

The background of the slide features a photograph of a large array of solar panels installed on a grassy hillside. The panels are arranged in neat rows and extend towards the horizon. In the background, there are several tall evergreen trees and a clear blue sky with scattered white clouds. The image is partially overlaid by a white diagonal shape on the right side, which contains the text.

# Introduction and objectives

Optimization and machine learning applied to  
microgrid optimal control, optimal design, and  
forecasting

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February 11, 2025

# Access to the course material

<https://github.com/bcornelusse/DENSYS-school>



# Overview

1. Introduction
2. Microgrids and distribution networks
3. Microgrid control levels

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# Introduction

# Goal of the week

Apply optimization and machine learning to microgrid optimal control, optimal design, and forecasting.

# The objectives are for you to learn to

- ▶ Model and optimize a microgrid (without the electrical grid)
- ▶ Build power and energy management systems
- ▶ Make some forecasts of electricity generation and consumption
- ▶ Apply optimization
- ▶ Apply machine learning
- ▶ Code in Python

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# Microgrids and distribution networks

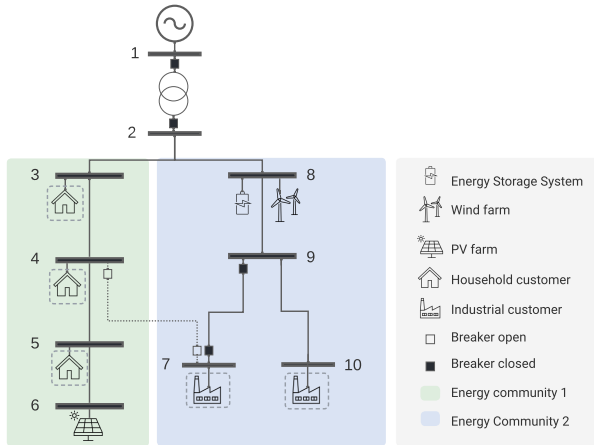
# Microgrids

## **A microgrid definition**

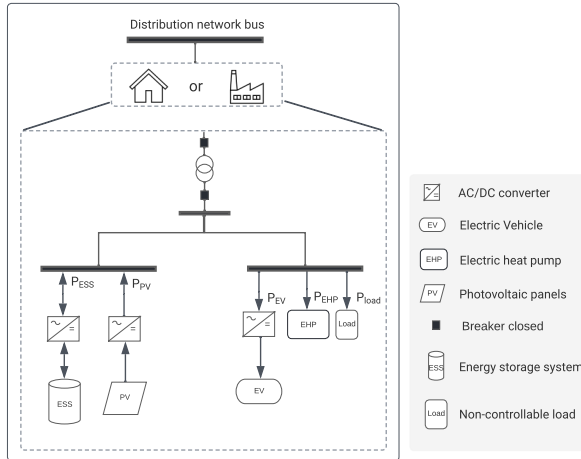
A small electrical network composed of decentralized energy resources, loads, and energy storage devices. It is controlled and operated locally. It can connect or disconnect from the main grid.



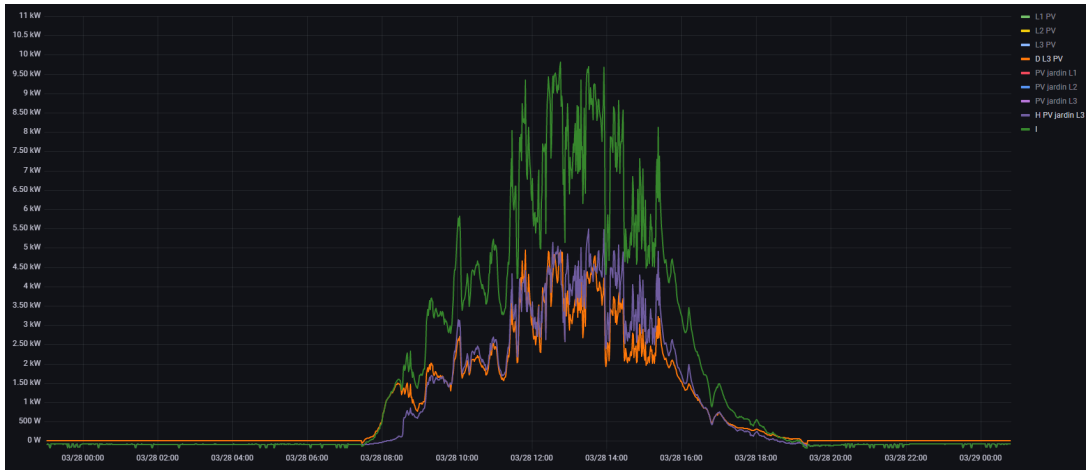
# Schematic representation of a microgrid



# Behind a connection point



# Temporal dimension: photovoltaic generation



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## Microgrid control levels

# Microgrid controller

## **Microgrid controller**

Software that senses the microgrid (currents, voltages, frequency, etc.) and takes control actions to operate the microgrid safely, reliably, and optimally.

In practice, a microgrid is run by multiple controllers because there are several levels of control, which differ by their spatial and temporal scopes.

Next to technological advances in production, consumption, and storage, controllers are crucial elements for advanced microgrids.

# The four control levels in a microgrid

**Table 1:** The four control levels

| Level | Function                |
|-------|-------------------------|
| 1     | Device level control    |
| 2     | Local area control      |
| 3     | Supervisory control     |
| 4     | Public grid interaction |

# Level 1: device level control

- ▶ Generator control
- ▶ PV panel + MPPT + inverter
- ▶ A great variety of interfaces for loads
- ▶ Battery storage: battery management system (BMS)
- ▶ Battery inverter/charger
- ▶ Islanding detection: Automatic transfer switch

## Level 2: local area control

- ▶ Fast, automatic load/generation control to ensure constant balance and achieve stable operating points:
  - ▶ regulate active and reactive power in AC microgrids
  - ▶ achieving stable operation may be a challenging problem because of the:
    - ▶ dynamic response mismatches between loads and sources,
    - ▶ generated power capacity close to the nominal load,
    - ▶ reduced added energy storage in generator rotors (if any).
- ▶ (Unplanned) disconnection management
- ▶ Resynchronization



## Level 3: supervisory control

- ▶ Generation and load dispatch
- ▶ Economic optimization
- ▶ Spinning reserve
- ▶ Forecasting
- ▶ Data visualization and data management

## Level 4: public grid interaction

- ▶ Distribution Management System interaction
- ▶ Electricity markets
- ▶ Ancillary services markets