Managing Demand Through a Smarter Distribution System

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Outline:

- Overview and Introduction
- Definitions of Smart Distribution System as a Microgrid
- Virtual Power Plant (VPP) operation of Microgrid
- Microgrid as a Building Blocks of the Smart Grid
    - Technology Requirements
    - Technical Challenges
        - Protection
        - Control
        - Management
- Research and Development Needs
- Concluding Remarks

Smart Grid Definition:

The Smart Grid vision is a globally unified operation of

- conventional power system apparatus,
- power electronic-based apparatus,
- information and communications technologies (ICTs),

through the "*appropriate*" control, protection, and energy management strategies to:

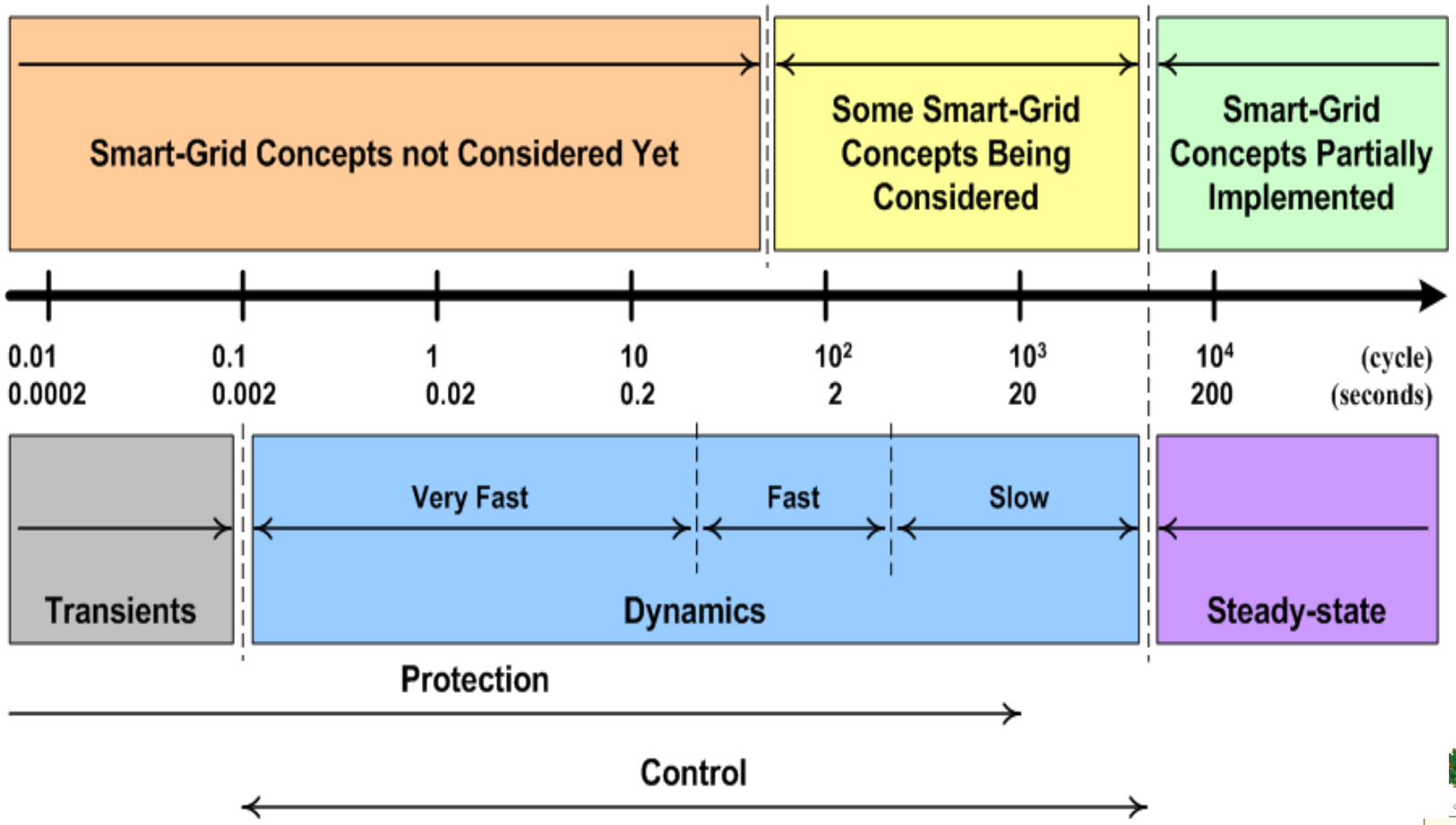
- minimize environmental adverse effects,
- improve asset utilization and performance,
- facilitate/enable real-time interactions among customers, operators, power producers, service providers and market.

The degree of grid "Smartness" is defined in terms of level of automation:

Present Status: Automated operation with human **assistance**

Envisioned Status: Automated operation with human **intervention**

Time-Frame of Events in the Power System and Applicability of Smart Grid Concepts



Proposed strategy for realization of smart grid:

A hirarchial grid management, control and protection that accommodates each distribution sub-system (distribution substation and down stream feeders) as a “manageable” and “controllable” entity with respect to it connection node to the grid.

Justifications:

Relatively higher degree of “smartness” of transmission and bulk-power generation units as compared to distribution sub-systems

Addressing challenges due to high-depth of DER penetration in distribution systems

Addressing anticipated issues due to high-depth of EV/PHEV penetration systems

Limited and gradual investment requirements

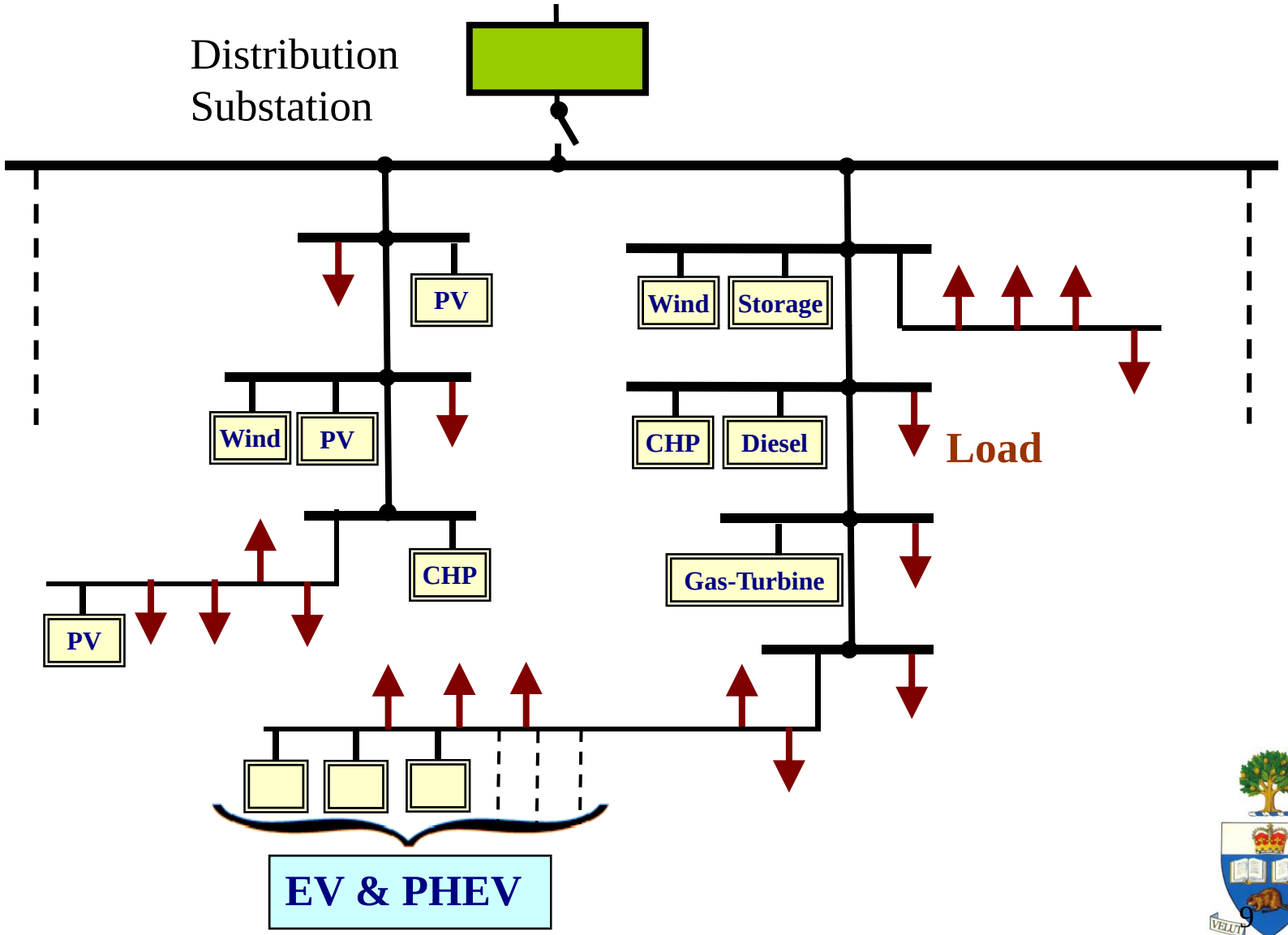
Justifications (continued):

Flexibility to (i) address specific system requirements and (ii) improve/modify strategies/algorithms as deemed desirable

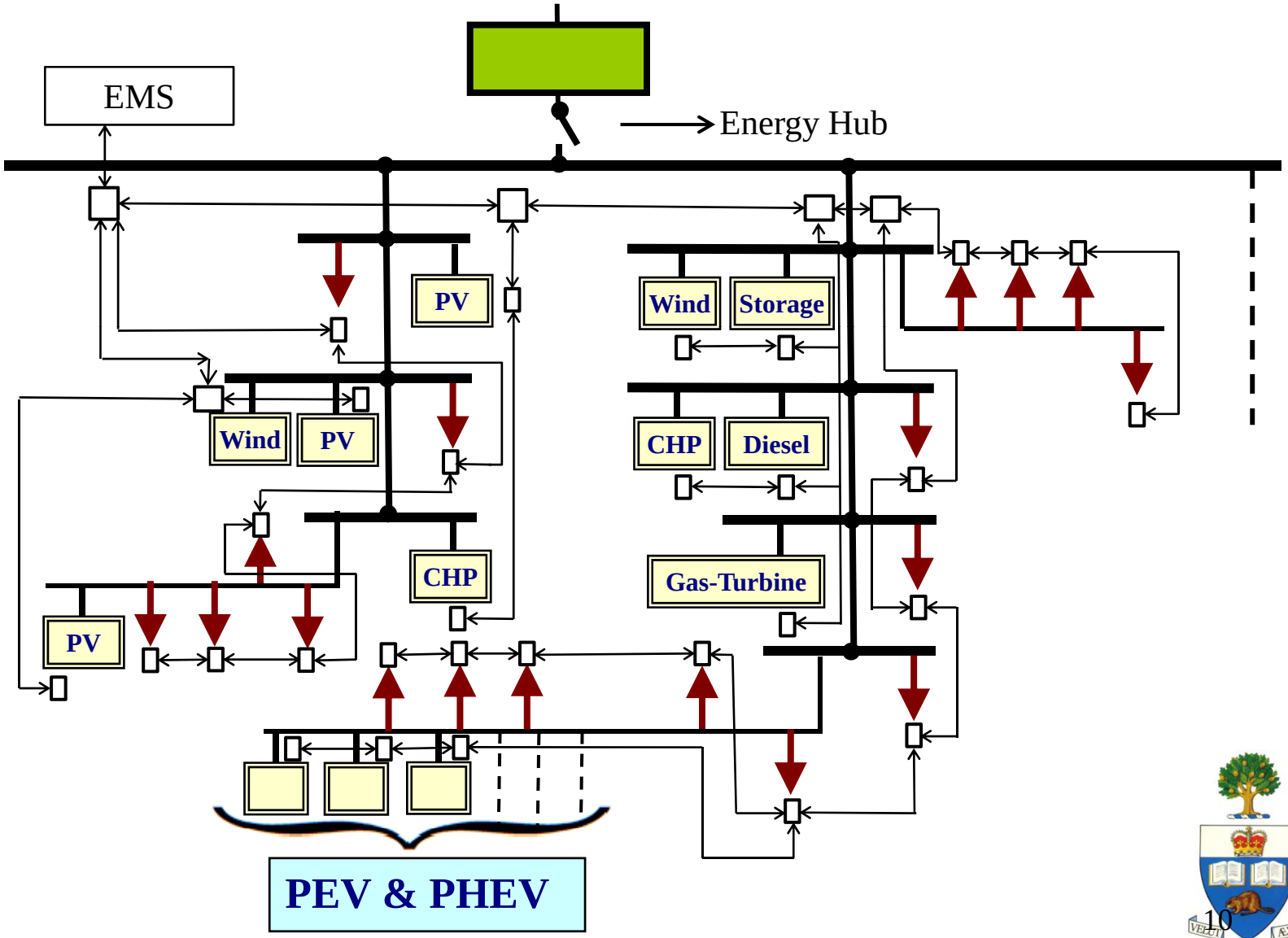
Flexibility to integrate “new” technology based on local decisions

Continuity of supply subsequent to natural disasters and man-made events

Distribution System



Microgrid

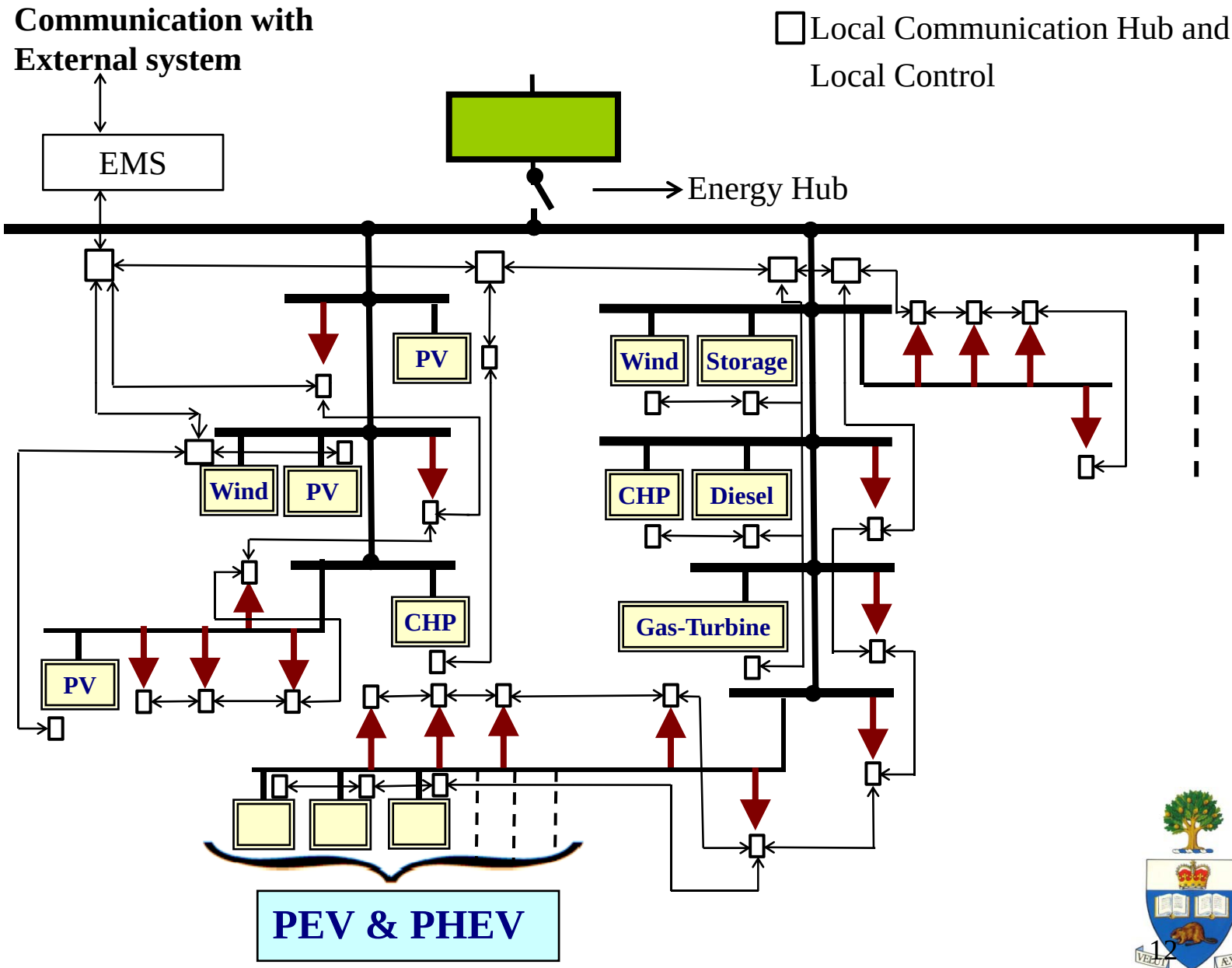

EMS
Energy Hub
PV
Wind
Storage
Wind
PV
CHP
Diesel
CHP
Gas-Turbine
PV
PEV & PHEV

Definition of “Microgrid”:

A “microgrid” is a cluster of distributed energy resource (DER) units and distributed loads, serviced by a distribution system, and can:

- operate in the grid-connected mode,
- operate in the islanded (autonomous) mode,
- provide transition between the grid-connected and the islanded modes.

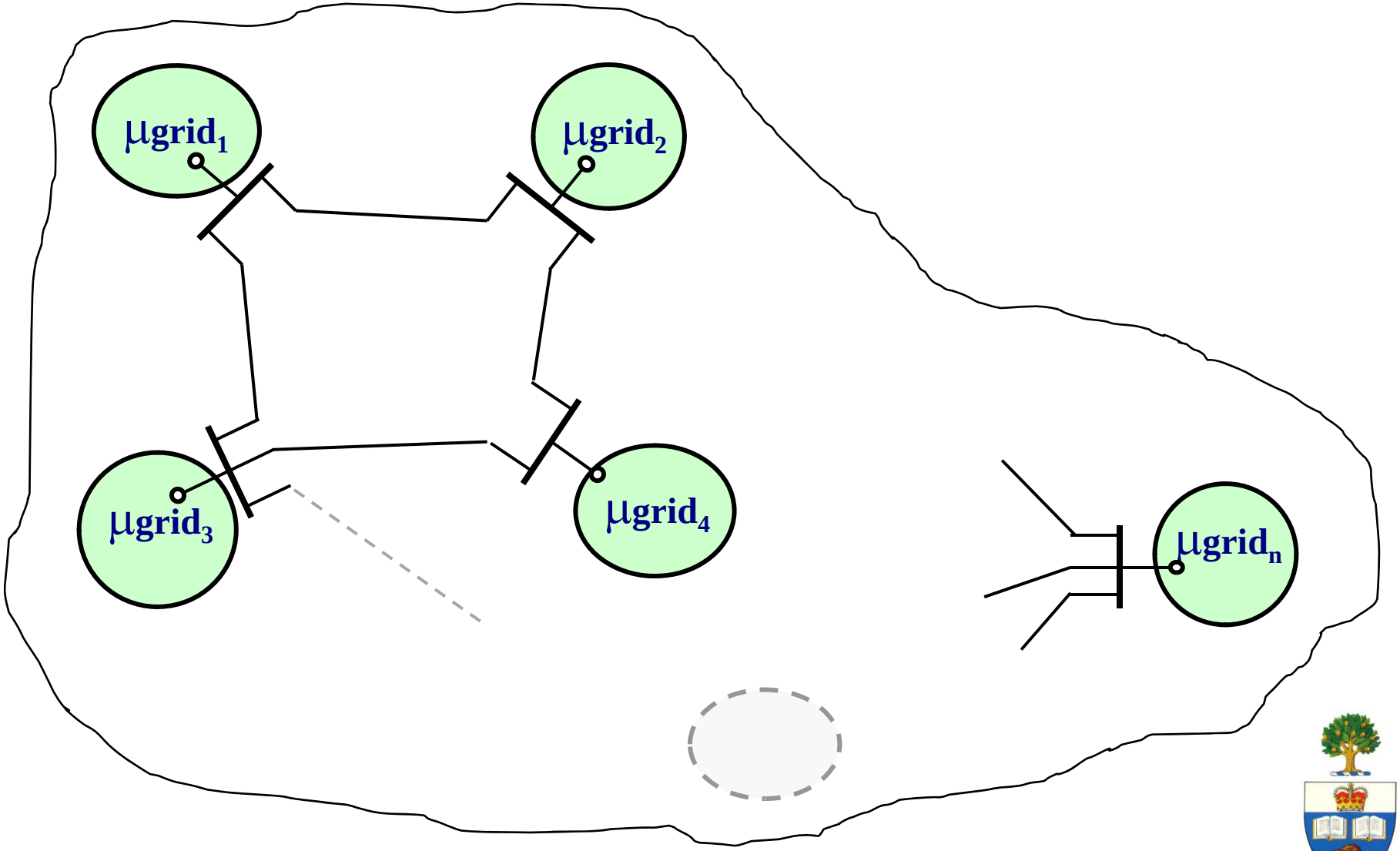
Virtual Power Plant Mode of Operation of Microgrid



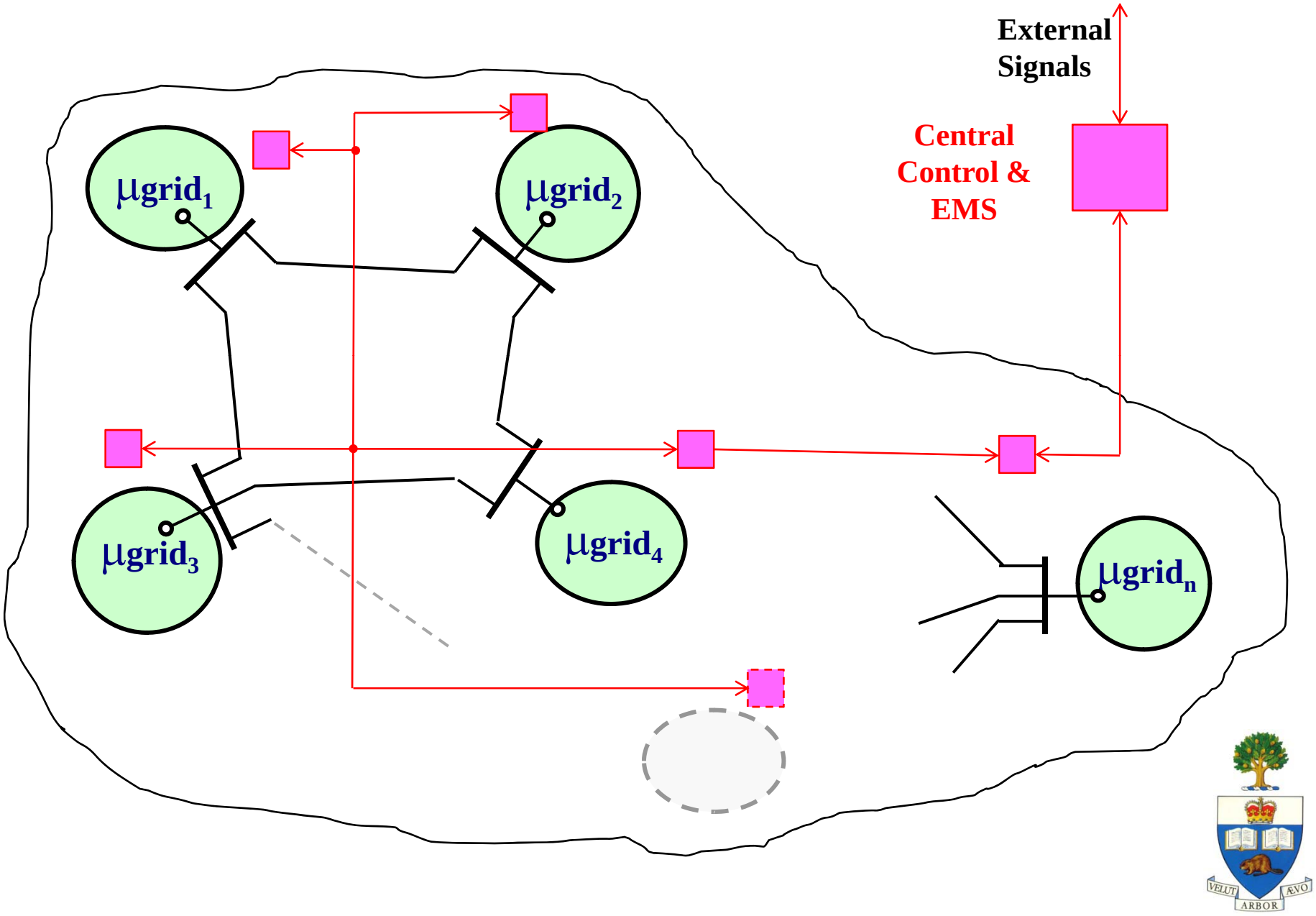
Virtual Power Plant (VPP) mode of Operation of the Microgrid:

With respect to the host grid, at its power gateway, the central controller and energy management of the microgrid can respond to the host grid *control/market* signals while maintaining autonomy of its internal operation.

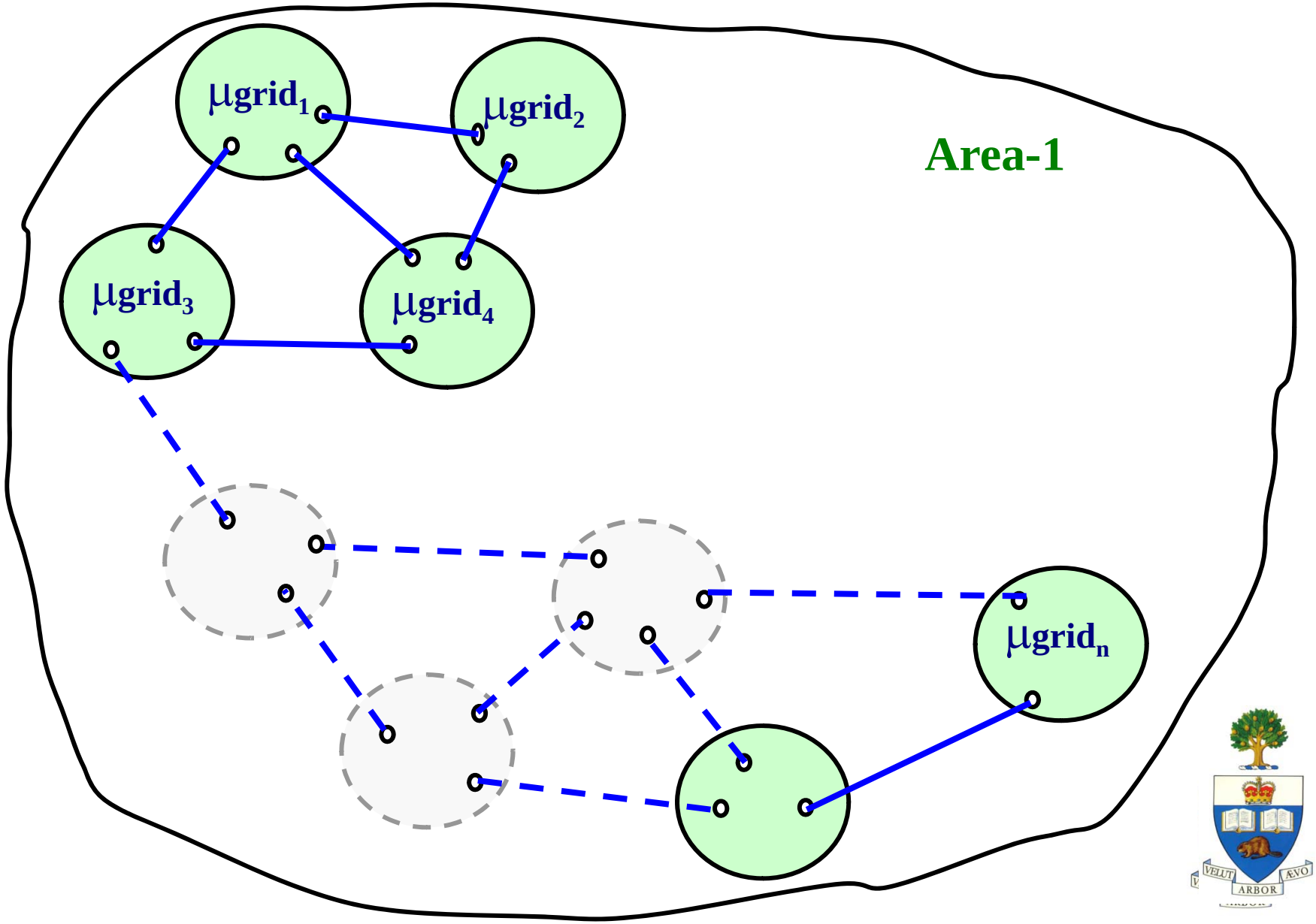
VPPs as Building Blocks of Smart Grid



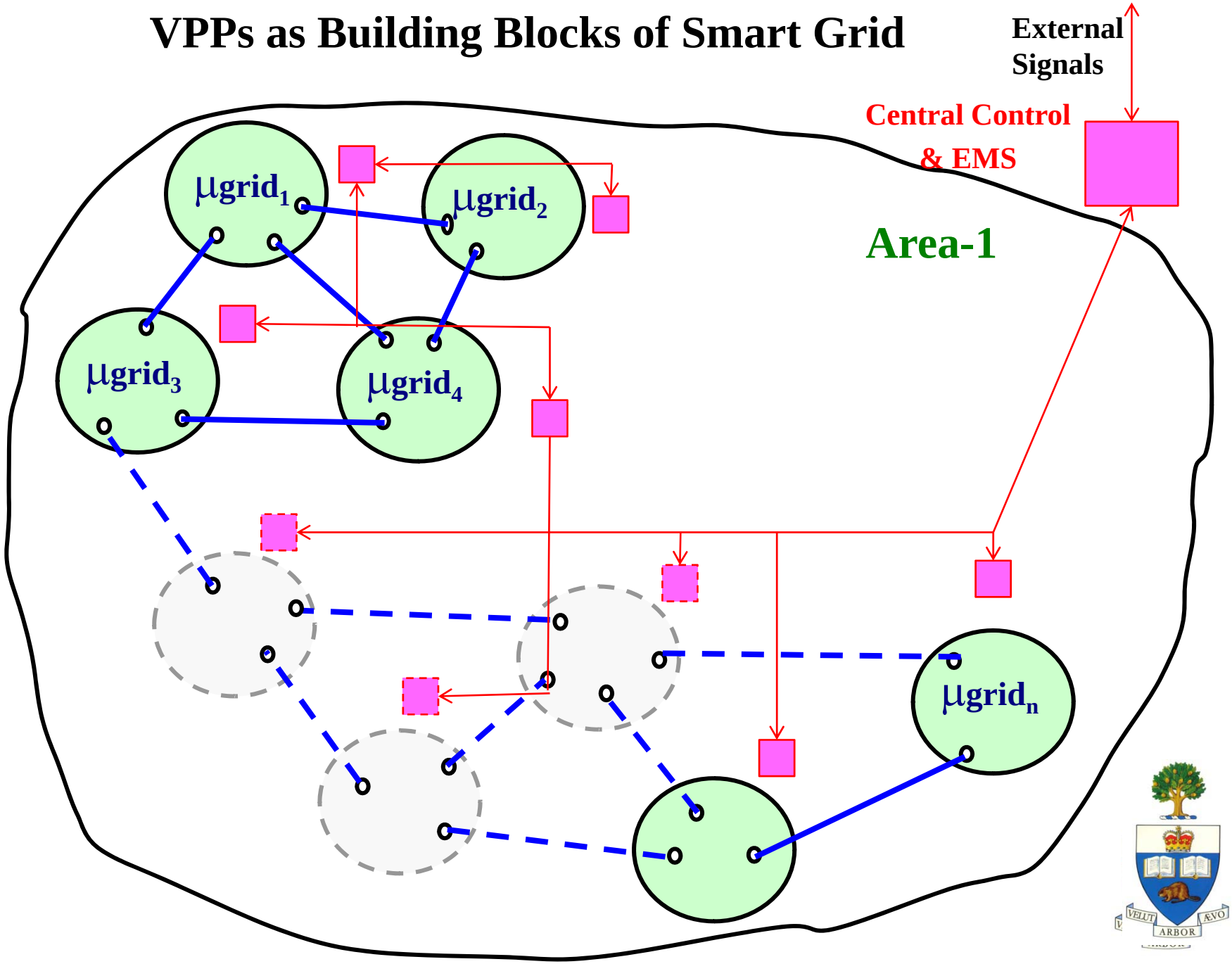
VPPs as Building Blocks of Smart Grid



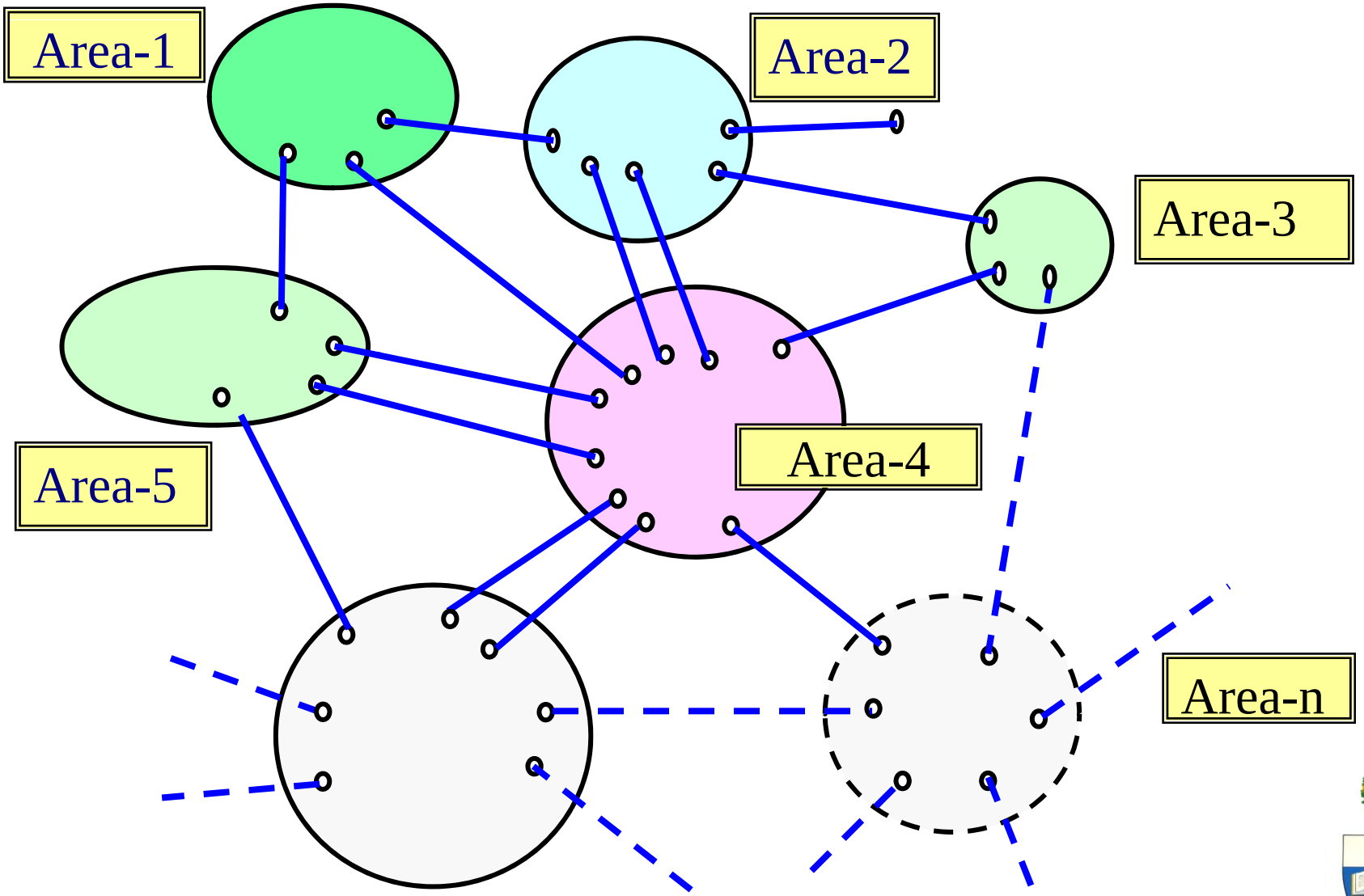
VPPs as Building Blocks of Smart Grid



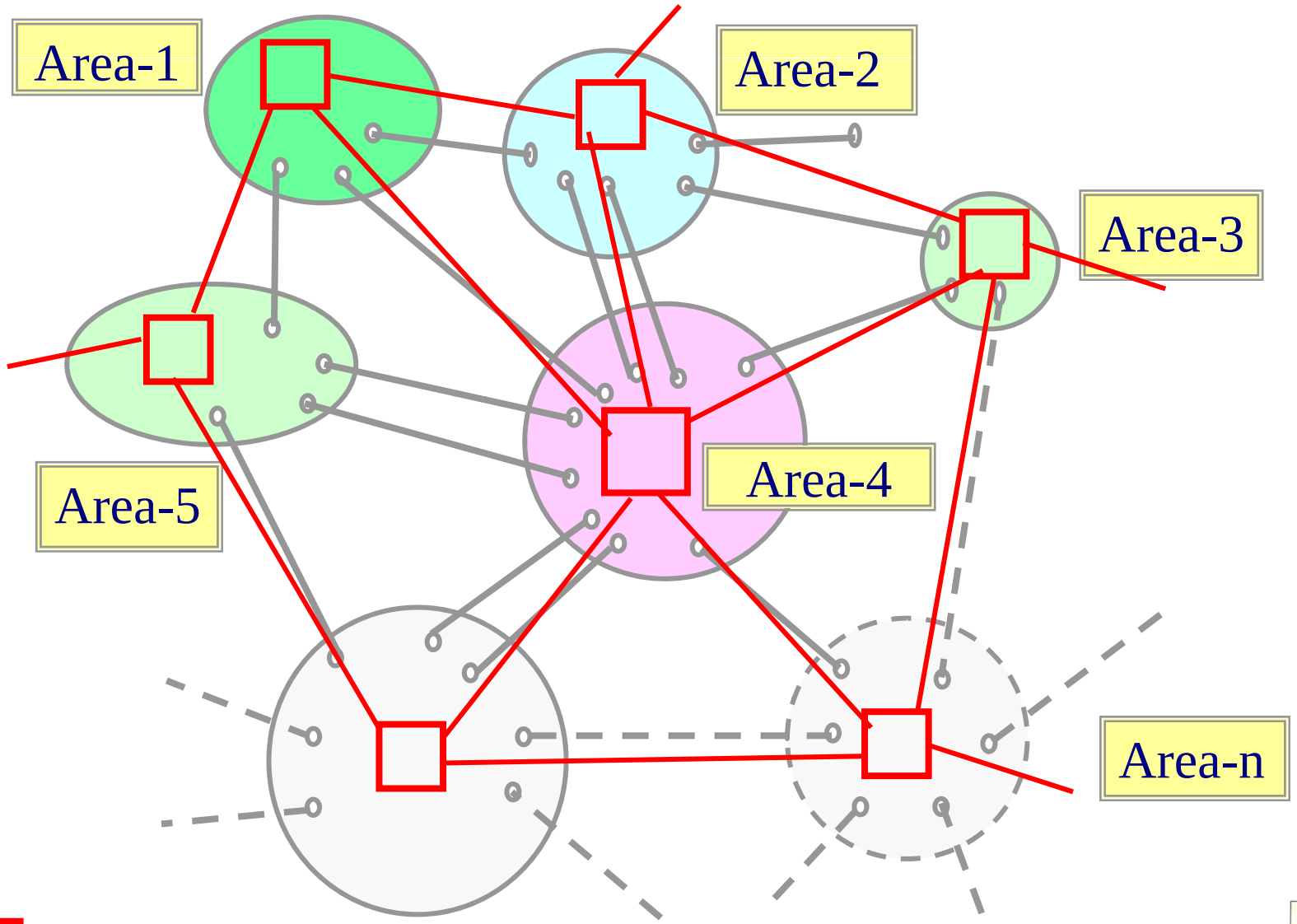
VPPs as Building Blocks of Smart Grid



Wide-Area Power System

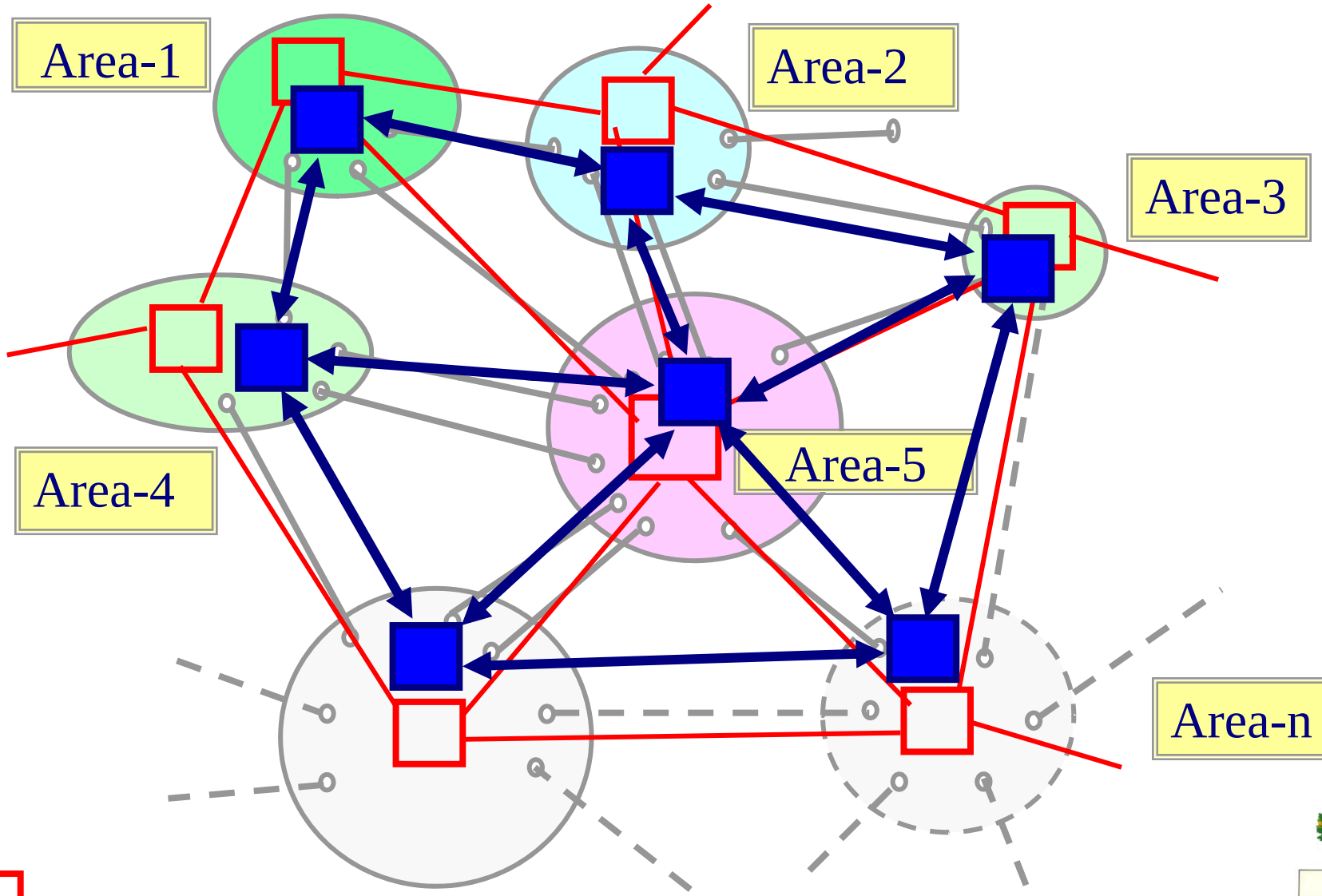


Wide-Area Power System



Existing (slow) communication links

Wide-Area "Smart Grid"



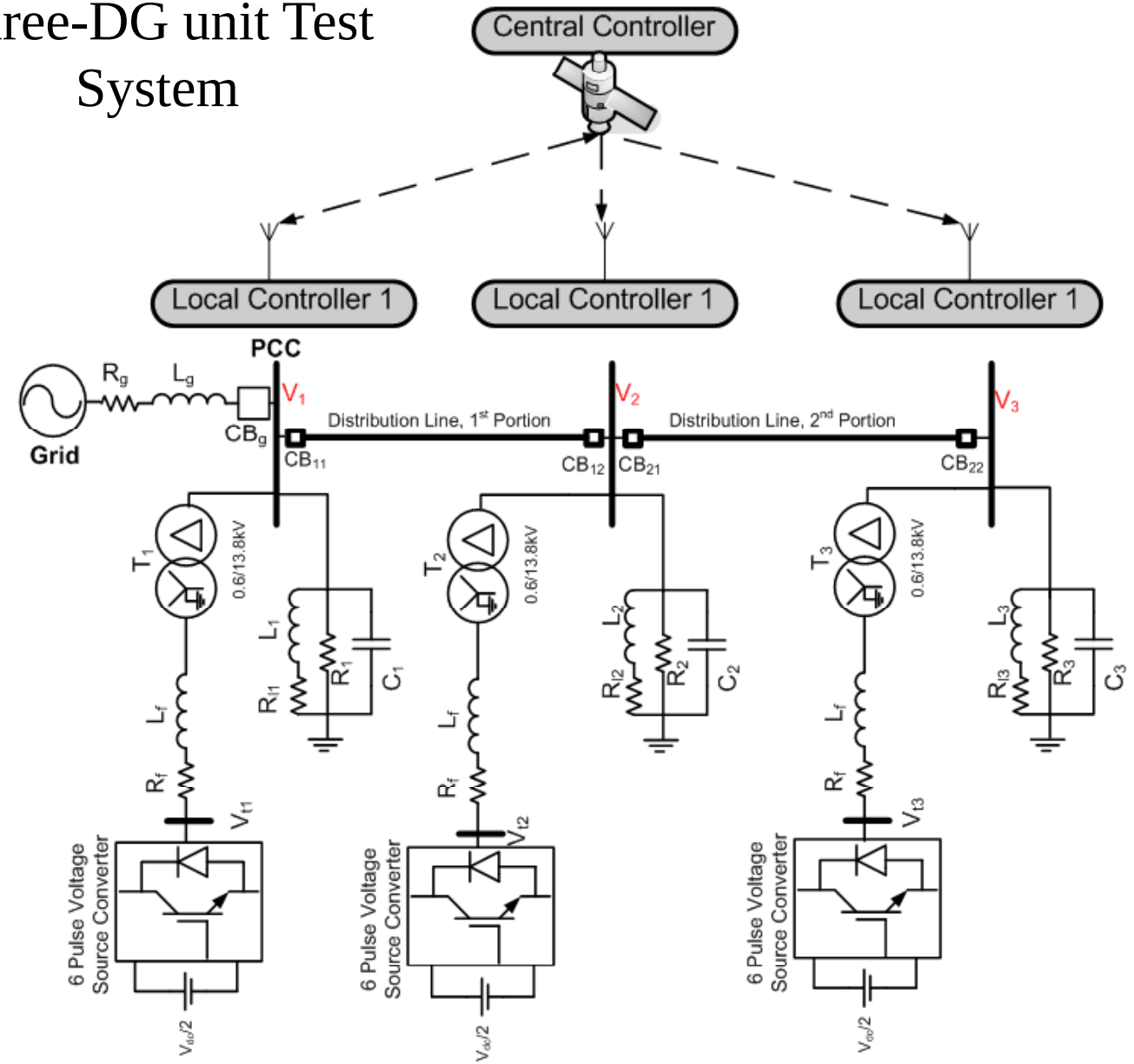
Challenges and Barriers:

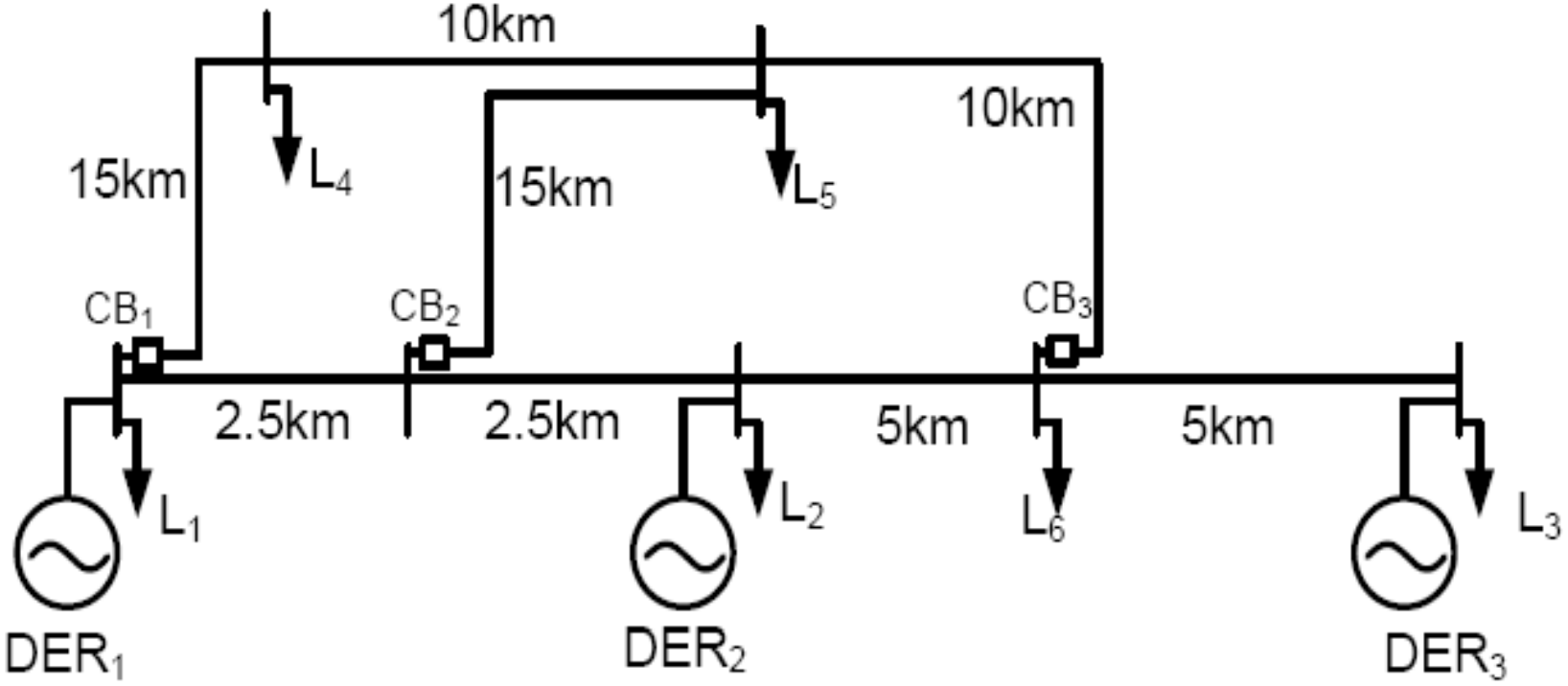
- Legacy regulatory requirements and standards
- Lack or consistency/uniformity of the incoming regulatory guidelines and/or standards
- Un willingness and /or inadequacy of technical knowledge and awareness of decision making bodies regarding technical possibilities
- Cyber security concerns associated with significant reliance ICTs
- Lack of knowledge (unwillingness) to applying unconventional control strategies
- Lack of knowledge (unwillingness) to applying unconventional protection strategies
- Lack of analytical methods and simulation tools for analysis, design and performance evaluation

VPP Control Challenges:

- load parameter variations,
- load configuration variations,
- variety of load types,
- microgrid topology changes,
- Inherent asymmetry of loads, DER units and lines
- presence of non-dispatchable DG units
- lack of inertia
- close electrical proximity of apparatus
- multi-control requirement for DER

Three-DG unit Test System





Single-line diagram of the extended microgrid to a loop configuration

Ongoing R&D of VPP concept:

- Development of a communication-based DER Units robust controller to accommodate structurally uncertainty due to changes in:
  - load parameters,
  - load configurations,
  - load types,
  - microgrid topology,
- Development of a back-up control to maintain microgrid operation when communication not available.

- Development of a real-time energy management system to enable VPP operation for the microgrid in the grid-connected mode

- Development of analytical and simulation tools

Concluding Remarks:

The concept of microgrid, based on high-depth of penetration of converter-interfaced DER units, as a building block for the smart grid is a technically viable option.

The main "technical" challenges in realization and performance evaluation of the concept are:

- **control design for DER units**
- **protection of the microgrid**
- **analytical and simulation tools**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