

Complexity and Vulnerability of Smartgrid systems

PhD thesis: “Control Challenges Related to
Renewable Energy Integration into City
Smartgrids”

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Outline

- Brief introduction into PhD research
- Preliminary planning
- 1st stage - understanding Smartgrid concept
- Simulation of energy distribution grid
- Results and step toward

Brief introduction into PhD research

- Constraints of current energy systems:
 - Centralized energy production vulnerable to failures
 - Dependence on scarce conventional resources
 - Low mix of production sources
 - Increased negative environmental performance
- Integration of renewable energies
- Major bottlenecks related to renewable sources integration into existing electricity grids:
 - Intermittent nature => forecasting and optimization difficulties of energy production, fluctuations vulnerable to aging electricity infrastructures
 - Increased cost, social acceptance, inexistent legislation
- Smartgrid concept

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Understanding Smartgrid concept

- Complex engineered systems

Understanding Smartgrid concept

- Architecture
- Heterogeneity
- Self-similarities
- Self-organization
- Decomposability
- Emergence
- Adaptive learning
- Evolution and growth

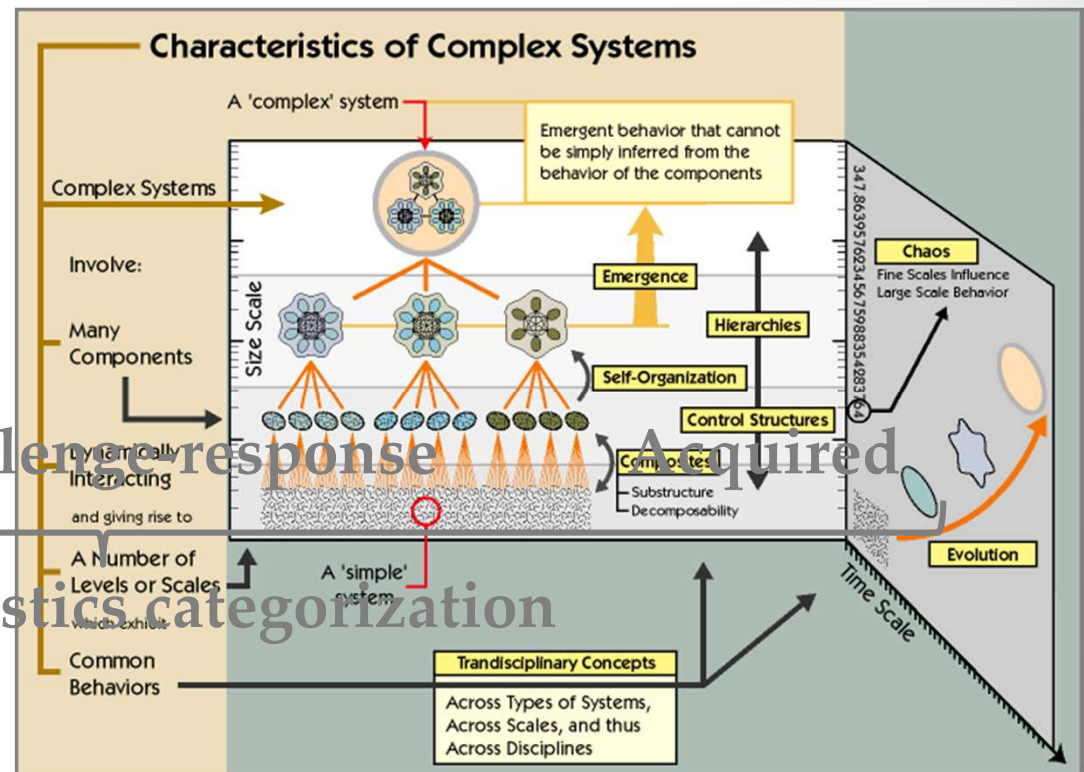
Inherent

- Chaos
- Multidisciplinary relations
- Vague boundaries
- Self-healing and attacks resistance

Challenge response

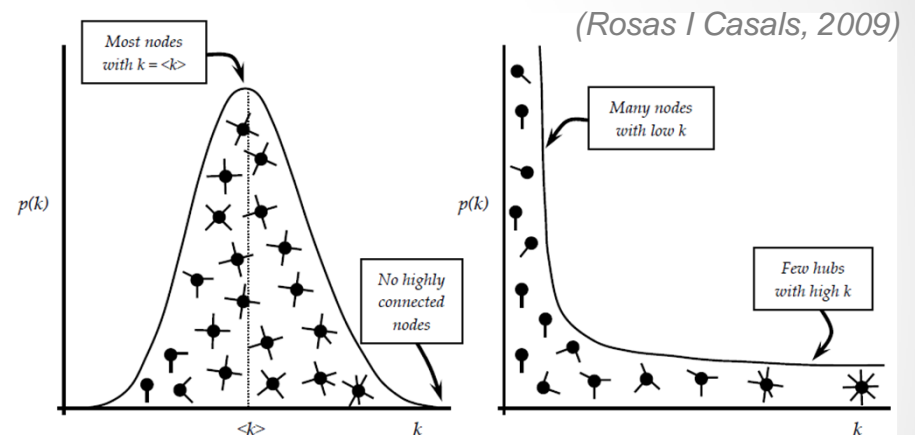
Characteristics categorization

Acquired

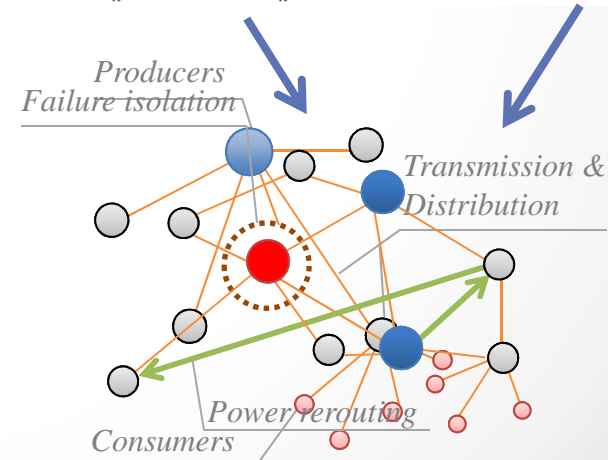


Characteristic: Architecture

- Topological/logic structure linking elements through their interrelations



- Vulnerability:
 - Centralized hierarchichal structure
 - Unidirectional transmission channels
 - Scale-free architecture
 - Vulnerable to direct attacks
 - Cascading failure propagation

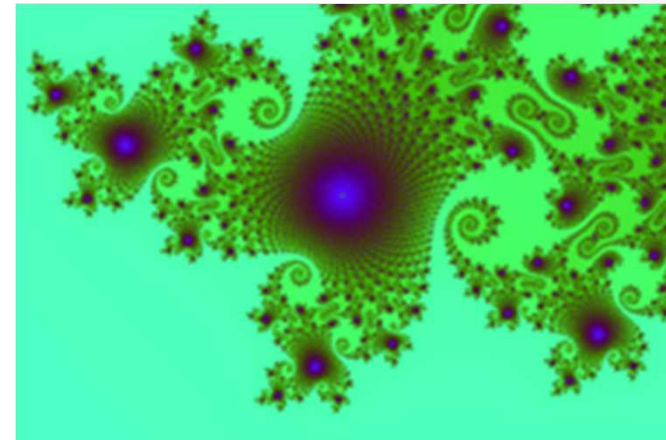


Characteristics: Self-similarities/fractals

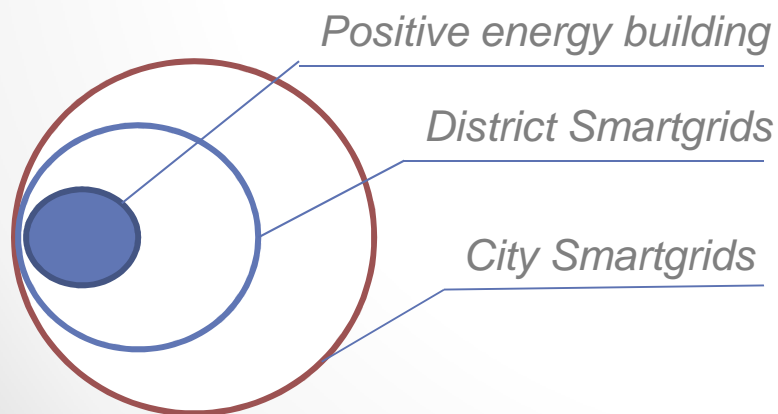
- «...a reduced-size copy of the whole system »

- Similar complexity
- Scalability

(Mandelbrot, 1982)

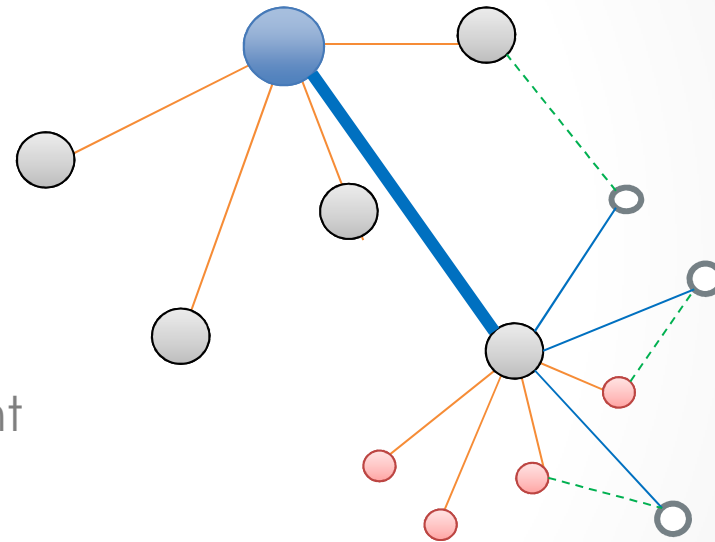


- Vulnerability – absence of fractals



Characteristics: Evolution and growth

- System evolution under external pressures
 - Central authority
 - Users implication
- Vulnerability
 - Preferential attachment
 - Scale-free nature reinforcement



Methods for Smartgrids Analysis

Inherent (engineering)	Challenge-response (updating)	Acquired (integration)
Architecture	Adaptive learning	Vague boundaries
Heterogeneity	Evolution and growth	Self-organization
Self-similarities	Self-healing	Emergence
Decomposability	Attack resistance	Chaos
		Multidisciplinary relations

- Statistical and probabilistic approaches, risk analysis, **complex network theory** and **agent-based modeling and simulation**

E. Kuznetsova, K. Culver and E. Zio.« Complexity and vulnerability of Smartgrid systems » for European Conference on Safety and Reliability (European Safety and Reliability Conference 2011)

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