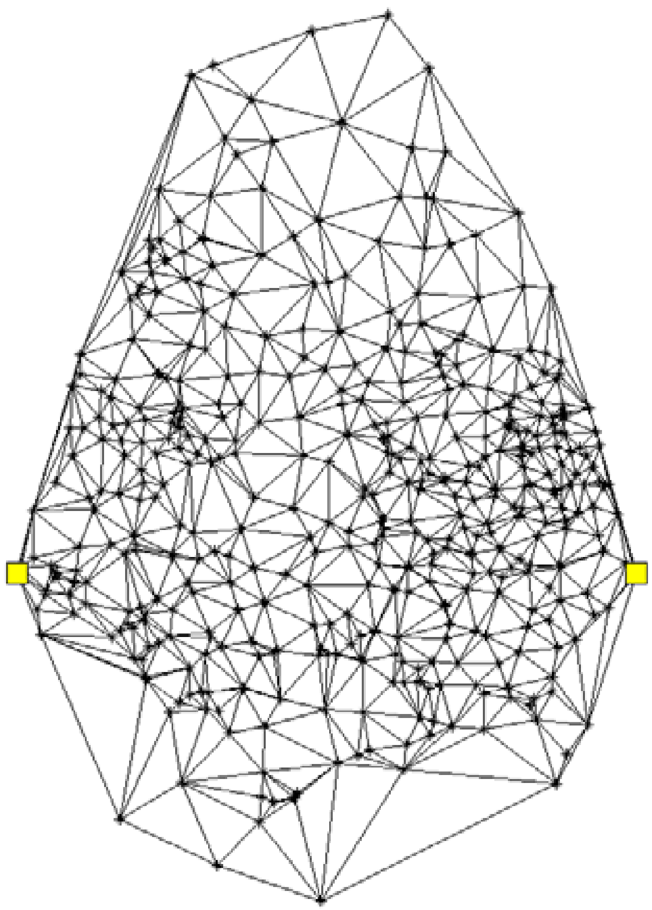




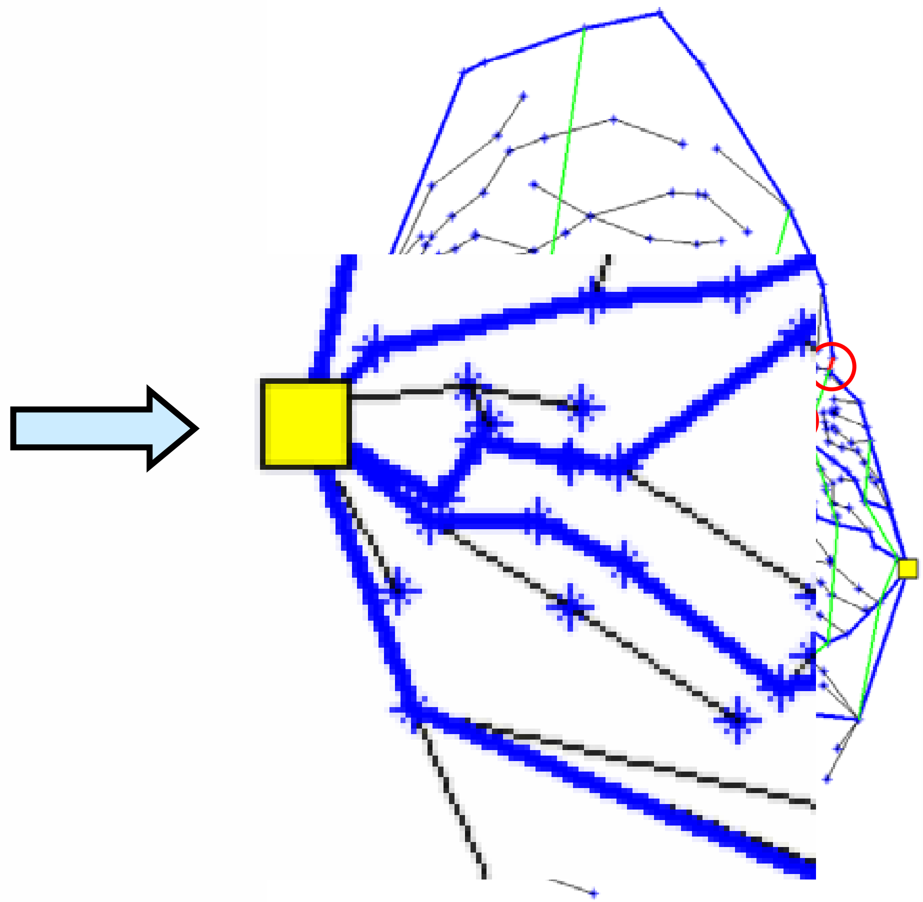
Delaunay's triangle

Wrong Delaunay's triangle

Research algorithms for optimal structures design



Delaunay's meshing

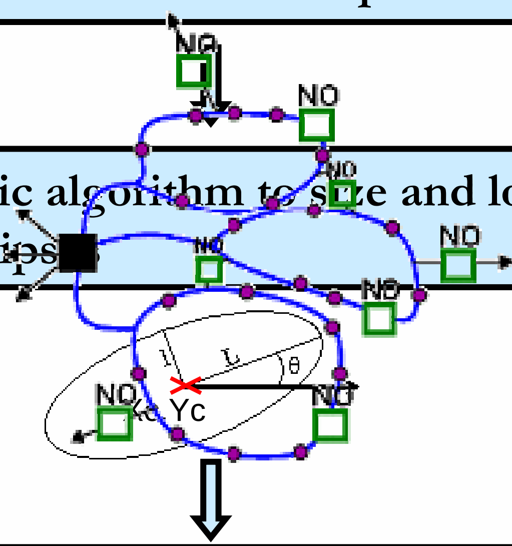


Research algorithms for optimal structures design

Elliptic structure

Approximation with ellipses

Genetic algorithm to size and locate the ellipses



Problems: too many parameters

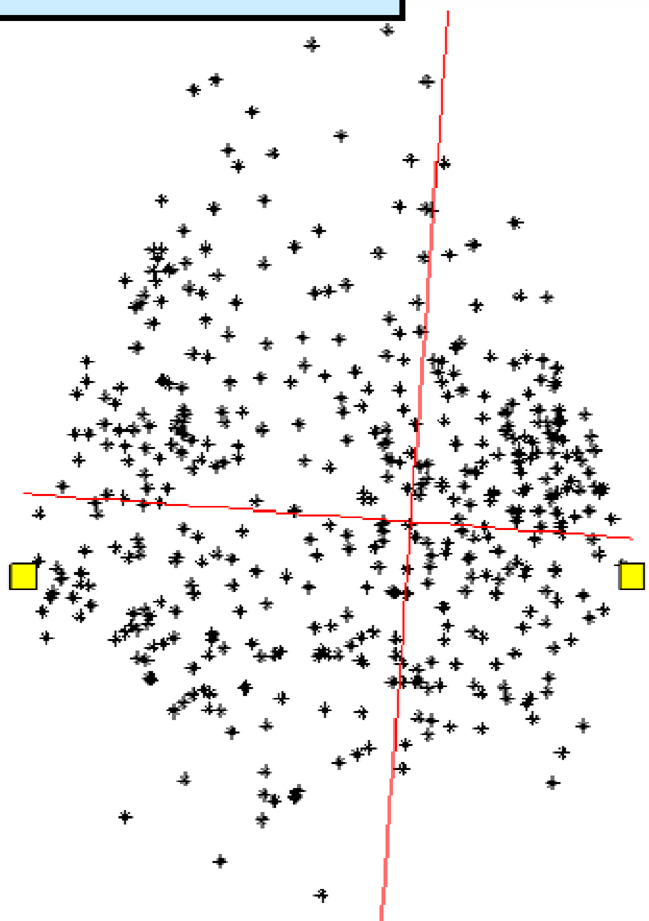
- Number of ellipses

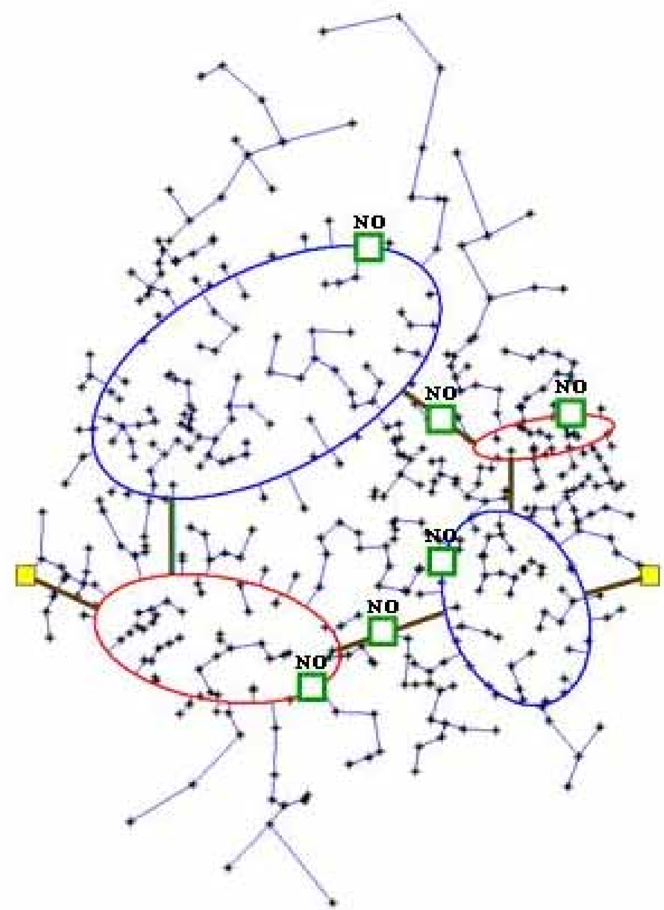
- 5 parameters per ellipse

- Which load affected to which ellipse

Research algorithms for optimal structures design

Ellipses Number = 4





Sub areas: two lines crossing the barycentre of all the loads

Ellipses centers: barycentre of the previously found sub areas

Synthesis

	Nb departures	Conductors volume (m3)	Conductors length (km)	Nb switches
		Secured feeder		
maximum rate = 10%	15	28,5	95,53	15
maximum rate = 20%	8	29,04	80,37	8
maximum rate = 30%	5	29,88	71,63	5
		Grid structure		
Radial	5	28,41	97,3	0
Inter-sub secured feeder		38,49	97,93	5
Intra-sub secured feeder		53,43	108,12	25
		Elliptic structure		
4 ellipses	2	29,55	189,66	6

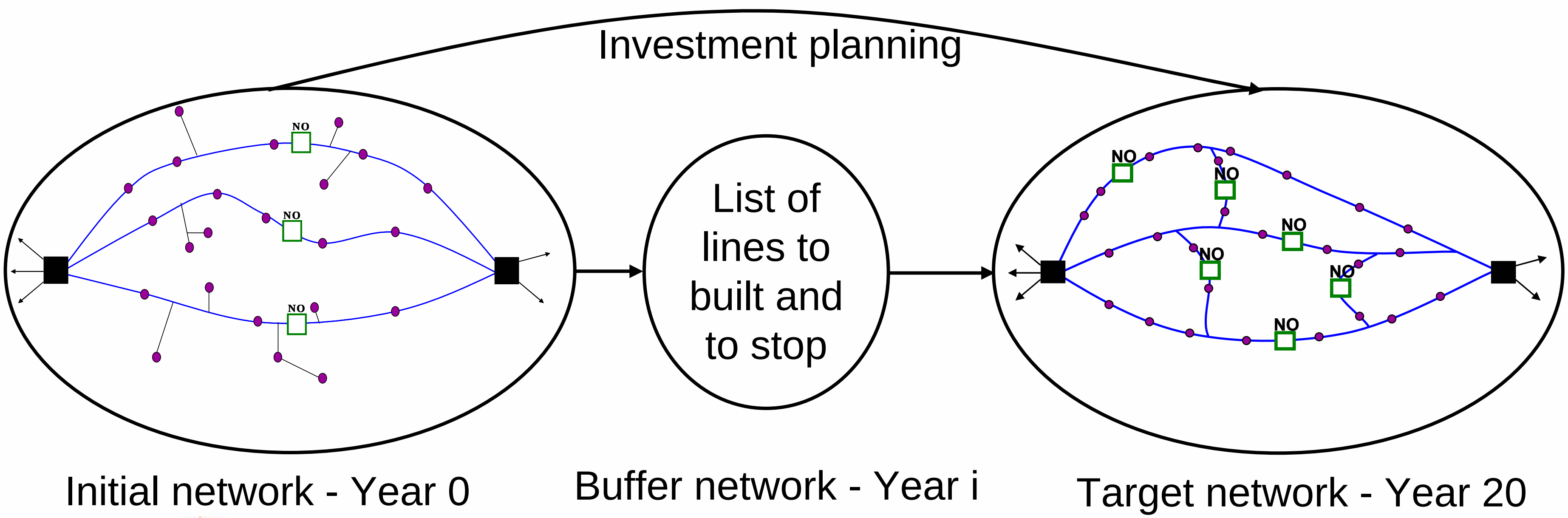
Conclusion and further works

- Looping/Meshing of distribution network with DGs → exciting improvement of the network behavior (voltage profile for instance)

- Development of robust algorithms to find the optimal pattern of a network, this pattern depends on:
    - the importance paid to reliability
    - the investment whished

Conclusion and further works

- Developing evolutionary algorithms to build mid term investment planning to reach the target network (acceptability of DGs)
    - defining the investments schedule
    - including non linear constraints (operation costs, annual investment costs, reliability constraints)
- Comparing with classical method (reinforcement)
- Comparing with other algorithm (operational research)
- Validate with stochastic DGs interconnection

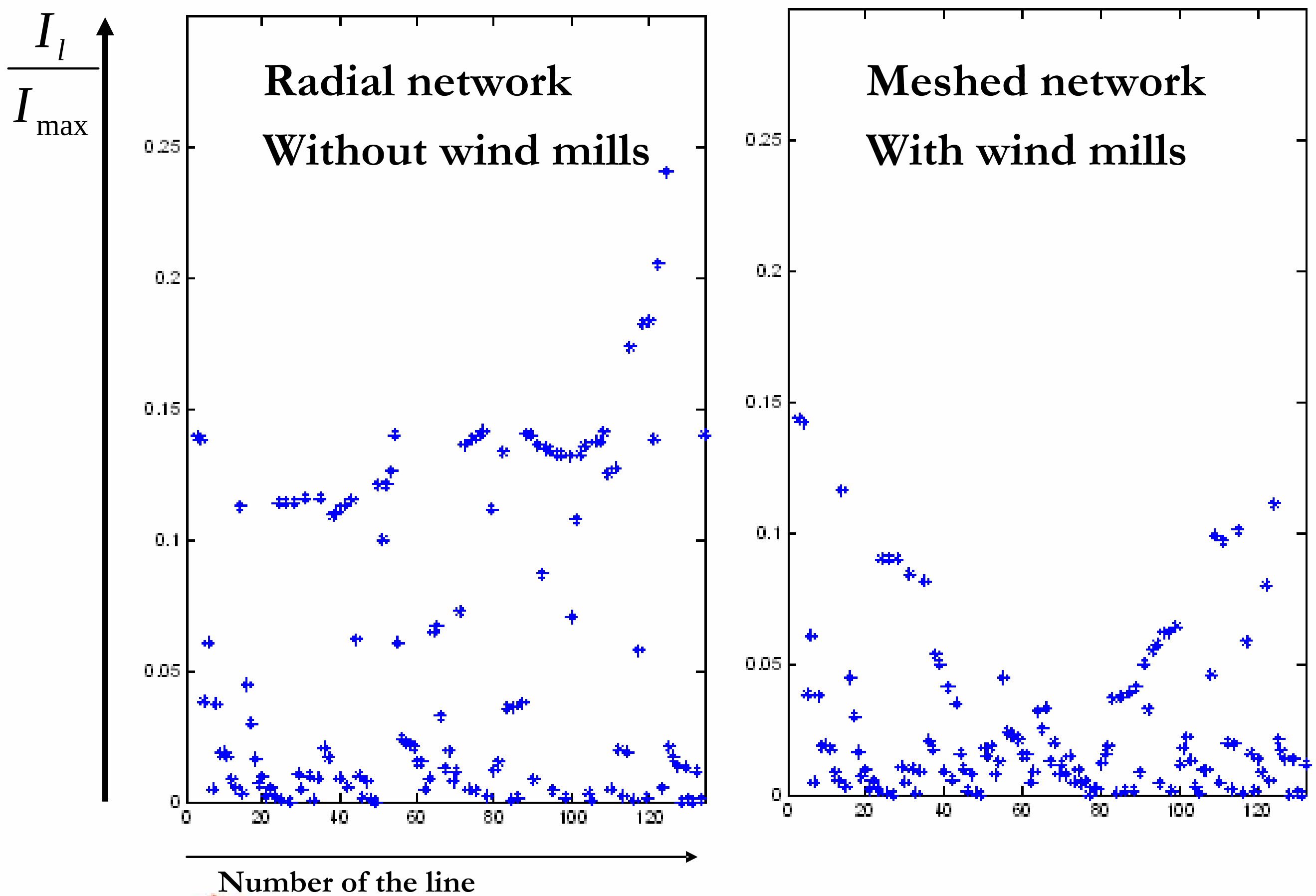


Thank you for your kind attention!

Annexes

I_l = line current

I_{max} = maximal admissible current in the line



Decrease of the current in the conductor

Research algorithms for optimal structures design

Usage rate

$$k = \frac{S_{max}\text{ in normal mode}}{S_{max}\text{ in secured mode}}$$

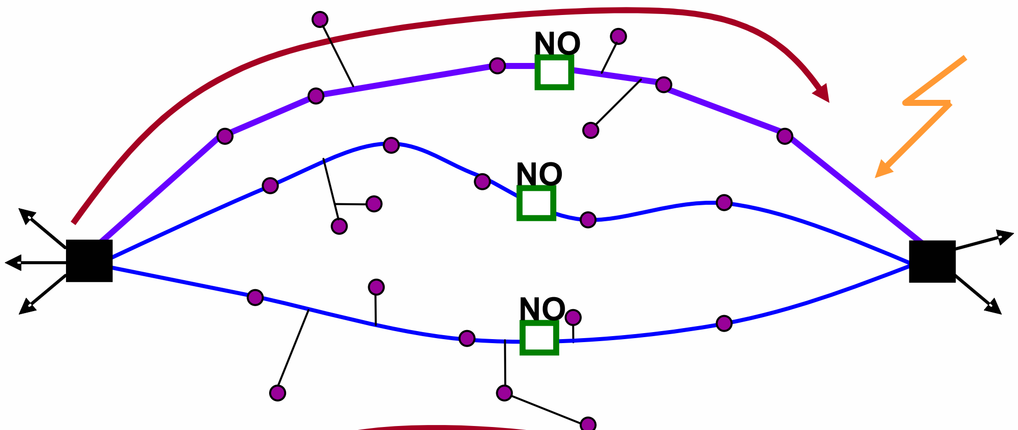
- Easy computation in some cases (secured feeder)

- More complicated for other structures

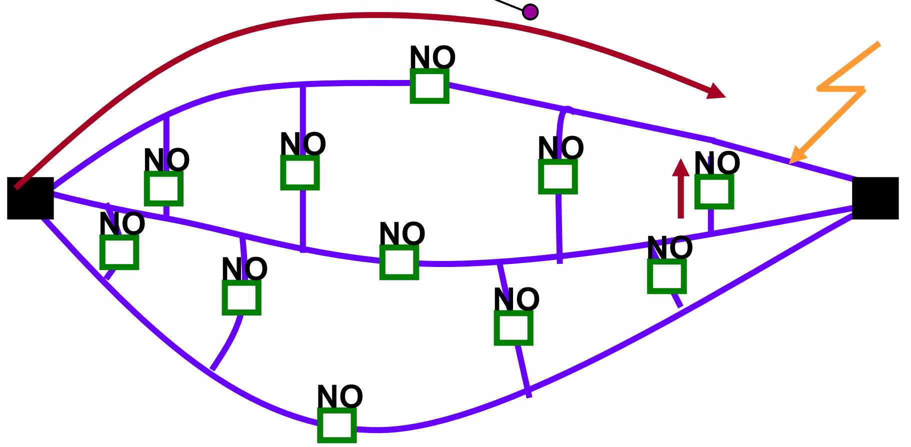
→ Results can be different regarding the various configuration among the same structure

Utilization coefficient

$$k = \frac{S_{max}\text{ in normal mode}}{S_{max}\text{ in secured mode}}$$



k=0.5

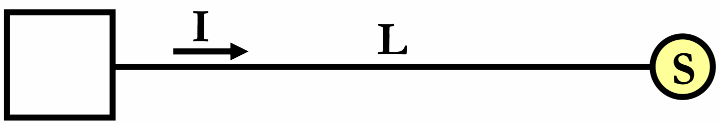


k>0.5

Utilization coefficient

	Secured feeder	Grid structure	Meshed structure
Usage rate	**0.5**	**0.75**	**0.75**

Loads concentrated at the end of the conductor



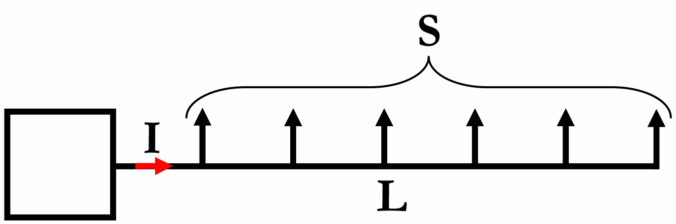
- r = Linear resistance of the conductor
- L = Length of the line
- S = Power of load

i(l) = L = constant

$$p = \int_0^L 3 \times r \times I^2 dl$$

$$\boxed{p = 3\, r\, L\, I^2}$$

Load uniformly distributed on the conductor



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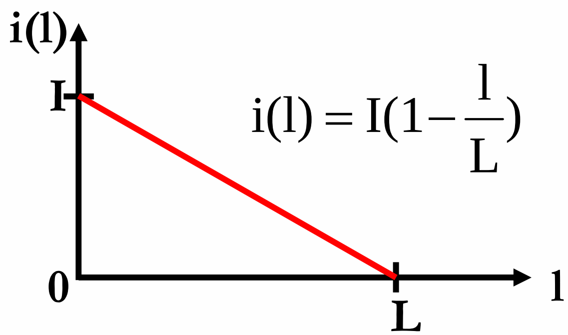

$$i(l) = I(1 - \frac{l}{L})$$

$$p = \int_0^L 3 \times r \times I^2 (1 - \frac{l}{L})^2 dl = 3 \times r \times I^2 \int_0^L (1 - 2\frac{l}{L} + \frac{l^2}{L^2}) dl$$

$$p = 3 \times r \times I^2 \left[l - \frac{l^2}{L} + \frac{l^3}{3L^2} \right]_0^L = 3 \times r \times I^2 (\frac{L}{3})$$

$$\boxed{p = r\,L\,I^2}$$