Workshop HEIBS

ESTIA INSTITUTE OF TECHNOLOGY

EMBEDDED ELECTRONIC SYSTEMS FOR POWER CONVERTERS CONTROL IN LOW VOLTAGE DC DISTRIBUTION GRIDS

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SUMMARY

- Introduction
- Overview of Embedded Electronic Systems (EESs)
- Low Voltage DC Distribution Grids
  - Main Topologies
  - Power Converters
- EESs for Power Converters Control
  - Generalities
  - Case-study
- Conclusion and Perspectives

INTRODUCTION

Development of Embedded Electronic Systems (EESs)

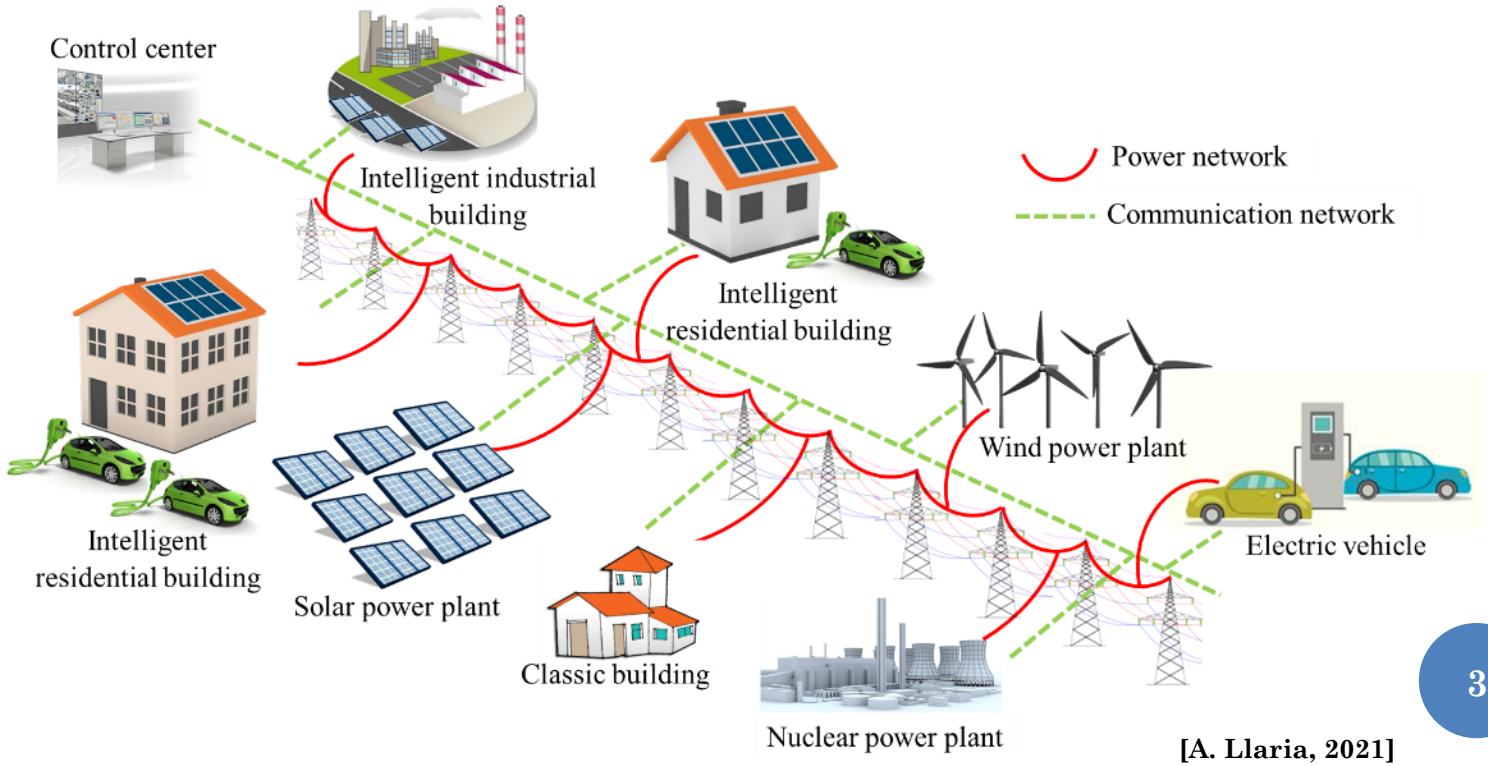
Smart Grid → IoT → EESs

[X. Yu, 2016]

Evolution towards a DC Distribution Grid

- DC loads in buildings
- Renewable energy sources (RES)
- Electrical vehicle (V2G)
- Efficiency improvement of power converters

EESs are needed to ensure the correct operation



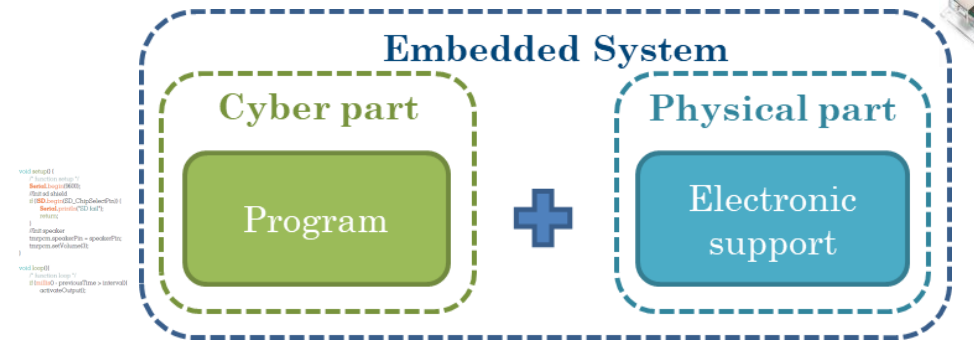
[A. Llaria, 2021]

Overview of Embedded Electronic Systems

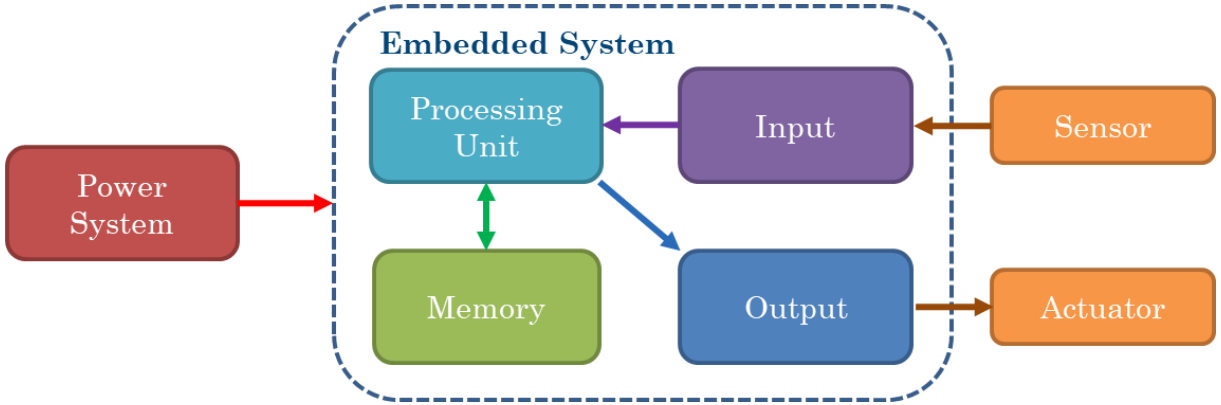
Generalities

- Definition
  - System designed to perform a function or a limited number of functions, often in real-time, following a program
  - Integrated into a complete system, including interfaces with its external world

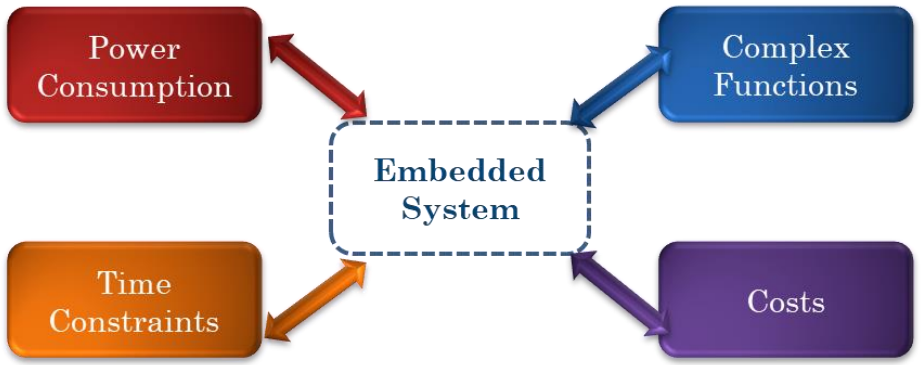
- Two main parts



- Physical architecture



- Constraints



Overview of Embedded Electronic Systems

Classification of EESs

- Three main categories

[M.O. Ojo, 2018]

- Low-End
  - Most constrained in terms of processing capacity, memory, connectivity, security…
- High-End
  - Single Board Computers

Category	CLK Max	RAM Max	Flash Max
LE	≈400 MHz	≈512 KB	≈8 MB
ME	≈1 GHz	≈2 GB	≈2 GB
HE	≈2 GHz	≈4 GB	≈16 GB

[R. Krishnamoorthy, 2021]

- Some choice criteria for an EES…
  - Total memory
    - RAM
    - Flash
    - Cache
  - Processing speed
  - Number of communication ports
  - Available network interfaces
  - Kind of compiler
  - Thermal and energy management

Overview of Embedded Electronic Systems

Arduino UNO R3

- Low-End EES

CLK	RAM	Flash	Cache
400 MHz	64 MB DDR2 2.5 KB SRAM	16 MB	None

Raspberry PI 3 B+

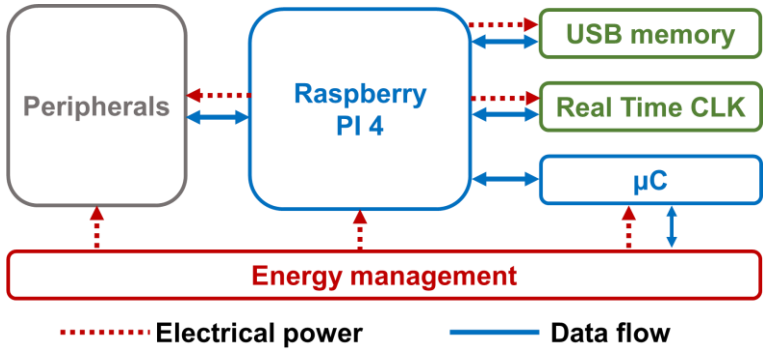
- High-End EES

CLK	RAM	Flash	Cache
1.4 GHz	1 GB LPDDR2 SDRAM	4 GB	L1 16 KB L2 128 KB

EES for Supervising Chemical Processes in the Industry 4.0

[N. Boussaada, 2022]

- Raspberry PI 4 model B
  - That acts as processing unit
- PIC18F1320 nano-watt technology microcontroller (µC)
  - Implements a duty-cycle strategy to save energy since the system is battery powered

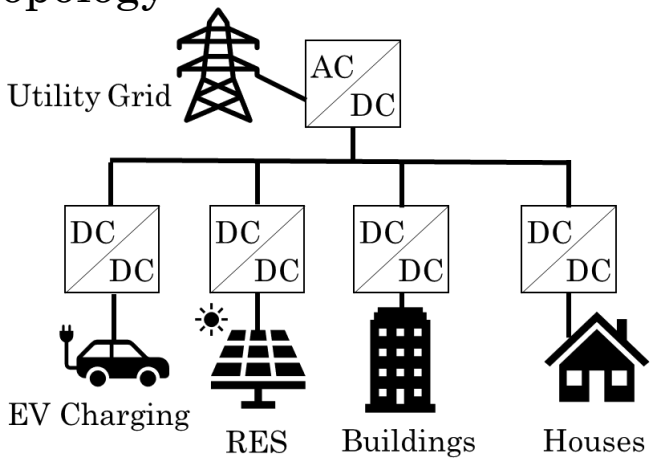


Low Voltage DC Distribution Grids

- Buildings are placed at the distribution grid level, including more and more DC elements…
  - Loads like LEDs, laptops, smartphones
  - Electrical vehicles (EV), sometimes offering the option Vehicle to Grid (V2G)
  - Renewable energy sources, such as PV panels

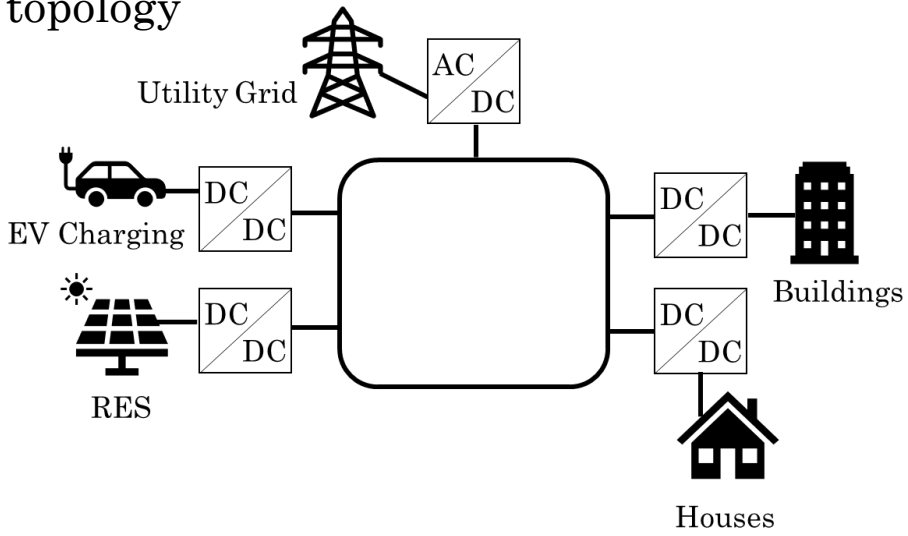
Main Topologies of LVDC grids [Y. Fan, 2021]

- Radial topology



  - Easy management, but only one point of failure

- Ring topology



  - Robust architecture, but more complex control methods needed

Low Voltage DC Distribution Grids

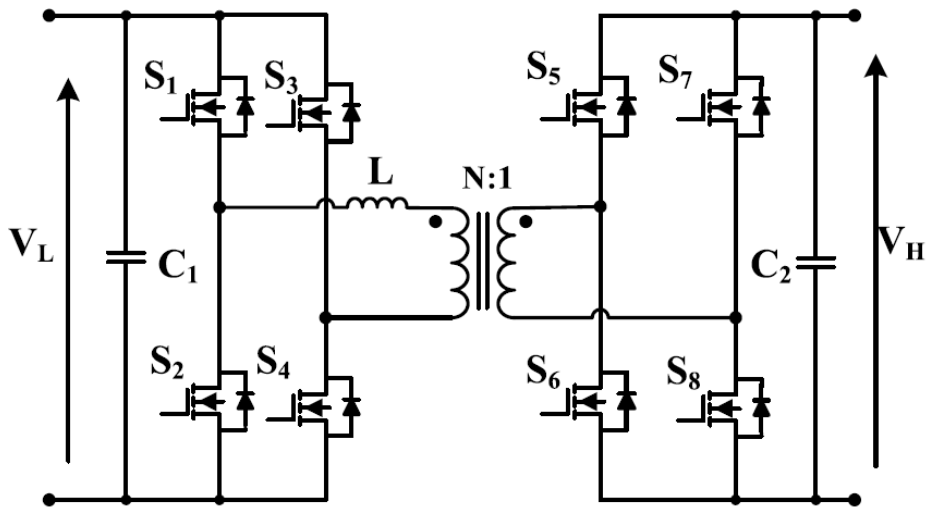
Power Converters

- DC/DC bidirectional architectures
  - They are becoming the most common ones in LVDC distribution grids
  - Presence of EV and V2G operation
  - Possibility of injecting power to the grid
  - Increasing scenarios where power flows in two possible directions
- Two main categories

Non-isolated DC/DC converter | **Isolated DC/DC converter**

- Particularities
  - Non-isolated benefit from a simpler configuration, but they do not offer galvanic isolation
  - Isolated converters include a transformer, whose design is crucial because of the inductance effects

- Dual active bridge DC/DC converter



[S.A. Gorji, 2019]

  - Switching losses can be reduced using silicon carbide (SiC) or Gallium nitride (GaN) devices
- Different control schemes
  - In general, based on digital controllers

EESs for Power Converters Control

Generalities & Case-study

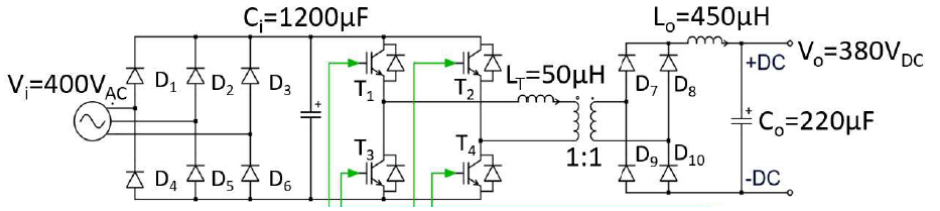
- Digital Real-Time technologies comparison
  - Programmable Logic Controllers (PLCs)
  - Microcontrollers (µCs)
  - Digital Signal Processors (DSPs)
  - Field Programmable Gate Arrays (FPGA)

Solution	PLC	µC	DSP	FPGA
Reliability	High	Medium	Medium	Medium
Flexibility	Medium	Medium	Medium	High
Advanced algorithms	Low	Low	Medium	High
Costs	High	Low	Low	Medium
Power Converter Friendly	No	Yes	Yes	Yes

[C. Buccella, 2012]

- Particularities
  - µCs
    - Up to 32 bits, RAM & Flash, ADCs, PWM units, communications
  - DSPs
    - Multiply and accumulate (MAC) unit, Harvard architecture
  - FPGA
    - On-chip functionalities, large number of configurable I/O ports

- Single active bridge AC/DC converter
  - Possibility for the front-end converter in an LVDC distribution grid
  - Interest of this choice
    - Medium frequency transformer reduces costs and volume
    - Galvanic isolation allows a current limitation through the control system in case of short-circuit



[A.C. Slongo, 2022]

- EES to implement the control
  - dsPIC33CK64MP105 device from Microchip

MAC	ADC	PWM
Yes	12 bits double core	4 pairs

Conclusion and Perspectives

- Nowadays, EESs are present everywhere, bringing intelligence to different applications in many areas like power converters control
- Another change is taking place in the grid: the transformation of part of the distribution system into a DC-based one
  - Because of the presence of DC loads in buildings, the deployment of renewable sources, and the efficiency improvement of power converters
  - Power converters are essential in LVDC grids
- EESs play a vital role to ensure the correct operation of these converters
  - Thus, the choice of the most suitable one is crucial for an efficient DC supply of buildings

- More efforts should be made in the future…
  - Regarding the performances of EESs working in harsh environments like power converters control
    - Temperature
    - Power consumption
  - About the efficiency of power converters, towards a large LVDC distribution grid deployment
  - Ensuring in parallel the wellness of the buildings' users and the respect of the environment

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