Zaphiro

Dynamic. Smart. Grid.

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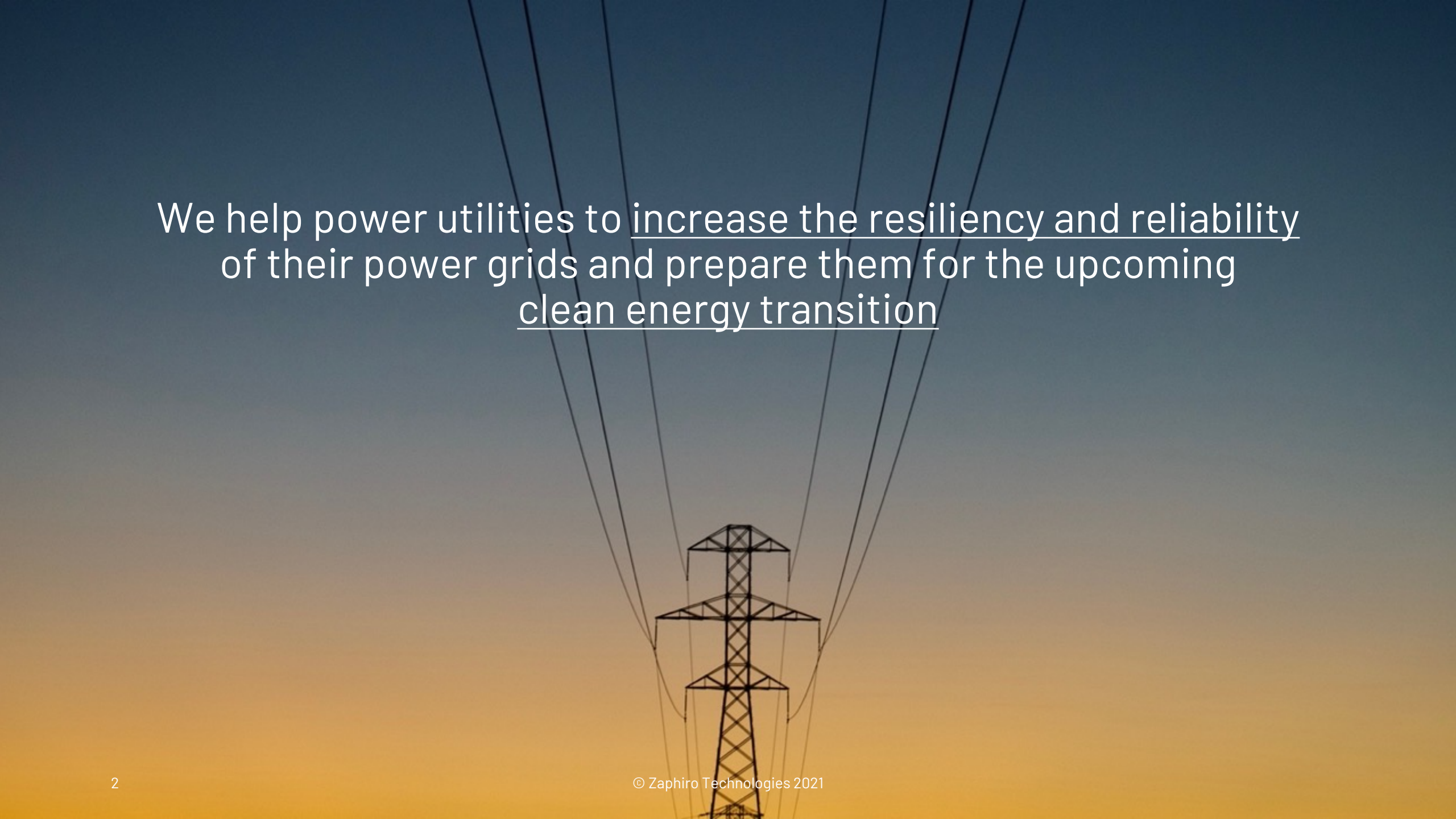
Co-founder and CEO

Technical Challenges and Solutions to PMU Rollout in Distribution Grids

IEEE SGSMA 2021 conference
May 25th - 27th 2021



We help power utilities to increase the resiliency and reliability of their power grids and prepare them for the upcoming clean energy transition

We are what we achieve

Strong traction
Growing client pipeline and 2nd capital raise

EPFL spin-off
founded by 3 former PhDs in 2017

8 paying clients
in EU and APAC with repeating orders

Zaphiro
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9 employees
experienced engineers & business team

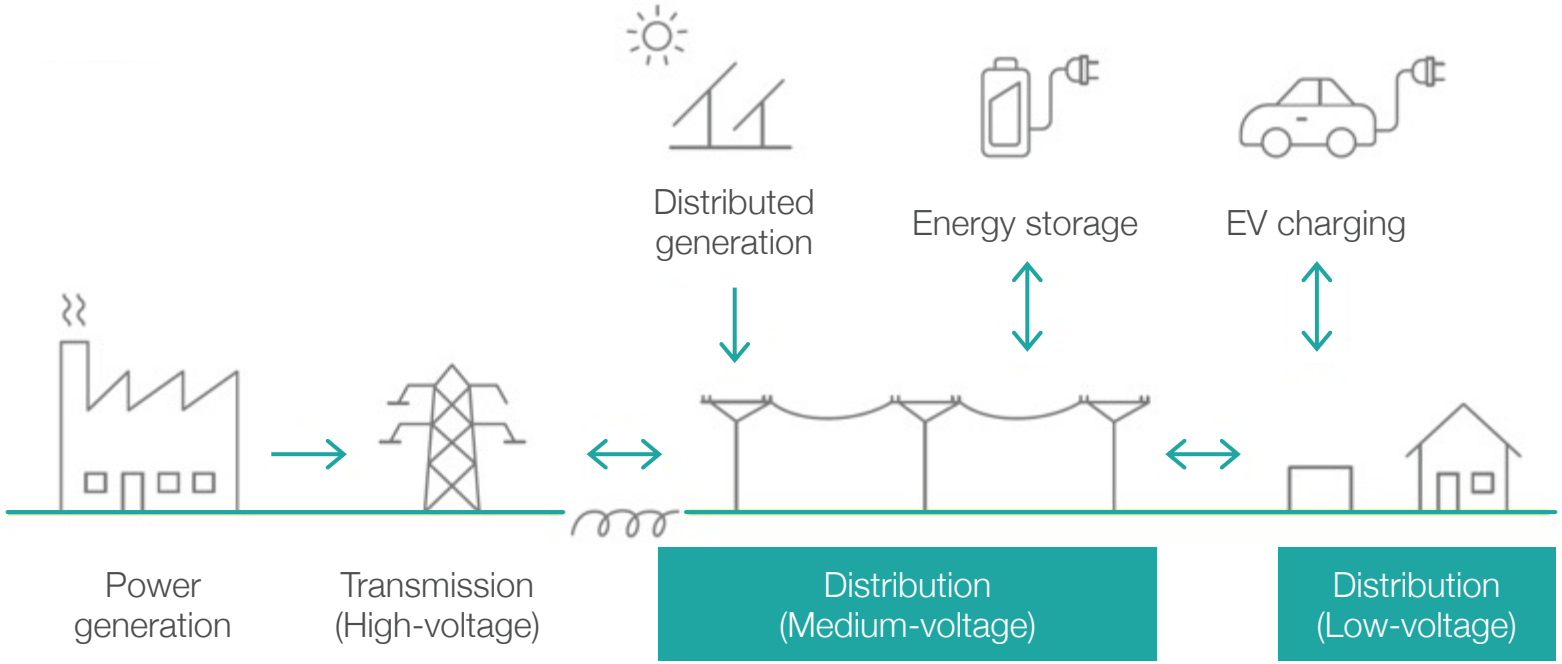
>1600 assets
monitored 24/7

2 patents
at international level

Our customers:

alliander
SIL Services Industriels Lausanne
CLP 中電 China Light and Power
Romande Energie
BKW
SIG
EPFL
Terna
ComEd

We help electrical utilities in their digital journey towards a clean energy future

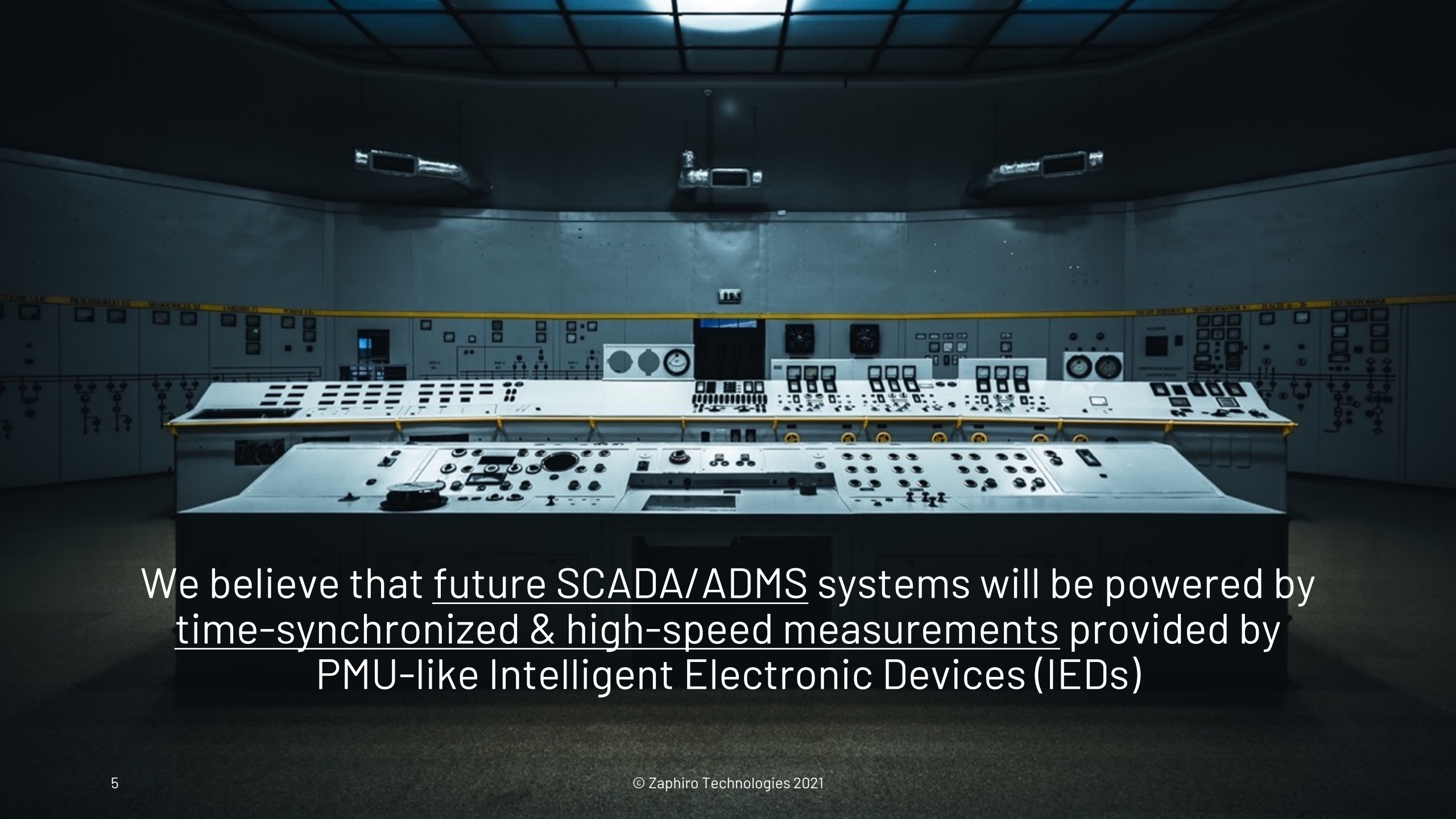


Distribution System Operators (DSOs) problems and challenges:

1. Limited visibility on grid assets

2. Inefficient black-out management

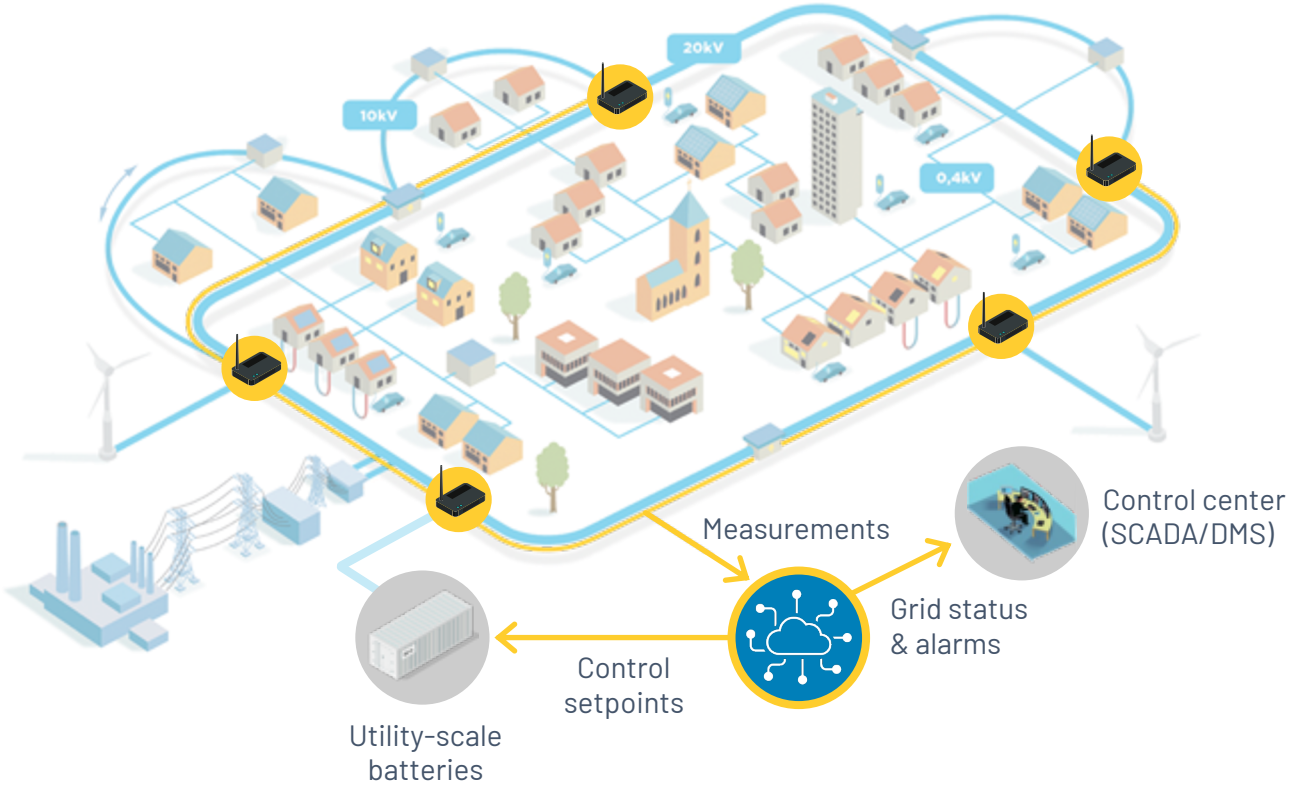
3. EVs/renewables unpredictability



We believe that future SCADA/ADMS systems will be powered by time-synchronized & high-speed measurements provided by PMU-like Intelligent Electronic Devices (IEDs)

Zaphiro develops the first grid automation system based on high-speed & time-synchronized PMUs

Proprietary PMU (Phasor Measurement Unit) **device**:
- Time-synchronized + high speed measurements
- Ideal for substation retrofitting



Modular and scalable software platform:
- Full interoperability with 3rd party devices
- Empowered by patented algorithm

Real-time grid monitoring
→ Estimation of entire grid state up to 50/60 times per second

Outage management
→ Automated fault location to reduce the duration or even prevent blackouts

Grid resources control
→ Automatic control of utility-scale batteries to always guarantee grid stability

Offline grid analytics
→ Advanced grid analytics for optimal grid planning and predictive maintenance

Use cases

Real-time grid monitoring

- Voltage profiles monitoring
- Line congestion/power flow monitoring
- Critical customer monitoring
- Distribution system state estimation
- Topology identification

Offline grid analytics

- Power quality analysis
- Optimal grid planning/reinforcement
- Predictive maintenance
- Post-event analysis
- Power losses estimation

Outage management

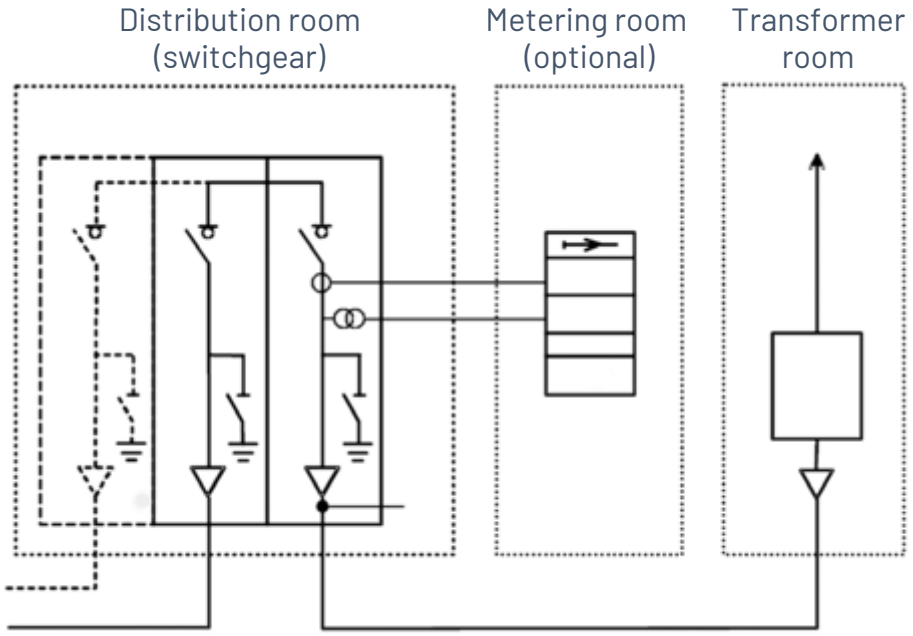
- Automatic fault location and service restoration
- Adaptive protections
- Unintentional islanding detection
- Wildfire prevention

Grid resources control

- DERMS
- Grid-aware BESS control
- Microgrid islanding operations
- Grid reconfiguration

Challenges and Solutions to PMU Rollout in Distribution Grids

Challenge #1: Distribution substations design and instrumentation



Wide variety of designs:

- Indoor vs pole mounted
- Air vs Gas insulated switchgear
- Lack of space for new equipment

Limited instrumentation:

- Lack of voltage/current sensors
- No access to swtich/breaker status
- Lack of communication equipment

Solution #1-A: Clamp-on current sensors based on Rogowski coil technology

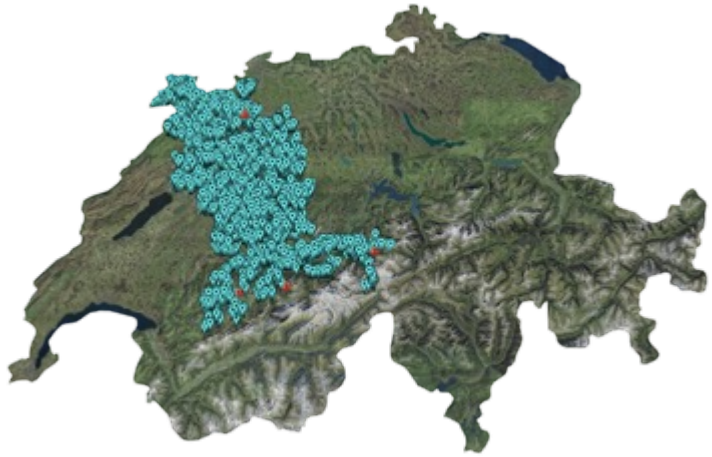
- High accuracy (class 0.5) with extremely low positioning error
- Wide dynamic range
- No saturation, linear, and not affected by DC
- Single sensor for monitoring and protection applications
- Clamp on (simple and non-invasive installation), small size and lightweight

Bürde 10 kΩ, 50 pF *Burden 10 kΩ, 50 pF*						
$I_{p,n}$ in A	M_n in nH	f in Hz	$I_p / I_{p,n}$ in %	I_p in A	ε_{iu} in %	δ_{iu} in crad
1000	71,619	60	600	6000	0,17	-0,02
			500	5000	0,17	-0,02
			200	2000	0,18	-0,01
			100	1000	0,18	-0,01
			50	500	0,18	-0,01
			25	250	0,18	-0,01
			20	200	0,18	-0,01
			12	120	0,17	0,00
			10	100	0,17	0,00
			2	20	0,16	0,03
			0,5	5	0,12	0,14

Solution #1-B: Native cellular network support

Wide network coverage

- 4G (and future 5G) networks guarantee complete coverage in most developed countries
- Example: 99.91% of BKW (major Swiss grid operator) distribution susbtations (MV-LV) are covered with public 4G network despite 50% of the supplied area is rural

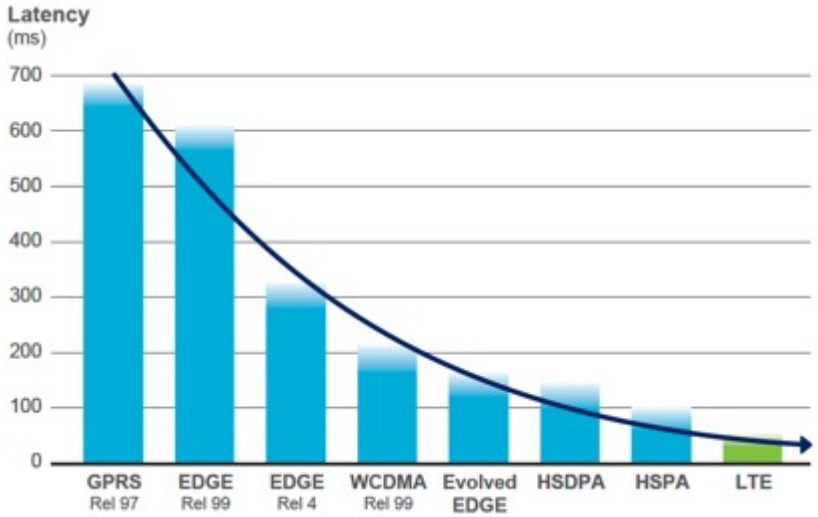


Guaranteed power-backup:

- Mandatory power back-up in LTE base stations

Low latencies for most PMU use cases

- Average LTE latency (30-40ms) allows to cope with most PMU uses cases under consideration



Solution #1-C: SynchroSense: compact, all-in-one design

- Proprietary grid device with multiple functionalities
  - Phasor Measurement Unit (PMU)
  - Digital Fault Recorder
  - Power Quality
- Superior measurement technology:
  - High speed (>200 times faster than conventional devices)
  - Time synchronized (via GPS or fiber)
- Communication via proprietary network (copper/fiber) or public cellular infrastructure
- Ideal for substation retrofitting
  - Parallel monitoring of up to 5 feeders
  - Fast & non-invasive installation
  - Cone/Support insulator type voltage sensors
  - Clamp-on current sensors (Rogowski coils)

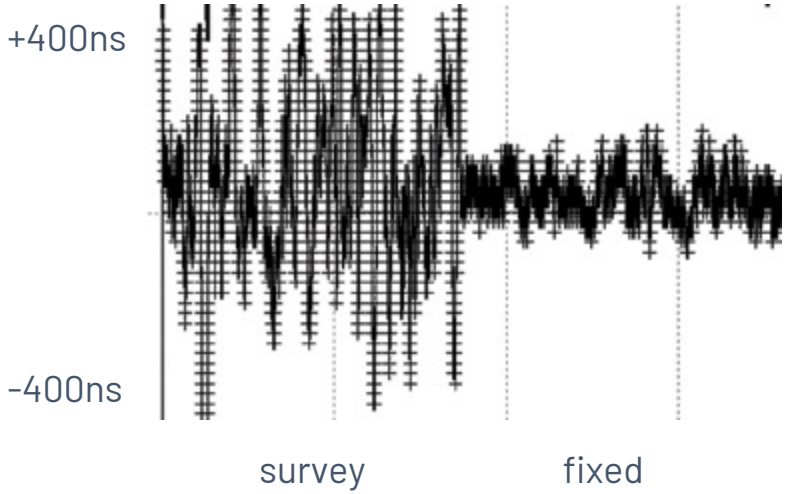
Solution #1-C: SynchroSense: compact, all-in-one design

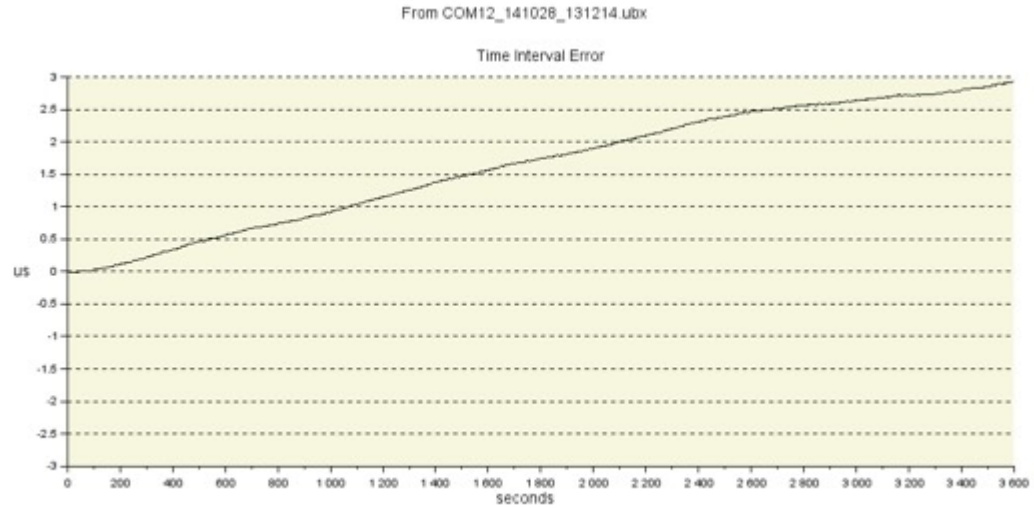
SynchroSense (PMU) + GPS/4G antenna

Clamp-on current sensors

Challenge #2: Limited sky visibility for GPS synchronization in congested urban environments

Solution #2-A: Multi-constellation GNSS receiver with stable clock for reliable free-running operations





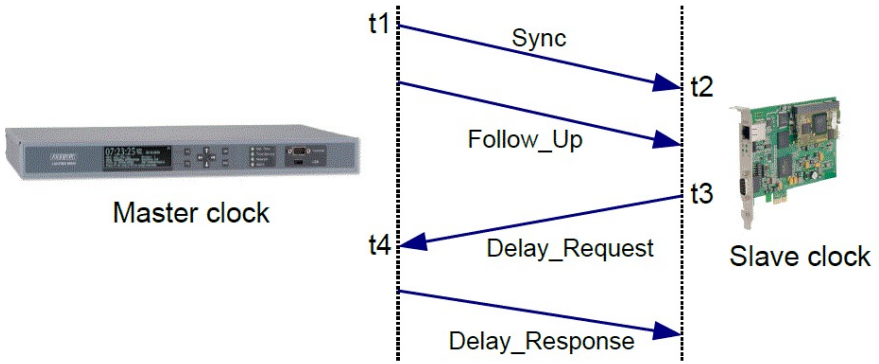
- Weak-signal start-up with aiding and single satellite capability support severe signal environments
- Survey-in provides error-free, self-determination of fixed position
- Fixed-position mode offers timing stability even in poor signal conditions

- <3 microseconds 1-hour internal oscillator holdover (lab measurement)
- Relibale free runnign operations also in temporary absence of GNSS satellites

Solution #2-B: Wide area PTP synchronization

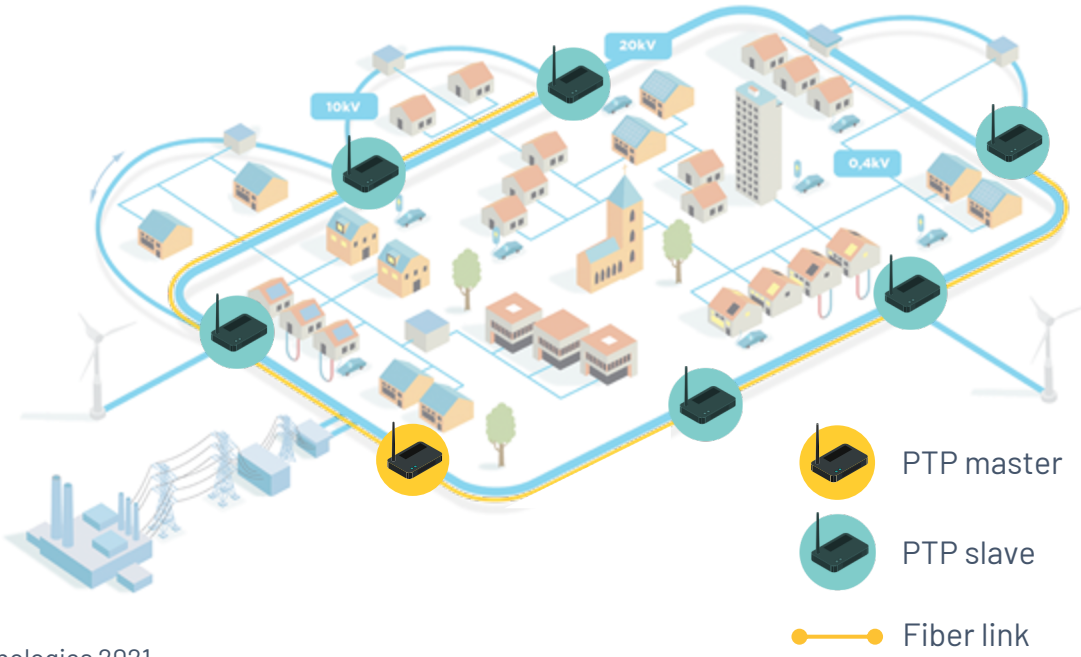
Precision Time Protocol (PTP)

- Protocol used to synchronize clocks throughout a computer network (IEEE 1588)
- Master-slave synchronization scheme (automatic master selection)
- Devices share synchronization packets to calculate propagation/internal delay and adjust/steer their internal clocks to stay in sync



Wide area PTP synchronization

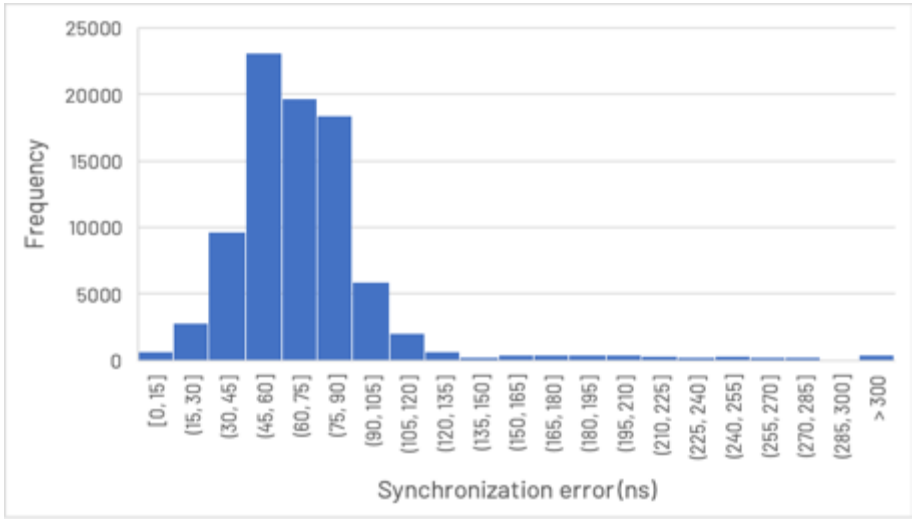
- Requires availaybility of fiber network
- Single GNSS-referenced clock (master)
- Simplified installation
- Increased timing reliability

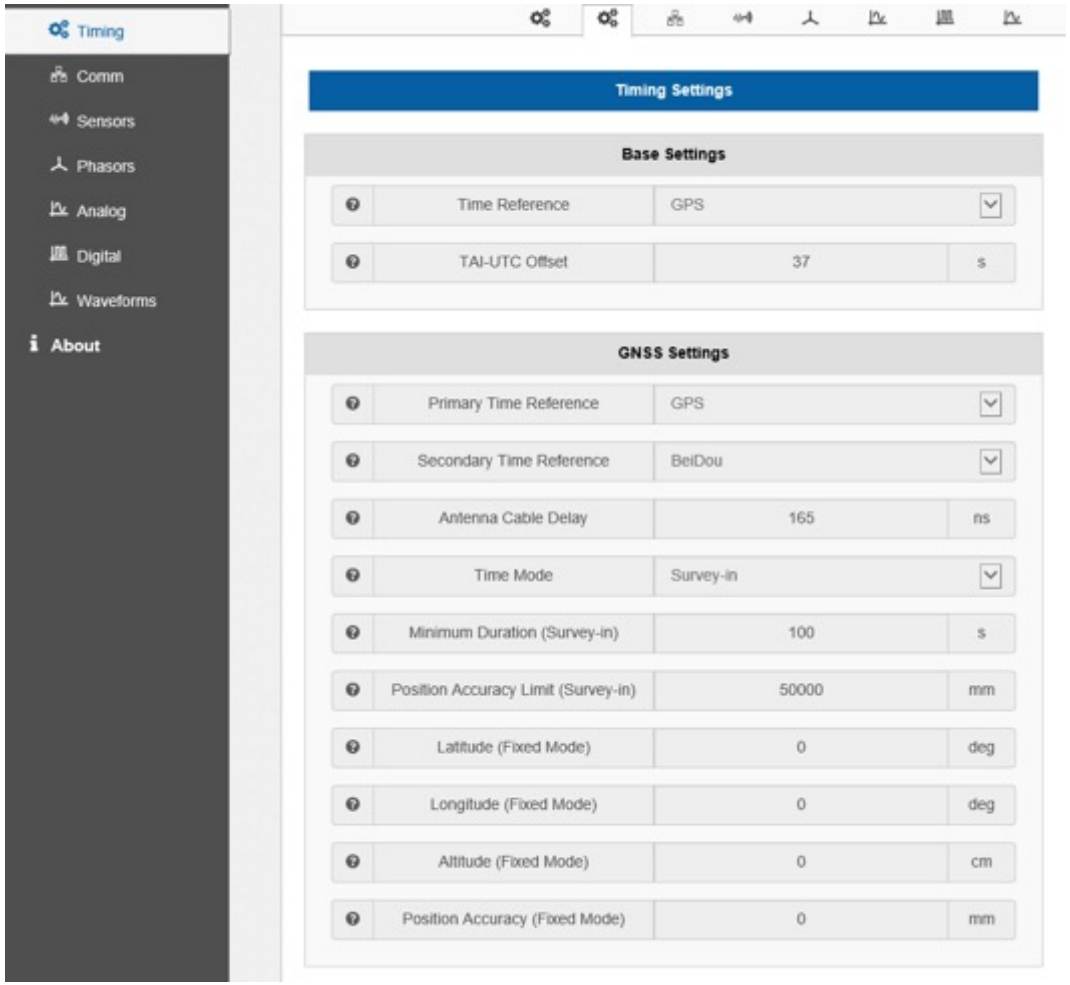


Solution #2-B: Wide area PTP synchronization

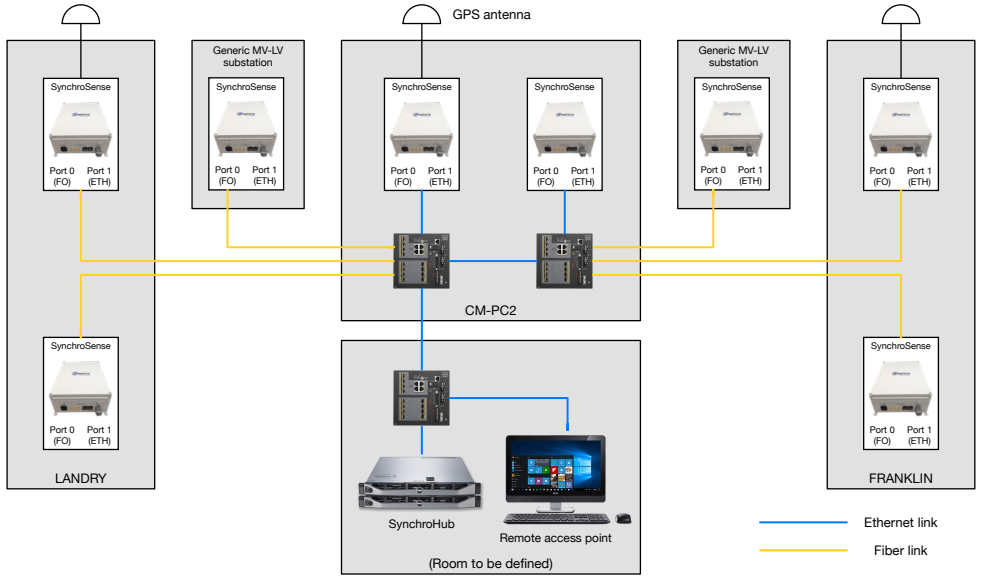
SynchroSense PTP features:

- Fully compatible with IEEE 1588 default PTP profile
- User selectable PTP master/salve functionality
  - PTP master: dissemination of internal time, optionally synchronized to internal GNSS receiver
- Synchronization error: <1 us, unaffected by distance





Solution #2-B: Wide area PTP synchronization



<u>The EPFL campus micro-grid:</u>

- 2 primary substations (50-20 kV)
- 45 secondary substations (20 kV – 400 V)
- >16km of MV underground cables
- Pervasive fiber installation

<u>System architecture:</u>

- 51 SynchroSense devices
  - 3 PTP grandmaster
  - 48 PTP slave
- Fiber infrastructure used for both time-dissemination and real-time data communication

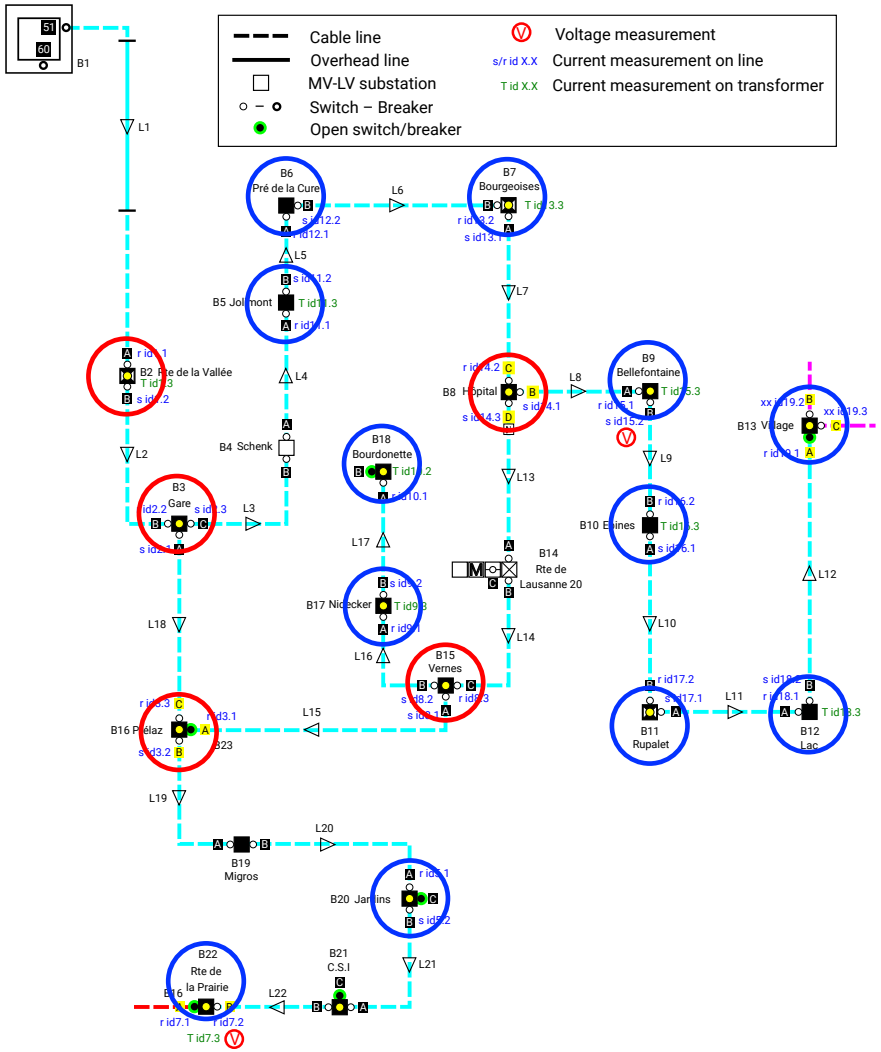
Challenge #3: Limited amount of measurement points

Most DSOs manage 1000s of distribution (MV-LV) substations…

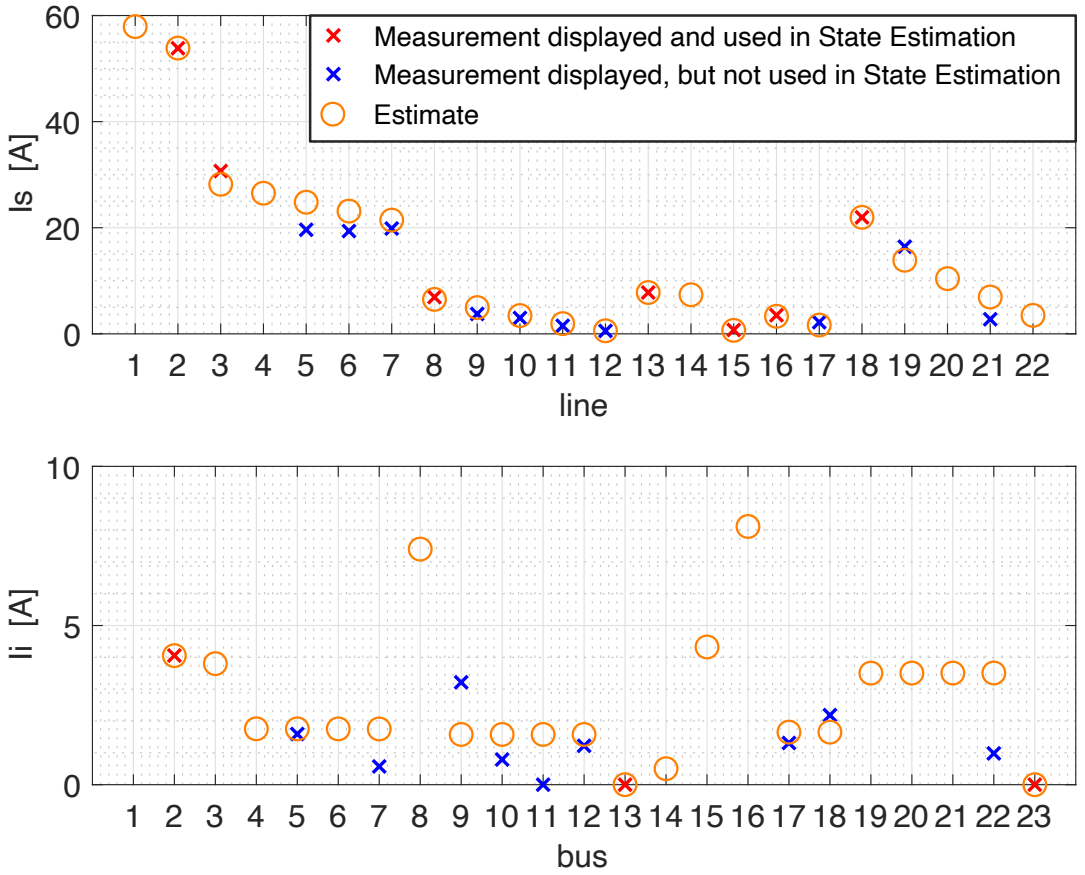
BUT

…they typically have a limited budget that only allows to instrument 5-10% of them with IEDs

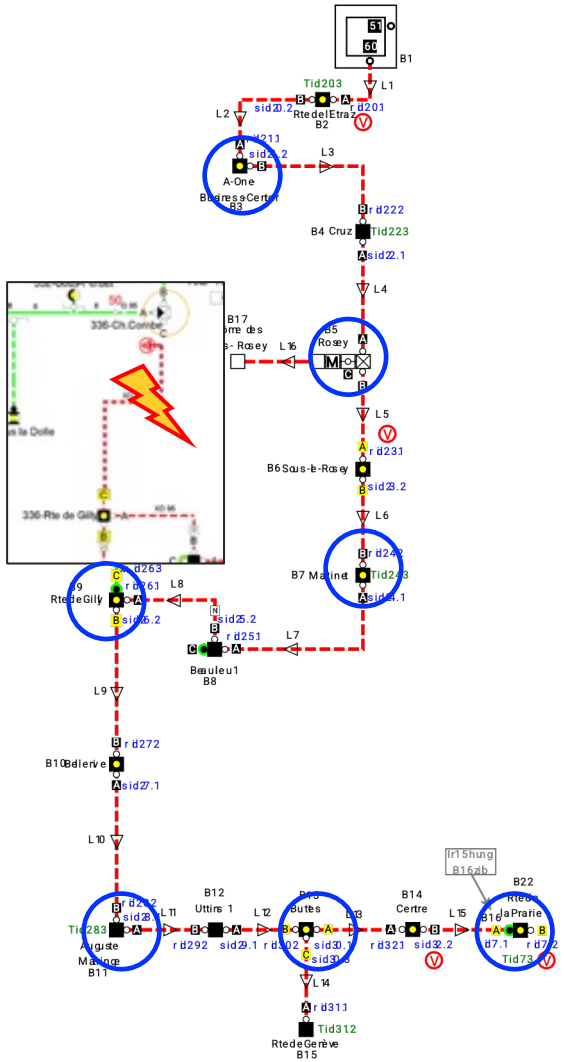
Solution #4-A: Develop software solutions relying on limited amount of measurement points



State estimation results (20% coverage)



Solution #4-A: Develop software solutions relying on limited amount of measurement points



Zaphiro PMU-based fault locator features:

- Location of single/multi-phase faults as well as high-impedance or intermittent faults with currents as low as few Amperes
- Not affected by network topology, neutral treatement or presence of distributed generation

Working principles:

- Faulted area identification: 100% reliability, accuracy depends on meas. placement
- Fault distance calculation: accuracy depends on meas. accuracy and placement

Conclusions

- → There is a huge opportunity for PMUs in the distribution network, mainly driven by the clean energy transition and more demanding regulations on the quality of the power supply
- → The adoption of the synchrophasor technology by DSOs requires re-tinking the concept of PMU hardware/software according to a different set of use cases and operational conditions
- → Zaphiro Technologies offers a turnkey solution based on proprietary PMU technology and software platform that is able to leverage syncvhrophasor measurements to tackle multiple use cases at the same time.
- → The interaction between academia, industry and power utilities is crucial to allow the development development of innovative hardware and software solutions able to address current and future challenges of DSOs

Unlock your grid potential!

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They support us:

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