Institut de Robòtica i Informàtica Industrial

CSIC

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

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DATA-DRIVEN CONTROL TECHNIQUES FOR MICROGRIDS

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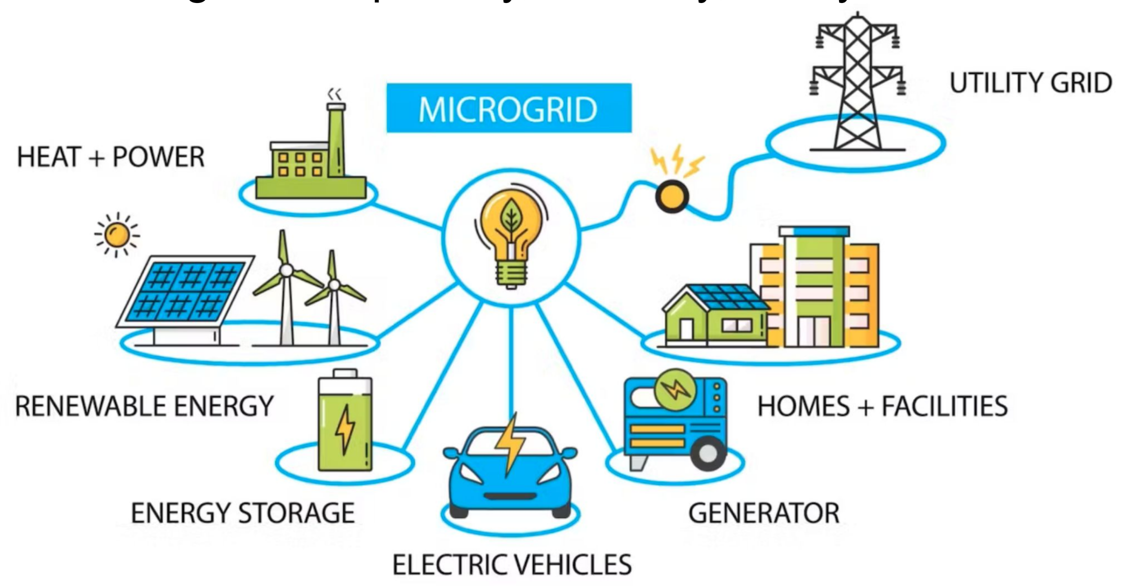
Context

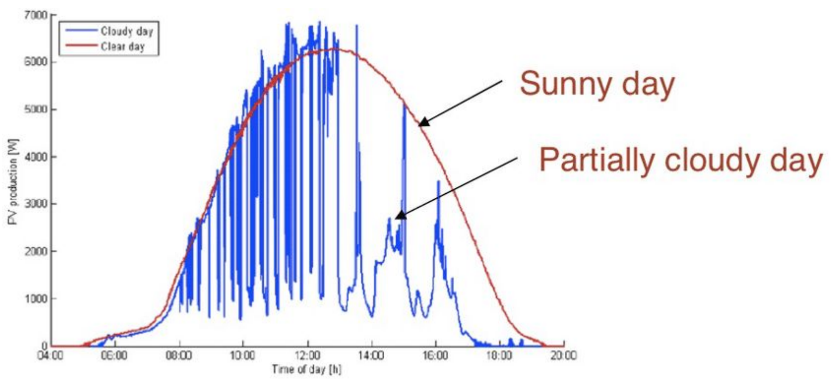
We are experiencing a shift in the energy production and consumption model. The emergence of **distributed power generation** sources with unpredictable availability presents new challenges for grid management.
Aggregating these sources into **low-power microgrids** can facilitate easier management and more reliable operations. Additionally, **energy storage** elements can enhance efficiency and reduce costs. Although initial installation may be costly, prosumers can benefit from significantly **reduced operating expenses.**
The aim of this thesis is to leverage the upsurge of **data availability** alongside with **data-driven techniques** to improve the efficiency of the microgrid controllers warranting the adaptability, reliability, safety and robustness.



Features

In a control context, those new characteristics can oppose new challenges to the correct management of the power grid:

- The presence of **renewable energy sources** implies a limitation of the energy production availability that is **hard to predict.**
- The **consumption** of energy can't be predicted, and the smaller the scale of the grid, the greater the variance.



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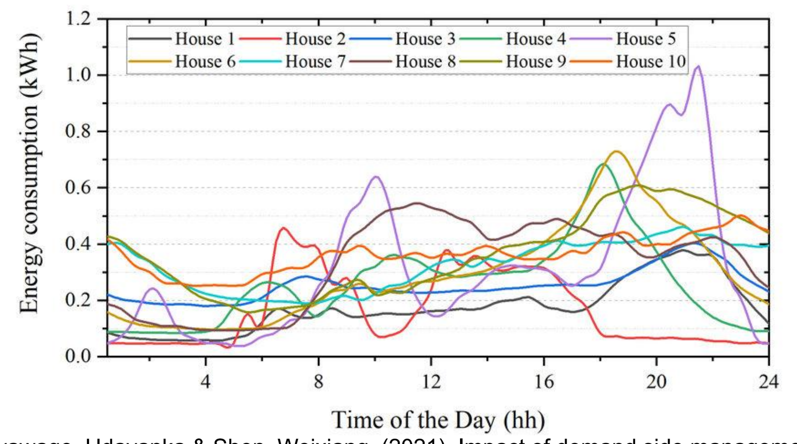
- The **stability** of the grid is also proportional to the **scale**.
- The capacity and efficiency of the storage systems may **drift** during the operative life.
- **Grid energy costs** depends on time, but generally can be predicted.
- It is **increasingly inexpensive to**
- **gather data** from the grid operation.



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Objectives

- Data driven control:
  - No model
  - Online data incorporation
  - Specificity
- Theoretical warranties:
  - Optimality
  - Robustness
  - Safety
  - Stability

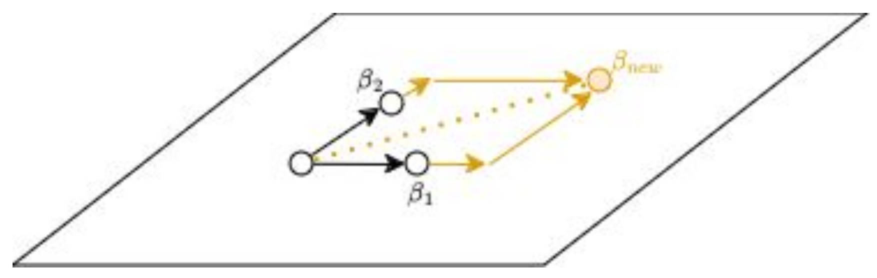
Results

Data Enabled Predictive Control (DeePC)

Behavioral theory:
Any finite trajectory of a system can be described with a set of states and control actions, in a T(m+n)-dimensional space with a set of restrictions depending on the model.

$$\beta = \begin{Bmatrix} x_1, \\ u_1, \\ \vdots \\ x_T, \\ u_T \end{Bmatrix} \in \mathbb{R}^{T(m+n)}$$

$$x_{i+1} = Ax_i + Bu_i$$



Fundamental lemma of the Behavioral theory: "any trajectory of the system can be described as a linear combination of other trajectories."

Predictive Control

We can now avoid the requirement of the model in the MPC by introducing the behavioral fundamental lemma.

$$\begin{aligned} \underset{x_i, u_i}{\text{minimize}} \quad & \sum_i^T c(x_i, u_i) \\ s.t. \quad & x_{i+1} = Ax_i + Bu_i \\ & x_1 = x_{initial} \\ & x_i \in \mathcal{X}, u_i \in \mathcal{U} \end{aligned} \quad \Rightarrow \quad \begin{aligned} \underset{g}{\text{minimize}} \quad & \sum_i^T c(x_i, u_i) \\ s.t. \quad & \begin{Bmatrix} x_1 \\ u_1 \\ \vdots \\ x_T \\ u_T \end{Bmatrix} = g * (\beta_1, \cdots, \beta_N) \\ & x_1 = x_{initial} \\ & x_i \in \mathcal{X}, u_i \in \mathcal{U} \end{aligned}$$

Demand compensation by projection

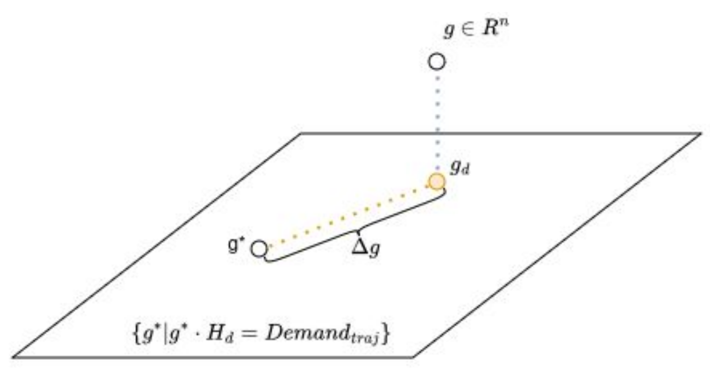
Predicted demand can also be considered in the system as an additional input extending the behavioral point.

$$g^* \cdot Hu = U_{traj}$$
$$g^* \cdot Hx = X_{traj}$$
$$g^* \cdot Hd = Demand_{traj}$$

With

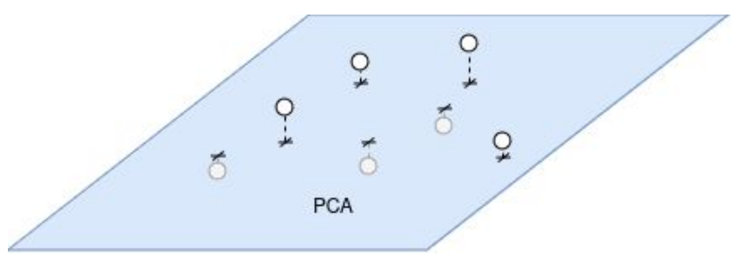
$$g^* = g_d + \Delta g$$
$$\Delta g \in ker(H_d)$$

$$\Rightarrow \quad \Delta g \cdot Hu = U_{traj} - Demand_{traj} \cdot pinv(Hd) \cdot Hu$$
$$\Delta g \cdot Hx = X_{traj} - Demand_{traj} \cdot pinv(Hd) \cdot Hx$$



Regularizations

As the obtained data might be susceptible to measurement errors, the matching to the subspace might not be perfect. We can address it by introducing new slack variables to the optimization problem.



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Research collaborations and research stays

- Pending

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