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ELECTRICITY CONSUMPTION ANALYSIS & ENERGY EFFICIENCY

INSTITUTO POLITÉCNICO DO PORTO

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Knowledge Engineering and Decision Support Research Center

First ELECON Workshop
Towards Efficient European and Brazilian Electricity Markets

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Energy resource management in smart grids considering an intensive use of electric vehicles

Outline

- **Energy resource management**
- **Problem formulation**
- **Programming tools**
- **Case study**

Energy resource management

- **Development of methodologies to solve the energy resource management**
  - In a smart grid context
  - To be used by a Virtual Power Player (VPP)
  - Considering an intensive use of electric vehicles

- **The main objective is to obtain the optimal scheduling for the next day**
  - **Minimizing** the total operation cost of the VPP
  - Without violate any technical constraint related with the network
  - Without violate any resource constraint
  - Obtaining a feasible solution in a **reasonable amount of time**

Problem formulation

- **The following mathematical formulation has been used in the energy resource management**

Objective Function

$$min\ f = f_1 + f_2 + f_3 + f_4$$

Operation cost of the Distributed Generation (DG)

$$f_1 = \sum_{t=1}^{T} \sum_{DG=1}^{N_{DG}} \left(\begin{array}{l} c_{A(DG,t)} \times X_{DG(DG,t)} + c_{B(DG,t)} \times P_{DG(DG,t)} + \\ c_{C(DG,t)} \times P_{DG(DG,t)}^2 \end{array} \right)$$

Operation cost of the energy bought from external suppliers

$$f_2 = \sum_{t=1}^{T} \sum_{S=1}^{N_S} c_{SP(S,t)} \times P_{SP(S,t)}$$

Problem formulation

- **The following mathematical formulation has been used in the energy resource management**

Objective Function

$$min\ f = f_1 + f_2 + f_3 + f_4$$

Operation cost of the energy bought from EV users

$$f_3 = \sum_{t=1}^{T} \sum_{V=1}^{N_V} c_{Dch(V,t)} \times P_{Dch(V,t)} - c_{Ch(V,t)} \times P_{Ch(V,t)}$$

Penalization cost of the excess available power and non-supplied demand

$$f_4 = \sum_{t=1}^{T} \left(\sum_{L=1}^{N_L} c_{NSD(L,t)} \times P_{NSD(L,t)} + \sum_{DG=1}^{N_{DG}} c_{EAP(DG,t)} \times P_{EAP(DG,t)} \right)$$

Problem formulation

- **Network power balance**
  - Active and reactive power balance with power loss at each bus
  - Voltage magnitude and angle limits at each bus
  - Line thermal limit at each line

- **DG and external supplier power limits**
  - Active generation limits
  - Reactive generation limits

- **EVs technical limits**
  - Energy balance in the battery of each EV
  - Minimum and maximum stored energy at each EV
  - Charge and discharge maximum limits at each EV

Programming tools

- **Deterministic technique**
  - Mixed-Integer Non Linear Programming
- **Metaheuristic**
  - Simulated Annealing
  - Particle Swarm Optimization
  - Hybrid Particle Swarm Optimization

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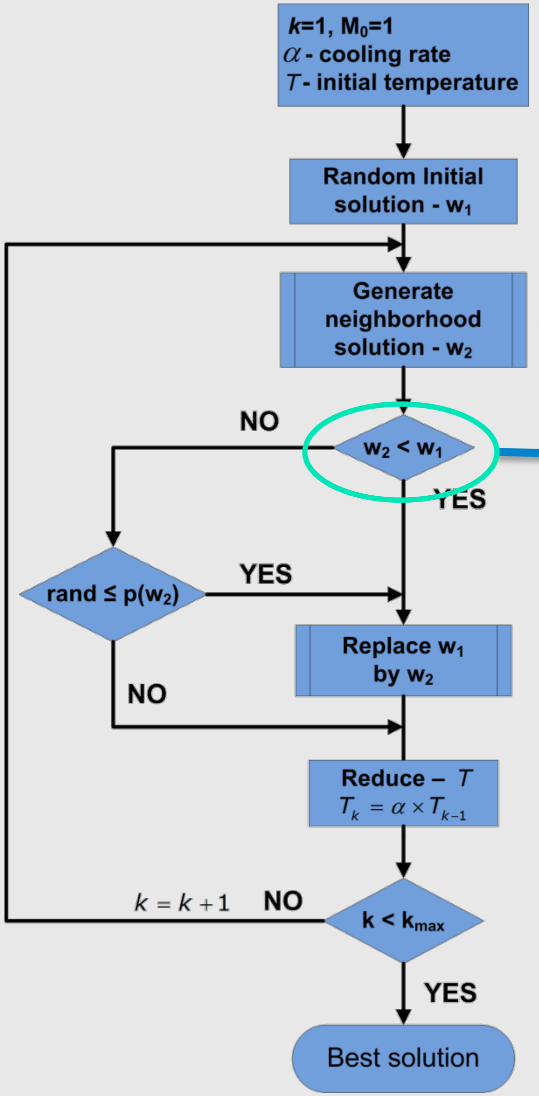
Programming tools



Generate a neighbor solution using two heuristics

- Order of merit – DG and Suppliers
- Charge and Discharge intelligent Allocation – V2G

Evaluation of the solution using the fitness function:

- Objective function
- Penalization functions related with some constraints

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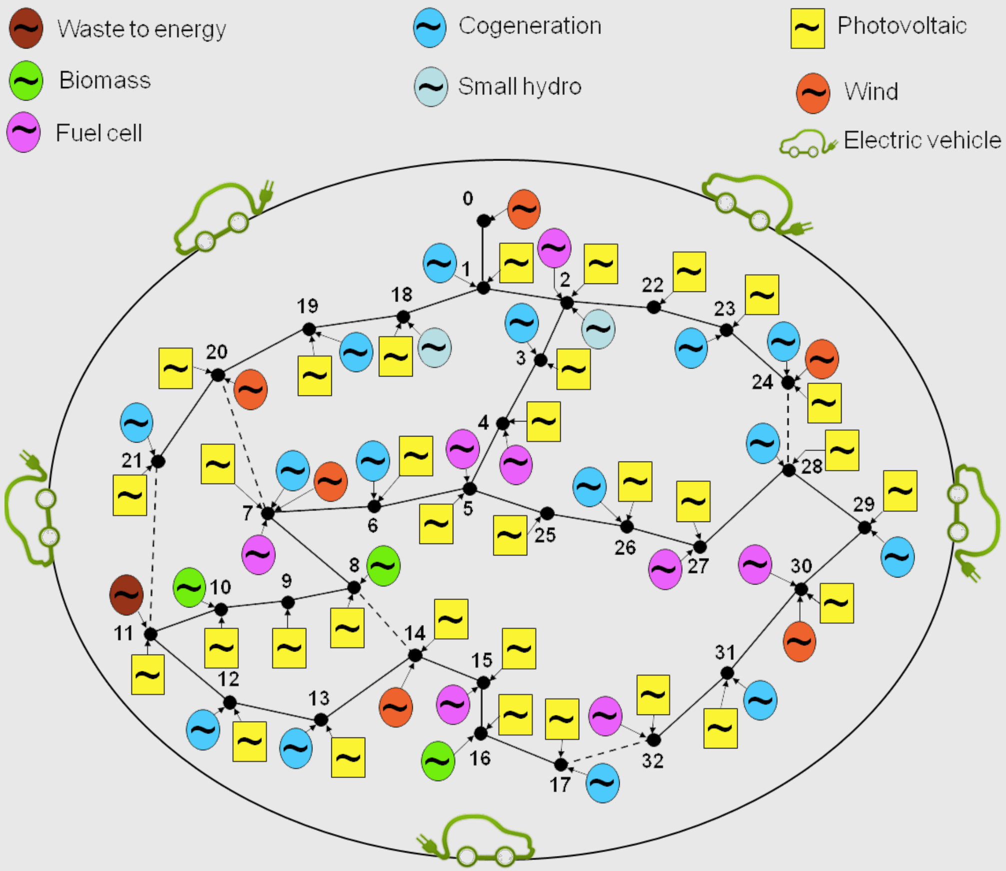
Case study



Case study	Number of EVs	Optimization technique
1	1000	MINLP and SA
	2000	
	3000	

- 33 bus distribution network
- 66 DG units
- 10 external suppliers
- Electric vehicles:

- **Case Study 1**
  - The proposed SA achieved worse operation costs than the MINLP methodology, however with a much lower execution time

Number of EVs	Approach	Operation cost (m.u.)			Execution time (s)
		Best	Worst	Mean	
1000	MINLP	6555.03	-	-	20,559.21 (5.71)
	SA	6594.08	6610.41	6599.86	20.72
2000	MINLP	6940.95	-	-	103,945.70 (28.9)
	SA	6997.28	7016.52	7007.83	39.54
3000	MINLP	7325.26	-	-	267,547.61 (74.3)
	SA	7422.00	7445.04	7431.50	75.63

  - In the 3000 EVs scenario, the SA achieves a solution around 0.03 % of the MINLP's execution time, and the difference in the operation cost is about 1.3 %

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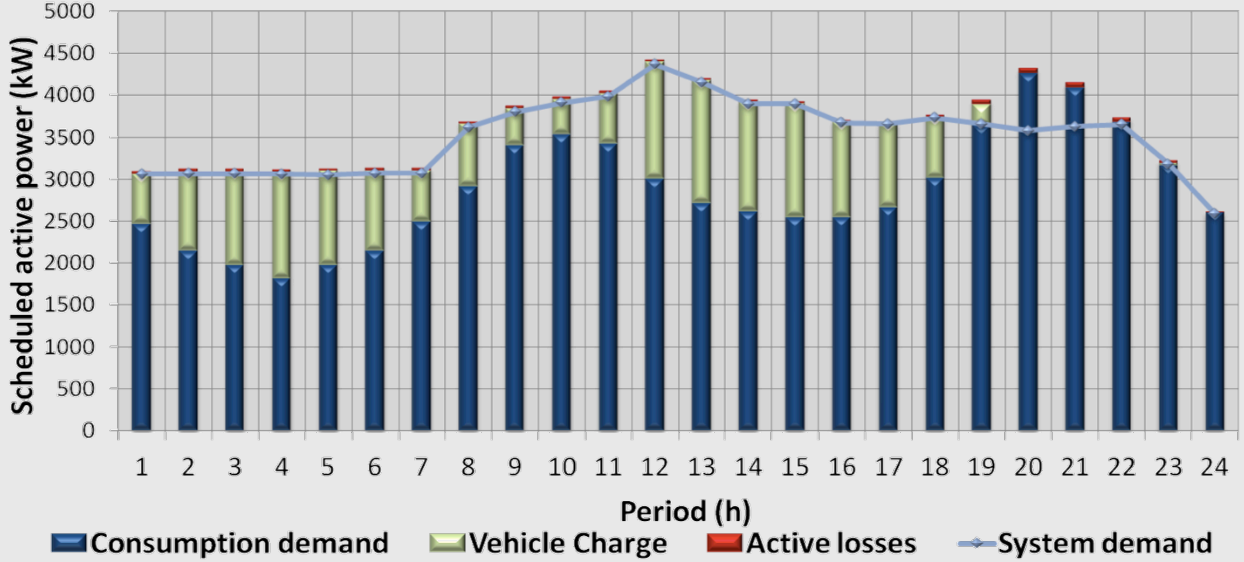
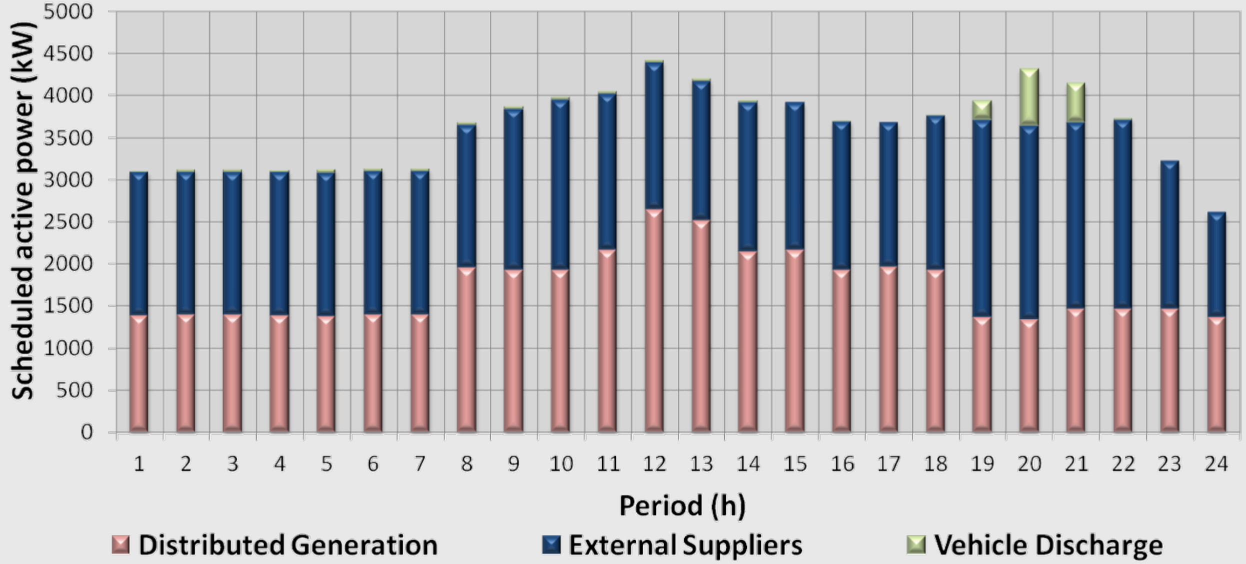
Case study

- **Optimal scheduling result of SA for 3000 EVs scenario**

Consumption



Generation



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