Research Group on Intelligent Engineering and Computing for Advanced Innovation and Development

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Test bed 2: Optimal scheduling of distributed energy resources

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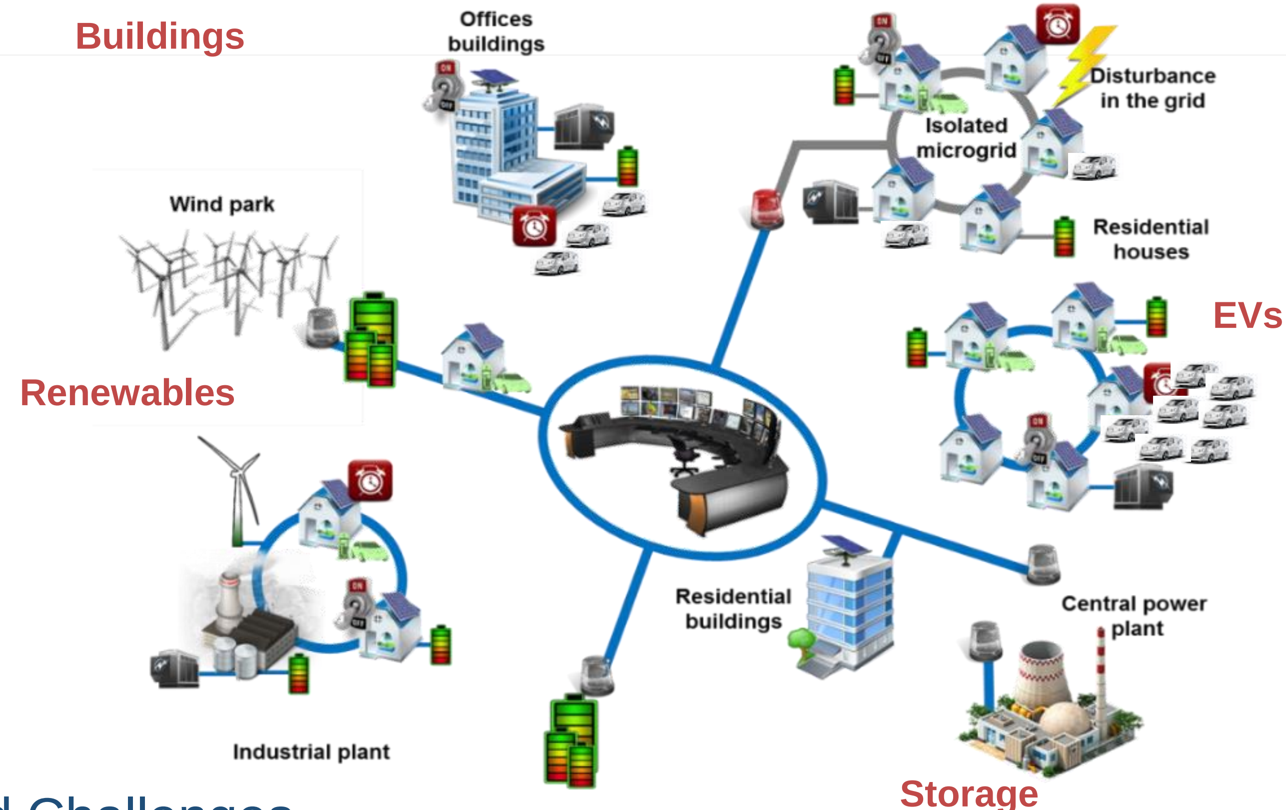
Agenda

- Introduction and main objective
- Optimal scheduling of distributed energy resources
  - Objective function
  - Metaheuristic method framework
  - General assumptions
  - Notes on the implementation of the problem
- Scenarios overview
  - 33-bus scenario
  - 180-bus scenario

Introduction



Some Smart Grid Challenges

- **Technical and economic integration of distributed resources (renewable energy sources, demand response, electric vehicles …)**
- Promotion and operation of competitive energy markets
- Self-healing
- Cybersecurity and privacy
- …

Introduction

Optimal scheduling of Distributed Energy Resources (DER)

- Hard combinatorial Mixed-Integer Non-Linear Programming (MINLP) problem
  - High number of continuous, discrete and binary variables and network non-linear equations
- Optimization of two large-scale centralized Day-Ahead energy resource scenarios
- Stochastic optimization (e.g. PSO, GA, SA, ABC, etc.) to reduce the execution time using traditional mathematical tools
  - State-of-the-art solvers' technology use considerable amount of time to solve

Optimal scheduling of DERs

Objective function

$$Minimize\ Z = OC - In$$

- Operation cost (*OC*) over a 24 hours period

$$OC = \sum_{t=1}^{T}\left[\begin{pmatrix} \underbrace{\sum_{I=1}^{N_{DG}} P_{DG(I,t)} \cdot c_{DG(I,t)}}_{\text{DG}} + \underbrace{\sum_{S=1}^{N_S} P_{Supplier(S,t)} \cdot c_{Supplier(S,t)}}_{\text{External Supplier}} + \\ \sum_{L=1}^{N_L} P_{LoadDR(L,t)} \cdot c_{LoadDR(L,t)} + \sum_{M=1}^{N_M} P_{Buy(M,t)} \cdot MP_{Buy(M,t)} + \\ \sum_{V=1}^{N_V} P_{Discharge(V,t)} \cdot c_{Discharge(V,t)} + \sum_{E=1}^{N_E} P_{Discharge(E,t)} \cdot c_{Discharge(E,t)} + \\ \sum_{L=1}^{N_L} P_{NSD(L,t)} \cdot c_{NSD(L,t)} + \sum_{I=1}^{N_{DG}} P_{GCP(I,t)} \cdot c_{GCP(I,t)} \end{pmatrix}\right]$$

DG

External Supplier

DR and market purchase

Discharge of ESS and EVs

Penalization of Non-supplied demand and DG units generation curtailment

Optimal scheduling of DERs

Objective function

$$Minimize\ Z = OC - In$$

- Incomes (*In*) over a 24 hours period

Consumers demand

Market sales

$$In = \sum_{t=1}^{T}\left[\begin{pmatrix}\sum_{L=1}^{N_L} P_{Load(L,t)} \cdot MP_{Load(L,t)} + \sum_{M=1}^{N_M} P_{Sell(M,t)} \cdot MP_{Sell(M,t)} + \\ \sum_{E=1}^{N_E} P_{Charge(E,t)} \cdot MP_{Charge(E,t)} + \sum_{V=1}^{N_V} P_{Charge(V,t)} \cdot MP_{Charge(V,t)}\end{pmatrix} \times \Delta t\right]$$

Charging process of ESS and EVs

Optimal scheduling of DERs

Constraints

- Energy balance (generated energy equal to consumption)
- Bus voltage magnitude and angle levels (at each bus assuming that the maximum and minimum limits remain fixed across the optimization horizon)
- Power flow (constrained by the thermal line limits)
- Power transformers limits (HV/MV and MV/LV limits considering the power flow direction)
- Generation (limits in each period of DG units)
- External Suppliers (limits in each period from external suppliers)
- Energy Storage System (charge and discharge rate limits, capacity)
- Electric Vehicles (charge and discharge rate limits, battery capacity, EVs' trips requirements)
- DR programs (Demand reduction of each load due to the DR programs)

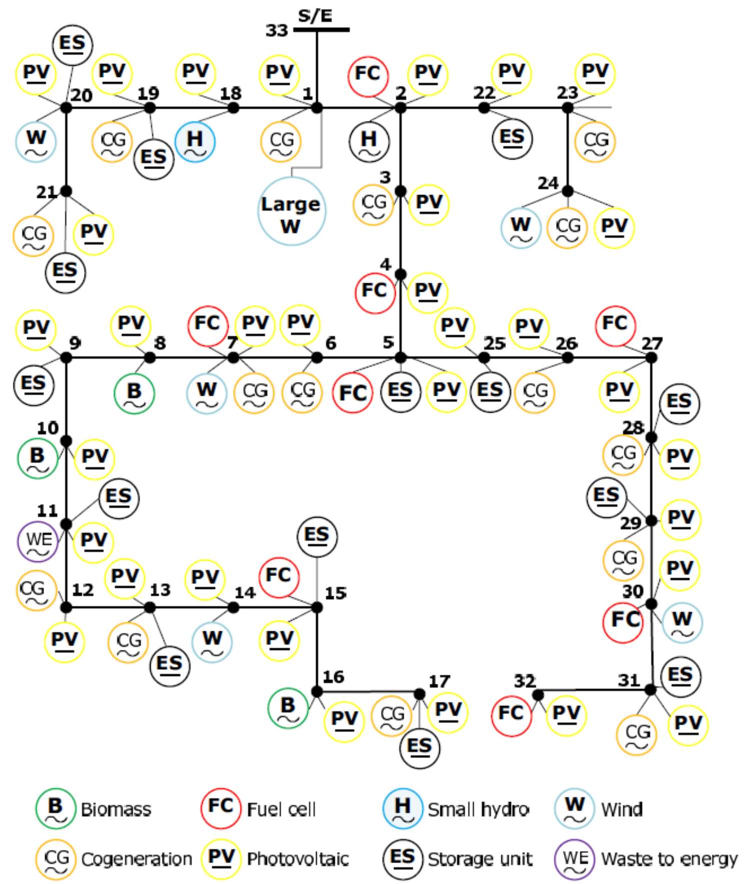
Scenarios overview

33-bus case study

The first scenario considers a 12.66 kV distribution network with:

- 33 bus
- 66 DGs
- 10 external Suppliers
- 1 large wind unit
- 15 storage units
- 1800 gridable EVs (V2G)
- 1 market
- 32 aggregated loads with demand response reduce program

EQUATIONS 280,729
SINGLE VARIABLES 234,541
DISCRETE VARIABLES 88,380
Total execution time: **~19 hours**



MINLP problem using MATLAB R2014a 64 bits, TOMLAB 64 bits software using a computer with one Intel Xeon E5-1650 processor and 10 GB of RAM running Windows 8.1. The solvers used in TOMLAB were SNOPT and CPLEX

Scenarios overview

180-bus case study

The second scenario considers a 30 kV distribution network with :

- 180 bus
- 116 DGs
- 1 external Suppliers
- 7 storage units
- 6000 gridable EVs (V2G)
- 1 market
- 90 aggregated loads with demand response reduce program

EQUATIONS 910,033
SINGLE VARIABLES 763,033
DISCRETE VARIABLES 290,568
Total execution time: more than **168 hours (1 week)**

MINLP problem using MATLAB R2014a 64 bits, TOMLAB 64 bits software using a computer with one Intel Xeon E5-1650 processor and 10 GB of RAM running Windows 8.1. The solvers used in TOMLAB were SNOPT and CPLEX

Thank you

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