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SmartGrid RTD 2013

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Real-time state estimation of the EPFL-campus medium voltage grid by using PMUs

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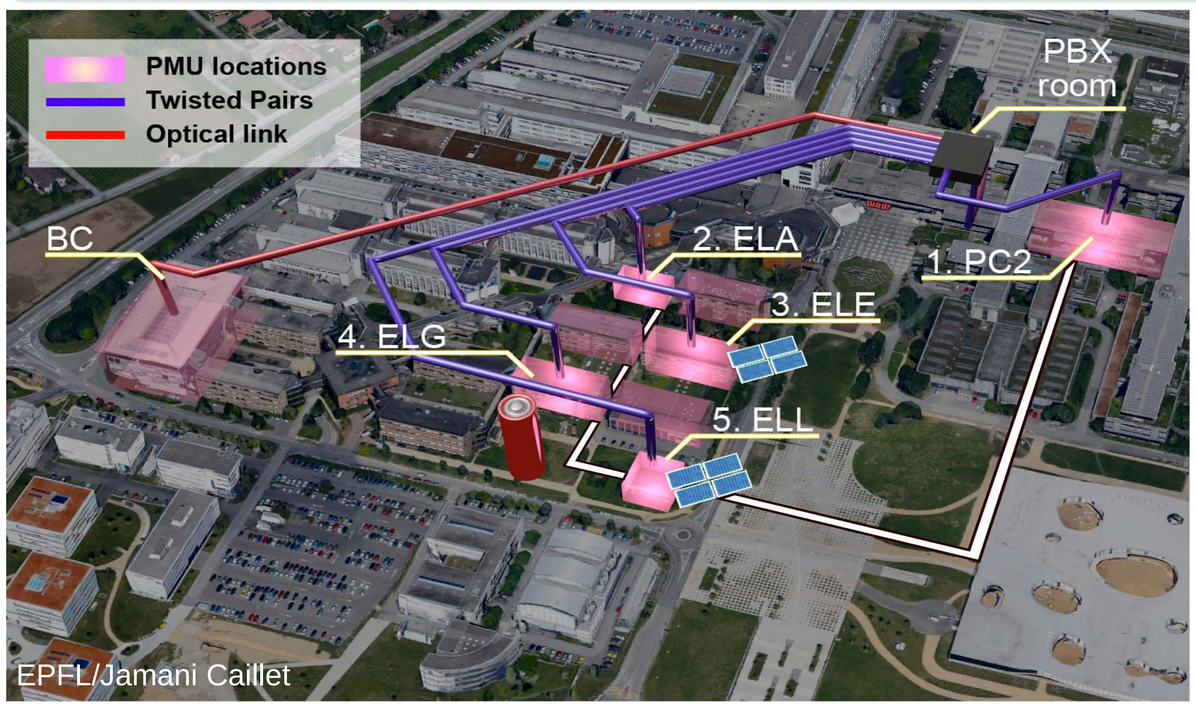
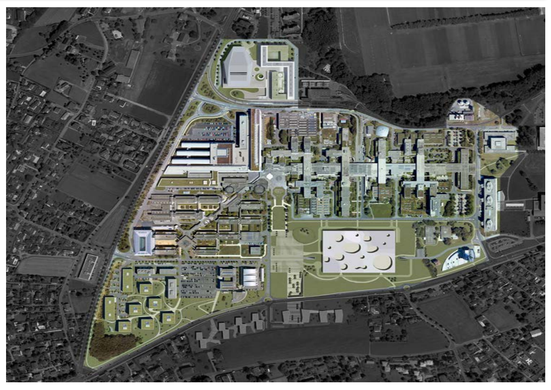
Aim of the research

We describe the real-time monitoring infrastructure of the smart-grid pilot on the EPFL campus. We experimentally validate the concept of a real-time state-estimation for a 20 kV active distribution network. We designed and put into operation the whole infrastructure composed by the following main elements: dedicated PMUs connected on the medium-voltage side of the network secondary substations by means of specific current/voltage transducers; a dedicated communication network engineered to support stringent time limits and an innovative state estimation process for real-time monitoring that incorporates phasor-data concentration and state estimation processes. The achieved latency is within 65ms. The refresh rate of the estimated state is 20ms.



The test bed



- Network complexity: 40 buses;
- 30 MW peak;
- 2.5 MW peak photovoltaic;
- 6 MW peak CHP;
- 1 MW peak, 0,5 MWh Li-Titanate storage system;
- DSM to be deployed in two buildings (EL-A and new IGM).

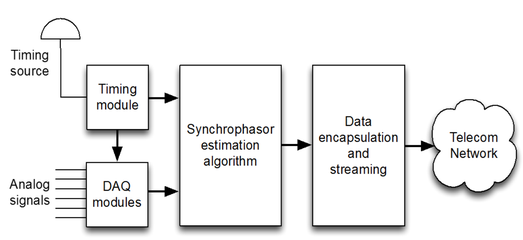
PMU-based monitoring

Phasor Measurement Units are devices that allow **synchronized** and fast measurement of frequency, amplitude and phase of the power-system waveforms.

Voltage and current **sensors**
- Class 0.1
- Nodal voltages and injected currents

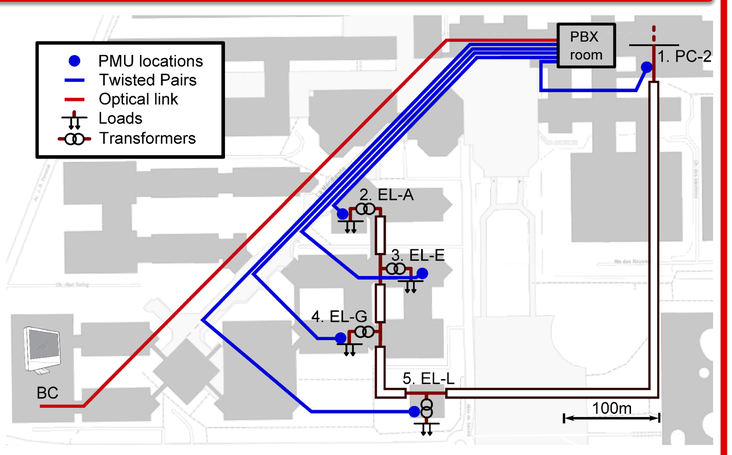
Phasor Measurement Units
- Synchrophasor estimation based on enhanced **IpDFT algorithm**
- Encapsulation and streaming according to IEEE c37.118.2-2011

Typical setup installed in the substation: GPS antenna, sensors, PMU device with modem and UPS.

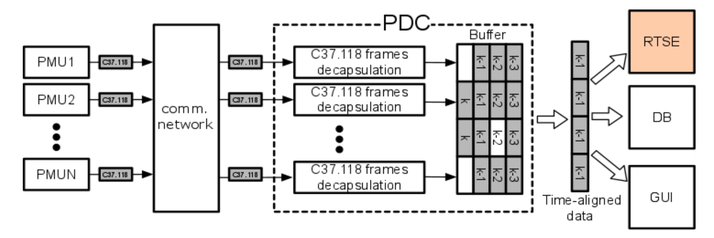


Communication network

- **Dedicated** communication network
- **Secured** against attackers
- **Resilient** to power outages
- **No** traffic **congestion**
- **No losses** (over observed period of 10h)
- **Telephone cables** between PMUs and EPFL telephone exchange room (PBX).
- **Optical link** for aggregated traffic

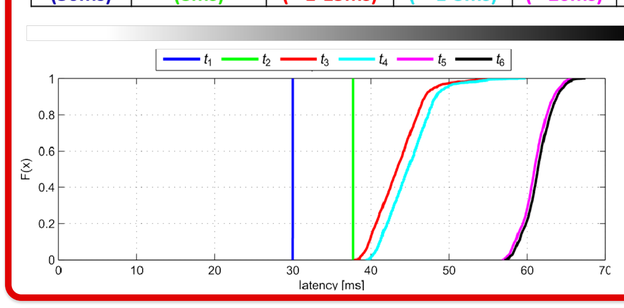


Data concentrator and state estimator



See it live at http://smartgrid.epfl.ch

PMU			Telco	PDC+RTSE	
Signal acquisition	Synchrophasor estimation	Data encapsulation	Network delay	Data-frame alignment	State estimation
t1 (30ms)	t2 (8ms)	t3 (~1-15ms)	t4 (~ 1-3ms)	t5 (~20ms)	t6 (<1ms)

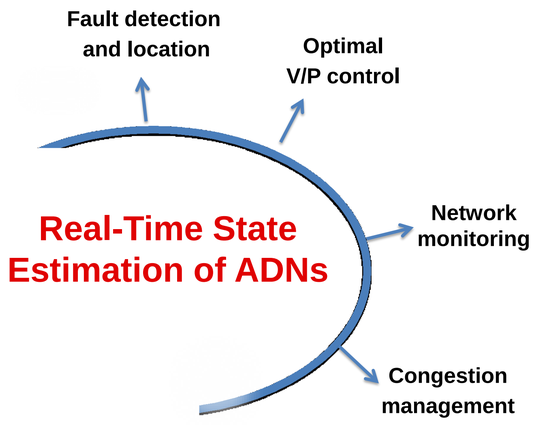


Total latency:
- **61 ms (mean)**
- **1.8 ms (std)**

Real-time **state estimation**:
- Linear Discrete **Kalman** filter
- Online **assessment** of the model error covariance matrix Q

Applications and future steps

Current research on:



Future steps will include:

- Equipment of a second feeder of the campus;
- Coupling with the control of the DESL micro grid;
- Coupling with the 1 MW Li-Titanate battery storage system from Leclanché.

References

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L. Zanni, M. Pignati, S. Sarri, R. Cherkaoui, M. Paolone, “Probabilistic assessment of the process-noise covariance matrix of discrete Kalman filter state estimation of active distribution networks,” Proceedings of PMAPS, Durham, UK, Jul. 7-10, 2014