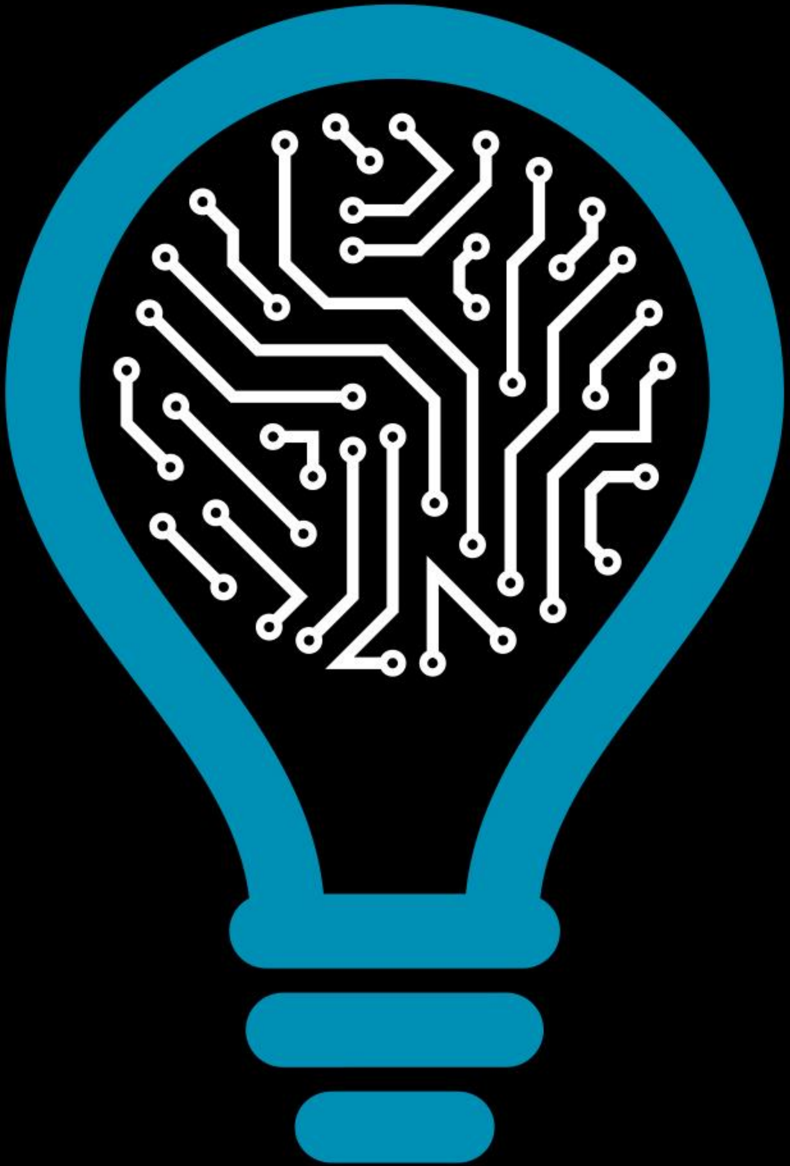
Technologies for clean energy transition in islands:

A system perspective



Carlos Moreira

Centre for Power and Energy Systems

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INSTITUTE FOR SYSTEMS AND COMPUTER ENGINEERING, TECHNOLOGY AND SCIENCE

Introduction

- From fossil fuel dependency to renewables – a paradigm shift
  - Dependence on energy imports
  - Climate goals and national contributions agreed upon at the COP21 in Paris
  - Increasing concerns for the environmental impacts and opportunities to become a prosumer

- Manufacturing costs for sustainable technologies decrease and their integration increases:
  - Mature technologies: solar, wind, hydro, geothermal
  - Door open to emerging technologies – tidal, wave, ocean thermal energy, CSP,

- Blueprints for decarbonization of island´s economies
  - Sector coupling – integration of power, heating, cooling and transport sectors
  - Green hydrogen as a new energy vector

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Sustainable islands

- **A system (island) view**
  - The input – targets for the planning horizon – points in time for RES integration
    - Load evolution, electrification of the consumption through sector coupling – ex: electric mobility
    - Shares of renewables integration
  - Planning the system evolution – medium/long term
      - Generation system expansion – technology share, considering:
        - System adequacy
        - Need for energy storage vs RES curtailment
  - Technical adequacy of the planning solution
    - Define reference disturbances – system faults/disturbances the planned system should survive
    - Determine system needs – identify the key supporting functionalities
      - RES integration is traditionally a technical problem in islands – technology evolution is pushing it to the side of the solution
      - Trend is to identify supporting functionalities regardless the technology
      - May include the need of sub-hour energy storage needs for fast system balancing
  - Define mechanism for supporting the provision of the supporting functionalities
    - Mandatory vs. remunerated
  - Formalization – grid codes definition, consultation and final publication

Sustainable islands

- **A system (island) view** – the planning the system evolution – medium/long term
  - Decision variables
    - Sizing power technologies in a given time horizon
    - Sizing energy storage (intraday, seazonal, etc)
  - Objectives – multi-objective problem
    - Maximize RES integration in the planning horizon
    - Minimizing reliability indexes (Ex: Loss of Load Expectation – LOLE h/year)
    - Cost minimization (investment, operation, energy costs)
  - The boundaries
    - Expected load evolution
    - Trends in RES power production from the past
    - Fuel costs evolution
    - Plans for decommissioning existing plants

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New challenges in islands

- From conventional fossil fuel based electrical generation to large scale sustainable solutions:
  - Renewable energy sources (PV, Wind)
  - Energy storage systems
    - Battery energy storage systems (BESS)
    - Hybrid storage systems (pumped hydro stations – PSP – and BESS)

Conventional System → **RES / Converter Dominated System**

New challenges in islands

- **Requirements**
  - Assure stable operation of the local grid – keep/improve security margins
  - Assure steady state operation of the grid without violating operational constraints
  - Increase (largely) renewable generation penetration

- **Challenges**
  - Need of storage (different scales)
  - Reduction of system inertia
  - Reduction of P/f and Q/V voltage support
  - Reduction of short-circuit current (converter interfaced units versus synchronous generators)
  - Special features to be required to converters (eg: grid forming versus grid tied in BESS)

Main Objective:

Definition of System Needs

Illustrative example – Madeira Island

Planning Horizon – 2025 – Summer/Autumn Noon Scenario

P [MW]	
98.4	LOAD
52.3	PUMPING
4.9	LOSSES
155.5	GENERATION
71.7	WIND
57.6	SOLAR
3.3	mini-HYDRO
18.1	THERMAL
4.8	WASTE-to-ENERGY

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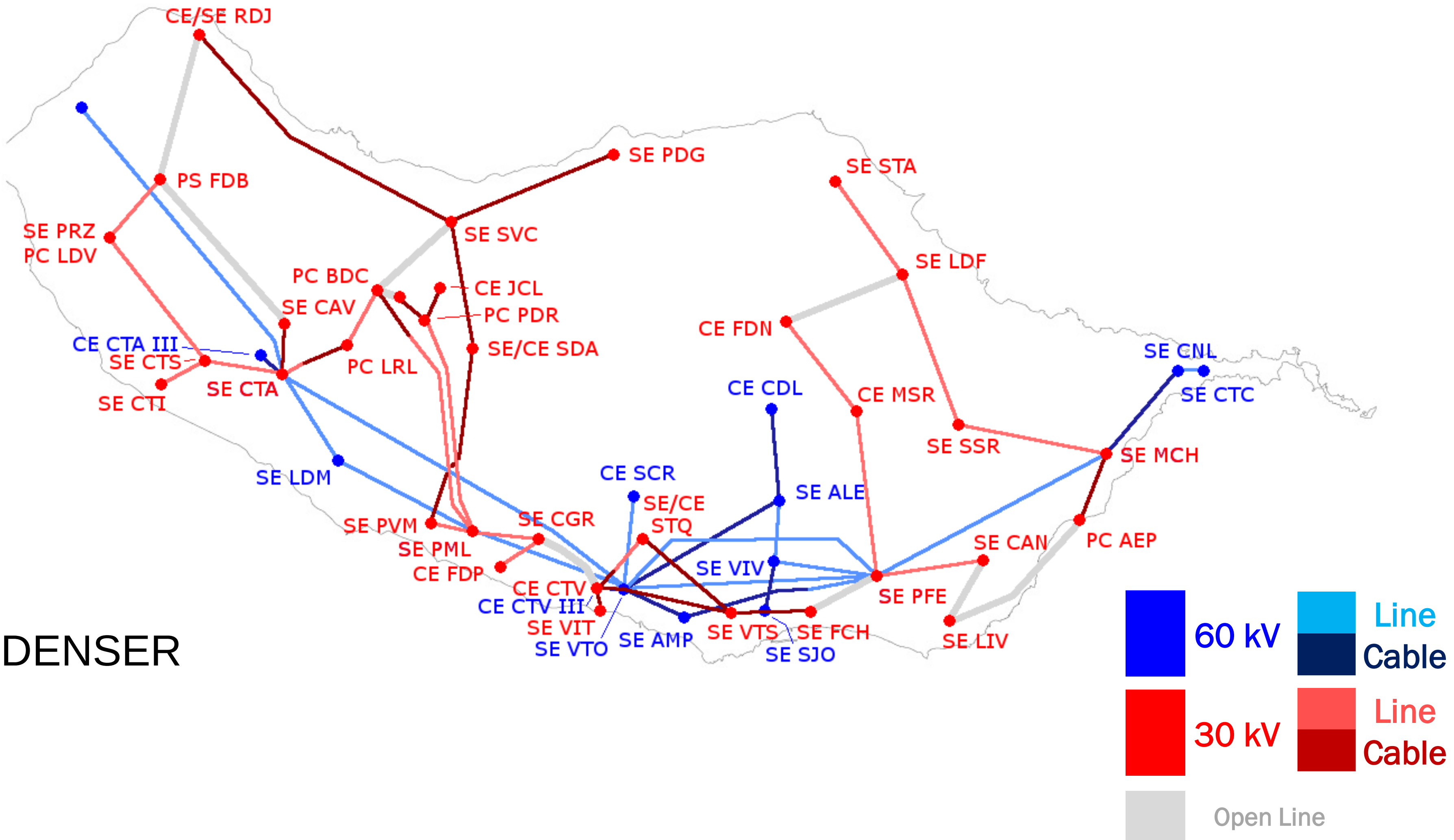
136 MVA SYNCH. CONDENSER



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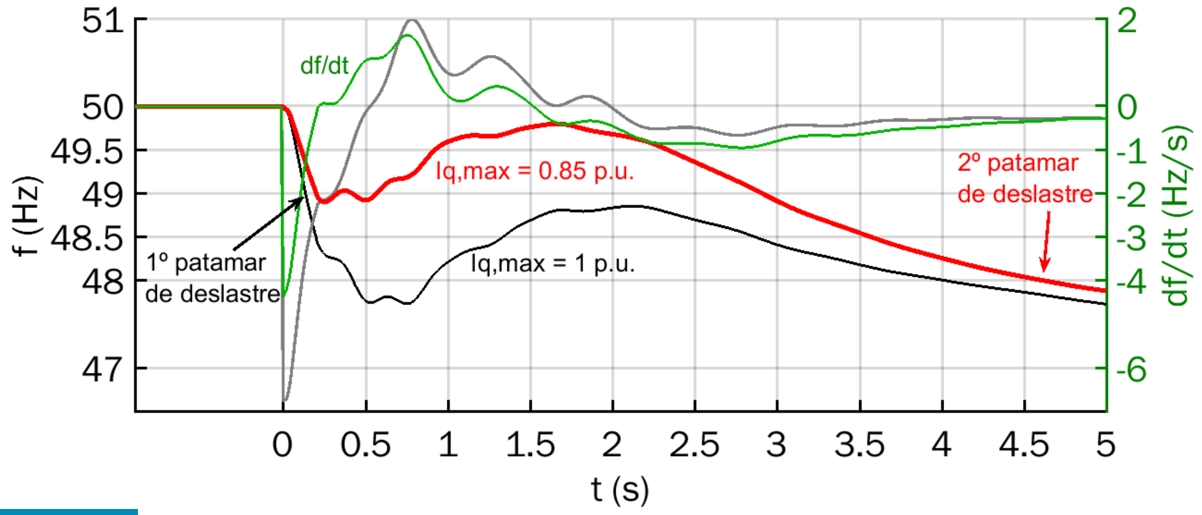
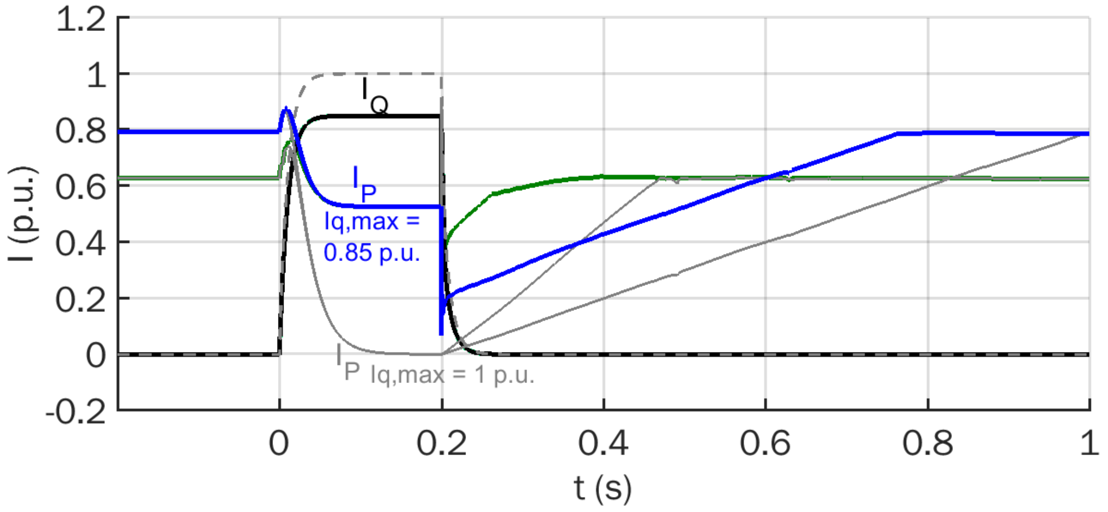
Illustrative example – Madeira Island

Technical adequacy of the planning solution

- **In isolated/autonomous systems, a fault conditions is a severe case leading to very low residual voltages in the overall system**
  - Fault ride through capability is a critical issue for RES and energy storage to avoid large power disconnections

- **During a grid fault, what is the preferable solution?**
  - Preference to reactive current injection?
  - Preference to active current injection?
  - **Expected contribution towards RoCoF reduction?**

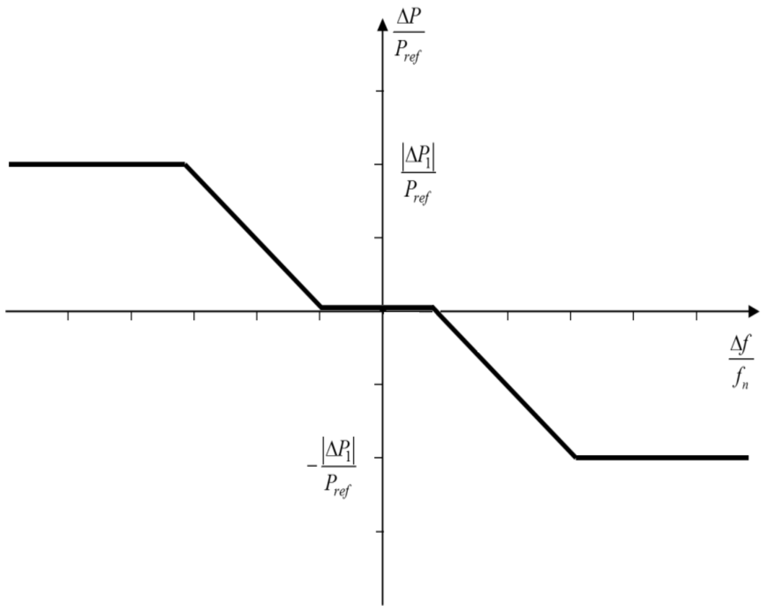


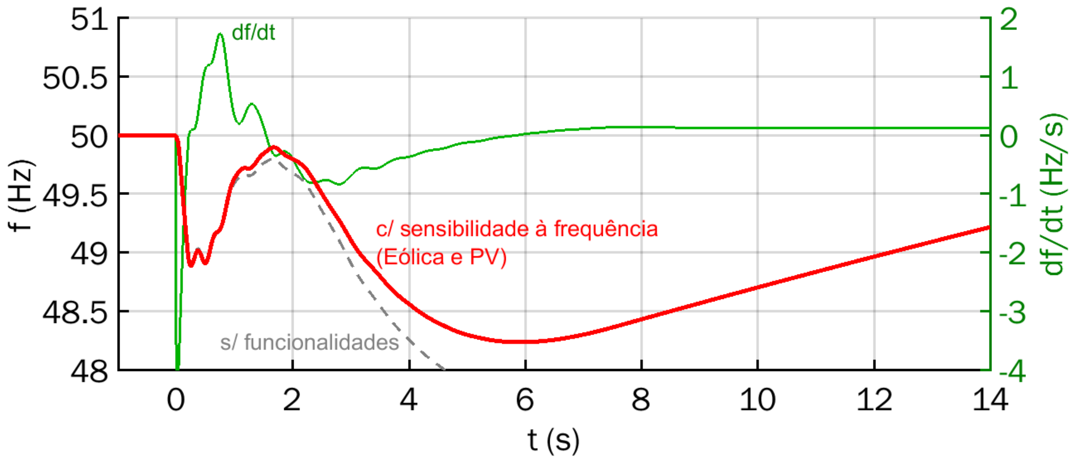


Illustrative example – Madeira Island

Technical adequacy of the planning solution

- **Frequency sensitive modes**
  - **Under-frequency:** requires the *deloading* of the RES unit with respect to the maximum power extraction point. The activation of this functionality shall be defined by the dispatch of the System Operator considering the existing operating conditions.
  - **Over-frequency:** Following short-circuits in scenarios of high renewable generation, the subsequent power ramp-up of RES may lead to grid over-frequency conditions. The disconnection of the pumping units (under voltage tripping), provoking relevant load deficits, may lead also do over-frequency events.





Final Remarks

- **Following the definition of the targets for RES integration, a system planning exercise considering multiple objectives is a fundamental step.**

- **Identification of specific system needs to ensure robustness regarding power system operation with increasing shares of renewable power sources:**
  - Advanced connection requirements for renewable generation facilities and BESS are fundamental – **Grid codes**.
  - System specific need to be considered as well as state of the art technology solutions
    - Islands are small systems with limited capacity to drive the market for specific solutions