Joint ELECTRA – ETP SG Workshop

December 10th 2015, Brussels

Web-of-Cells Architectural Concept

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European Commission

The research leading to these results has received funding from the European Union Seventh Framework Programme (*FP7/2007-2013*) under *grant agreement* n° 609687

EERA
European Energy Research Alliance
Smart Grids Joint Programme

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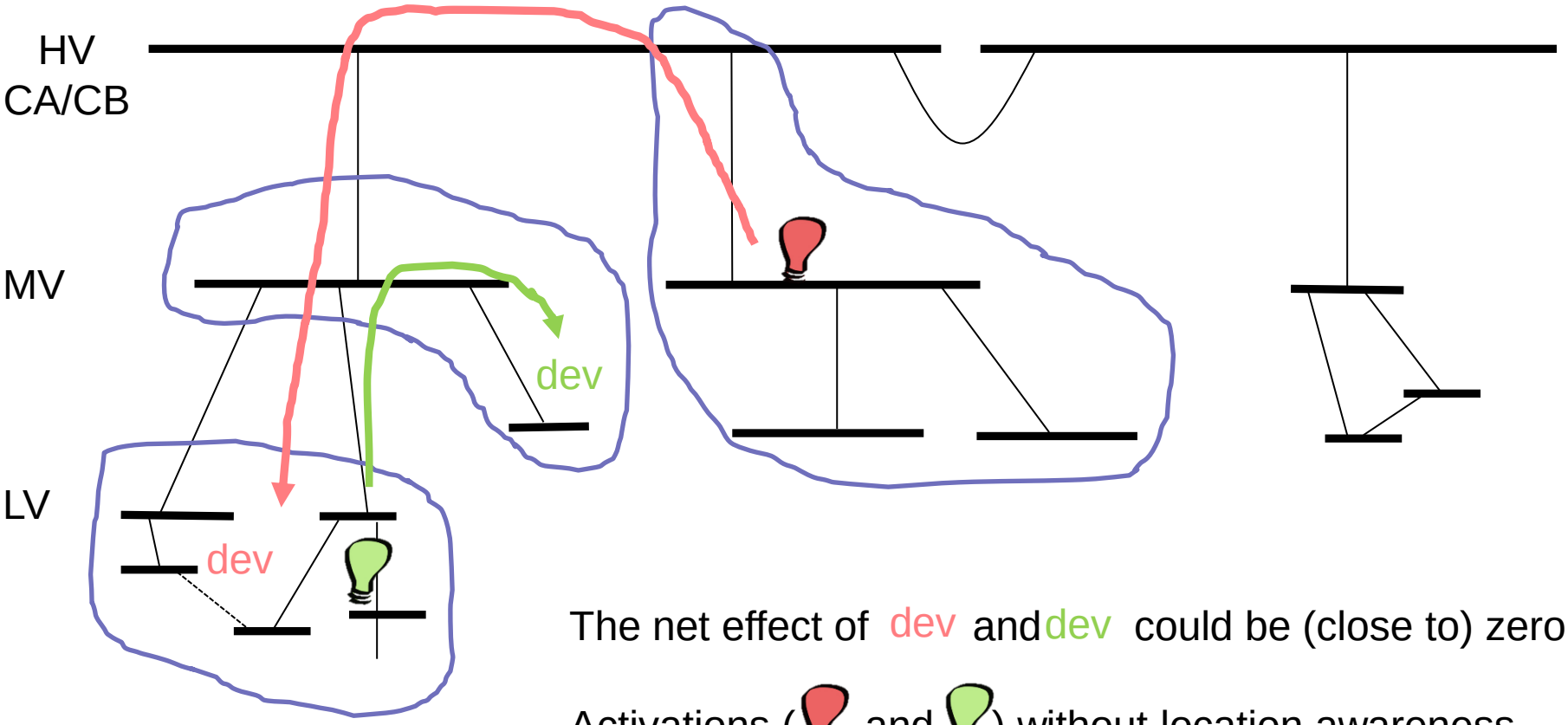
Web-of-Cells Scope and Need

- The power system is changing rapidly …
  - Large amounts of RES (intermittency, forecasting, '*non-controllable*') at all voltage levels
  - Large amounts of flexible loads and DR activations at all voltage levels

- **Real-time** frequency and voltage control by System Operator **AFTER** market clearing by BRP/TSO/markets

- Challenges related to
  - Detection : system frequency is not adequate for detecting local (regional) deviations/problems (counterbalancing effect of different sign local deviations)
  - Resolution : how much, what and where to dispatch in an efficient manner with respect for all local constraints (all voltage levels)

Web-of-Cells Scope and Need



The net effect of dev and dev could be (close to) zero.

Activations (and) without location awareness could be inefficient and/or insecure.

Web-of-Cells Scope and Need

- Centralized Detection and Resolution
  - Local monitoring and data collection at all voltage levels by local operator
  - Sending upstream and aggregation of large amounts of data by central operator (communication)
  - Central decision taking and optimization based on large data set (computational complexity)
  - Dispatching reserves activation downstream to local operators
  - In real-time …
- Alternative : delegate responsibility for local **balance**/frequency and voltage control to local operators
  - Solve local problems locally : less complexity, less communication, more efficiency (less losses), more secure (less reverse power flows)
  - Divide-and-conquer : less complexity

Web-of-Cells Concept

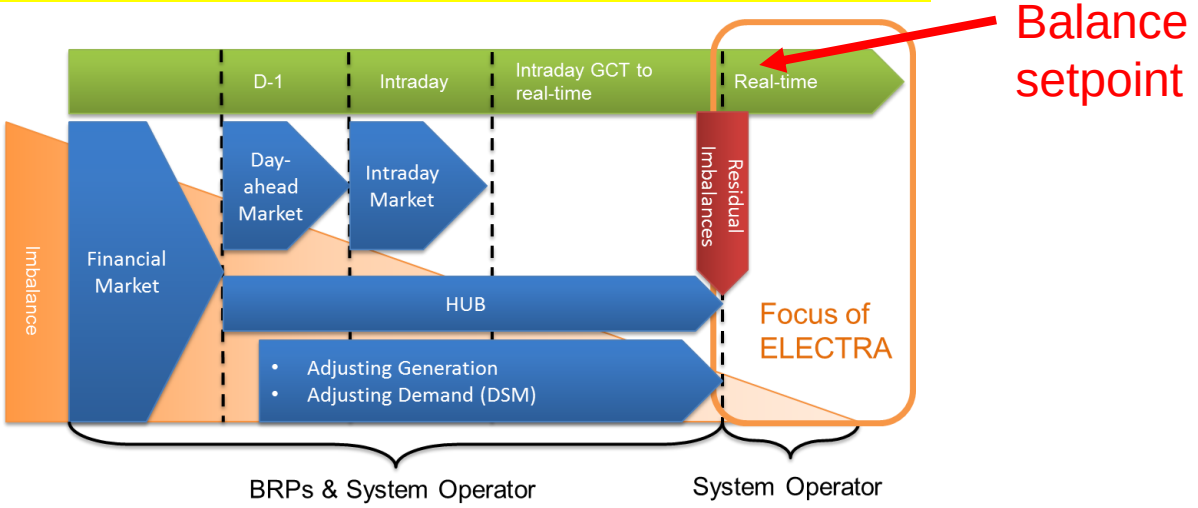
- Divide the power system (grid) in smaller entities (geographical areas) – **cells** – with local observability and control by a cell operator that is responsible for the real-time balance/frequency and voltage control of the cell
  - Local problems are solved locally, in a secure manner, without system-wide communication, aggregation and central decision making
- Cells are connected with each other via tie-lines (one or multiple, radial or meshed)
  - Neighboring Cells can support each other in a autonomous distributed collaborative way (adjacent ⇔ central aggregation)
  - Neighboring cells can decide on local activation optimization (neighbor-to-neighbor ⇔ central)

Web-of-Cells Concept

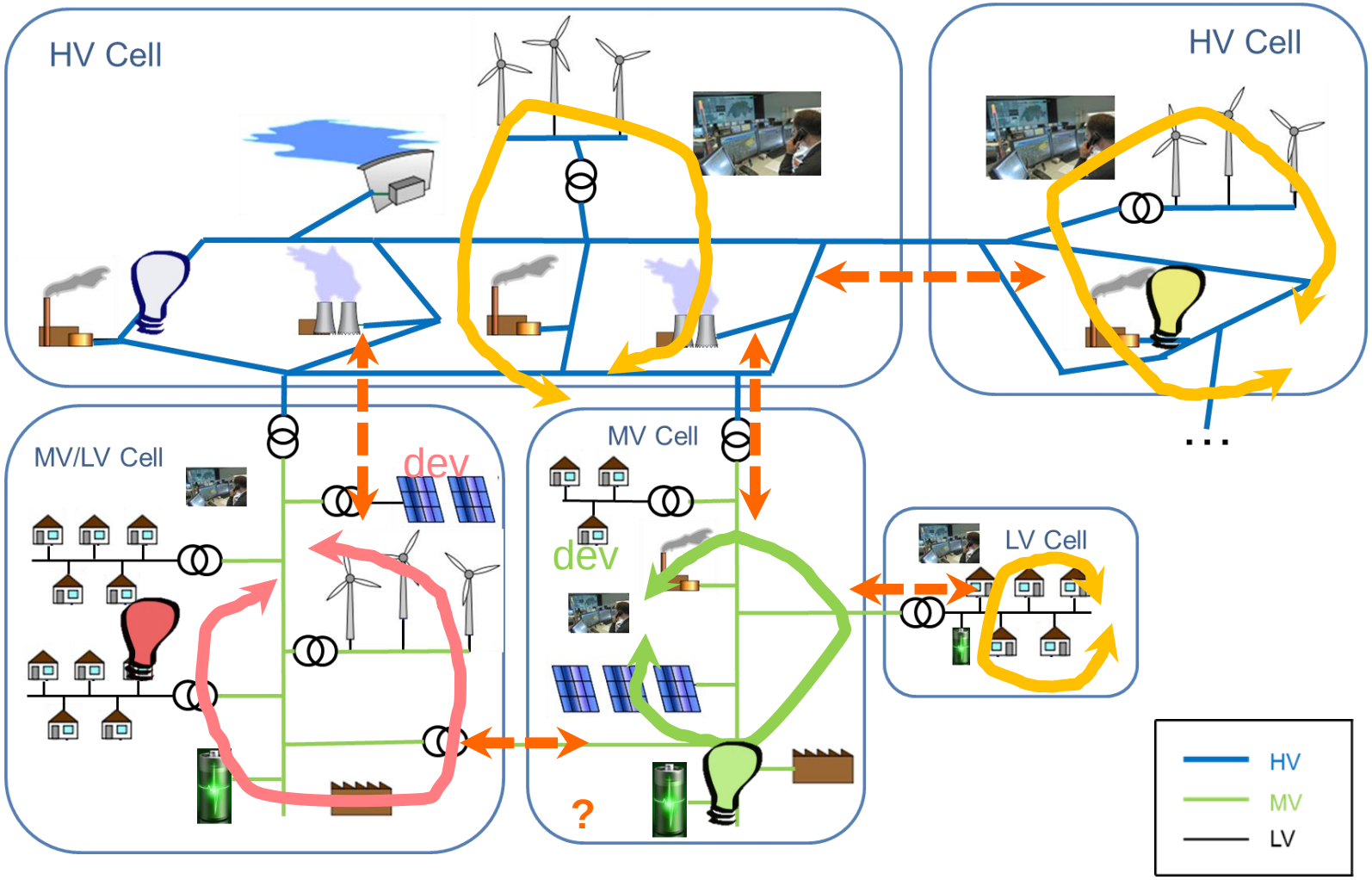
- Cells can contain/span multiple voltage levels
- Cells are dimensioned in relation to
  - Computational complexity of Detection and Resolution (secure dispatching of reserves)
  - Sufficient reserves providing resources
  - Spatial correlation of weather forecasting for RES
- Cells do not need to be self-reliant for matching demand with supply
  - They may depend on structural energy imports or exports (e.g. coming from large central RES power plants) as cleared in a system-wide optimized setpoint calculation

Web-of-Cells Concept

- Cells receive a balance setpoint determined by BRP/TSO market clearing leveraging system-wide optimization
  - Balance setpoint = cell's import/export schedule (per time-step in real-time control time window) i.e. what is its secure scheduled net import/export
  - **Cell Imbalance = deviation from this balance setpoint**
    - **Importing/exporting more than what was scheduled**



Web-of-Cells Concept



Web-of-Cells Control Functionalities

- Need to detect and correct local imbalances (deviations from the cell's setpoint)
- ~~Frequency deviation~~ ➔ Cell import/export deviation (e.g. power-flow based)
- ~~Frequency Control~~ ➔ Balance Restoration Control

- Cells are connected : coordinated response
  - locality and proportionality : neighboring cells will be impacted more and react stronger than distant cells

- Fast acting (ramping) reserves (loads, storage elements)

Web-of-Cells Control Functionalities

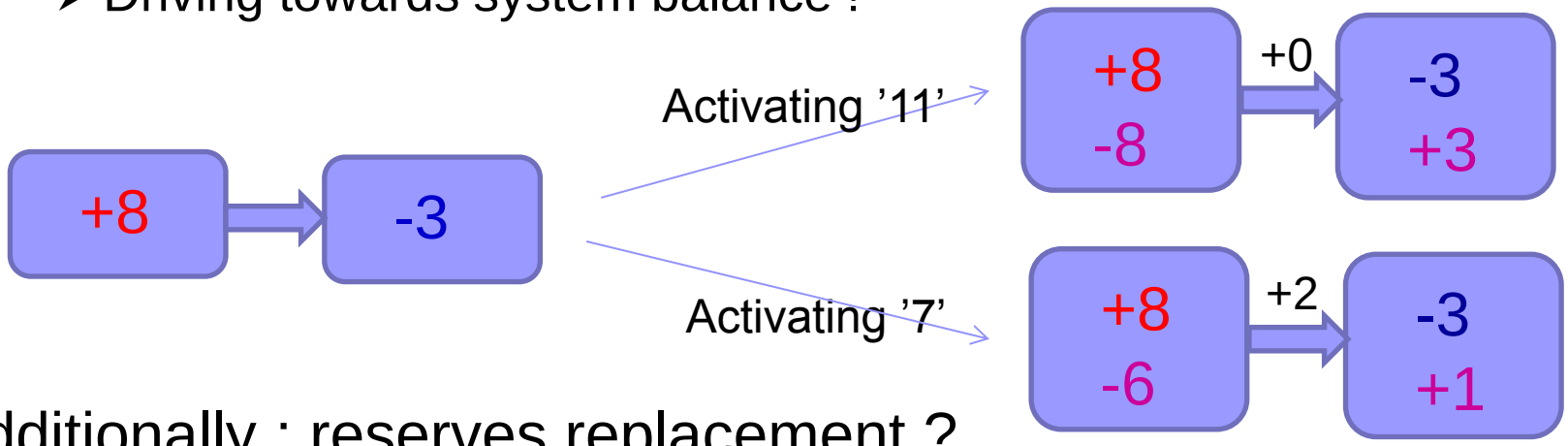
- Frequency Containment Control
  - For containing frequency deviations (system imbalance instead of cell imbalance) : still needed ?
  - Because Balance Restoration Control may not be restoring system balance fast enough ?
    - Correct each cell's import export <> correct generation = load
    - System balance must be restored fast even if frequency containment is not an issue
- System control ⇔ distributed cell control
  - Introduce locality and proportionality by adding smarter controller paradigms

Web-of-Cells Control Functionalities

- Inertia Steering Control : support frequency containment in a world with less synchronous machines and less physical/kinetic inertia
- Controls Virtual/Synthetic Inertia providing resources to ensure a minimal inertia level (setpoint) irrespective of the energy mix (day/night, sunny/cloudy, windy/calm day, …)

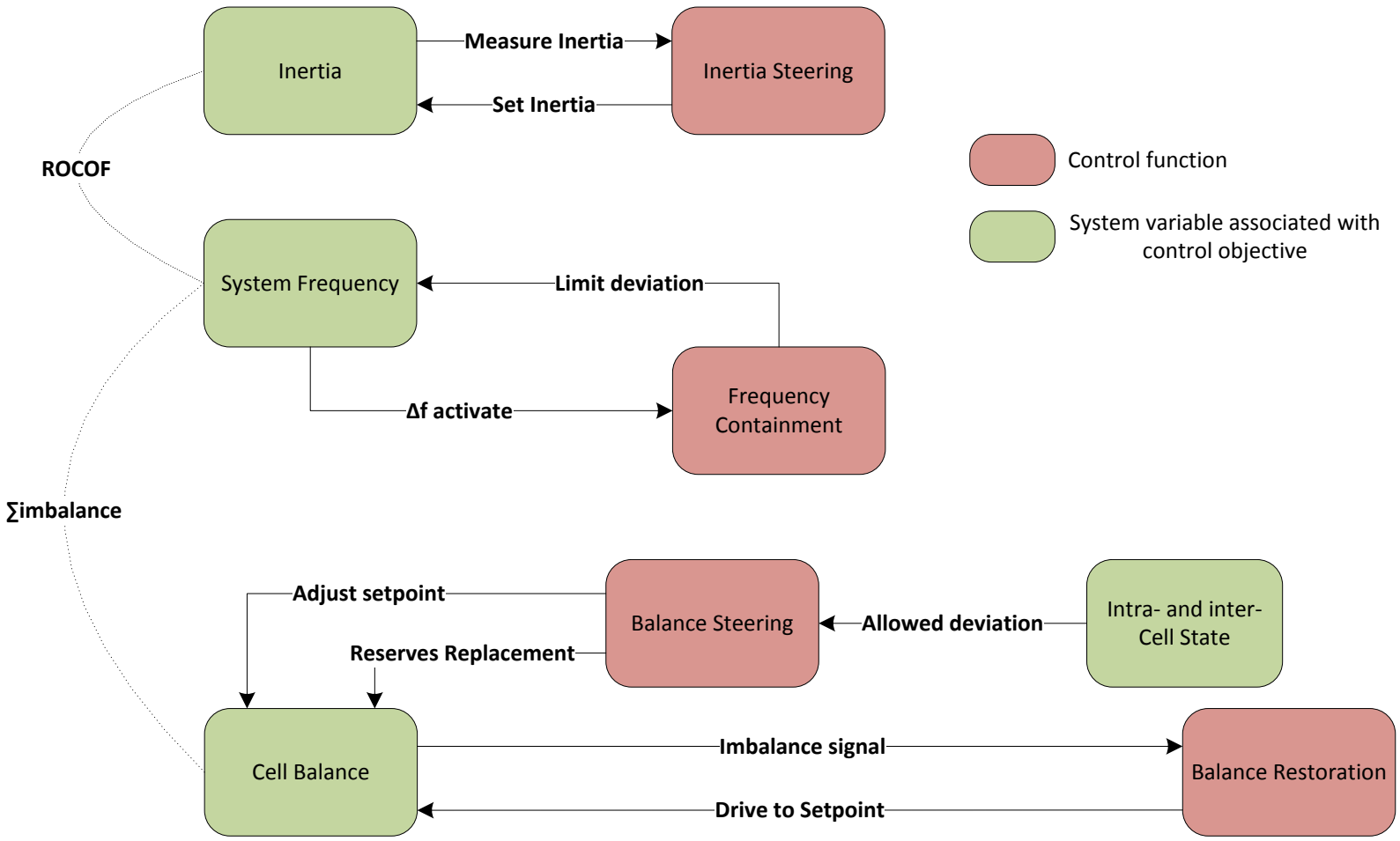
Web-of-Cells Control Functionalities

- Balance Steering Control : economic optimization of reserves activation
  - Minimize amount of reserves activations by neighbor-to-neighbor negotiation of new setpoints
    - Intra-cell and inter-cell (tie-line) constraints !
    - Driving towards system balance !



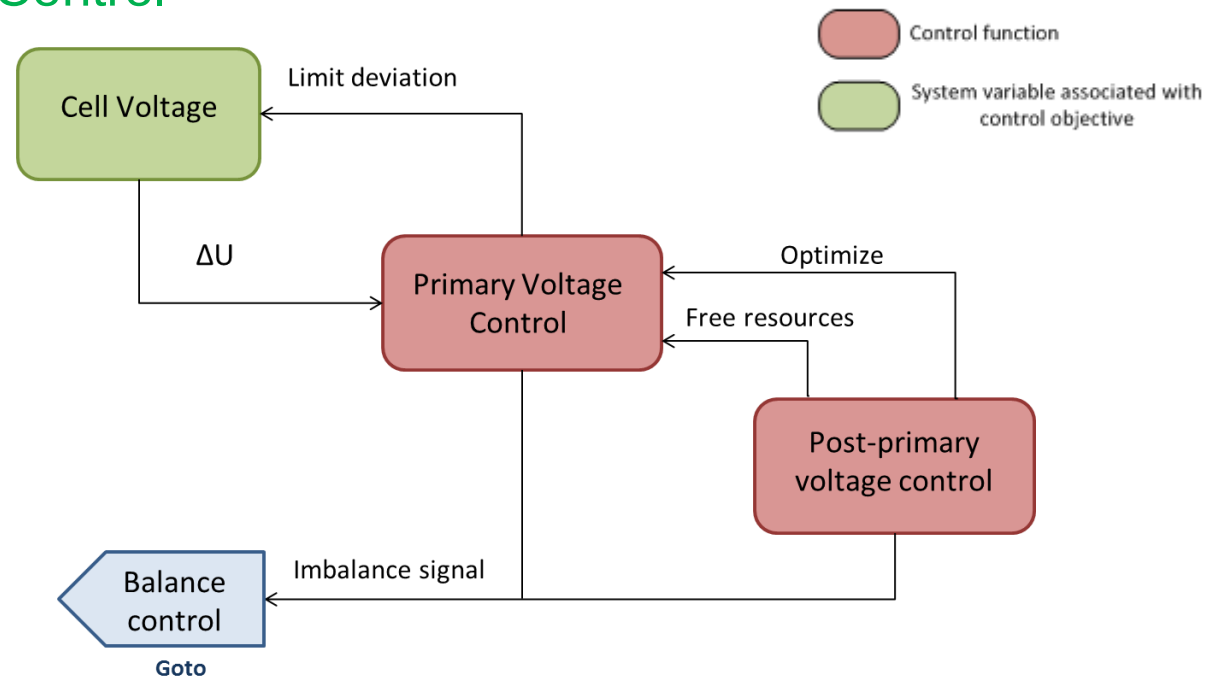
- Additionally : reserves replacement ?
  - part of BRC activation schedule calculation ?

Web-of-Cells Control Functionalities

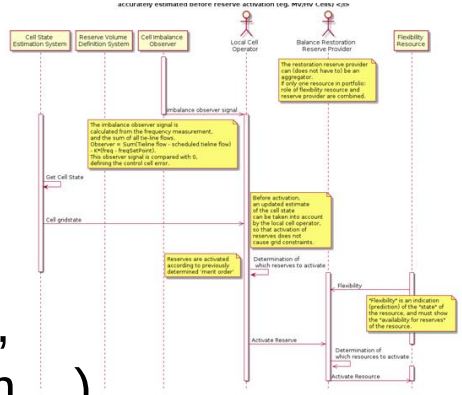


Web-of-Cells Control Functionalities

- Voltage control
  - Primary Voltage Control as of today at all voltage levels
  - No need for subsequent two step Secondary and Tertiary control: can be combined in a single Post-Primary Voltage Control



Current Status and Next Steps



- Finalize discussions (and selection) on conceptual solutions/options
  - Specific objectives (e.g. cell setpoint or tie-line setpoint)
  - Architectural Options (e.g. control loop architecture, controller paradigm, resource activation mechanism, ..)
  - Identification and specification of required functions and interactions
- Detailed specification of selected solutions incl. SGAM mapping
- Design, implement and test (simulation ➔ Lab)
- Standard gap analysis, conflict analysis, cyber security analysis

- And engage with stakeholders along the way …

CONTACT

INFORMATION

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ELECTRA IRP website link:

www.ElectraIRP.eu