Controlling the digital power grid – what do we need to know?

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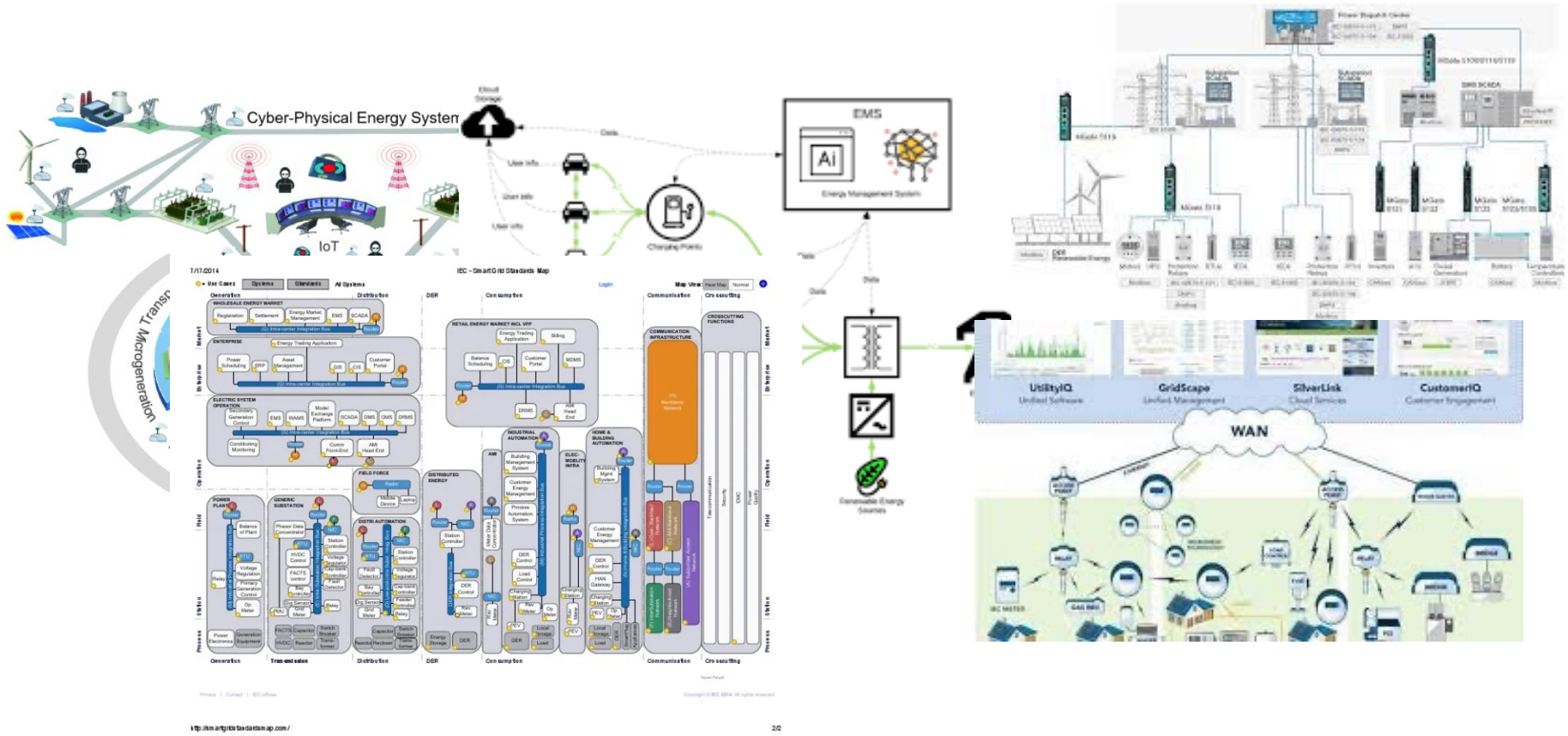
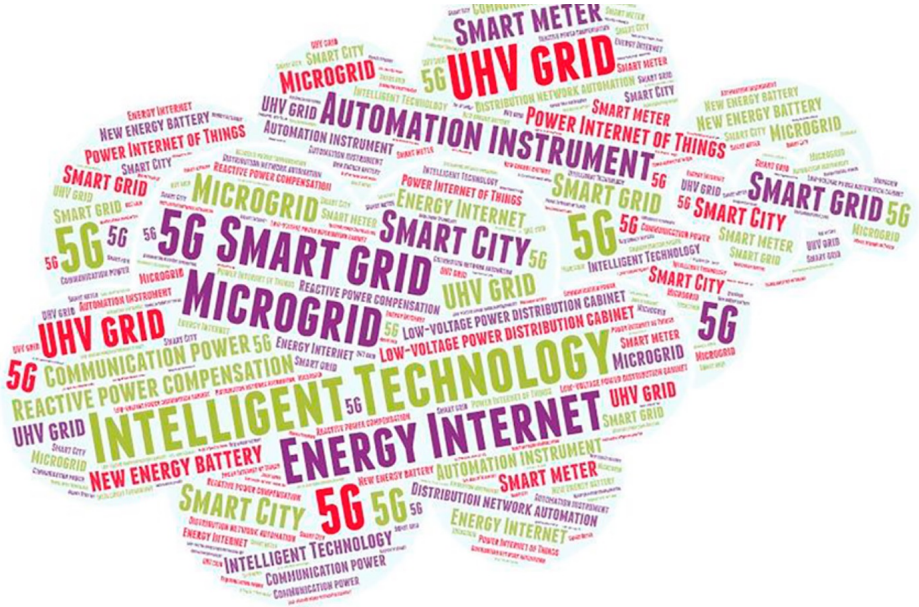
The Digital Power Grid



It appears to be terribly complicated.....

Some consensus, possibly….



- To design, develop and control the digital power you need to **know**:
  - Power Systems
  - Power electronics
  - Dynamic systems and control
  - Optimisation
  - Electriticy markets
  - Communicaiton technology
  - Software development
  - Cybersecurity
  - Databases and data quality
  - Machine learning and AI
  - Sensor networks
  - Wireless communication
  - Weather forecasts
  - 5G, 6G, IoT
  - …..

Lets look at an example...

Load Frequency Control

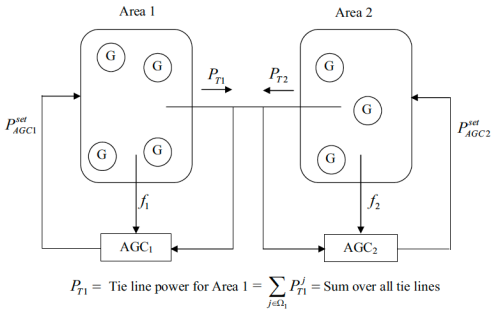
- Load Frequency Control is a secondary frequency control mechanism with one or two control objectives:

  Restoring the frequency to nominal f_0

  and/or

  Restoring tie-line power flows to nominal

  - .....
- Normally implemented as a Proportional Integrating (PI) Controller
  - Tuning of the C_{pi} and T_{Ni} parameter non-trivial
- Area Control Error to be minimised, based on setting of a.o. bias factor B per control area
- Output is new setpoints for P_{AGC} to be shared among participating generators.



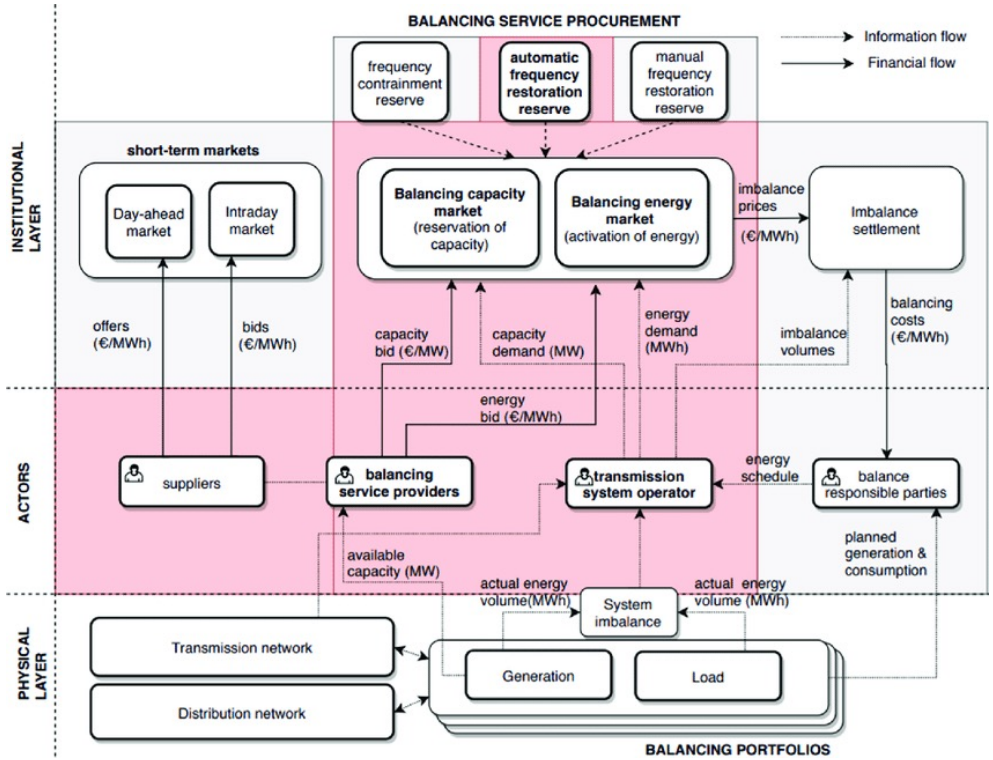
$$\Delta P_{AGCi} = -(C_{pi} + \frac{1}{sT_{Ni}})\Delta e_i$$

$$ACE_i = \sum_{j\in\Omega_i}(P^j_{Ti} - P^j_{T0i}) + B_i(f - f_0) \quad i = 1, 2, \ldots, N \ .$$

Core Knowledge:
Electrical Engineering
Systems Engineering
Control Systems

Tools & Tricks:
MATLAB/Simulink
Python scripting
PSS/E - PowerFactory

aFRR – automatic Frequency Restoration



- In an unbundled / deregulated power market, generation is separated from grid operation
- The market perspective of LFC is aFRR
- Balance Service Providers owning resources bid into markets indicating their willingness to participate in LFC
  - Amounts of Power, Duration and time,...
- Participation across several markets optimises revenue streams for assets

Core Knowledge:
Electricity Markets
Optimisation
Forecasting

Tools & Tricks:
GAMS
Python scripting

Multi-actor interaction

- For market transparency, effectiveness and efficiency data must be shared among several actors – data that includes :
  - Technical parameters, e.g. amount of reserves needed, timeframe
  - Bids, amounts, values
  - Acceptance of bids
  - Control signals (ACE, setpoints, participation factors)
  - Acknowledgements
  - Billing information

Core Knowledge:
Information modeling
Software Engineering
Standards

Tools & Tricks:
UML
Enterprise Architect

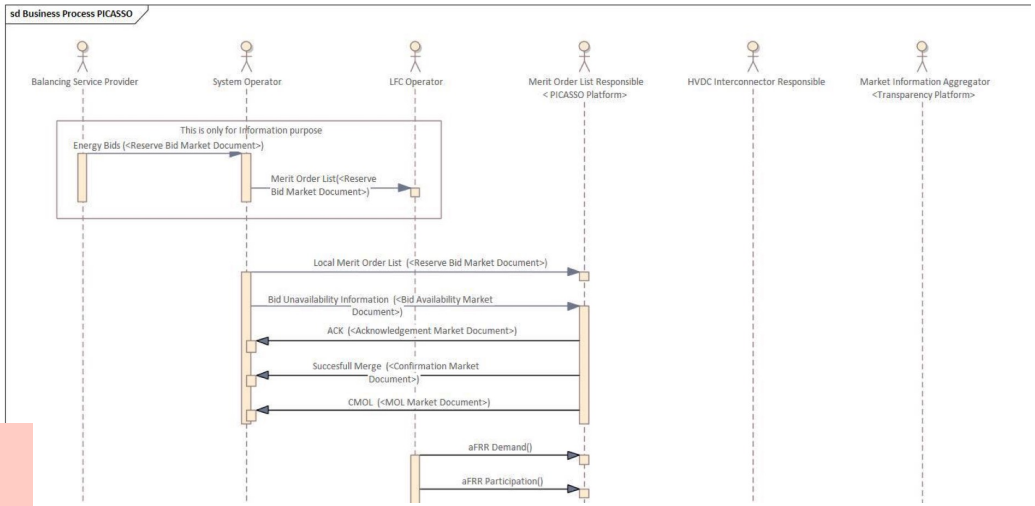
entsoe

European Network of Transmission System Operators for Electricity

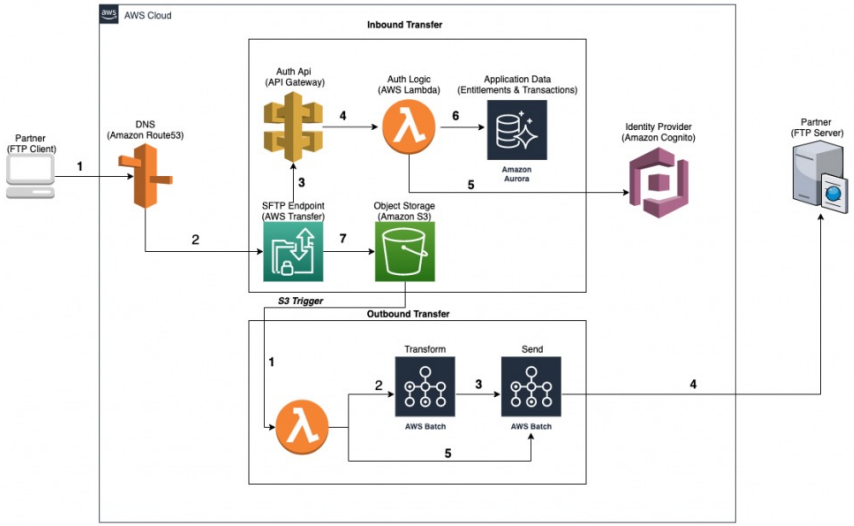
ENTSO-E
AUTOMATIC FREQUENCY RESTORATION RESERVE PROCESS

IMPLEMENTATION GUIDE

2021-01-27
APPROVED DOCUMENT
VERSION 1.1



Information and Communication Technology

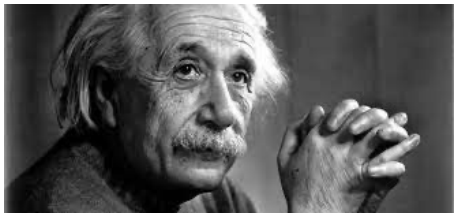


- The implementation of an LFC function across several actors in an unbundled and de-regulated power market depends on computing and communication.
- Often involving critical systems and sensitive data
- Secure and reliable transmission, processing and storing of data including e.g.:
  - Setpoints and measurements. E.g. P and f_0
  - Bids from service providers
  - Optimisation of parameters
  - Historical records for billing, etc etc

Core Knowledge:
Communication systems
Computing platforms
Cybersecurity
Communication Protocols

Tools & Tricks:
SQL, XML, ftp, http, json, ssh, cron, VPN,...

Some implications



A single person* **cannot know** all the disciplines needed for a complete understanding of how an LFC function is implemented across multiple actors in an de-regulated power system.

The quality of the LFC function is never better than the **weakest link** in the chain from control system, via market setuo, actor interaction and ICT platform

Designing, developing and deploying new functions in the Digital Power grid can be **time consuming and expensive** due to lacking coordination and interoperability between the domains.

** OK, possibly some - but definitely not as many as are needed to develop the Digital Powergrid*

So, what gets the job done?

- Based purely on personal experience and no scientific facts whatsoever….

- Form small teams of people (6 max) and make sure to cover all competencies in the team
- Ensure core knowledge in EE, only those individuals with clear knowedge of the core function can provide guidance on compromises, priorities and quality limits
- Share and present details of technical design choices e.g. algorithms, code and communication protocols – do not satisfy yourself with powerpoint slides. (nothing can be learned from slides)
- Foster an open curious environment where everyone can learn from eachother – ask stupid questions.
- Work iteratively, so that there is always a small working prototype to relate new ideas to.

To know what you know and what you do not know, that is true knowledge.

-Confucius