Fractal Grid

Towards the future Smart Grids

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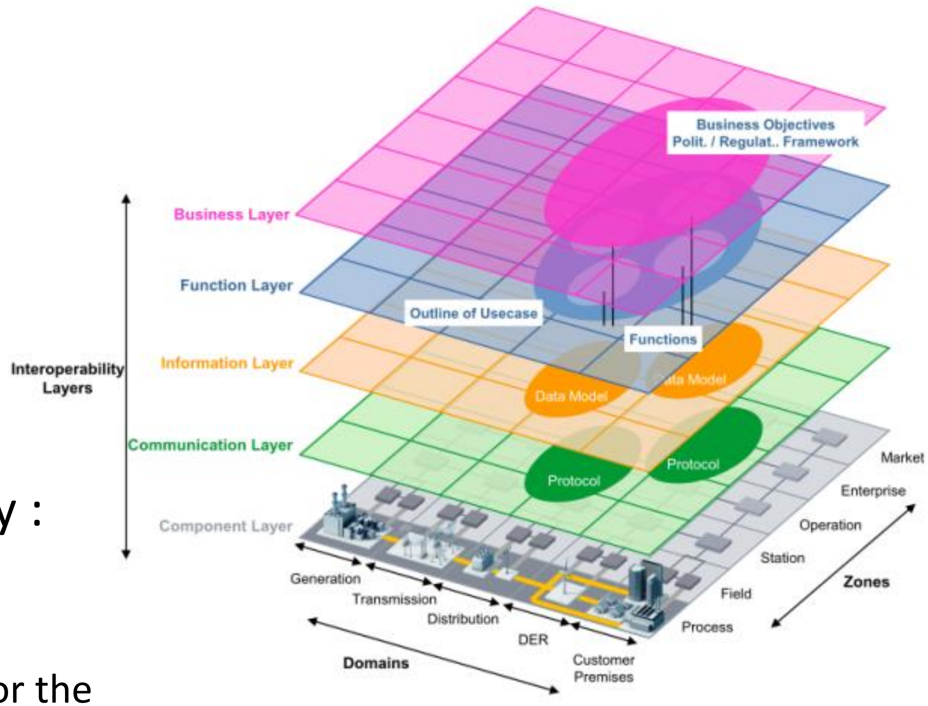
2nd ELECTRA/ETP SG WG1 Joint Technical Workshop
Brussels, 10th December 2015

Smart grids are complex systems

- Main factors of complexity :
  - –Multilayered and hierarchical architecture
  - –Heterogeneity of the grid components
  - –Numerous dynamical interactions
  - –Chaotic behavior (blackouts)
  - –Self-organization (self-healing)

- Modeling the complexity is necessary :
  - –To understand how Smart Grids properties emerge from their complex organization
  - –To design resilient and agile architectures for the optimization of Smart Grids operations

- The proposal of a framework for standardization of Smart Grids is a key challenge
  - – To achieve interoperability of Smart Grids



Smart Grid Architecture Model [1]

[1] CEN-CENELEC-ETSI Smart Grid Coordination Group, SG-CG/ M490/F_ Overview of SG-CG Methodologies, version 2.0 (August 2014)

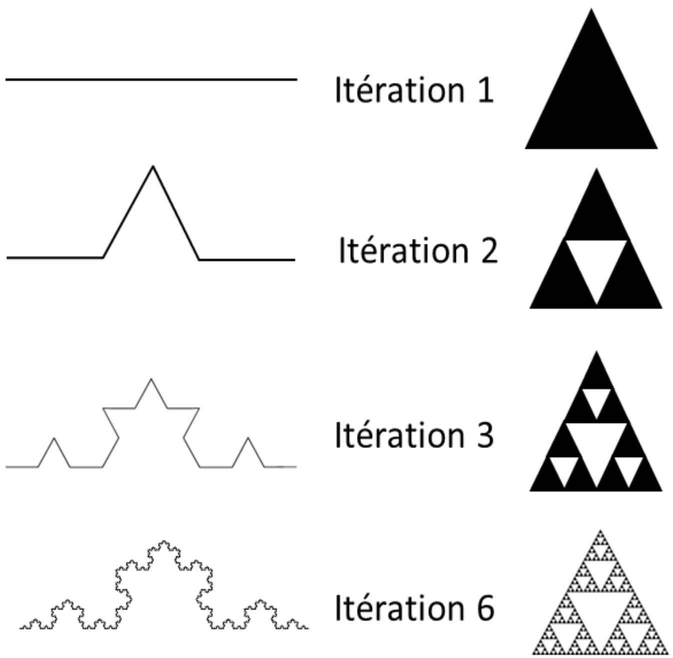
Project summary

- **About the use of fractality as a core concept to analyze, understand, design and operate the future Smart Grids**
- Academic partners :
  - *G2Elab* (Grenoble Electrical Engineering Lab, UMR 5269 Grenoble-INP – UJF – CNRS) – Power systems team
  - *ARMINES* (Association dédiée à la recherche en partenariat avec MINES ParisTech) – Centre of Processes, Renewable Energies and Energy Systems
  - *LMI* (Laboratoire de Mathématiques de l'INSA de Rouen, EA 3226, FR CNRS 3335) – Applied mathematics
  - *ThéMA* (Théoriser et Modéliser pour Aménager, UMR 6049, Univ. Franche Comté et de Bourgogne - CNRS) - Mobility, City and Transport
- With the support of **RTE, EDF R&D, ErDF, Schneider Electric and RATP**

- Starting of the project : 15th january 2016
- Duration: 42 mois
- Funded budget: 498 189 euros

Some basic definitions about fractals

- Fractals = self-similar objects characterized by non-integer dimensions



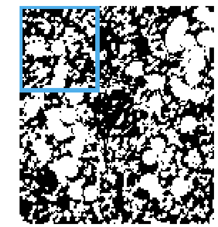
Fractale de Van Koch

$$D = \frac{log(4)}{\log(3)} \approx 1{,}26$$

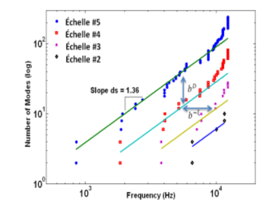
Ensemble de Sierpinski

$$D = \frac{log(3)}{\log(2)} \approx 1{,}58$$

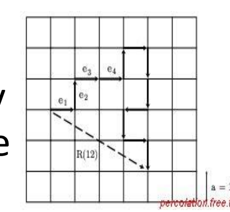
- Fractal dimension D
  - –It characterizes how the fractal fills in the euclidean space
  - –Mass(lenght) α length^{D}



- Spectral dimension ds
  - –It characterizes the frequency distribution of the dynamic modes
  - –Number of modes(freq) α freq^{ds}



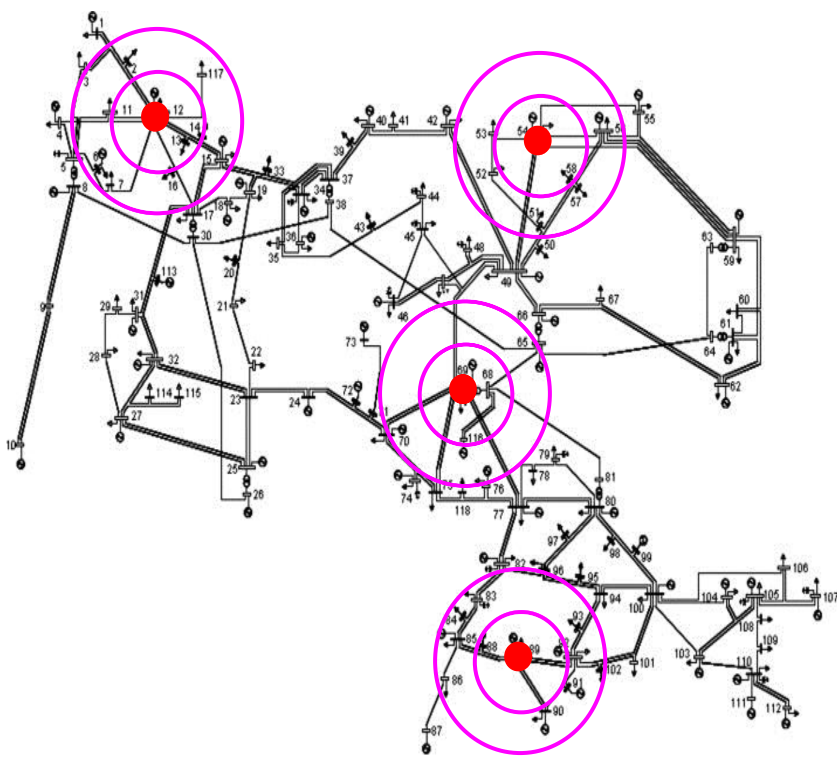
- Random walk dimension dw
  - –It characterizes the distance done by a random walker on a fractal structure
  - –Distance(time) α time$^{1/dw}$

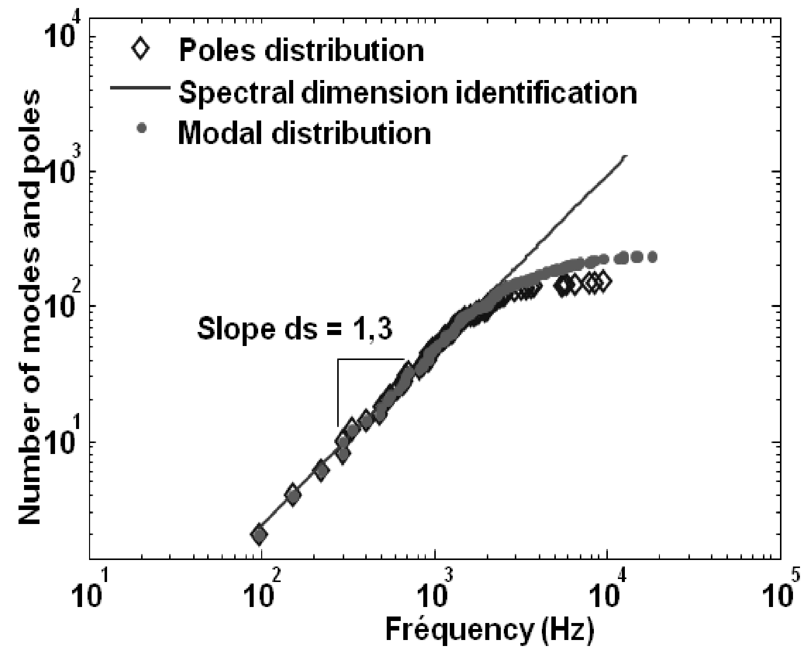


- ds=2D/dw

Fractal dimensions of power systems

- IEEE 118-bus test network [2]
  - Meshed transmission network
  - Fractal dimension D = 1.76
  - Spectral dimension ds = 1.3

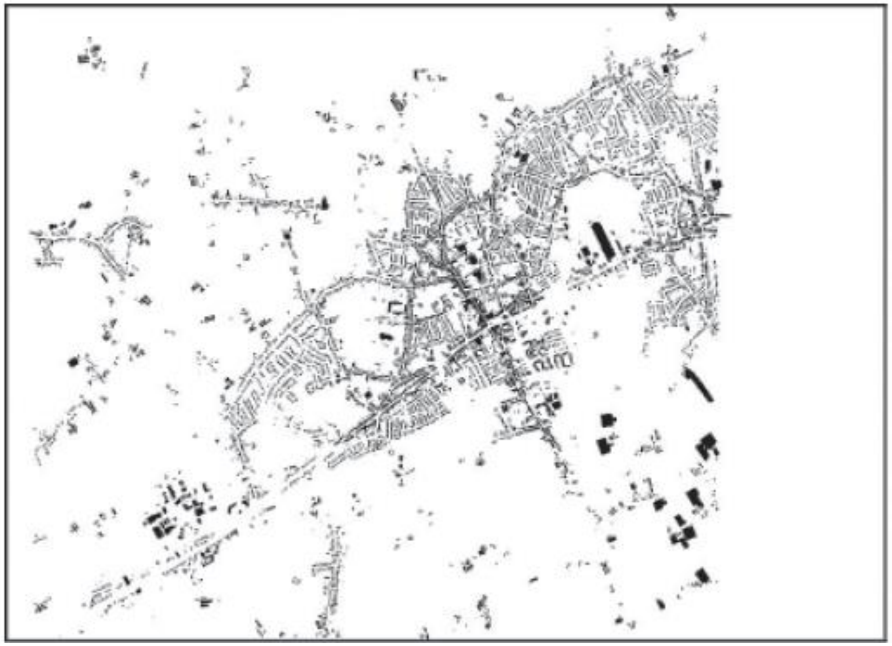


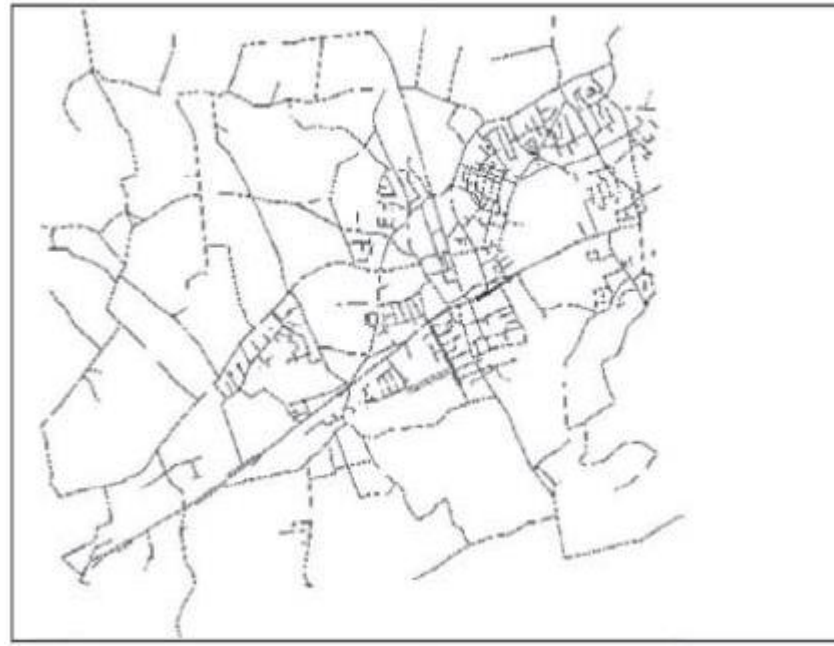


- IEEE 118-bus power system is scale invariant over a range of observation
  - Limited range due to the finite size of te power grid
  - Complexity is reduced to a small number of dimensional parameters [2]

[2] Thi-Tinh-Minh Le, Nicolas Retière, Approximation of the frequency response of power systems based on scale invariance, Mathematics and Computers in Simulation 2015, 10.1016/j.matcom.2015.08.015

Fractal dimensions of built-up spaces





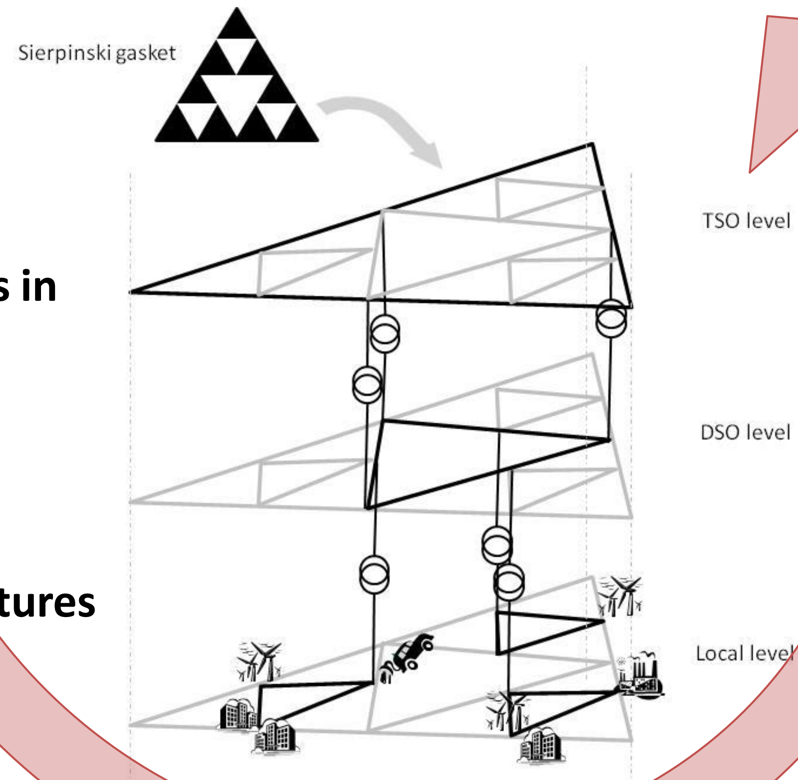
- Comparison of fractal dimensions for built-up spaces and road networks.
  - Example of Beveren (Belgium) - Dsurf = 1.722 / Dnetw = 1.75
  - Building are distributed rather homogenously along the streets
  - Accessibility is good
  - Fractality is used to analyze the coherence between built-up spaces and road networks

[2] Isabelle Thomas, Pierre Frankhauser, Fractal dimensions of the built-up footprint: buildings versus roads. Fractal evidence from Antwerp (Belgium), Environment and Planning B: Planning and Design 2013, doi:10.1068/b38218

Project strategy

Understanding the multi-scale properties of power grids

A dissemination plan involving our industrial partners



Assessing accessibility to electrical distribution grids in urban areas

Developing new power system management and planning approaches

Designing fractal architectures of the power grid

Tuning flexibility and resilience of the grid by the choice of the fractal pattern

Expected results

Power systems fractal analysis : results and interpretation

Fractal Grid architectures for an urban distribution network

Theoretical framework and numerical tools to assess flexibility of power grids

a breakthrough for the grid architecture by the radical transformation of Smart Grids into Fractal Grids

Control schemes for Fractal Grids.

Analysis of spatiotemporal characteristics of renewable generation and demand

A simulation tool for the Fractal Grid management

www.fractal-grid.eu

2010 Robert Fathauer