EASY-RES

SUMMER SCHOOL
"ENABLING DRES TO OFFER ANCILLARY SERVICES"
20th – 24th SEPTEMBER 2021

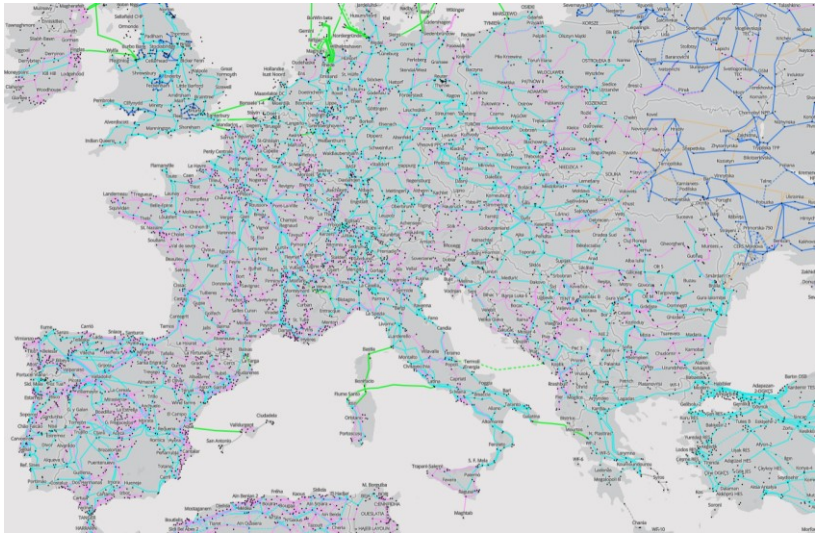
OVERVIEW OF THE LOCAL CONTROL SYSTEM OF THE DRES CONVERTERS

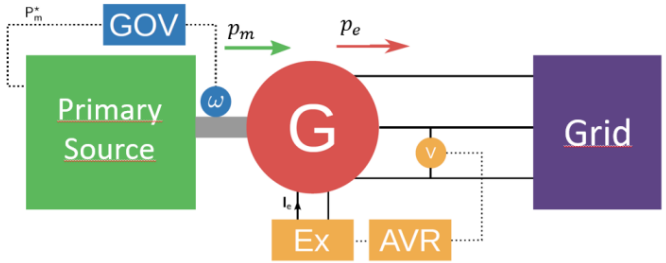
Juan M. Mauricio // 20-09-2021

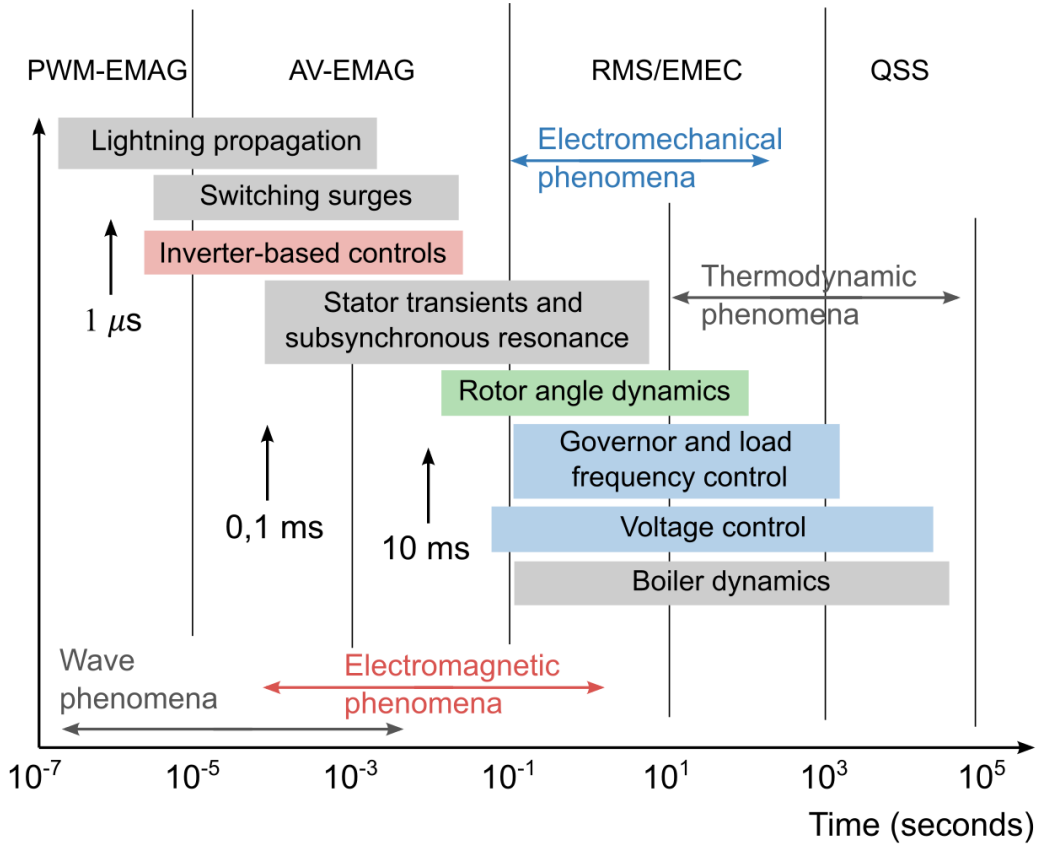
This project has received funding from the European Union´s Horizon 2020 Programme for research and innovation under Grant Agreement no 764090.

Contents

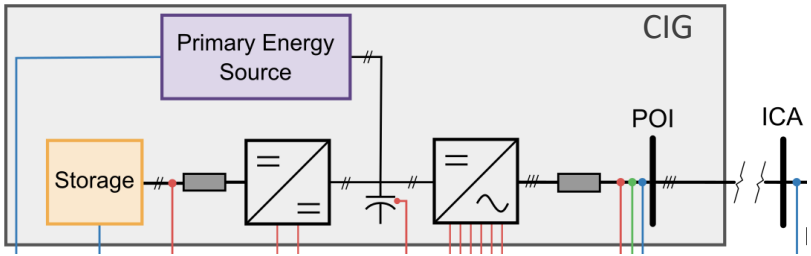
- Introduction
- LOW control level
- MID control level
- HIGH control level
- Centralized control level

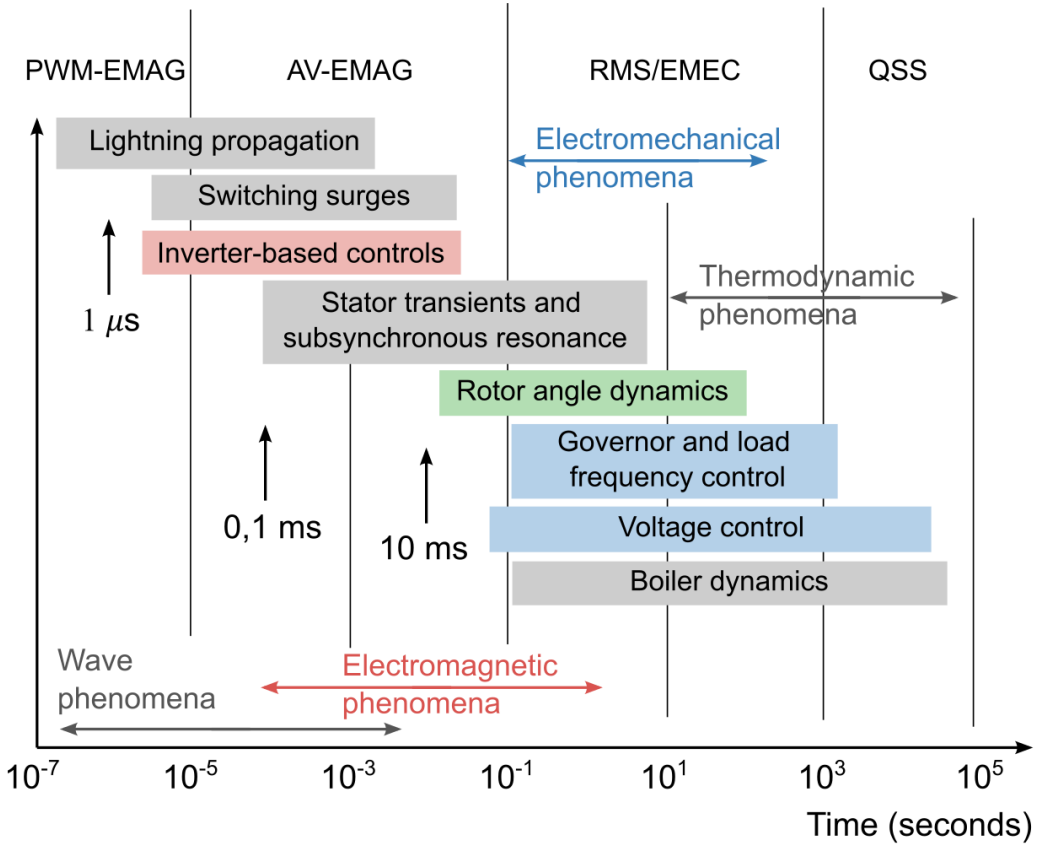



P*m
GOV
pm
pe
Primary Source
ω
G
Grid
V
Ex
AVR


PWM-EMAG
AV-EMAG
RMS/EMEC
QSS
Lightning propagation
Switching surges
Inverter-based controls
Electromechanical phenomena
1 μs
Stator transients and subsynchronous resonance
Thermodynamic phenomena
Rotor angle dynamics
Governor and load frequency control
0,1 ms
10 ms
Voltage control
Boiler dynamics
Wave phenomena
Electromagnetic phenomena
10-7
10-5
10-3
10-1
101
103
105
Time (seconds)

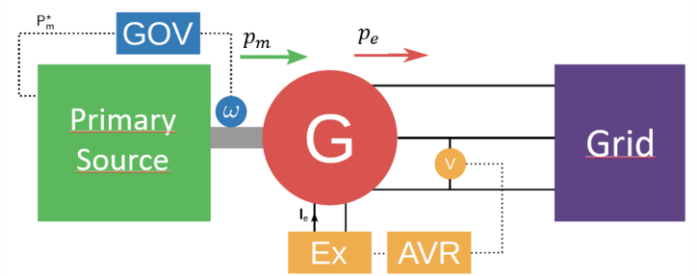
- **SMs** are being replaced by **CIG**
- The **ancillary services** provided by SMs should be supplied by the new CIG.
- One of the basic concepts behind this is that **CIGs** time constants are **"faster"** than the required ancillary services.

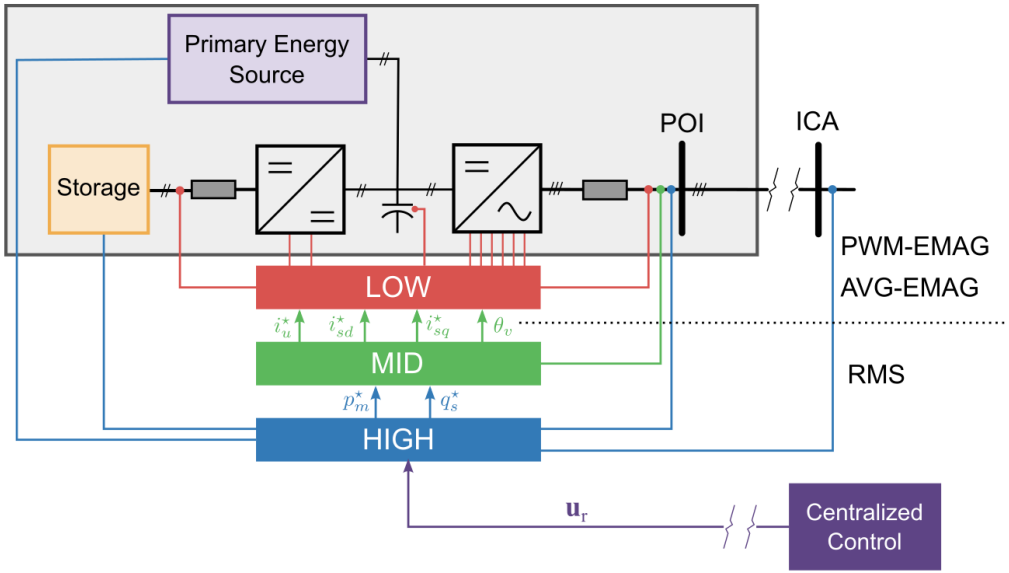




From SM to CIG

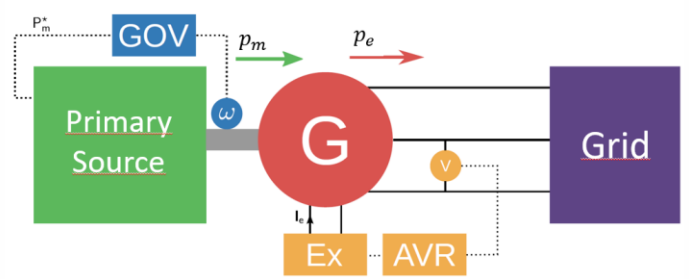
- Conventional power systems have the synchronous machines as the main generators
- **SMs** based generators consist of the electrical machine, the primary energy source and the **controllers** (AVR, GOV, PSS)

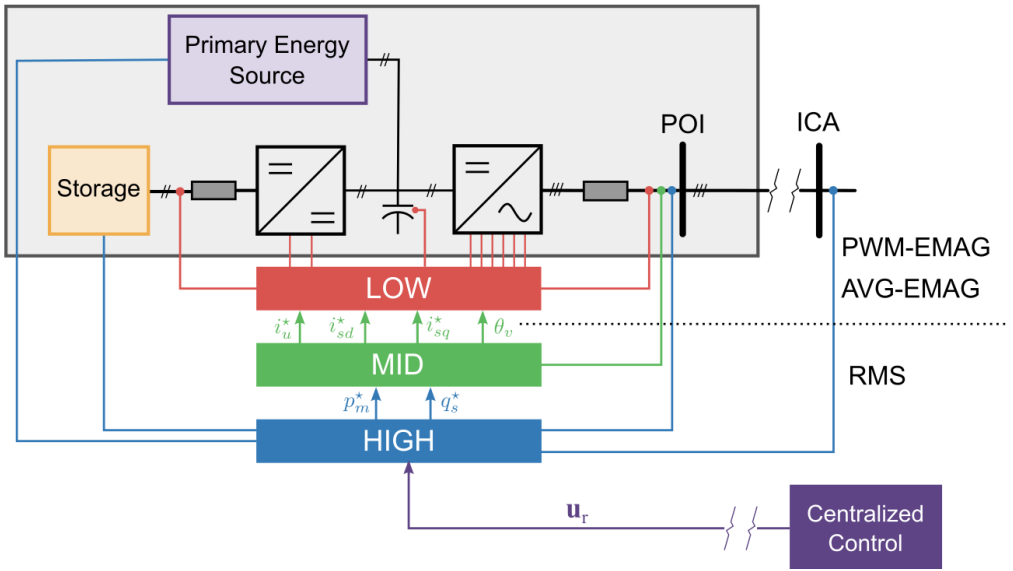




From SM to CIG

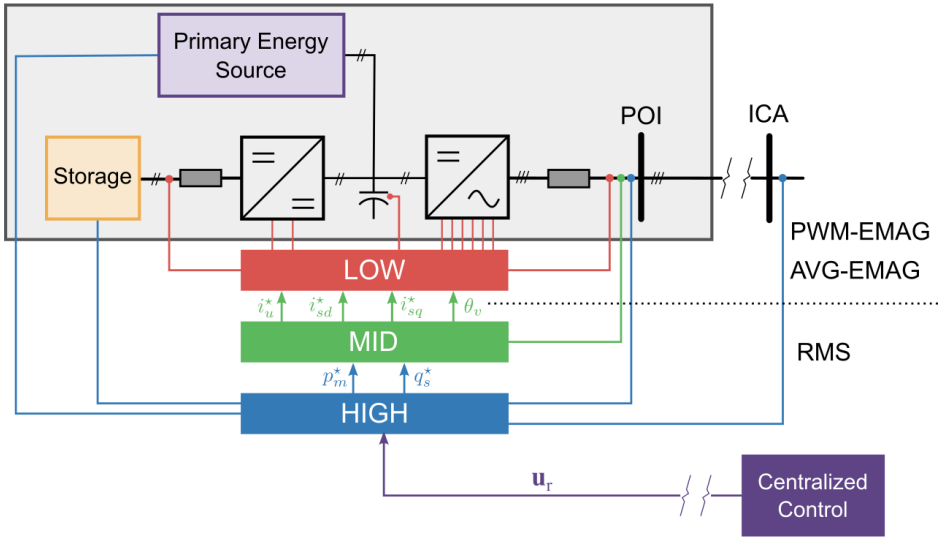
- In **EASY-RES the CIG** is controlled by a complex structure with different levels called **LOW, MID and HIGH**.
- These three control levels enable functionalities to a CIG making it possible to **emulate a SM** based generator and its controllers.





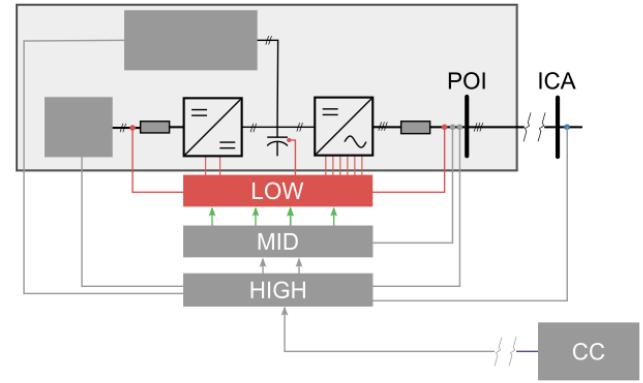
Control structure

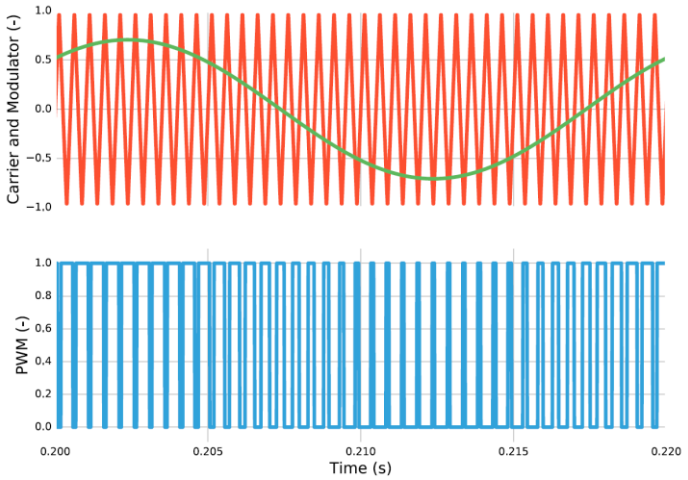
- The hierarchical structure is related to **time scales**:
  - LOW: PWM-EMAG
  - MID: AVG-EMAG/RMS
  - HIGH: RMS
- The hierarchical structure is related with different **research fields**:
  - LOW: Power Electronics
  - MID: Power Systems Dynamics
  - HIGH: Power Systems Optimization
  - CC: Communication Engineering
- This approach enables **parallel development**



LOW level controllers

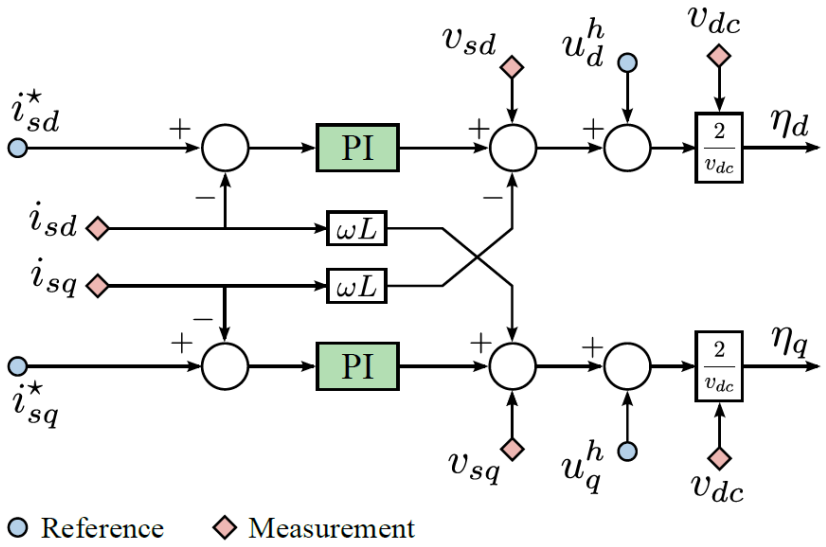
- Performs the **switching of VSCs IGBTs** (i.e. PWM)
- Receives current references from MID level control
- **Simulations** are in the **PWM-EMAG** domain ($1\mu s$):
  - Matlab/Simpower
  - PSIM
  - EMTDC/PSCAD
- Tipycal control level embedded in comercially available converters:
  - Regatron
  - PV converters (particular cases)
  - WECS (DFIM and Full converter)
  - Etc.

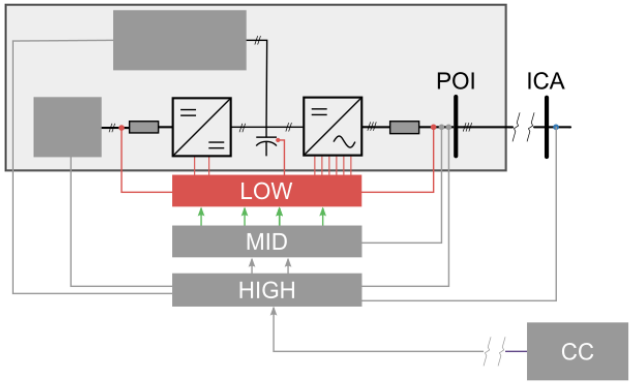




LOW level controllers

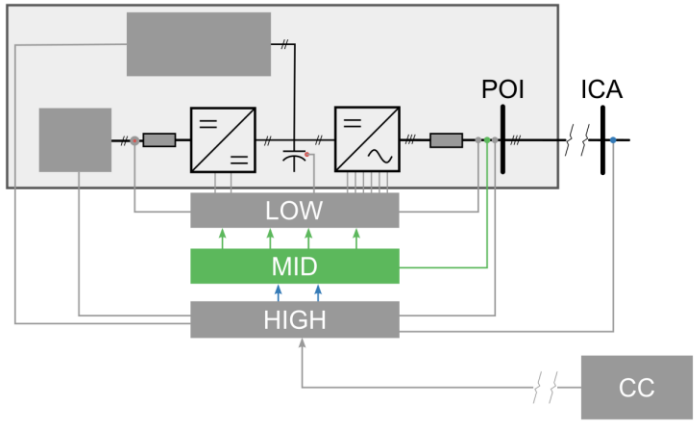
- Controllers are obtained considering **AV-EMAG** models:
  - d-q coordinates
  - Two PI
  - with cross terms decoupling





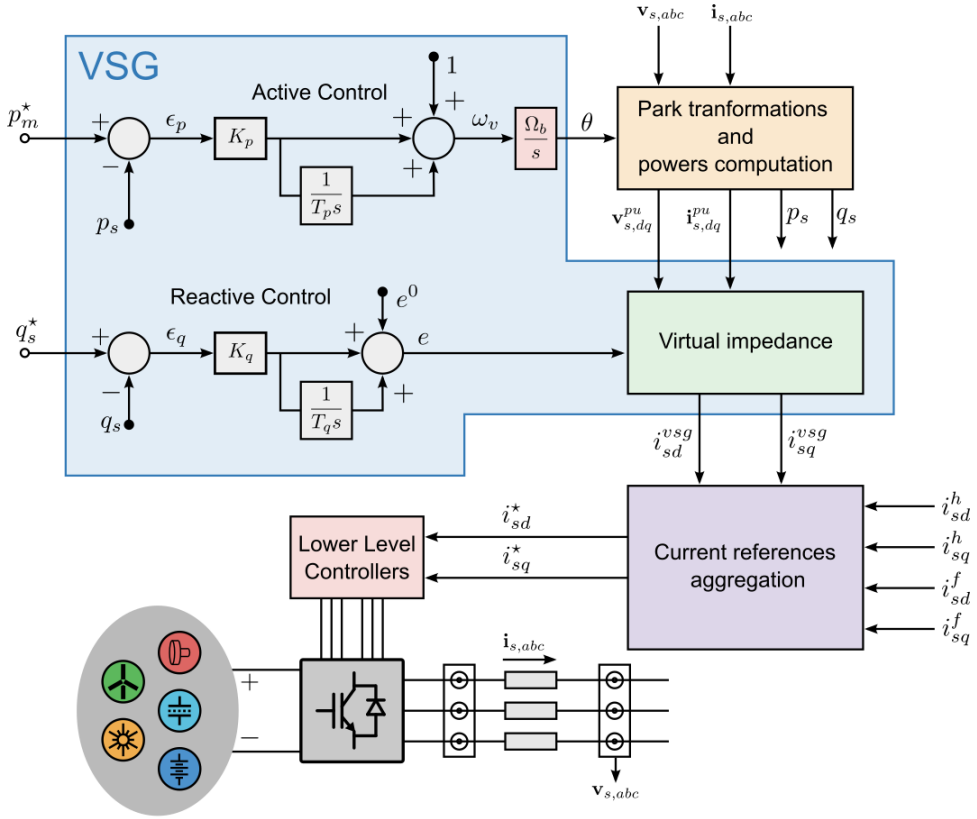
- In EASY-RES **LOW** is implemented in a **DSP** with sampling times of 50μs

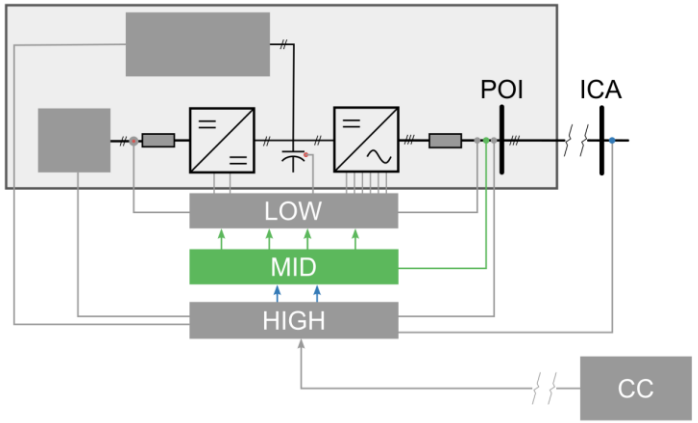
MID level controllers



- In EASY-RES is the **synchronous machine virtualization** level
- The VSGs can be implemented in several ways:
  - Synchroconveter
  - Swing equation VSG
  - **PI based VSG**
- By emulating a SM some functionalities can be obtained:
  - **Inertial response**
  - **Reactive power**
- The outputs of this level are the **reference currents for LOW**
- The inputs are similar to the present in a SM:
  - Virtual mechanical power
  - Reactive power reference
- Models and simulations can be perdormed in **RMS domain** with typical power system tools:
  - PowerFactory/DIGsilent
  - PSS/E

MID level controllers

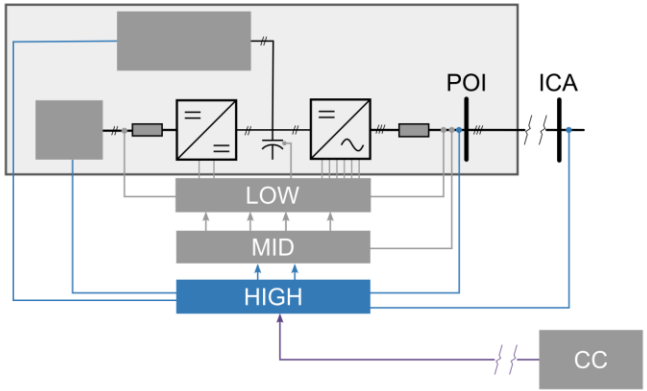




- In EASY-RES MID is implemented in a DSP with sampling times of 50μs
- However, if required, this level can be implemented in another hardware with sampling times as high as 10ms

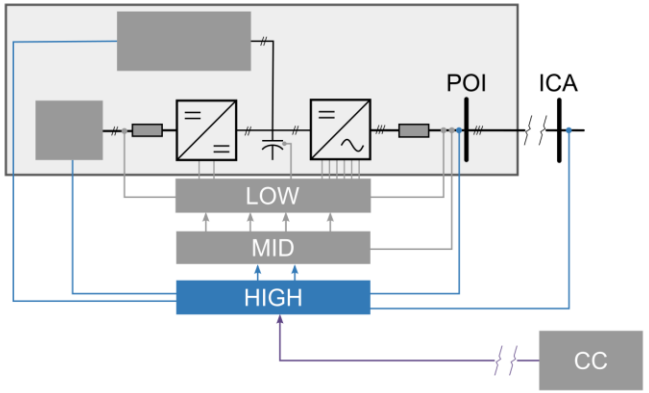
HIGH level controllers

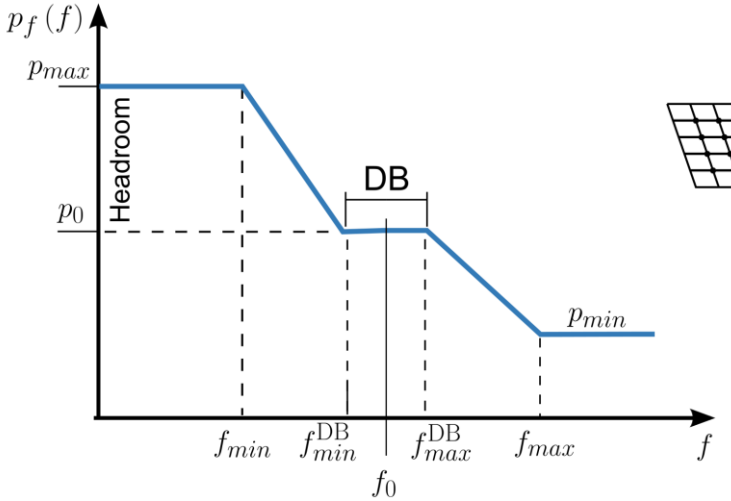
- High level controllers performs those functionalities that have larger time constants (>100ms):
  - **PFR**: Power Frequency Response
  - **HFPS**: High Frequency Power Smoothing
  - **SoC**: Storage State of Charge control
  - **POI-V**: Voltage control

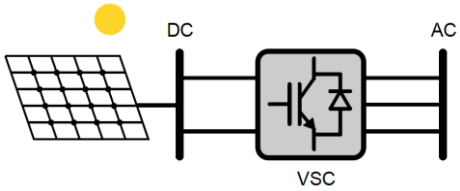


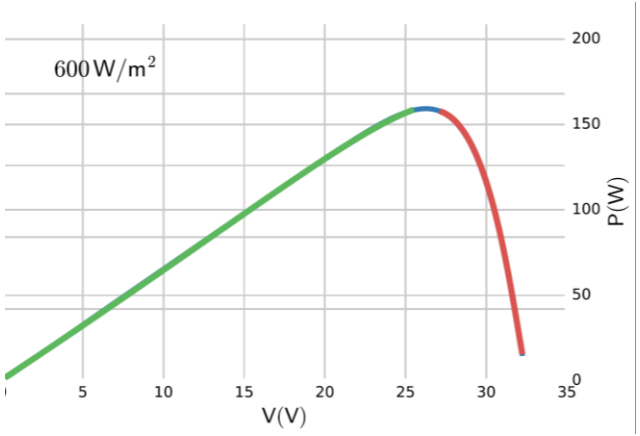
HIGH level controllers

- **PFR**: Power Frequency Response
- In EASY-RES the **PFR** is perfomed by modifying the **primary source power reference**.
- Therefore **headroom** is required in the case of underfrequency event (curtailment).



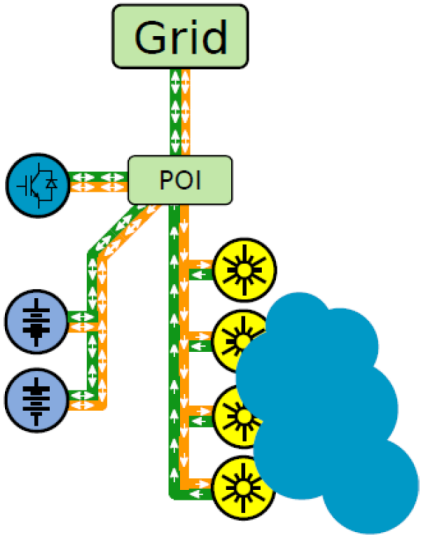


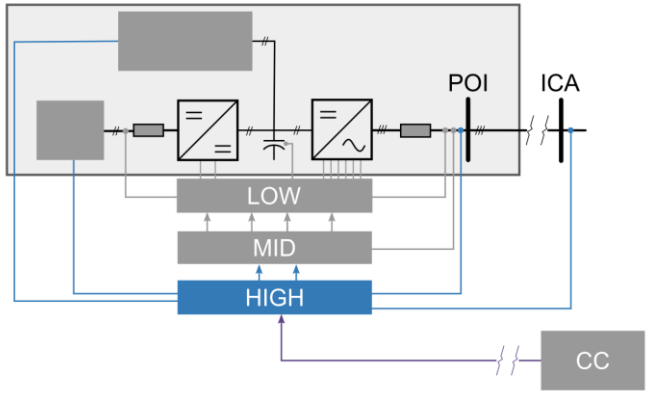


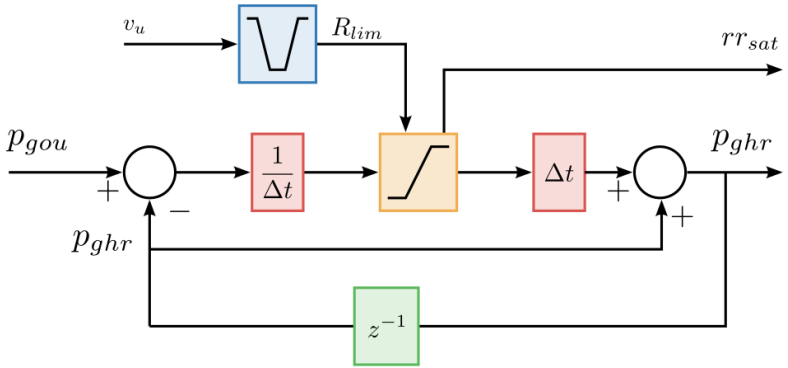


HIGH level controllers

- **HFPS**: High Frequency Power Smoothing.
- By using storage it is possible to implement a power variation **ramp limitation**.
- With limited energy high frequency component is limited.

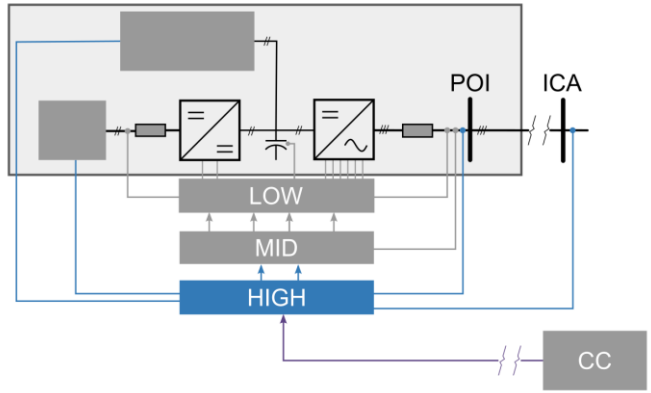


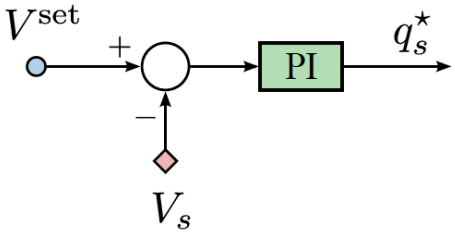




HIGH level controllers

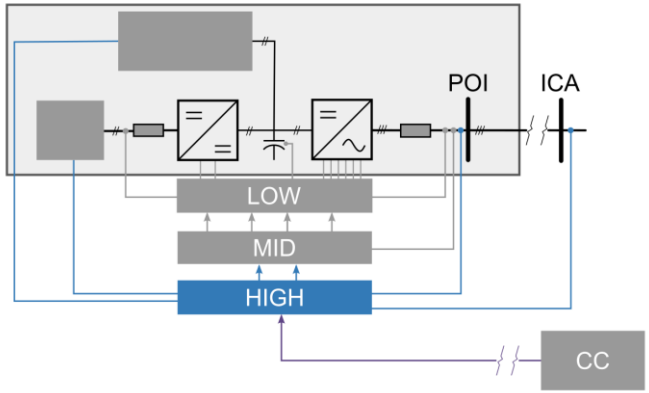
- **POI-V**: Using the MID level reactive power control, HIGH level this reference for regulating the POI voltage to a desired value.
- The **POI-V** control emulates an **SM AVR.**





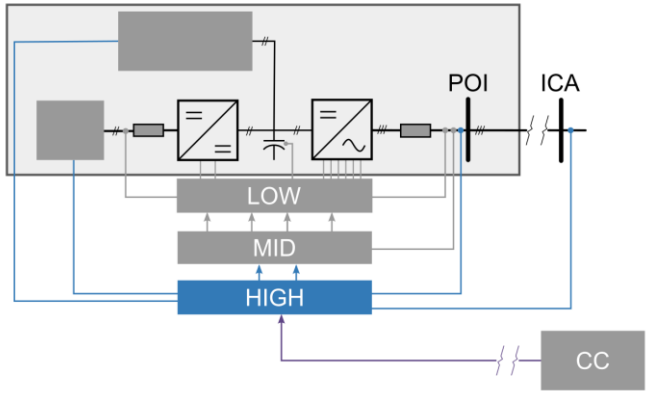
HIGH level controllers

- **SoC**: State of Charge control.
- This controller adds a term in the virtual mechanical power $p_m^\star$
- When $p_m^\star$ is larger than the primary source power the storage is discharged, when smaller the storage is charged.



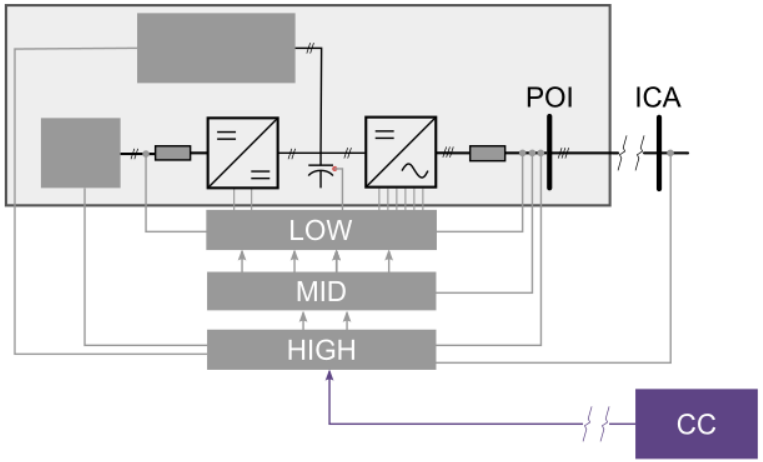
HIGH level controllers

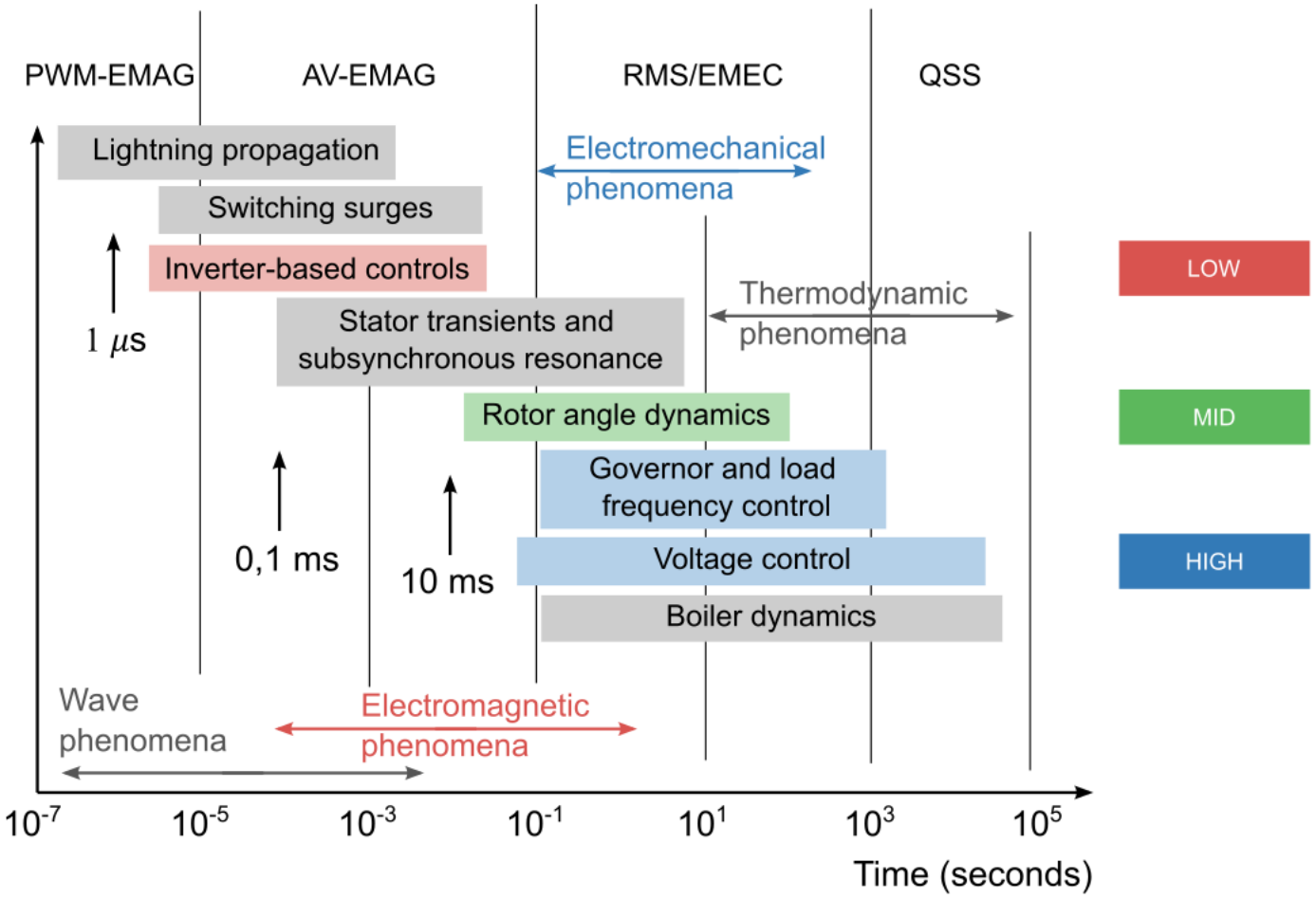
- In EASY-RES HIGH is implemented in the DSP with sampling times of 50µs
- However it can be implemented in a **PLC, PC or a low cost computer** (Rpi), with sampling times around 1s



CC Centralized controllers

- Centralized Controllers will make the ICA to bring ansilliary services optimally.
- Also will send parammeters to the local controllers and receive from them measurements for provided ansilliary service accounting.
- It is the most important level from the comminication point of view




PWM-EMAG
AV-EMAG
RMS/EMEC
QSS
Lightning propagation
Switching surges
Inverter-based controls
1 μs
Stator transients and subsynchronous resonance
Electromechanical phenomena
Thermodynamic phenomena
Rotor angle dynamics
Governor and load frequency control
0,1 ms
10 ms
Voltage control
Boiler dynamics
Wave phenomena
Electromagnetic phenomena
LOW
MID
HIGH
10-7
10-5
10-3
10-1
101
103
105
Time (seconds)

The EASY-RES Consortium

ARISTOTLE UNIVERSITY OF THESSALONIKI

UNIVERSIDAD DE SEVILLA

UNIVERSITÄT PASSAU

Lancaster University

TU Delft

ΑΔΜΗΕ
ΑΝΕΞΑΡΤΗΤΟΣ ΔΙΑΧΕΙΡΙΣΤΗΣ ΜΕΤΑΦΟΡΑΣ ΗΛΕΚΤΡΙΚΗΣ ΕΝΕΡΓΕΙΑΣ

elektro gorenjska

Stadtwerke LANDAU a.d.ISAR

stadtwerk haßfurt

fenecon
ENERGY ENGINEERING

ZD.B ZENTRUM DIGITALISIERUNG. BAYERN

This project has received funding from the European Union´s Horizon 2020 Programme for research and innovation under Grant Agreement no 764090.

Thank you!

Presenter‘s name: Juan Manuel Mauricio

Affiliation: EASY-RES

E-Mail: jmmauricio@us.es

EASY-RES website: http://www.easyres-project.eu/