LINK - a model for an overall power system architecture

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Popular concepts in Smart Grids

Virtual Power Plants

Microgids

After more than 15 years research the question arises:

Are these concepts sufficiently broad to properly characterize the variety of the smart grid operation?

Popular concepts in Smart Grids

The adoption of microgrids as the

paradigm

for the massive integration of distributed generation **will allow technical problems to be solved in a decentralized fashion**, reducing the need for an extremely ramified and complex central coordination and **facilitating the realization of the Smart Grid.**"

Source: IEEE-PES Task Force on Microgrid Control, *"Trends in Microgrid Control"*, IEEE Transactions on smart grid, Vol. 5, No. 4, July 2014

What is a paradigm?

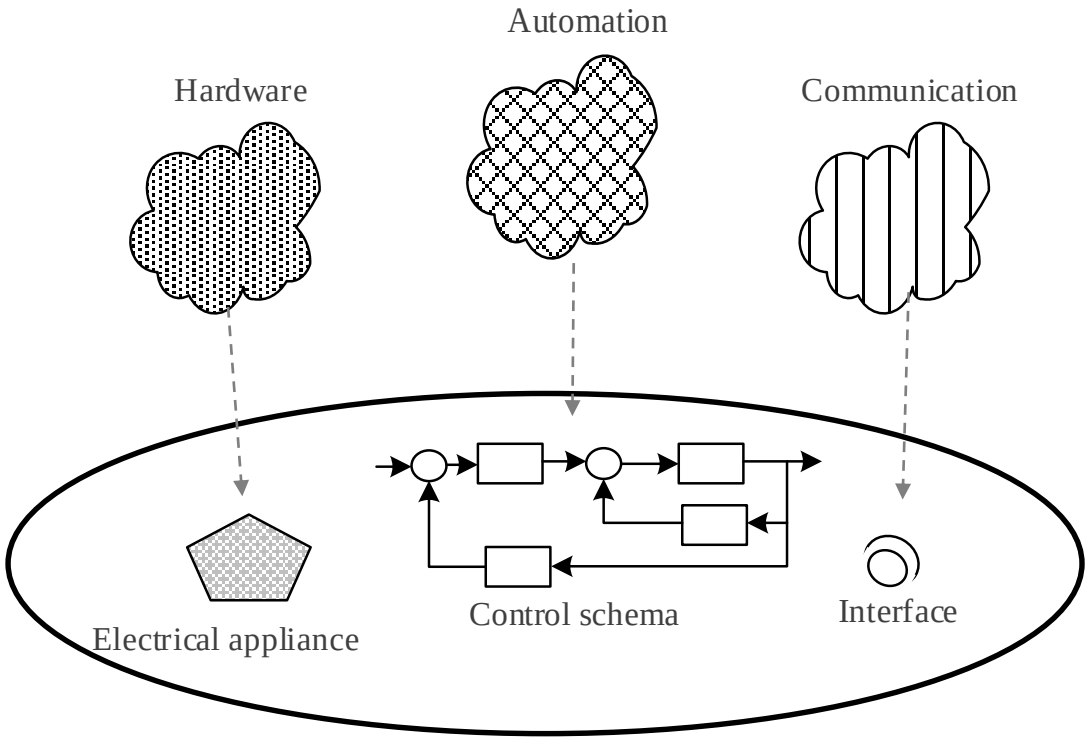
A

paradigm

is a symbolic model or diagram that makes it easier for us to understand the essential characteristics of a process

The *LINK* Paradigm

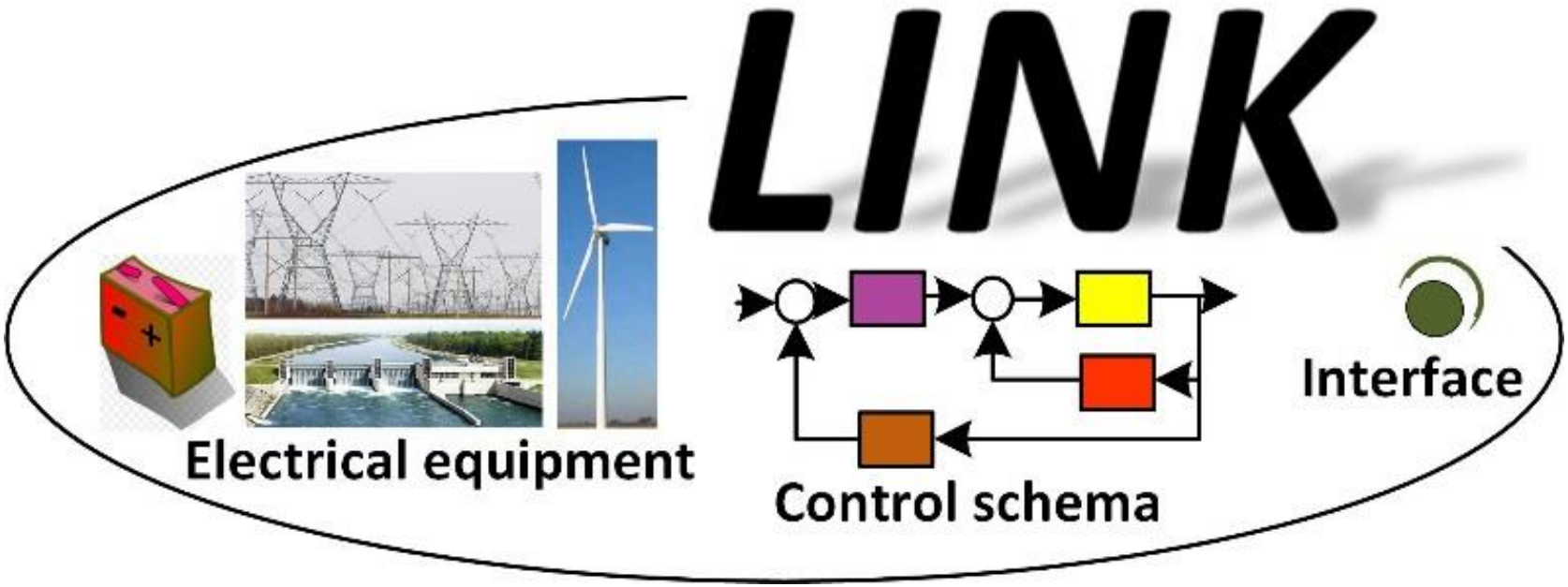
A technical system consists of three major elements:



***LINK* - Paradigm**

Source: *A. Ilo, "Link- the Smart Grid Paradigm for a Secure Decentralized Operation Architecture", Electric Power Systems Research - Journal* – Elsevier, Volume 131, **2016**, pp. 116-125.

The *LINK* Paradigm



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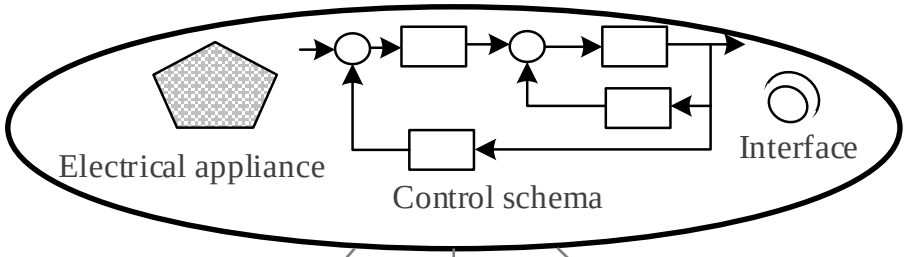
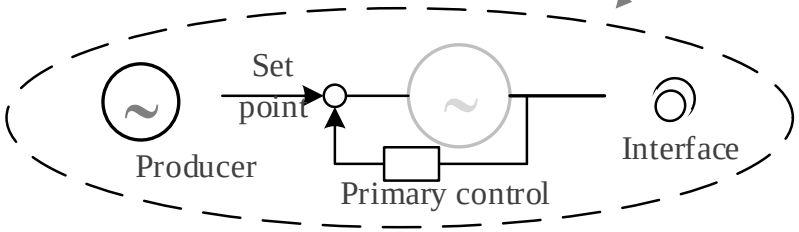
Architecture Elements

Link - Paradigm

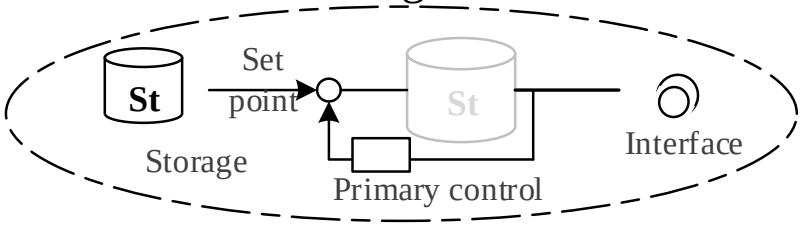


Architecture Elements

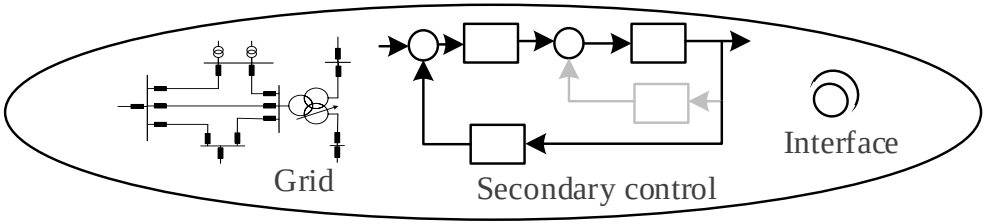
Producer - Link



Storage-Link



Grid - Link



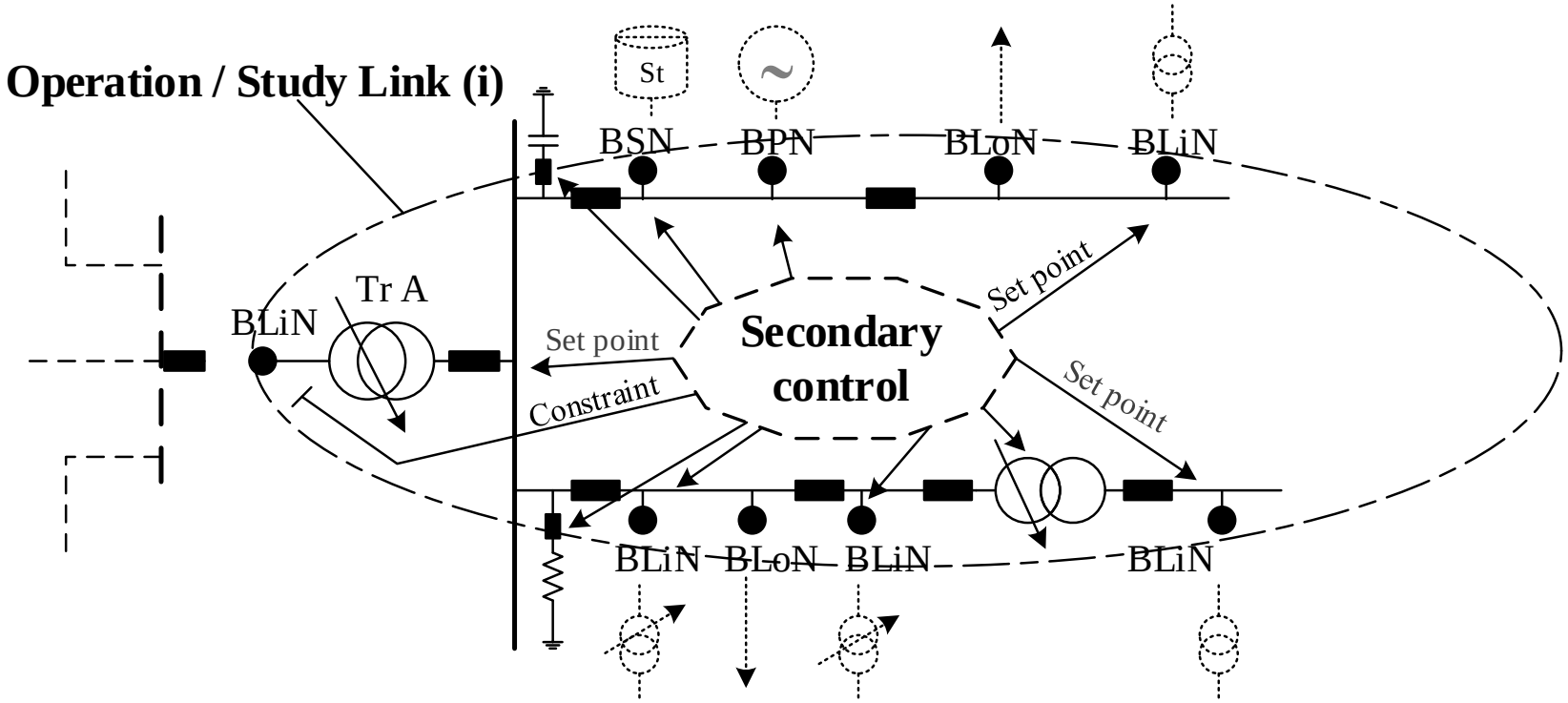
Source: *A. Ilo, "Link- the Smart Grid Paradigm for a Secure Decentralized Operation Architecture", Electric Power Systems Research - Journal* – Elsevier, Volume 131, **2016**, pp. 116-125.

Major architecture components:
the Link

The Grid-***Link*** is defined as a composition of a grid part, called Link_Grid, with the corresponding Secondary-Control and the Link_Interfaces.

- The ***Grid-Link*** refers to electrical equipment like lines/cables, transformers and reactive power devices, which are connected directly to each other by forming an electrical unity.

- The ***Grid-Link size*** is variable and is defined from the area, where the Link_Secondary-Control is set up.



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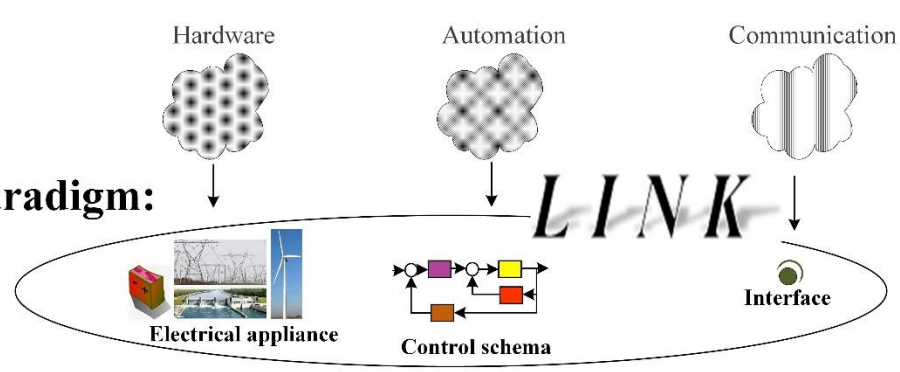
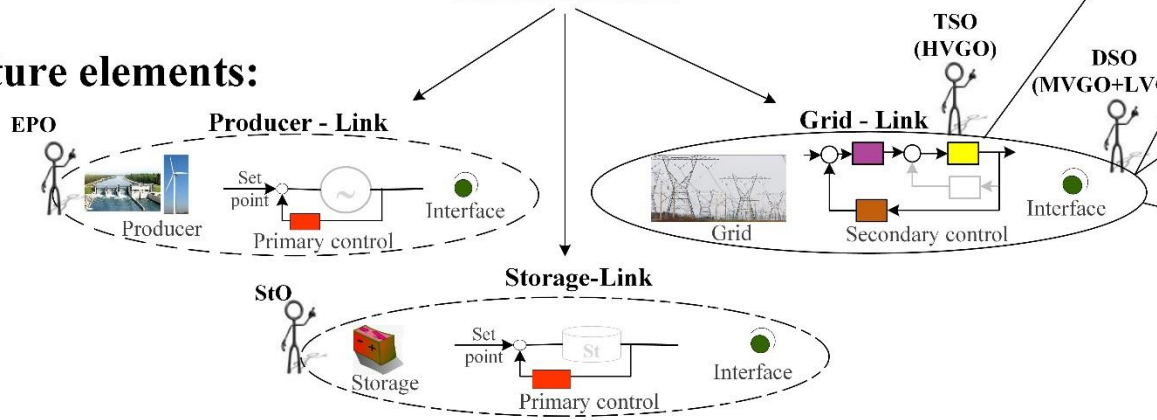
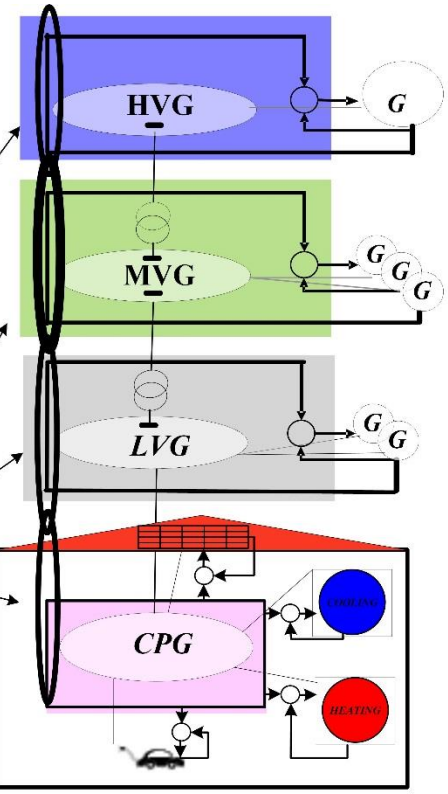
Smart Grid Paradigm:

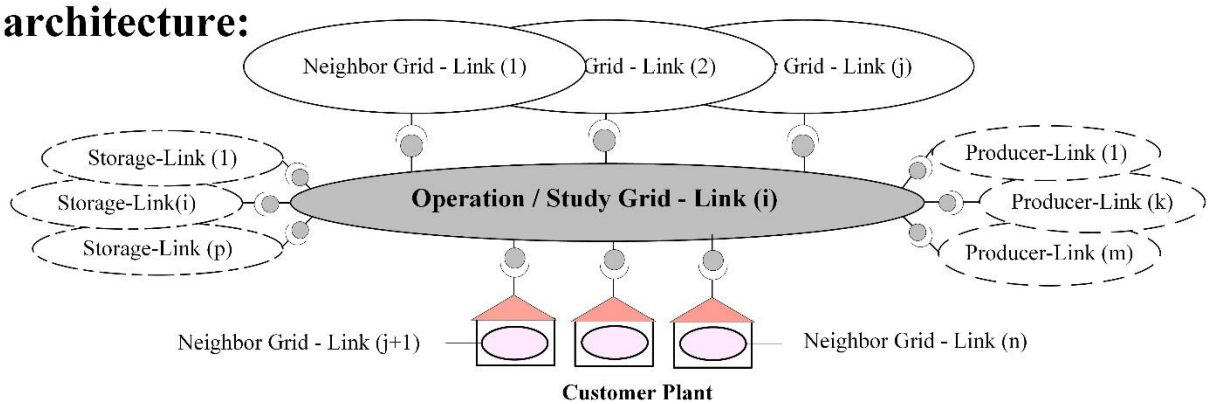


Architecture elements:



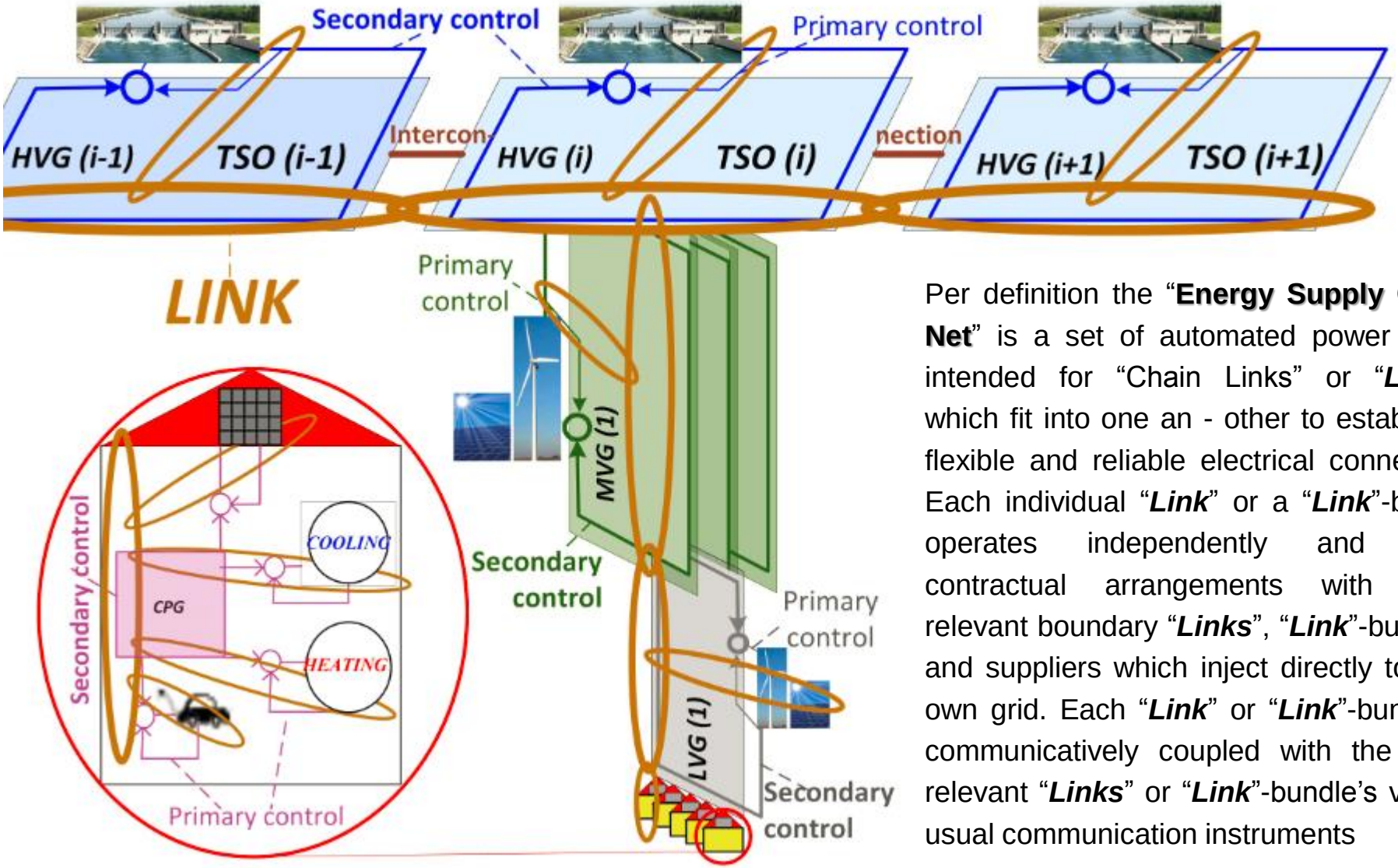


LINK-based architecture:



EPO – Electricity Production Operator
StO – Storage Operator
HVGO – High Voltage Grid Operator
MVGO – Medium Voltage Grid Operator
LVGO – Low Voltage Grid Operator
TSO – Transmision System Operator
DSO – Distribution System Operator

Power system overview based on the "Energy Supply Chain Net" model: horizontal und vertical axis

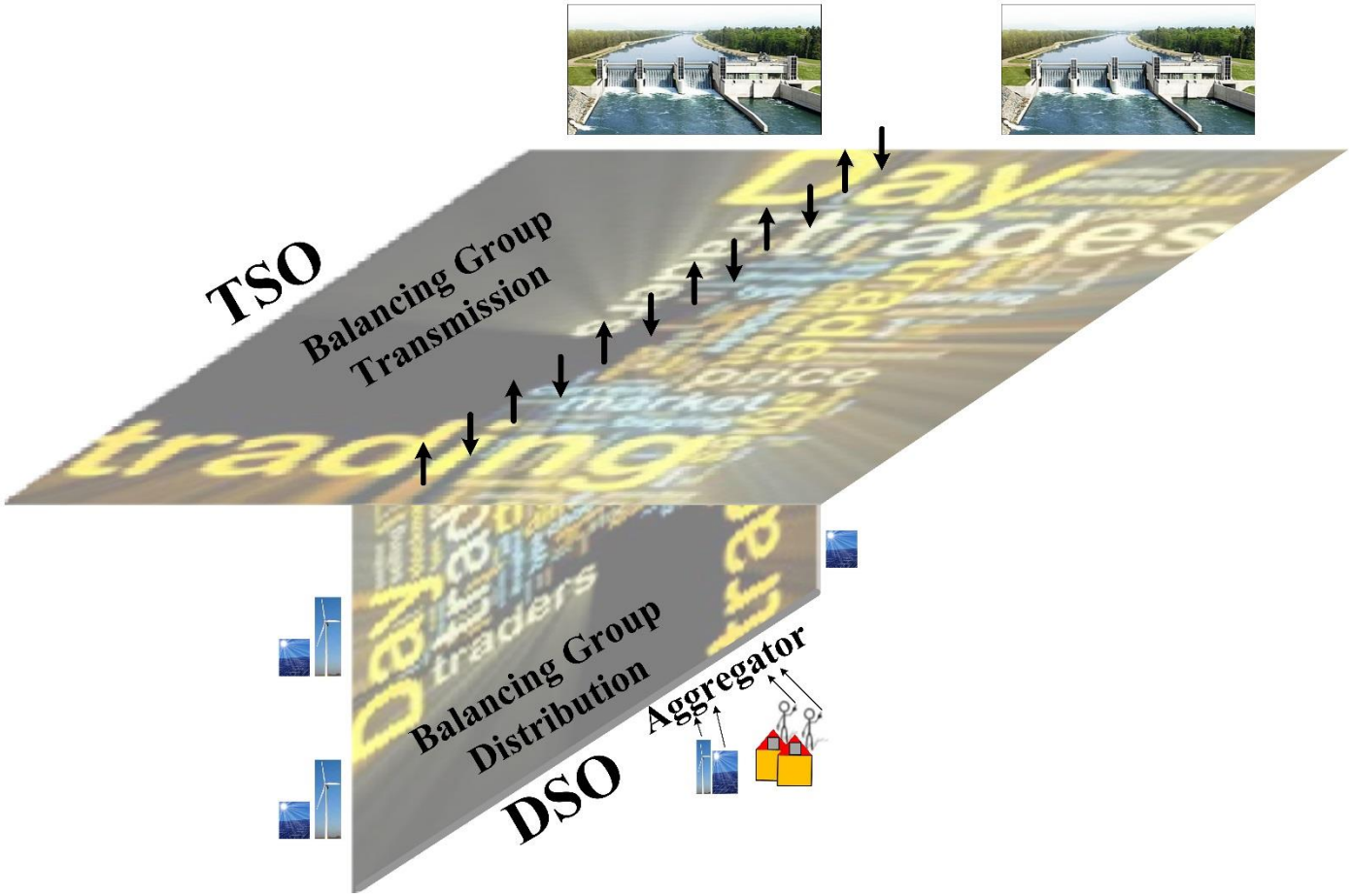


Per definition the "**Energy Supply Chain Net**" is a set of automated power grids, intended for "Chain Links" or "***Links***", which fit into one an - other to establish a flexible and reliable electrical connection. Each individual "***Link***" or a "***Link***"-bundle operates independently and have contractual arrangements with other relevant boundary "***Links***", "***Link***"-bundles, and suppliers which inject directly to their own grid. Each "***Link***" or "***Link***"-bundle is communicatively coupled with the other relevant "***Links***" or "***Link***"-bundle's via the usual communication instruments

Source: *A. Ilo "The Energy Supply Chain Net", Energy and Power Engineering, Volume 5 (5), July 2013.*

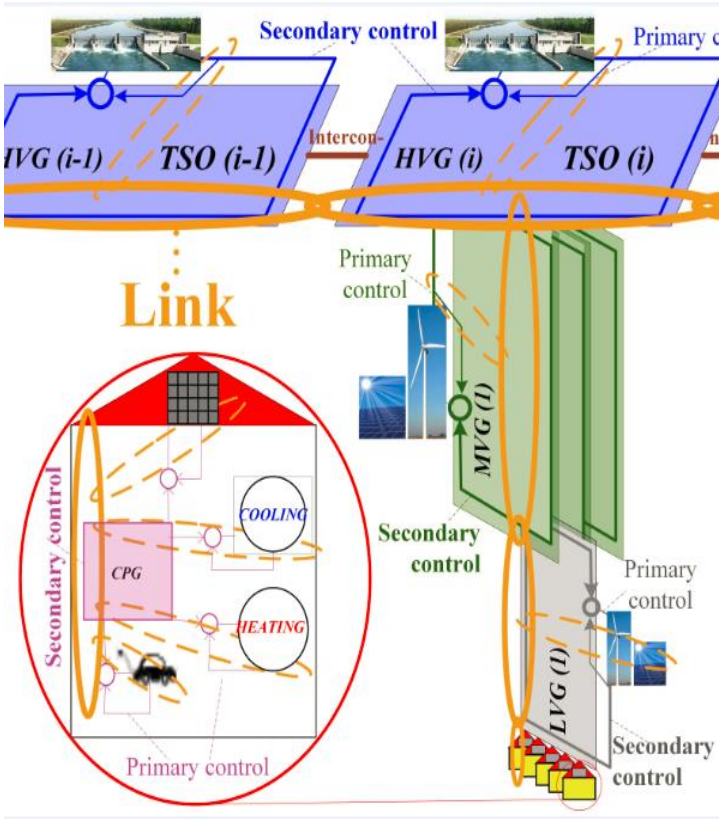
Holistic power market model

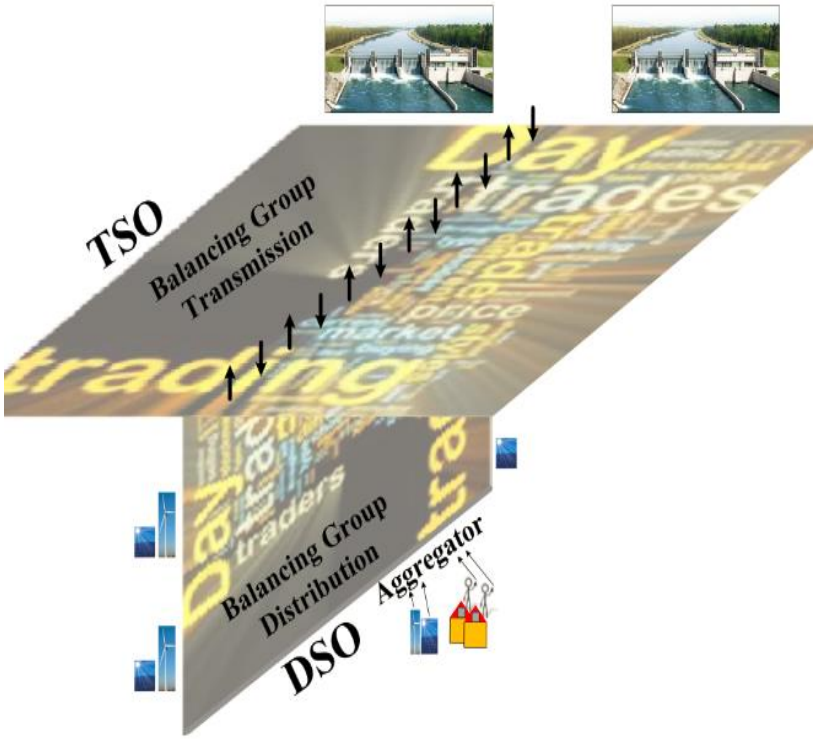
Flat business model of the electricity industry

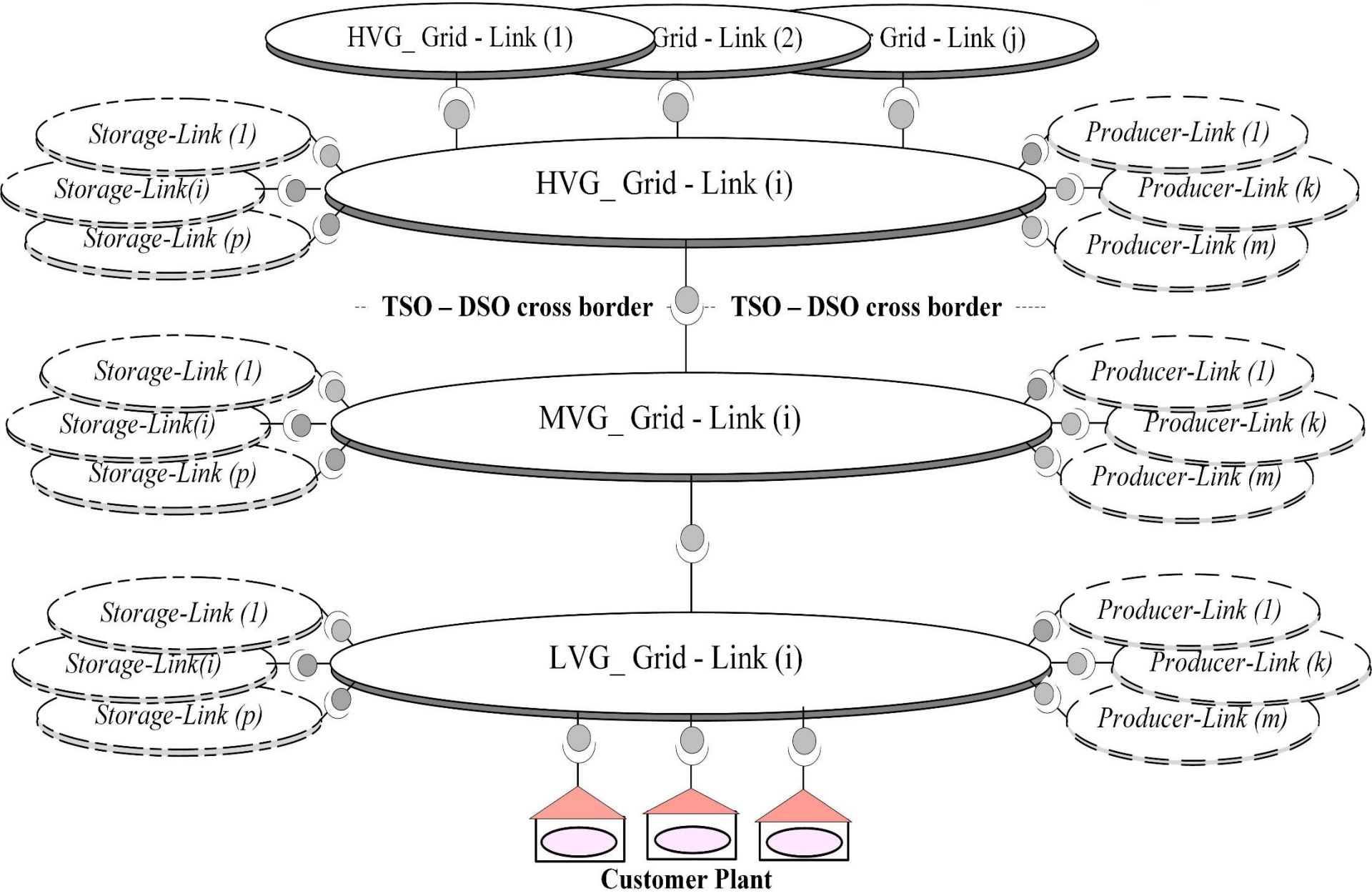


Holistic model of the electrical industry

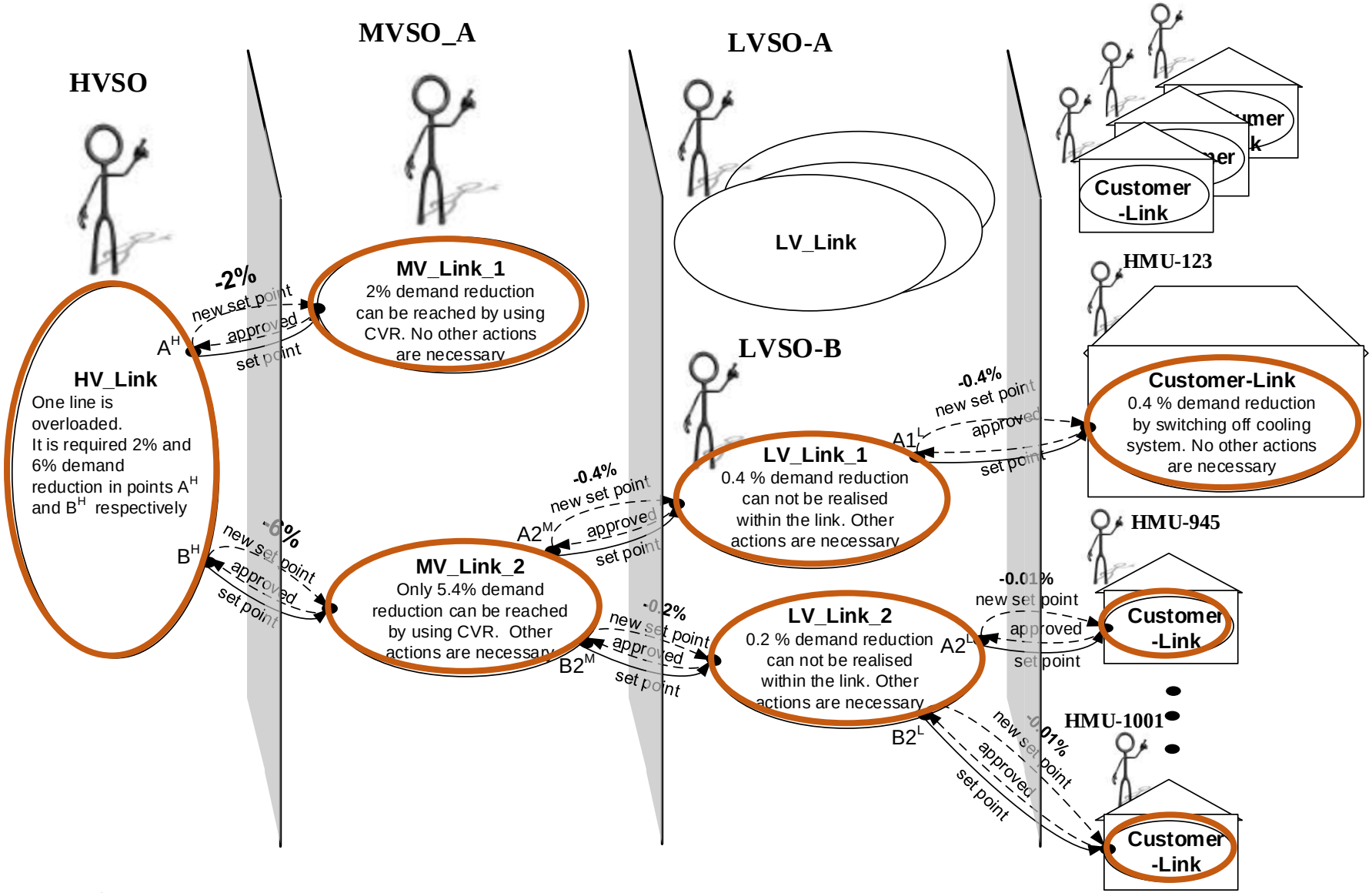
Harmonisation of power grid physics and market rules






HVG_ Grid - Link (1)
Grid - Link (2)
Grid - Link (j)
Storage-Link (1)
Storage-Link(i)
Storage-Link (p)
HVG_ Grid - Link (i)
Producer-Link (1)
Producer-Link (k)
Producer-Link (m)
TSO – DSO cross border
TSO – DSO cross border
Storage-Link (1)
Storage-Link(i)
Storage-Link (p)
MVG_ Grid - Link (i)
Producer-Link (1)
Producer-Link (k)
Producer-Link (m)
Storage-Link (1)
Storage-Link(i)
Storage-Link (p)
LVG_ Grid - Link (i)
Producer-Link (1)
Producer-Link (k)
Producer-Link (m)
Customer Plant

Demand response process:
line overload on high voltage grid



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The scheduled data exchange on:

a) centralized and b) decentralized architectures

Article 25

Scheduled data exchange between TSOs, DSOs and Significant Grid Users according to Article 1(5)(a) and Article 1(5)(d)connected to the Distribution Network

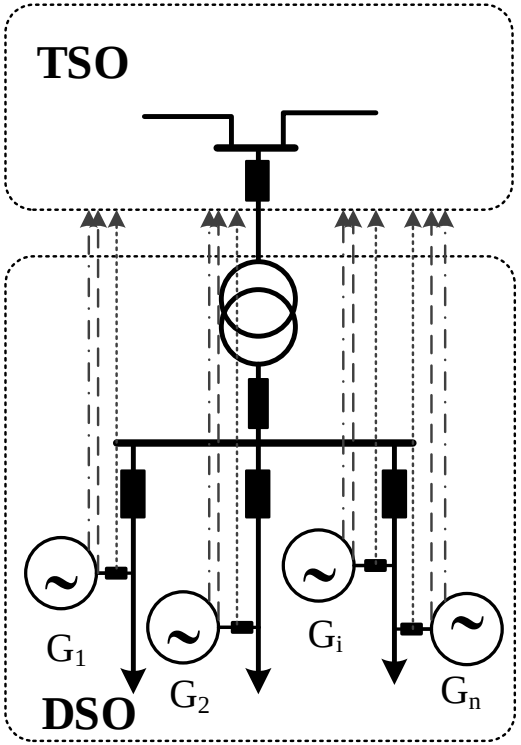
1. **Each Significant Grid User which is a Power Generating Facility Owner** according to the Article 1(5)(a) and Article 1(5)(d) and with Connection Point to the Distribution Network, **shall provide its TSO** and/or its DSO **with its scheduled unavailability**, **Active Power restriction and its forecast scheduled Active Power output at the Connection Point.** Organization of the data exchange shall be defined according to the key organisational requirements, roles and responsibilities established in Article 16(6) to Article 16(8).

2. **Each Significant Grid User which is a Power Generating Facility Owner** according to Article 1(5)(a) and Article 1(5)(d) **shall provide to its TSO** and/or its DSO **any forecasted restriction in the Reactive Power control capability**. Organization of the data exchange shall be defined according to the key organisational requirements, roles and responsibilities established in Article 16(6) to Article 16(8).

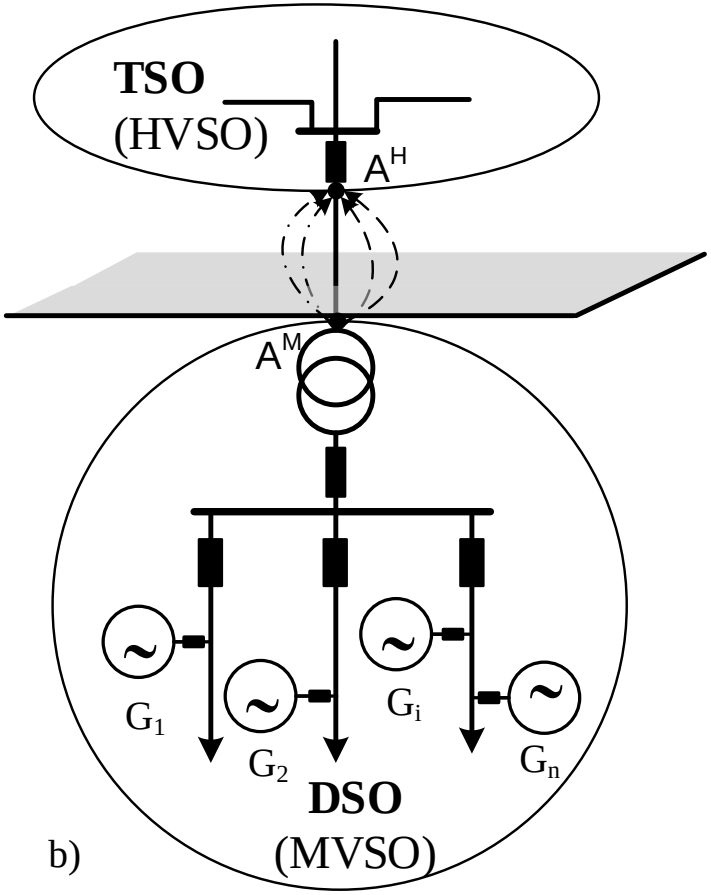
***Source**: Network Code on Operational Security, 24 September 2013, ENTSO-e homepage*

The scheduled data exchange on:

a) centralized and b) decentralized architectures



a)



b)

Number of exchanged schedules ⟹ **3·*N*** **4**

N – Number of Significant Grid Users (Power Generating Facility Owner)

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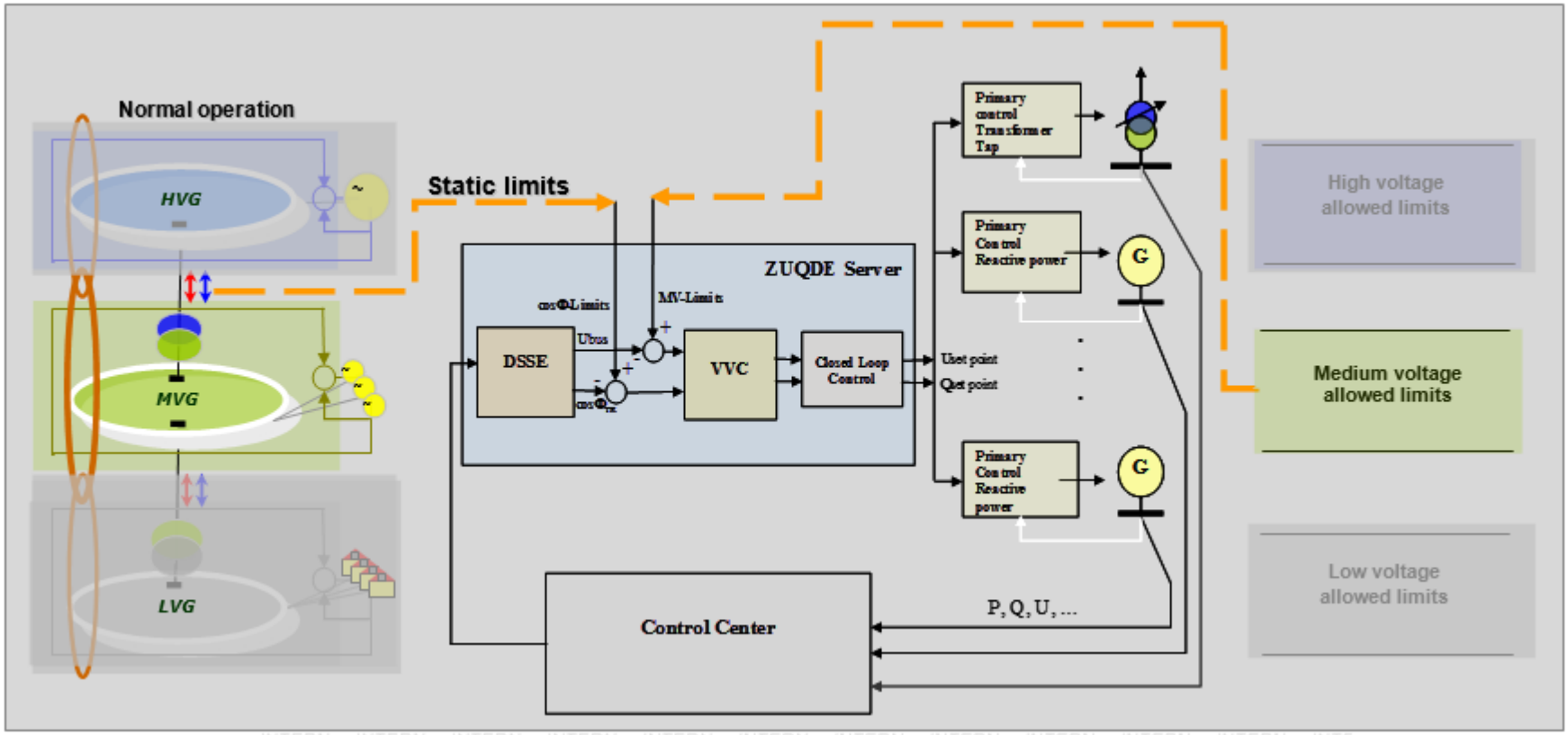
MV-Grid-Link and Producer-Link, realized and operated in the framework of ZUQDE project

Reactive power and voltage control



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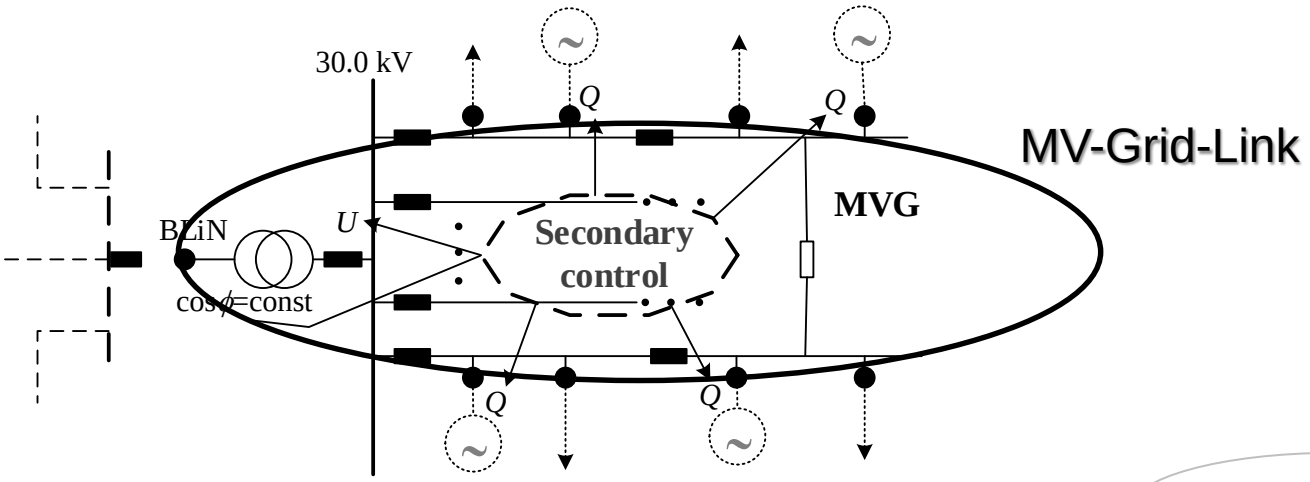

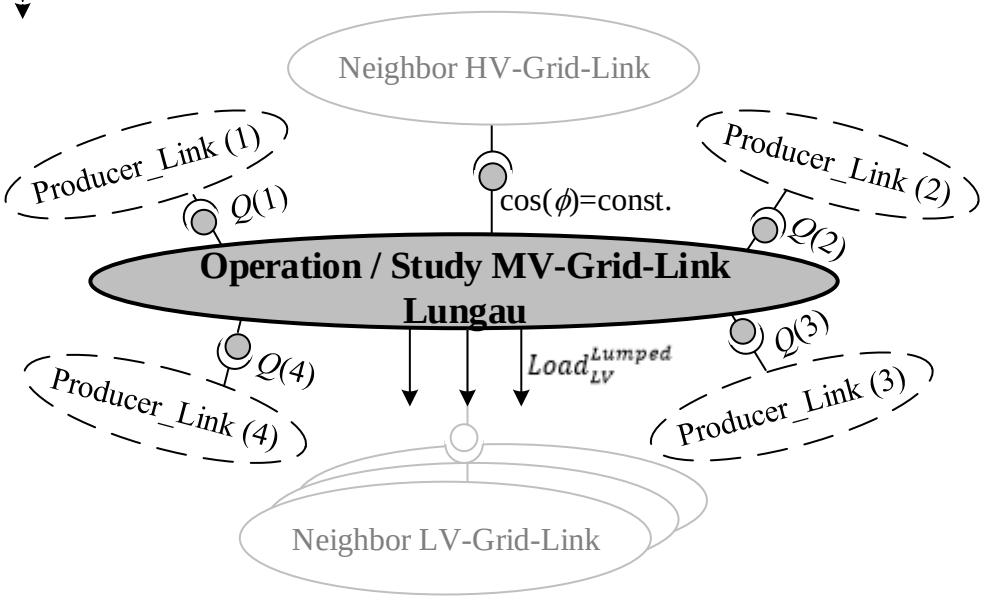

Conclusions

- The LINK paradigm helps to present the entire power grid and the costumer plants and to present all operation processes.

The new, *LINK* – based decentralised architecture for the power system operation:

- It is kept simple and distinct

- Provides cyber security and data privacy by minimizing the number of the exchanged data

- Facilitates all actual power system operation processes like load-generation balance, voltage assessment, outage managements, etc.

- Facilitates the involvement of demand response in the grid operation

- Fulfils the electricity market rules

Thank you for your attention

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