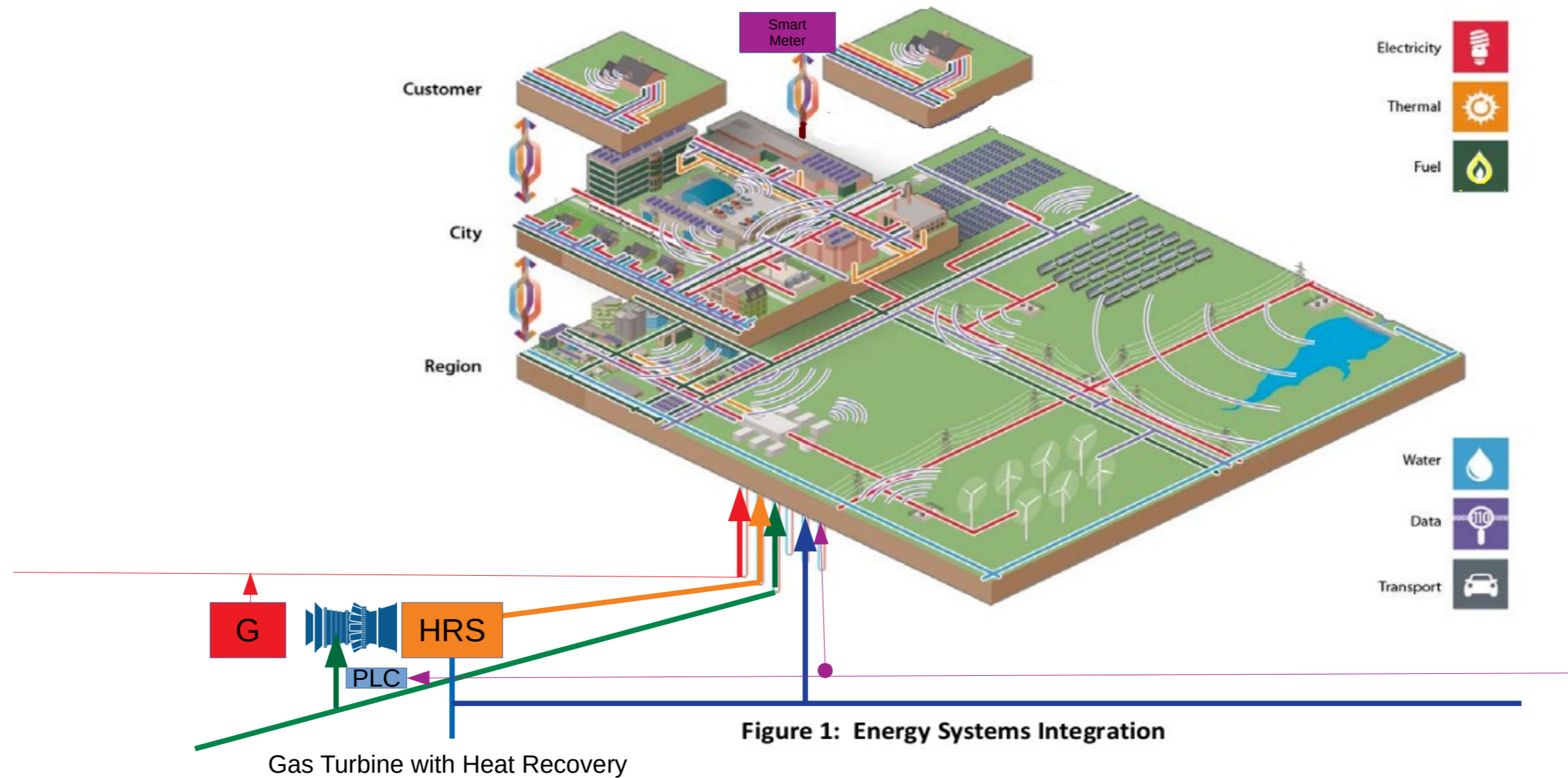
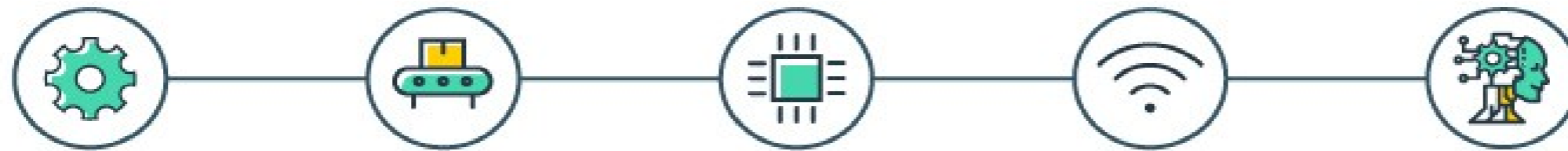
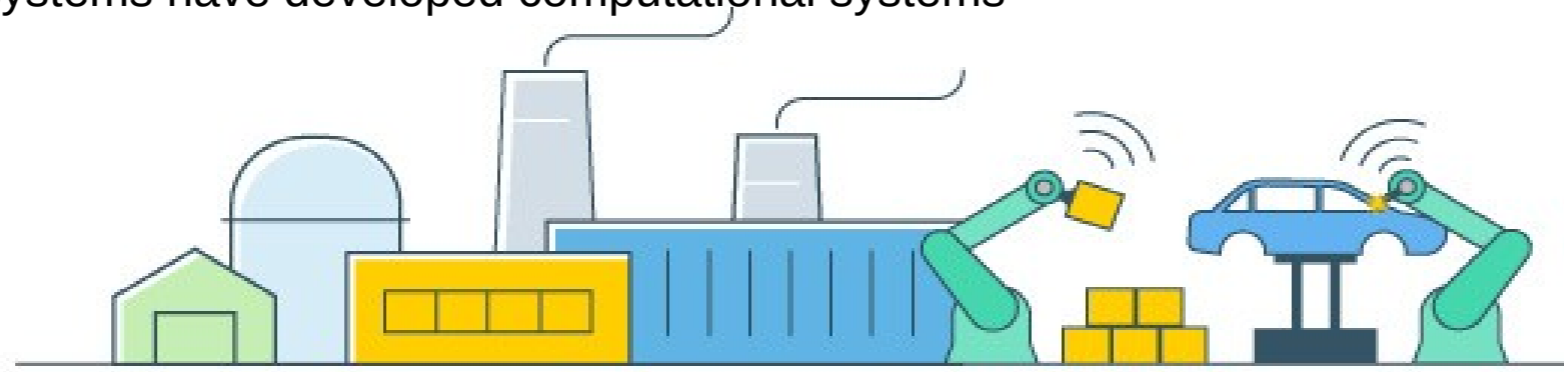


What is a ESI (Energy Integration System) ?



What is a Cyber Physical System ?

The industrial systems have developed computational systems



Industry 1.0

Mechanization,
water power,
steam power

Industry 2.0

Mass production,
assembly line,
electricity

Industry 3.0

Computer and
automation

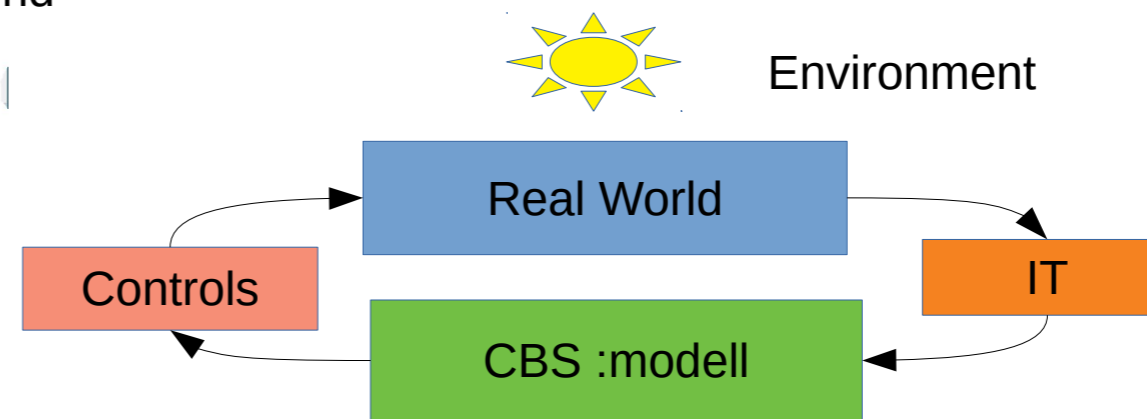
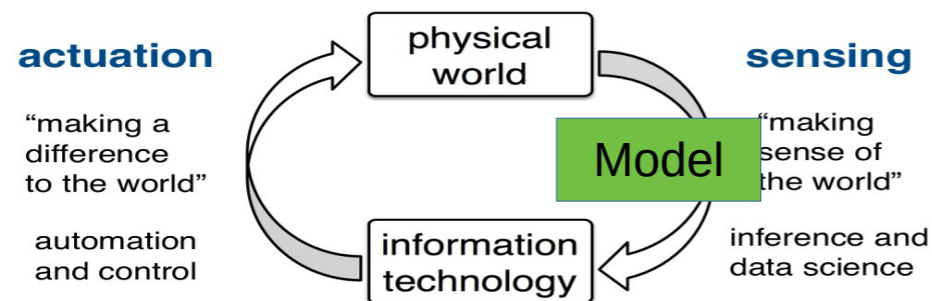
Industry 4.0

Cyber physical
systems

Industry 5.0

Mass customization
& cyber physical
cognitive systems

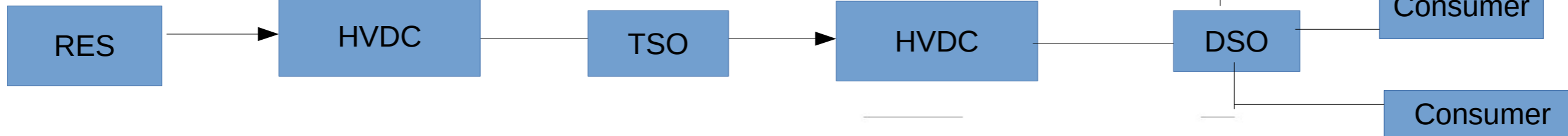
Cyber Physical Thinking is modelling the real world



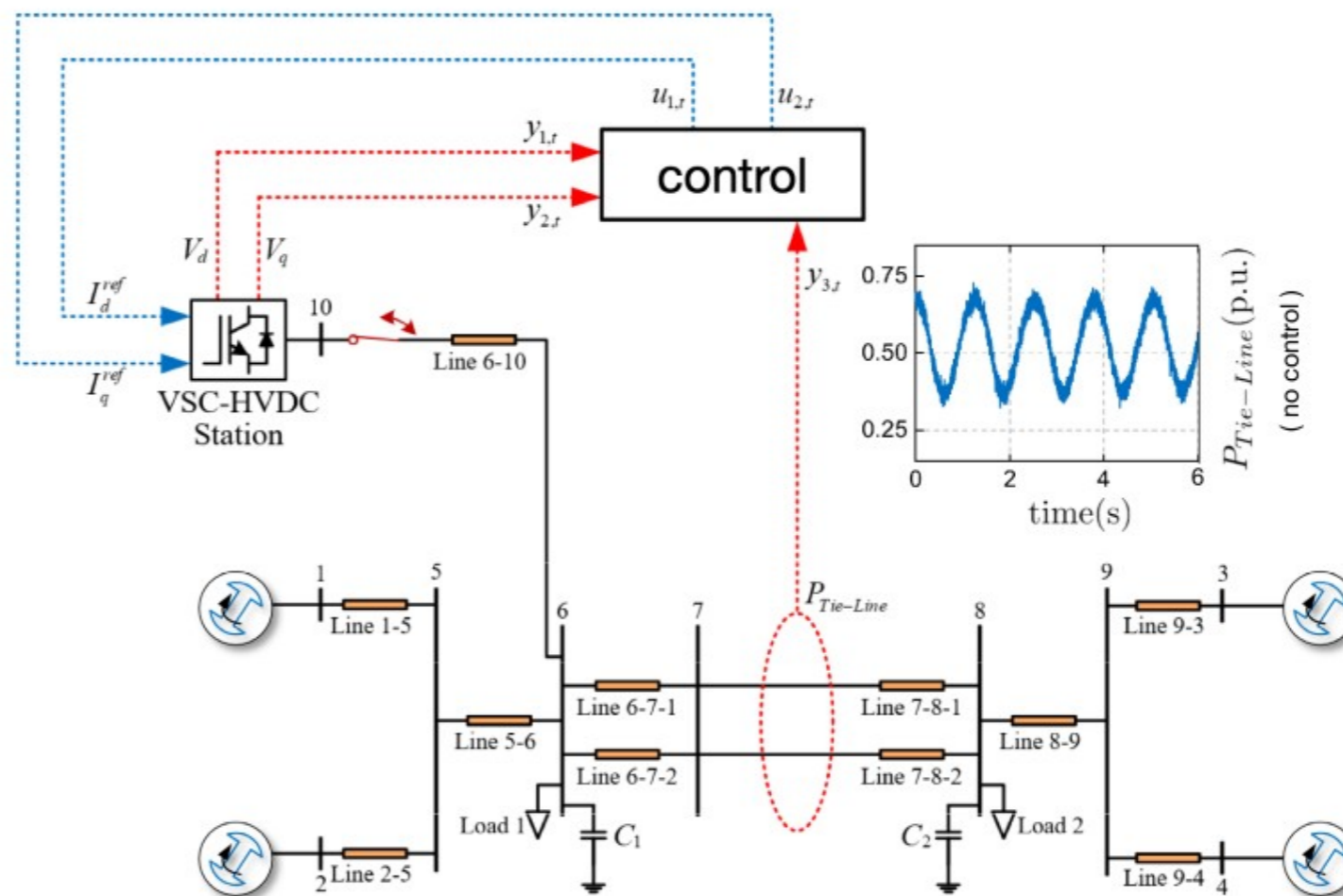
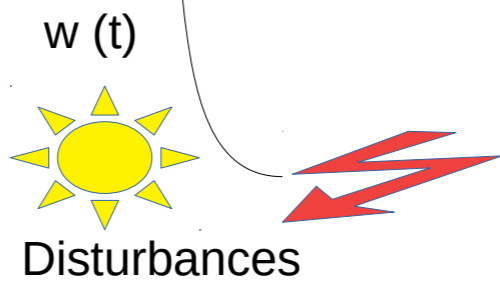
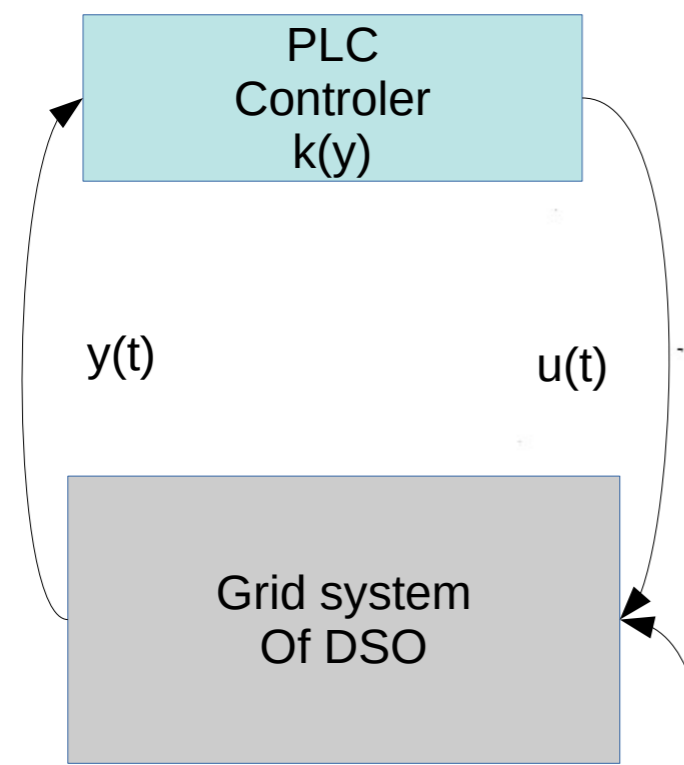
The CBS creates digital twin from the real world



Electrical Grid Network Control

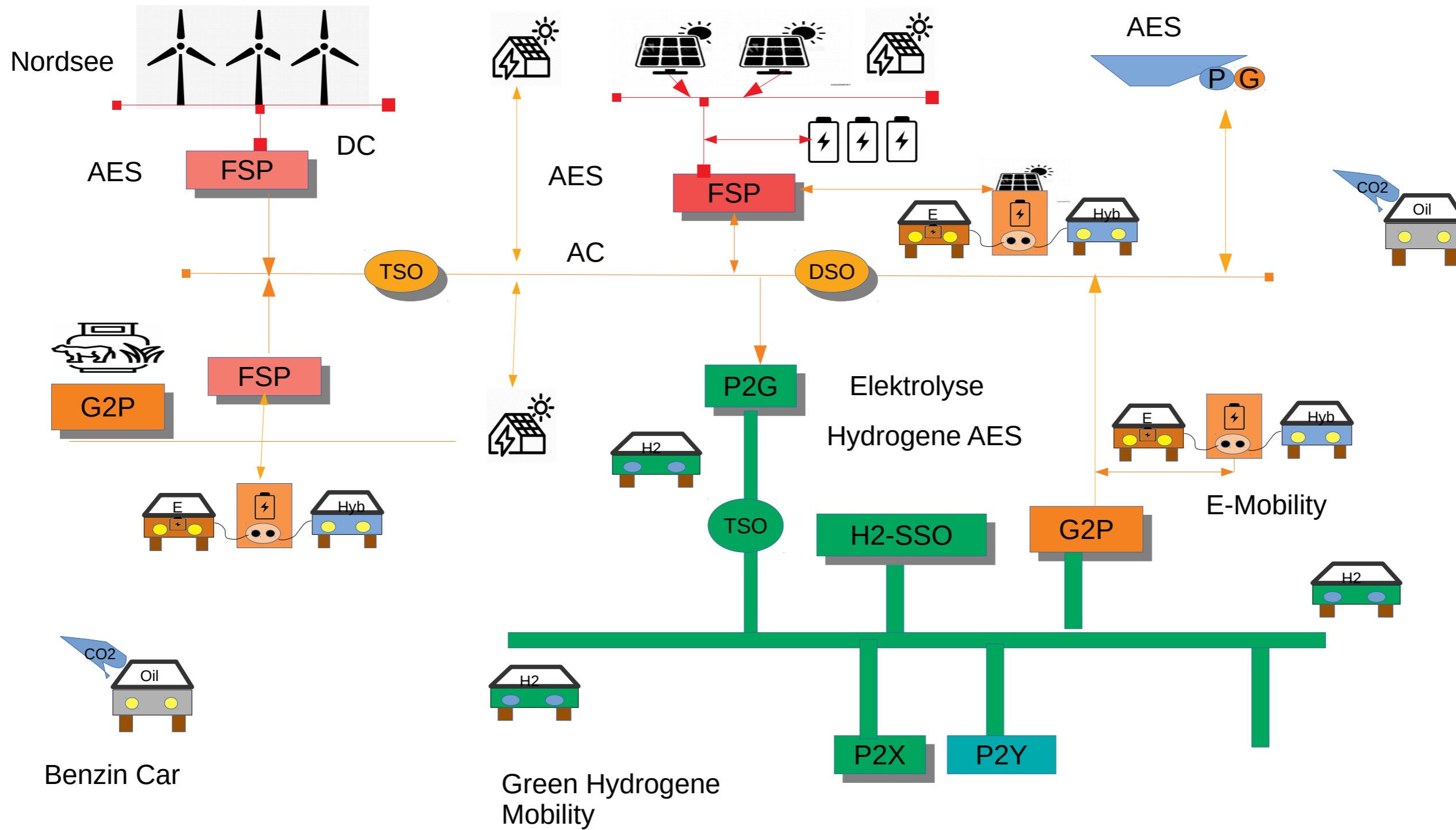


Time dynamic closed Loop



Different AES in a common Grid

ASI- Electricity, Wind, Bio, PV, Hydrogen, Water



The Idea is to put the model in a Neural Network

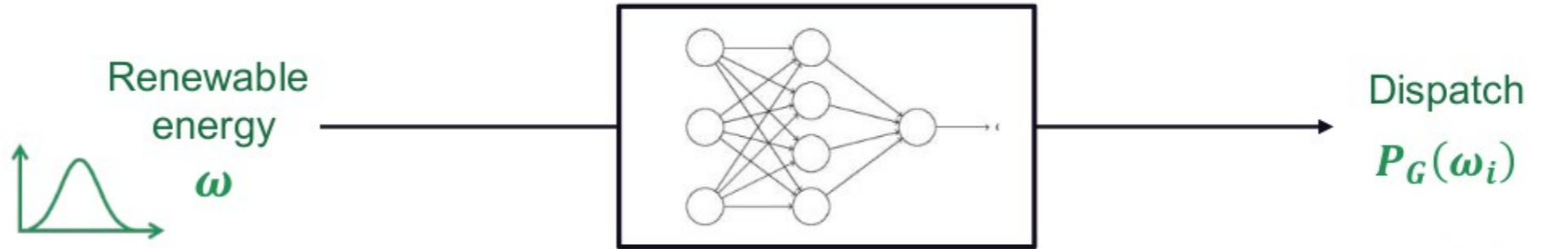
With few constraints, Voltage, Ampere, Frequency

Opimal Power Flow roald-aes.pdf — On Active Constraints in Optimal Power Flow: Learning Optimal Solutions and Identifying Important Constraints

Datei Bearbeiten Ansicht Gehen zu Lesezeichen Hilfe

Vorherige Nächste 23 (23 von 97) Breite einpassen

Vorschaubilder



- **This didn't work well...**
 - Hard to satisfy safety constraints!
 - Projection back onto feasible space cause suboptimality...
 - Challenging: High-dimensional input → *High dimensional output*
- **This can work well under some circumstances** Wide enough and deep enough, and with enough data! [Karg and Lucia, 2018]

Windows taskbar: [LNG] [Social Movem... Papers Robust... Opimal Power ...]

The Idea is to put the model in a Neural Network

With few constraints

Opimal Power flow roald-aes.pdf — On Active Constraints in Optimal Power Flow: Learning Optimal Solutions and Identifying Important Constraints

28 (28 von 97) Breite einpassen

Vorschaubilder

```
graph LR; A[Renewable energy] --> B[Predict optimal active set]; B --> C[Optimal active set A*(ω_i)]; C --> D[Predict/recover optimal solution]; D --> E[Optimal dispatch P_G*(ω_i)];
```

- Why?
 - Optimal active set is the “minimal” information we need to recover optimal solution
 - Inherently encodes information about physical constraints and technical limits
 - Finite, low dimensional object
 - Nice physical interpretation (power system operational pattern)

4/16/19 | 28

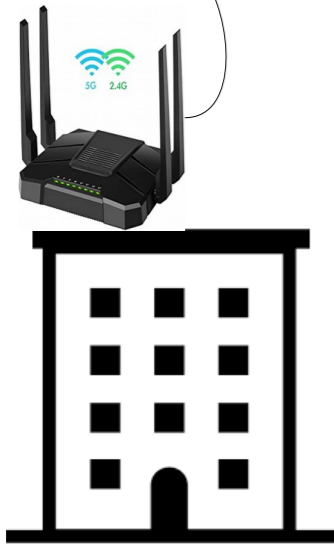
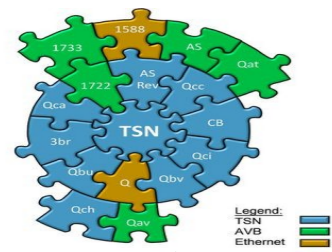
[LNG] [Social Movem... Papers Robust... Opimal Power ...]

Autonomous Energy Systems within a complex ESI

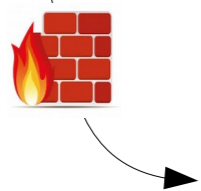
Enabler System
 5G- Mobile
 Wifi 6.0 Building
 TSN- Ethenett

Autonomous Energy Systems

TSN Networks



Wifi 6 in Building



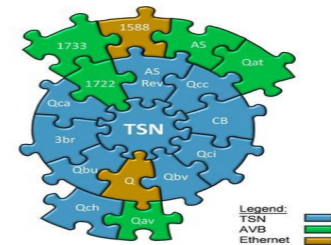
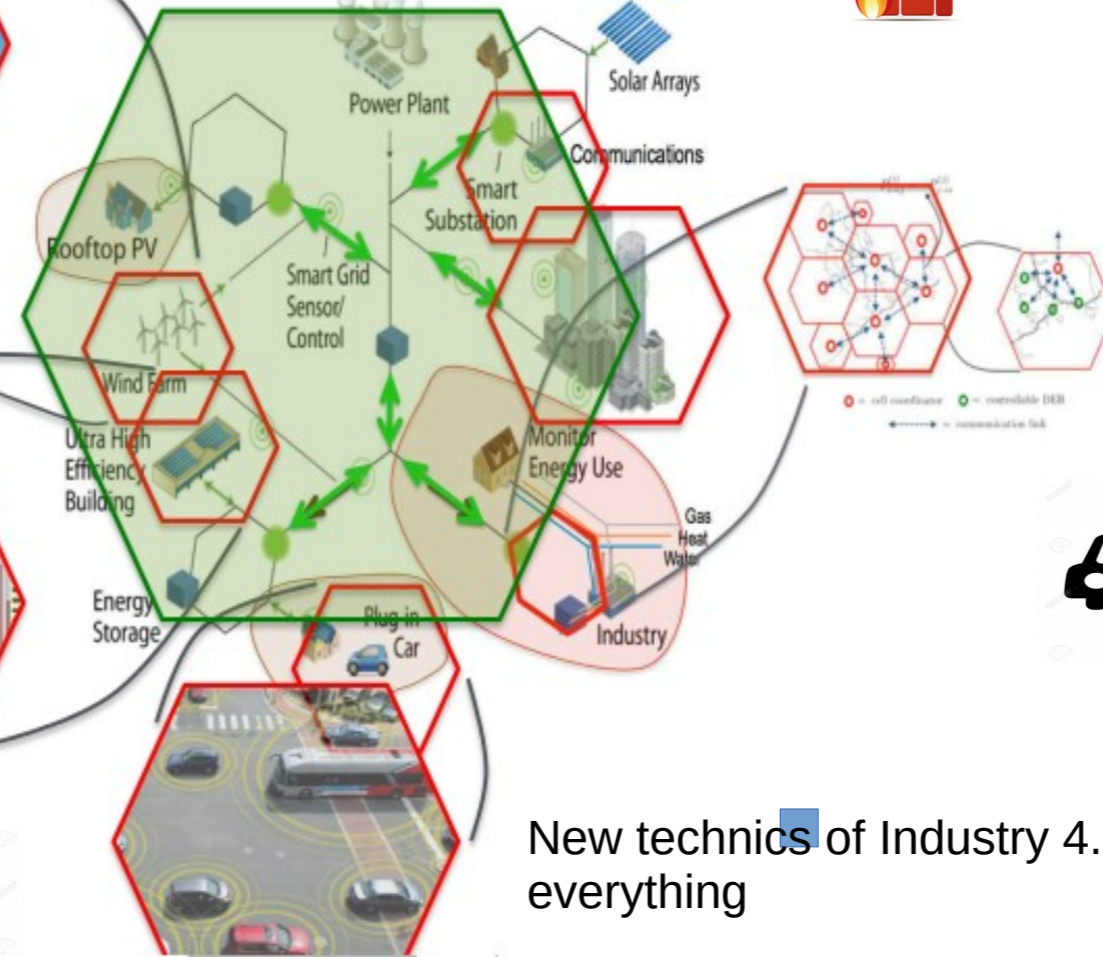
Wind Plant Controls to AES



Buildings to AES



5G in Cars



Legend:
 TSN
 AVB
 Ethernet

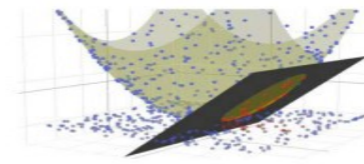


New techniques of Industry 4.0..5.00 are connecting everything

AES Priority Research Directions

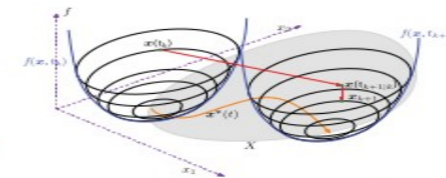
Big Data Analytics

- Develop ways to use heterogeneous grid data (addressing access and privacy) to better conduct ensemble forecasting of grid states and enable automated and distributed decision making from machine learning techniques.



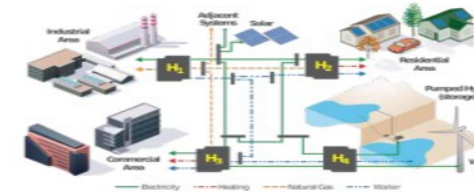
Optimization Theory

- Develop computationally-affordable, stable, and provably optimal algorithms that can be implemented in real-time and distributed fashions.



Controls Theory

- Develop scalable, real-time, decentralized and distributed controls that take into account inherently asynchronous operations as a result of communications delays, losses, and distributed (asynchronous) control actions.



Complex Systems Theory

- Develop modeling and simulation methods that address integration and interdependencies of many different energy and communications systems at various temporal and spatial scales.

- Equivalent in idea to autonomous vehicles, "Autonomous Energy Grids" do not require operators and make independent decisions. They can self-reconfigure and optimize themselves for reliability and economic performance while integrating energy in all forms

- Need to advance foundational science:
 - Smart Device/ Power Electronics
 - Cybersecurity
 - Non-linear Control Theory
 - Optimization Theory
 - Complex System Theory
 - Big Data Analytics

Need to develop new mathematical formulations and a common analytical framework for modeling, optimization, and control of complex systems at multiple spatial and temporal scales

