ELECON
ELECTRICITY CONSUMPTION ANALYSIS & ENERGY EFFICIENCY

INSTITUTO POLITÉCNICO DO PORTO
gecad
Knowledge Engineering and Decision Support Research Center

First ELECON Workshop
Towards Efficient European and Brazilian Electricity Markets

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ISEP, Porto, Portugal

24th September 2013

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Voltage Magnitude Analysis Considering Load Curtailment Minimization in Sub-Transmission Networks with Distributed Generators

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Outline

- **Introduction**
- **Methodology**
- **Case study**
- **Conclusions**

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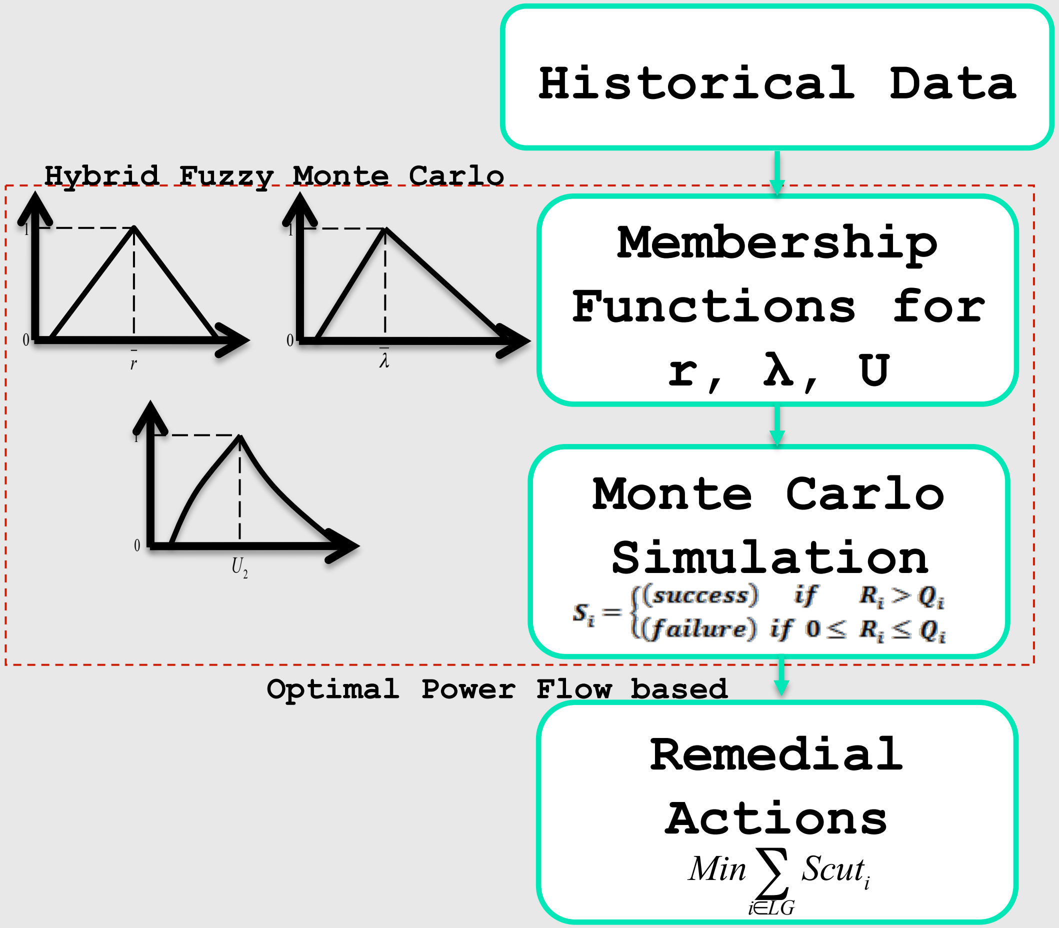
Introduction

- **Minimizing the unserved power by minimization of load curtailment leads to a reliability maximization in electrical systems**
  - Avoiding important monetary loss due to undelivered power, economic damage and inconvenience to the power system user
  - Reliability criteria can be deterministic or probabilistic
  - Exhaustive statistical analysis of all the available information, such as failure rates (λ) and average repair times (r)

- **It is proposed a voltage magnitude study in presence of fault considering realistic specifications found in Brazil**
  - Fuzzy-probabilistic modeling for system component outage parameters
  - Hybrid method of fuzzy set and Monte Carlo simulation
  - A remedial action algorithm, based on OPF is used to minimize the total load curtailment

Methodology

- **Diagram of the proposed methodology**



Methodology

- **Difficult to distinguish precisely the effects of:**
  - Weather conditions
  - Environment
  - Operational conditions
  - Insufficient statistical records

Fuzzy approach allows to obtain adequate models

Methodology

$$\min \sum_{i \in LG} Scut_i$$

Subject to:

Generator limits

- $PGEN_i^{min} \leq PGEN_i \leq PGEN_i^{max} \quad i \in GN$
- $QGEN_i^{min} \leq QGEN_i \leq QGEN_i^{max} \quad i \in GN$

Load curtailment limit

- $Pcut_i \leq Lp_i \quad i \in LG$
- $Qcut_i \leq Lq_i \quad i \in LG$

Generator buses power balance

- $PGEN_i - Lp_i - P_i(v,\delta) + Pcut_i = 0 \quad i \in GN$
- $QGEN_i - Lq_i - Q_i(v,\delta) + Qcut_i = 0 \quad i \in GN$

Load buses power balance

- $P_i(v,\delta) + Lp_i - Pcut_i = 0 \quad i \in LN$
- $Q_i(v,\delta) + Lq_i - Qcut_i = 0 \quad i \in LN$

- $V_i^{min} \leq V_i \leq V_i^{max} \quad i \in N$
- $\delta_i^{min} \leq \delta_i \leq \delta_i^{max} \quad i \in N$

- $S_k(v,\delta) \leq S_k^{max}$

Voltage limits

Lines thermal limits

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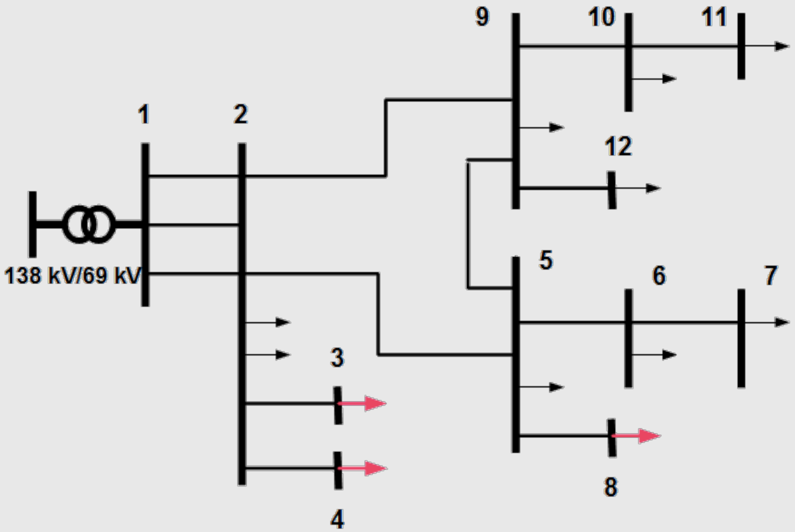
Case study

- **Real 12 buses sub-transmission network**



- 69kV
- 1 - substation
- 11 - load points
- 8 - capacitor banks (buses 2, 5, 6, 7, 9, 10, 11 and 12)
- 3 - load levels (referred as light, moderate and heavy load)

- **Distributed generators**
  - Can be located at buses 2, 5, 6, 7, 9, 10, 11, 12)
  - Size - 1, 3, 5, 7, 10 for steady state and additional 20, 30 MVA in failure analysis
  - Power factor - 0.9

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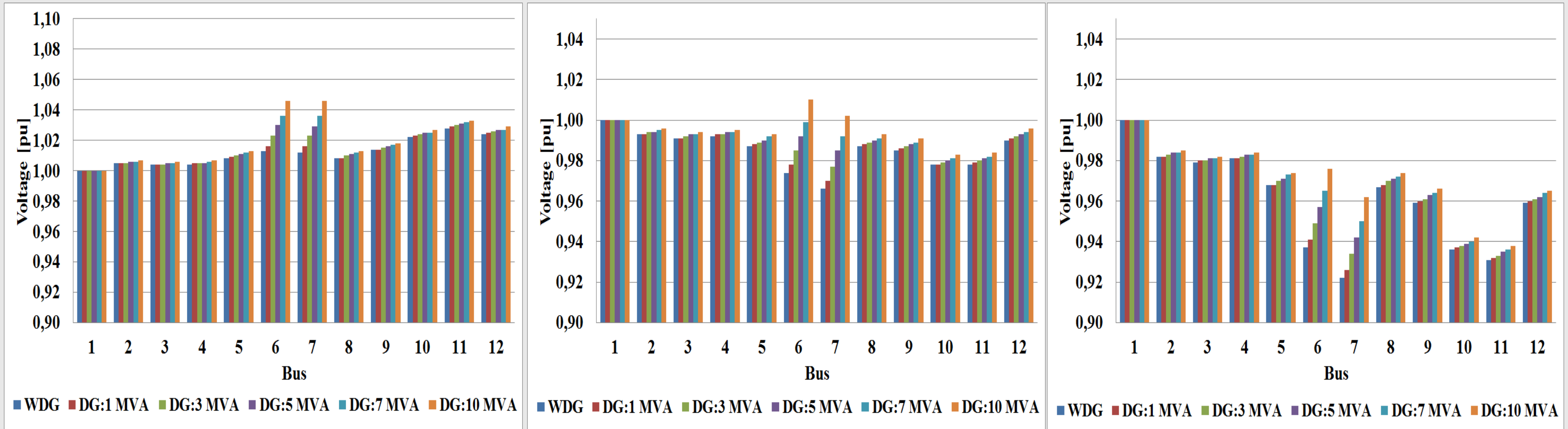
Case study

- **Considering DG in bus 6**

Steady state



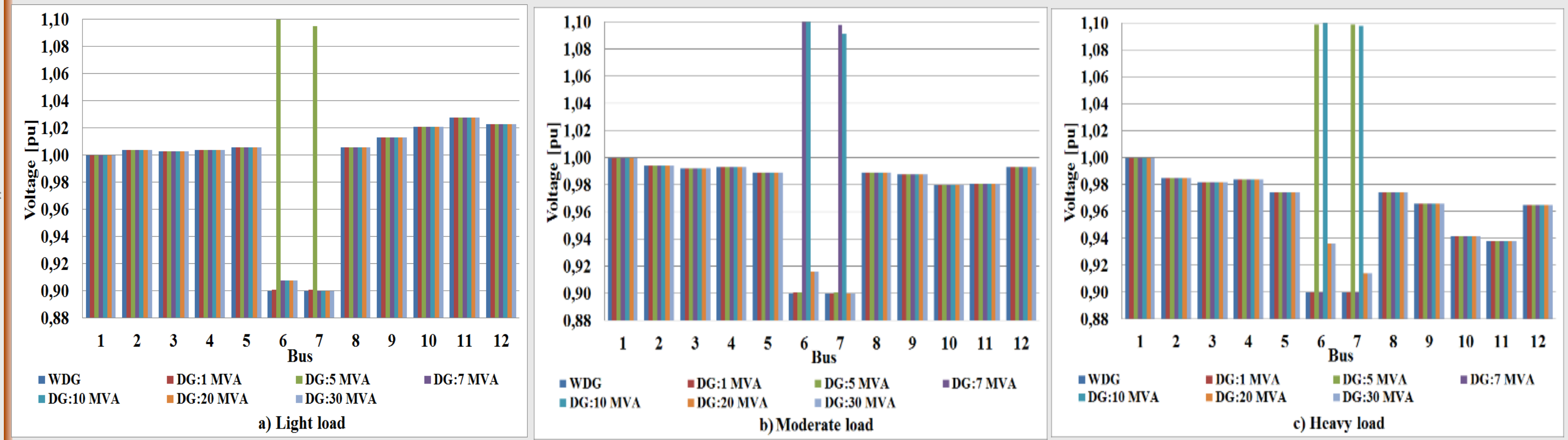
a) Light load b) Moderate load c) Heavy load

Strong impact in voltage magnitude occurs when heavy load is considered

Case study

Considering DG in bus 6

Fault state



a) Light load
b) Moderate load
c) Heavy load

- Line 5-6 presents the highest fault probability (0.17%)
- Line 5-6 in down sate
- Buses 6 and 7 are the most affected
- These buses are close to the fault and are in radial lines

Total load curtailment for a fault in line 5-6

DG (MW)	Light Load Curtailment		Moderate Load Curtailment		Heavy Load Curtailment	
	(p.u.)	(%)	(p.u.)	(%)	(p.u.)	(%)
1	0.036	6.49	0.1	9.61	0.137	9.88
5	0.013	2.34	0.064	6.15	0.101	7.28
7	0	0	0.046	4.42	0.083	5.98
10	0	0	0.02	1.92	0.056	4.04
20	0	0	0	0	0	0
30	0	0	0	0	0	0

MVA base = 100

- Load curtailment don't exceed 10%
- DG contributes to the reliability increase

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Conclusions

- Voltage magnitude study in presence of fault conditions
- Realistic specifications found in Brazil
- The load influence and network topology are essential factors in sub-transmissions network studies
- Fault conditions in radial lines leads to a considerable variation in voltage magnitude in buses that proceeds that line.
- Strong contribution in reliability increasing in fault condition when DG is present in the network

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PEOPLE

MARIE CURIE ACTIONS

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