Grid integration of small distributed energy resources

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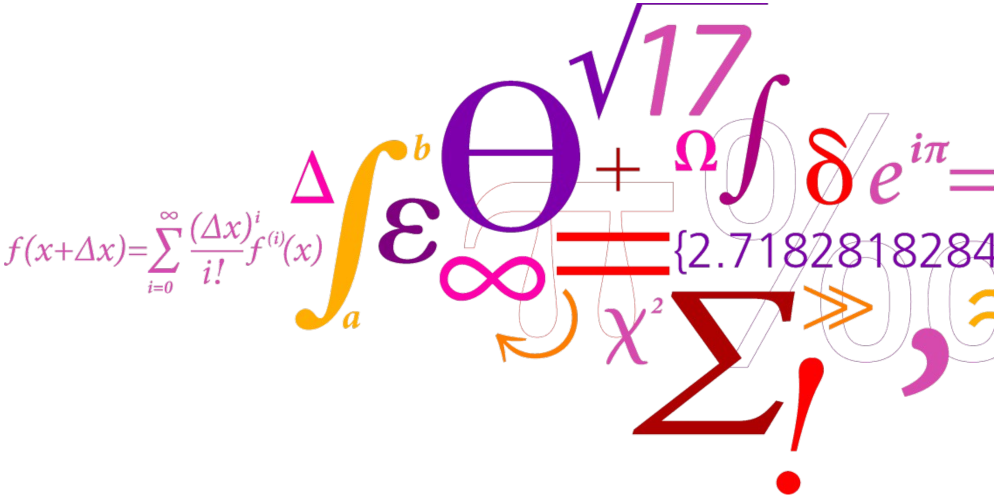
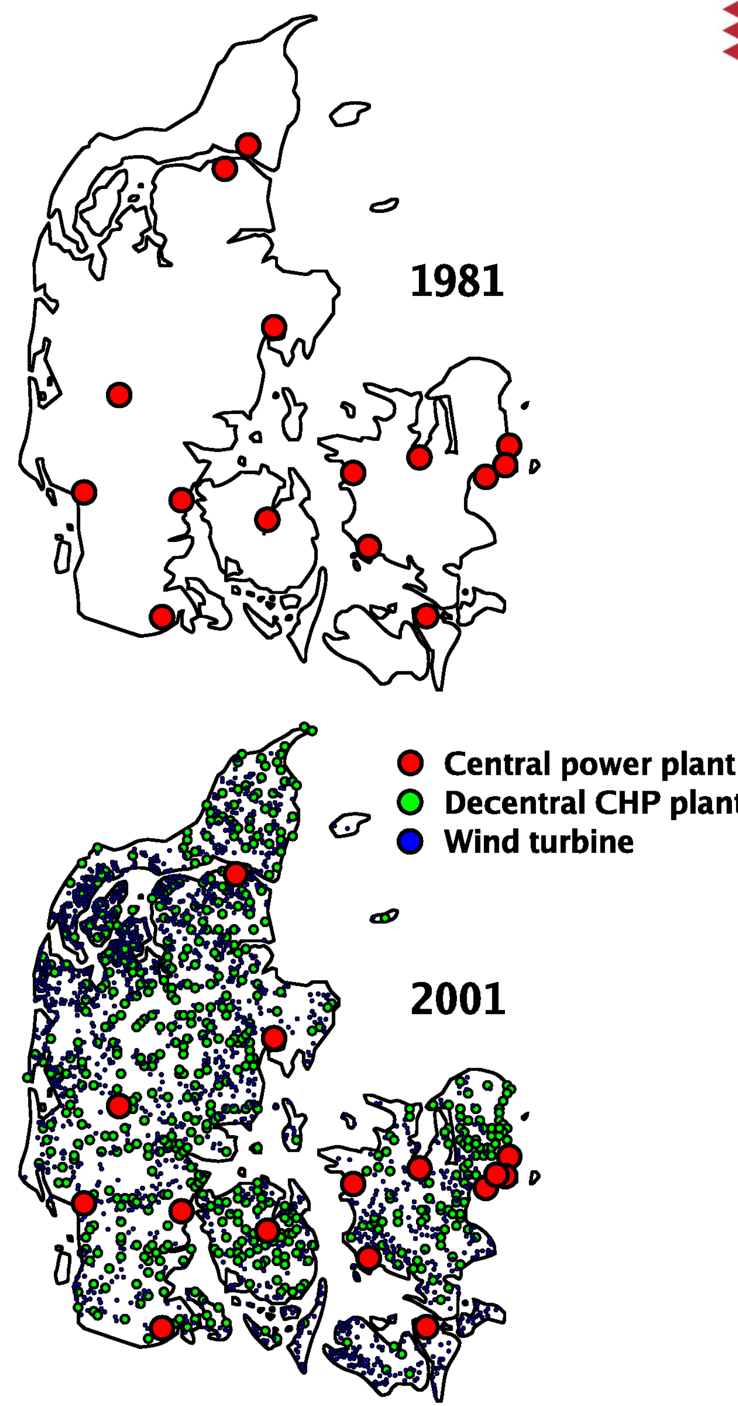


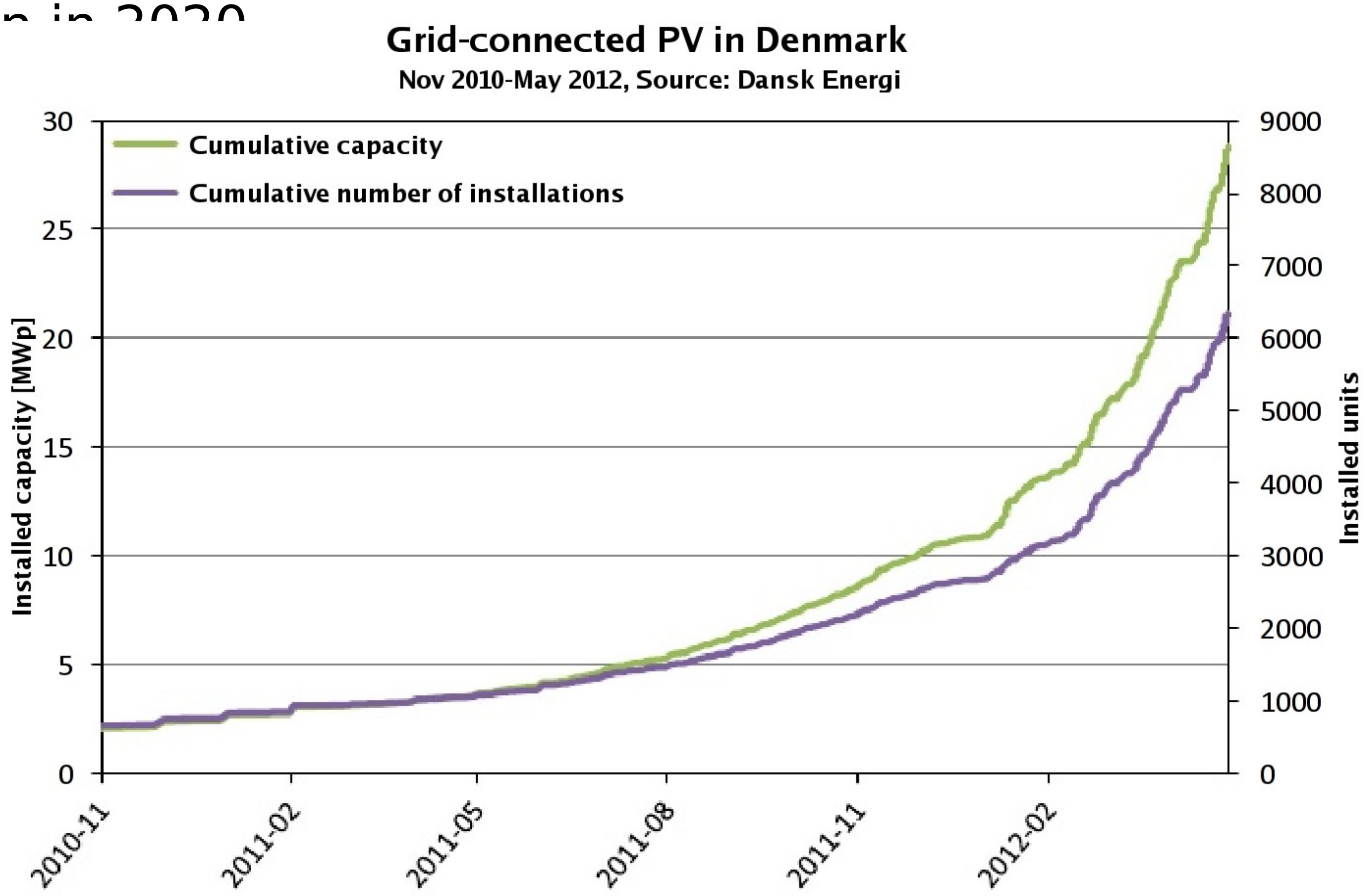
The Danish challenge (I)

- Electricity supply ca. 1980:
  15 coal-fired power plants
- Political desire to exploit renewables and to increase energy efficiency ->
  subsidies and other incentives
- Electricity supply ca. 2000:
  about 500 distributed CHP plants and
  about 5000 wind turbines
- Wind power penetration ca. 29% (2011)
- Government target:
  50% wind power in 2020



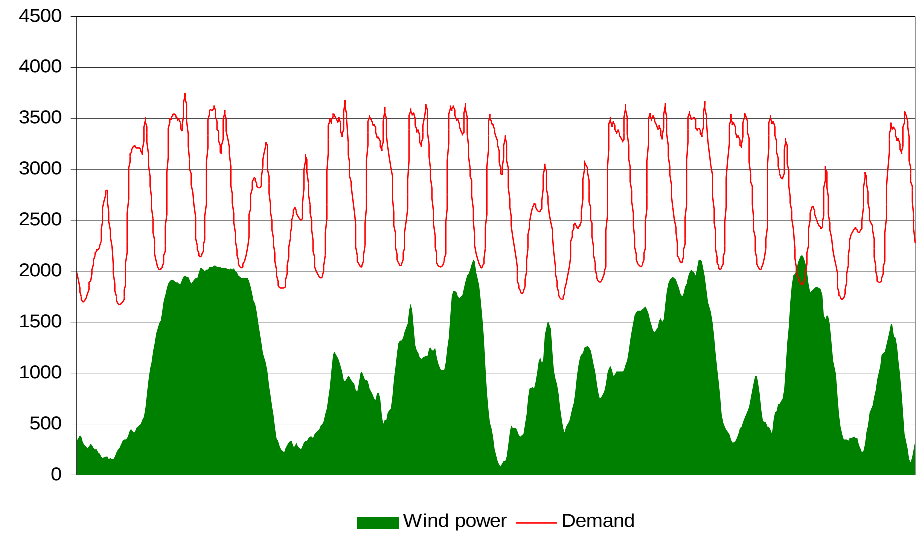
The Danish challenge (II)

- Growth of PV installations turned exponential in late 2011
- DSOs expect close to 10% penetration in 2020

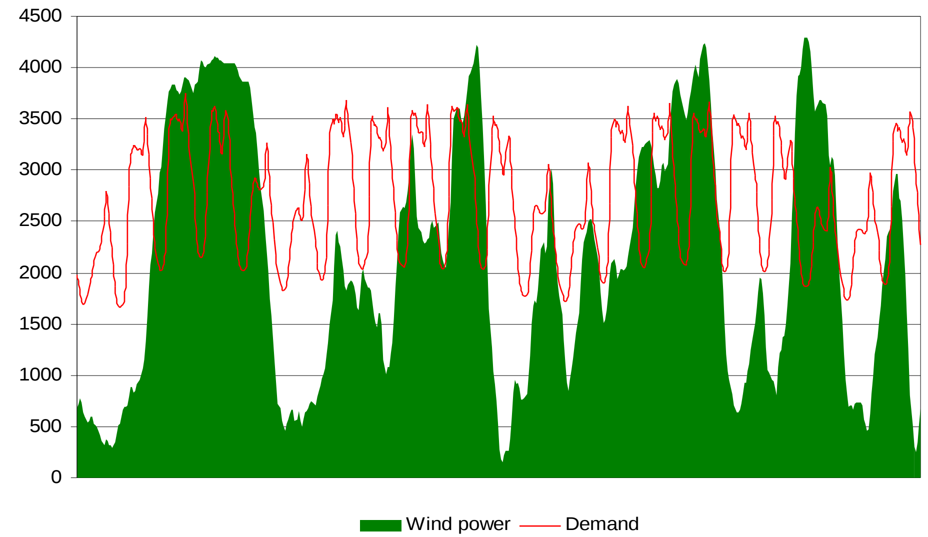


Towards 50% wind power

- Already at 20% wind penetration, wind production exceeded total consumption on some occasions
- In an energy system with 50% wind and 10% PV, overflow will be massive.
- In a business-as-usual scenario, wind production would have to be curtailed for more than 1000 hours per year.



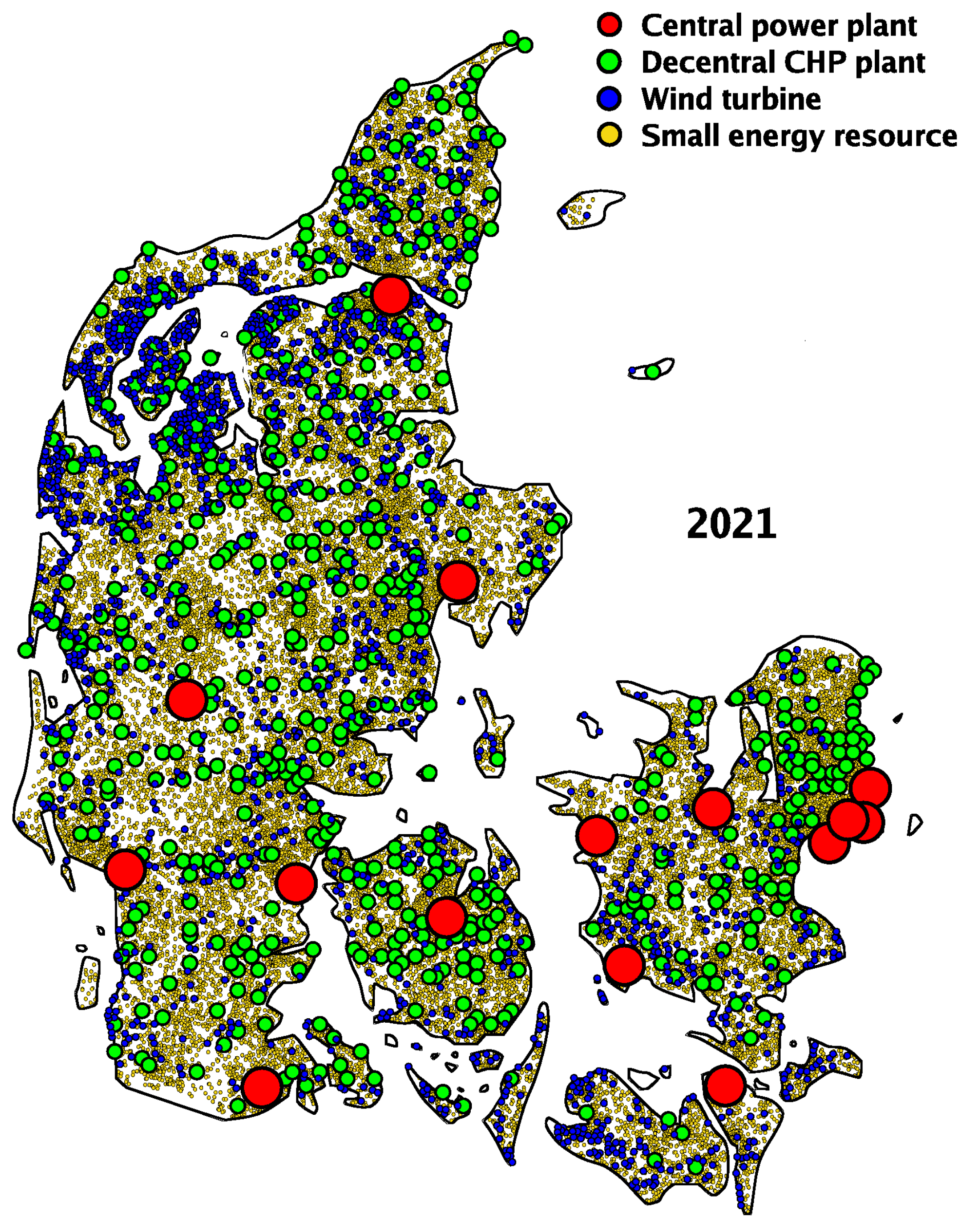
DK West, January 2008



DK West + 3GW

Contribution of small DER

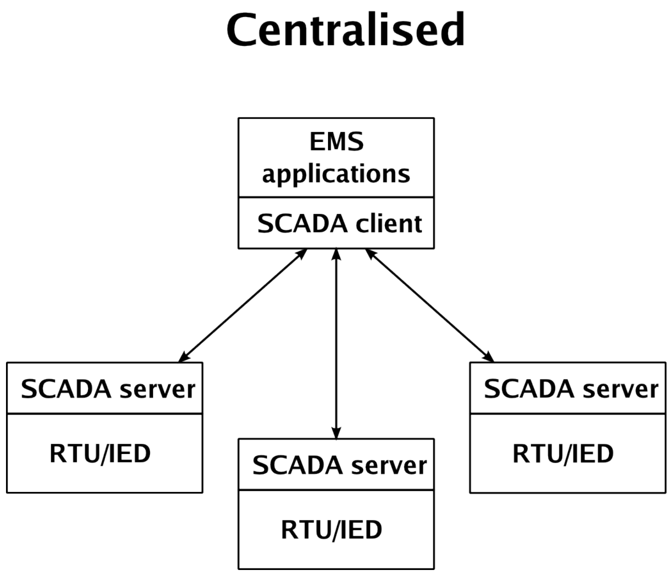
- The impact of traditional providers of system services (power balancing, voltage regulation etc.) is decreasing
- In a grid with a high penetration of fluctuating sources, system services will have to be provided by all capable units
- System integration and control of small DER is necessary, particularly with respect to flexible demand.
  - Heating (air, water)
  - AC and refrigeration
  - Battery charging (EVs in particular)
  - Fans and pumps
  - Lighting (some applications, e.g.



Small DER interactions with the grid

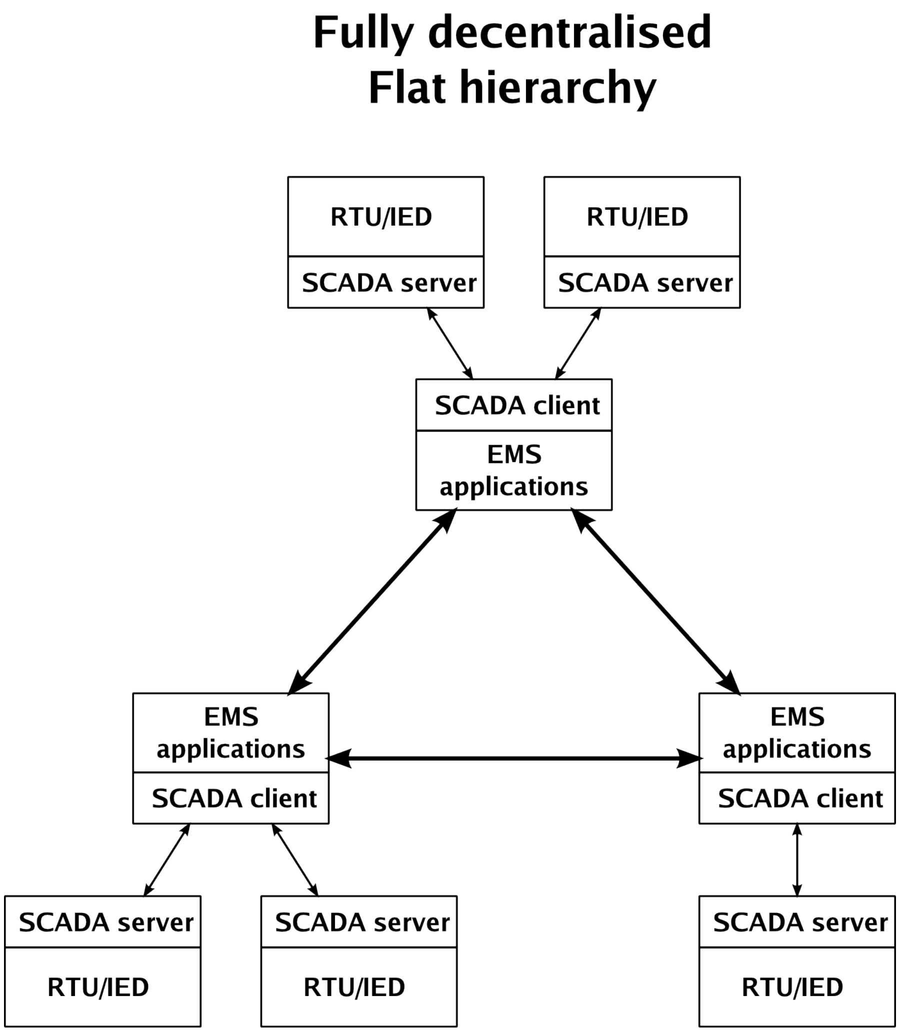
- Data acquisition (power system state)
- Provision of ancillary services
  - Frequency control (power balancing)
  - Allocation of reserves
  - Voltage control
  - Black start coordination
- Business operations
  - Interactions with energy markets
  - Metering

Control structures: Centralised



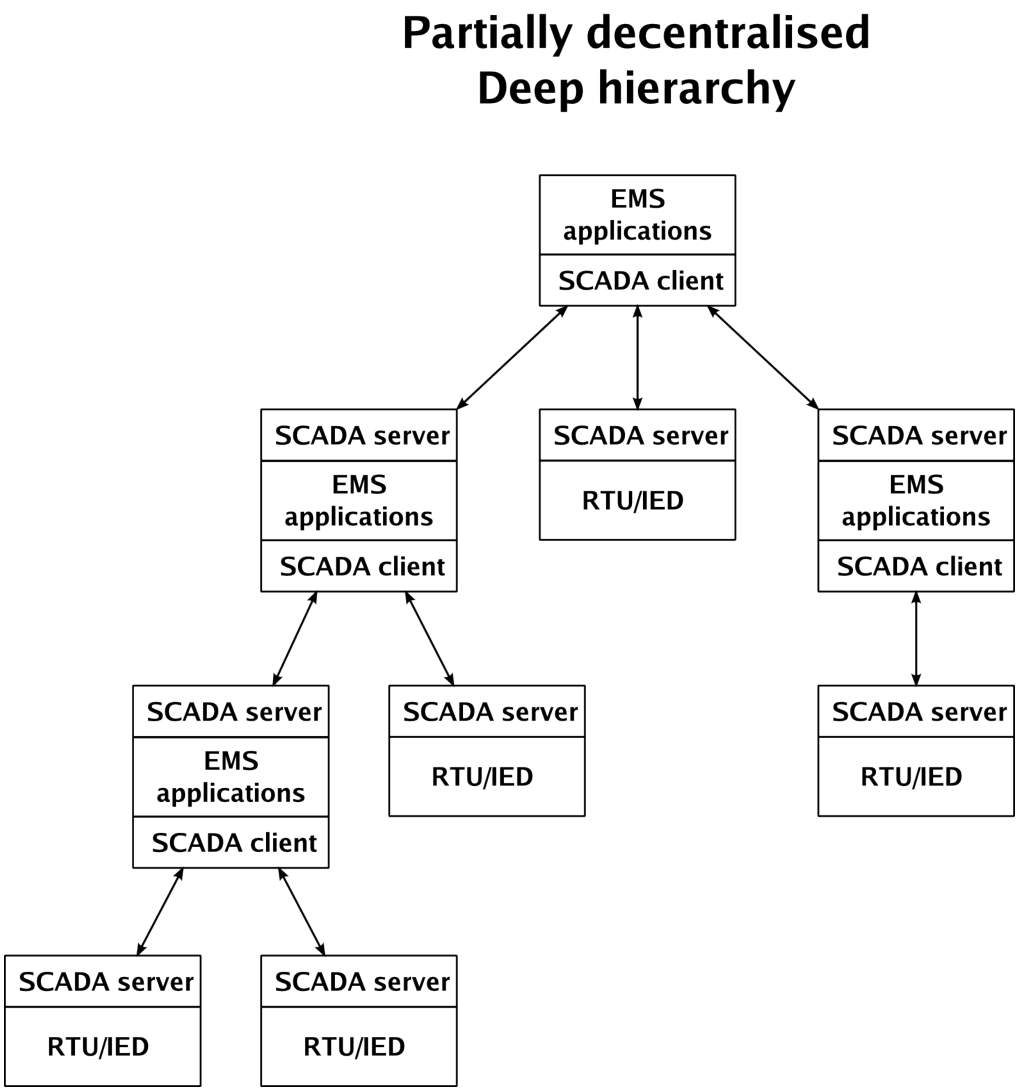
- Dominant architecture in today's EMS/DMS/SCADA systems
- Difficult to scale to a large number of distributed energy resources due to inherent bottlenecks
- Single point of failure

Control structures: Fully decentralised



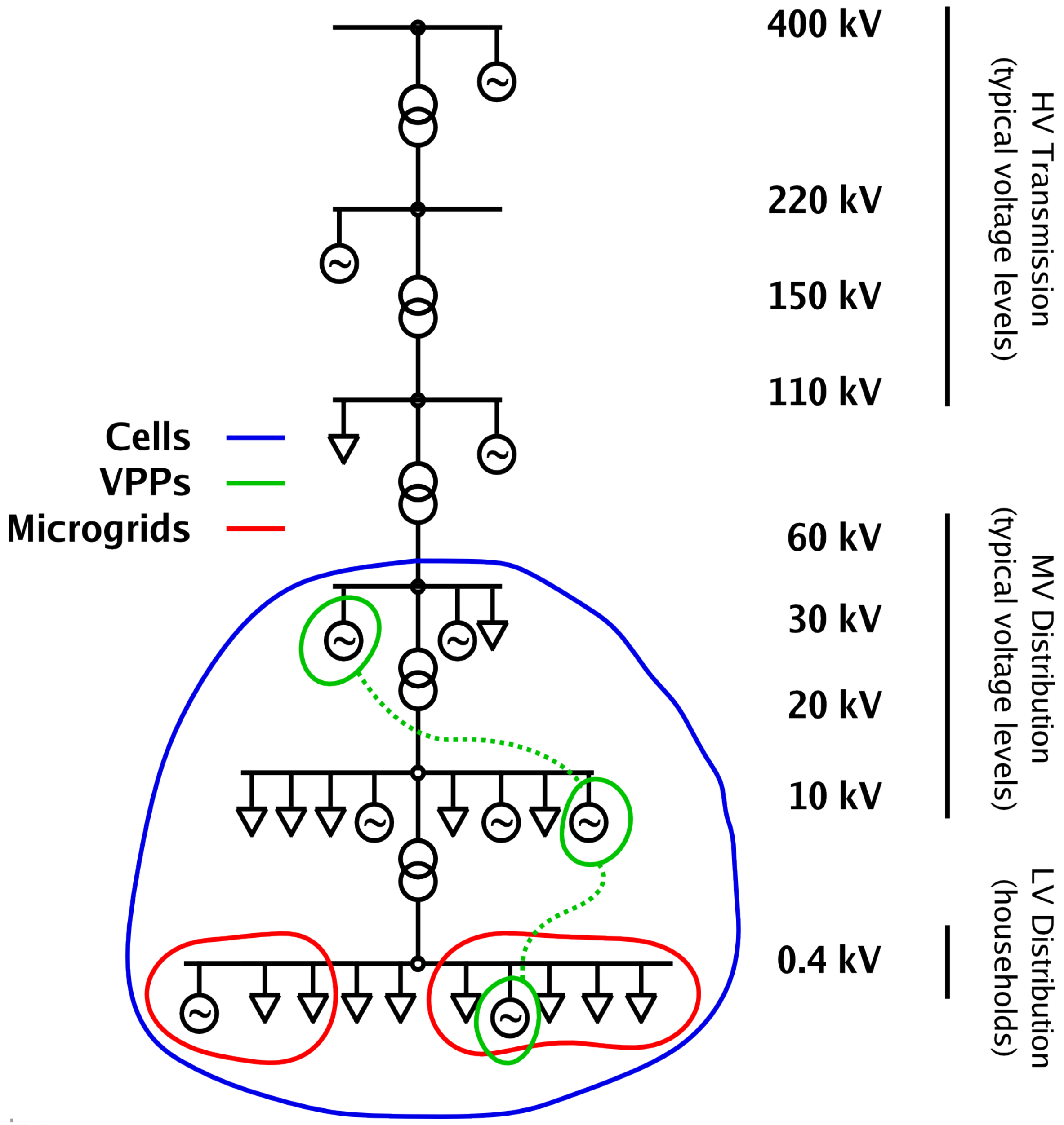
- Vision "Electricity like the internet"
- Loose federation of communicating controllers
- Implemented where globally observable quantities exist (primary frequency control)
- If a control task requires explicit global coordination, it will become difficult to scale due to inefficient communication
- Decentralisation of isolated tasks may not improve anything without decentralisation of dependencies
- Power system control has

Control structures: Aggregation



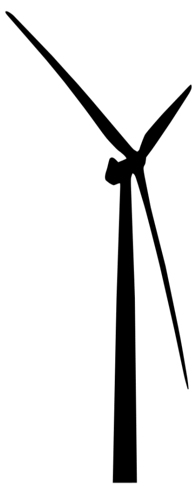
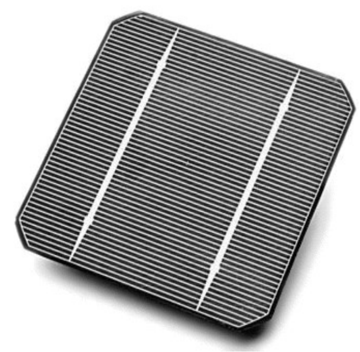
- Compromise: Hierarchies of aggregators
- Gain of scalability (divide and conquer)
- Aggregation: Grouping or clustering of resources which offer an identical or functionally equivalent service, into a larger entity
- The resources in the aggregate are maintained by the aggregator in a way as to appear as a single unit

Existing aggregation concepts

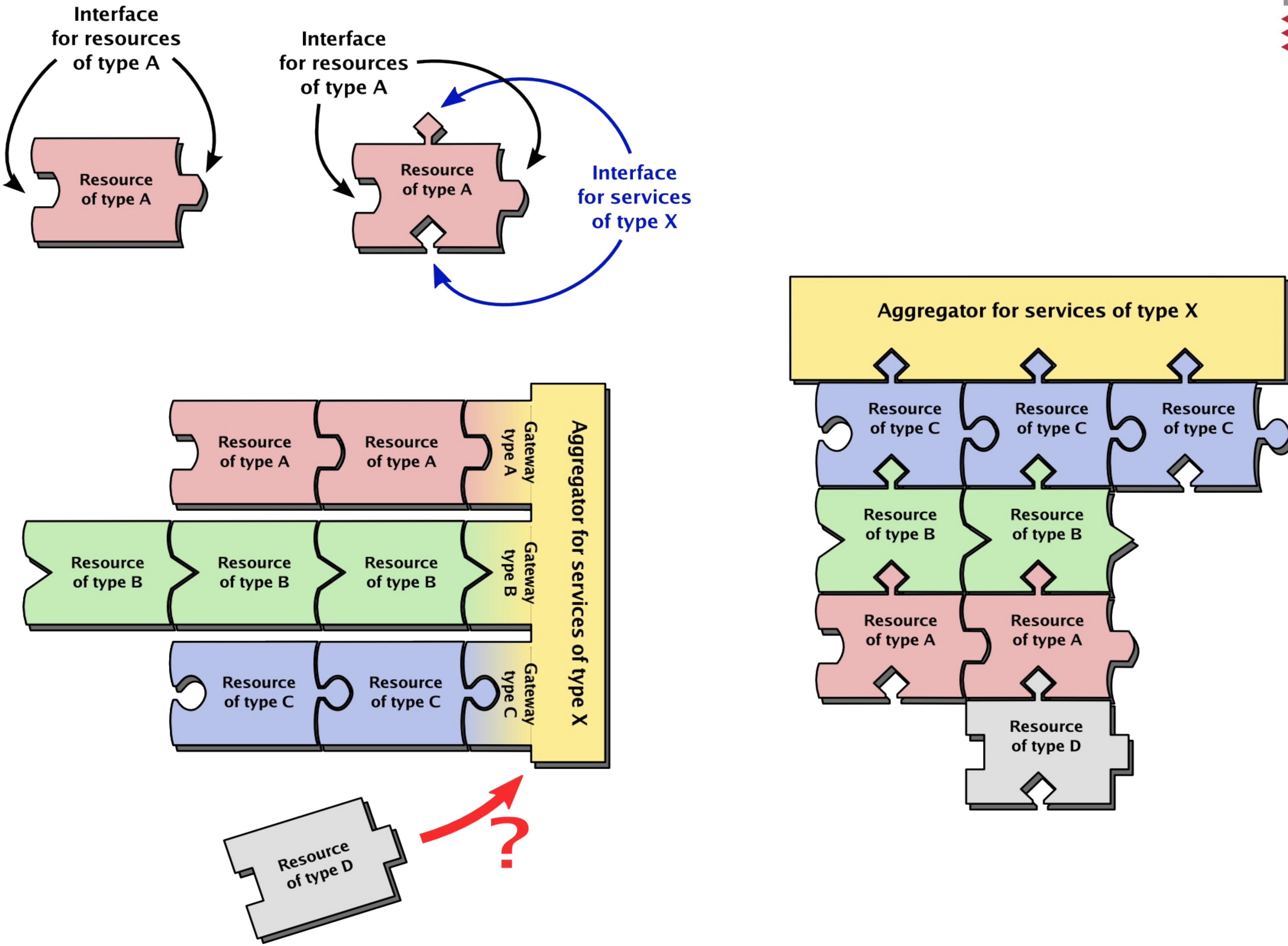


(1) Aggregation needs similarity

- Aggregation of dissimilar entities is difficult or impossible
- Lack of similarity creates difficulty for discovery as well
- Similarity is difficult to exploit in the present communication model which emphasises structure, not function

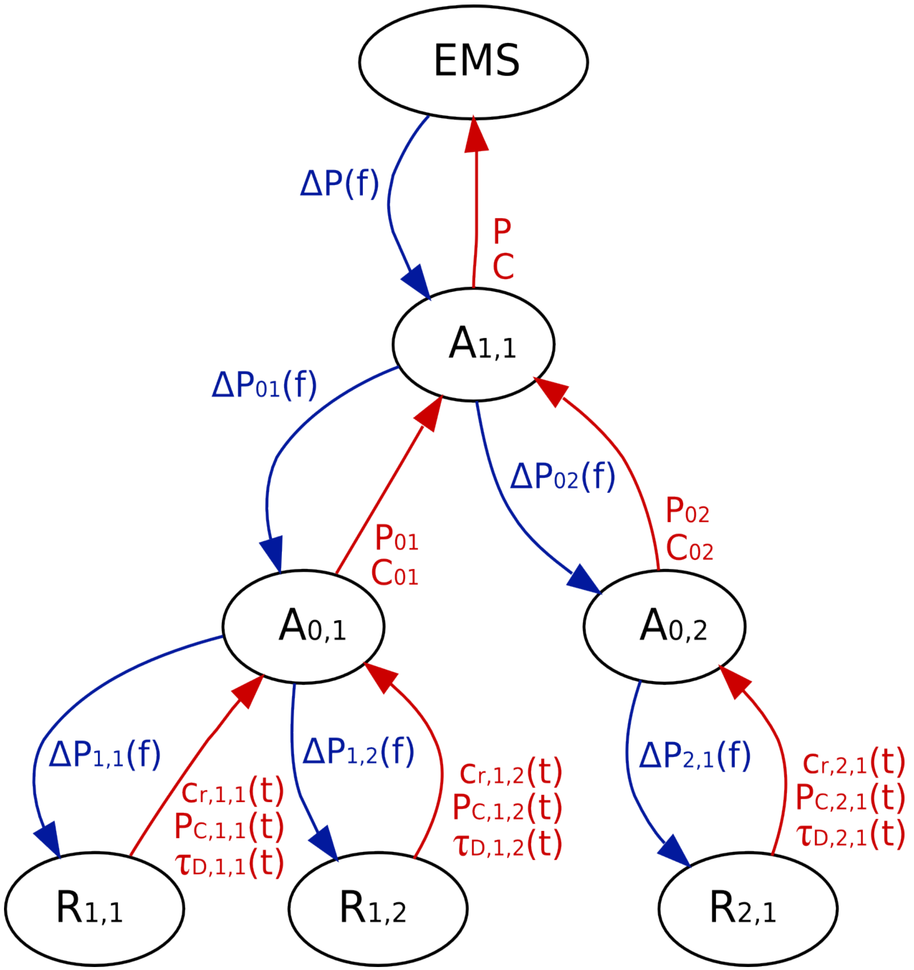
3  + 5  = ?

- Distributed resources should have the ability to advertise their function in immutable terms, in addition to identity and structure


Interface
for resources
of type A
Resource
of type A
Interface
for resources
of type A
Resource
of type A
Interface
for services
of type X
Resource
of type A
Resource
of type A
Gateway
type A
Resource
of type B
Resource
of type B
Resource
of type B
Gateway
type B
Resource
of type C
Resource
of type C
Gateway
type C
Aggregator for services of type X
Resource
of type D
?
Aggregator for services of type X
Resource
of type C
Resource
of type C
Resource
of type C
Resource
of type B
Resource
of type B
Resource
of type A
Resource
of type A
Resource
of type D

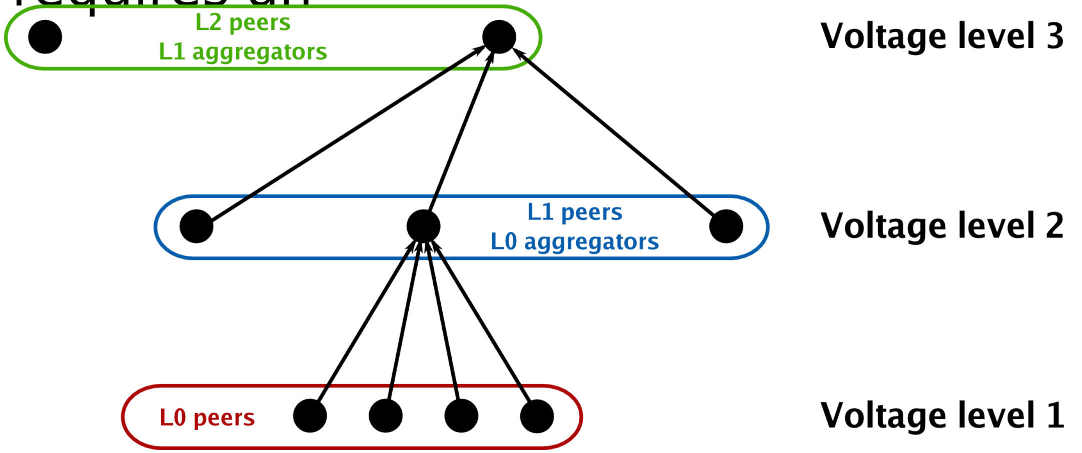
(2) Aggregation and deaggregation

- Beyond simple data collection, control requires both aggregation (upstream) and deaggregation (downstream)
- In many applications, **aggregation** rules require only simple arithmetics (summation, averaging etc.) while **deaggregation** is more complex and involves fair and/or optimal dispatch or scheduling of resources.
- The different stages in an aggregation hierarchy must be decoupled to preserve scalability



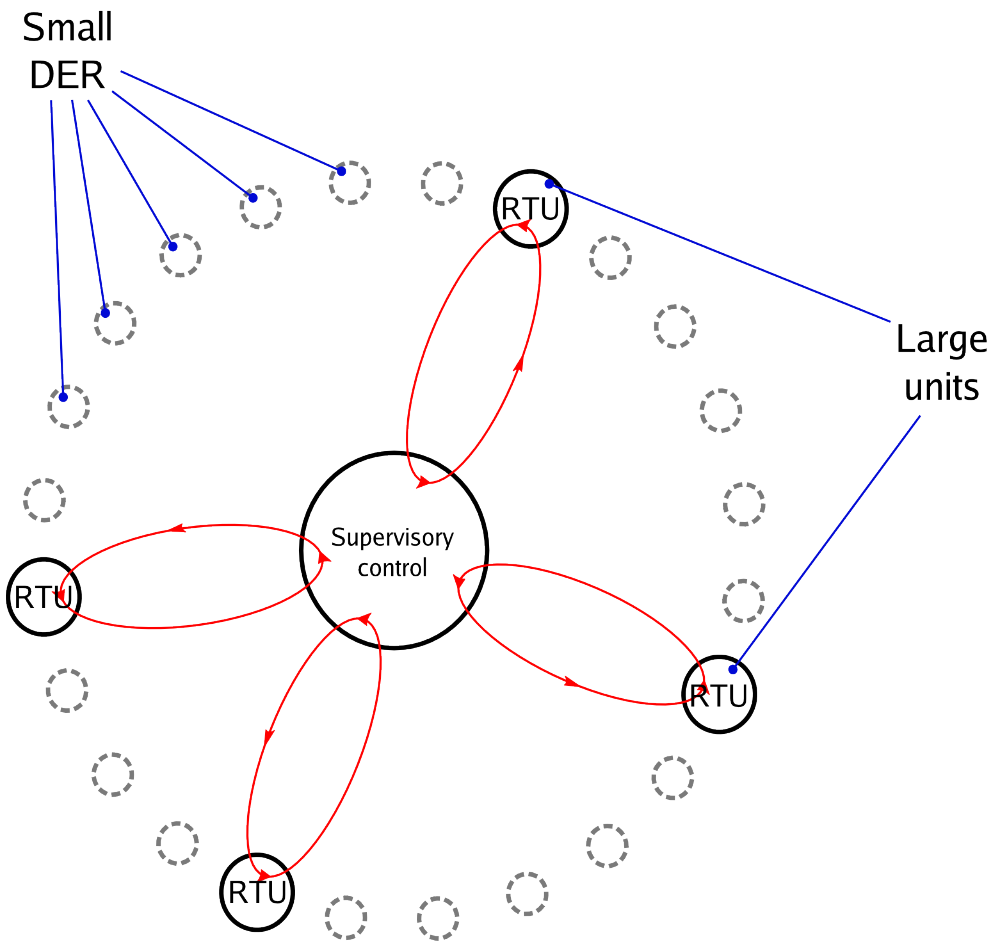
(3) Keeping the structure updated

- Unlike e.g. sensor networks, communication path and service delivery path are not necessarily the same in power system control
- The most useful aggregation structure would therefore be one that matches the physical topology of the grid
- Changes in grid topology have to be detected, tracked and adapted to
- The large number of peers requires an automated system



(4) Handling low-grade communication

- Current SCADA systems use synchronous communication. They assume reliable links, sufficient bandwidth and defined latency
- Small energy resources require low-cost communication solutions which do not have those properties
- Control stategies must be adapted to allow asynchronous interaction between supervisory controllers and energy resources



(5) Security isssues

- Wherever programmable systems are deployed *en masse* within the physical reach of end customers, they will be hacked
- Existing low-cost, mass-market systems (e.g. SIM cards) provide some degree of secure authentication, but not enough
- To contain a breach, authentication and verification must occur on all stages of an aggregation hierarchy.