Micro-synchrophasors (µPMUs) for Distribution Systems

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Three-year, $4M ARPA-E project starting March 1, 2013

Research partners CIEE, UC Berkeley, LBNL, Power Standards Lab

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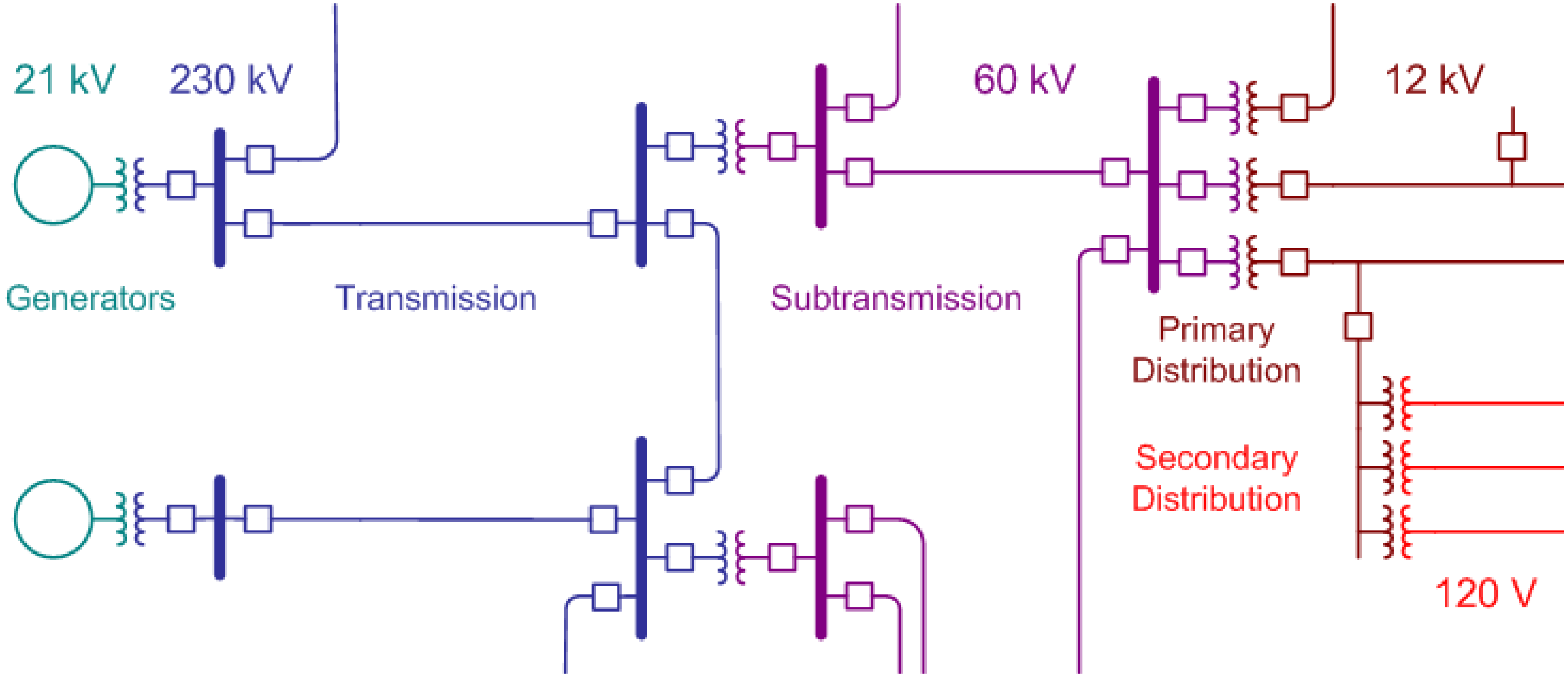
Distribution vs. transmission
Important differences:

- architecture
- diversity
- time variation
- vulnerability
- opacity

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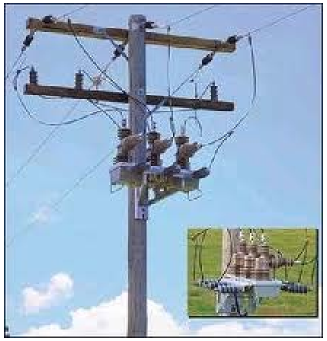
Why PMUs mostly on transmission, not distribution?

- cost / value proposition
- more challenging measurements – fractions of a degree
- historically, no need:
  - unidirectional power flow, from substation to load
  - unquestioned stability of distribution system

  but this is changing…



µPMU concept – Power Standards Lab

- very low cost: piggy-back on existing distribution instrument, PQube
- allows sync with disturbance recordings
- local data storage on SD card as low-cost backup
- µPMU can connect to single- or 3-phase, secondary distribution or substation PT

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µPMU concept – Power Standards Lab

- higher resolution than conventional PMUs: aiming for < 0.05°
- 512 samples per cycle
- phase-locked sampling for power quality measure-ments, and time-based sampling for synchronized measurements

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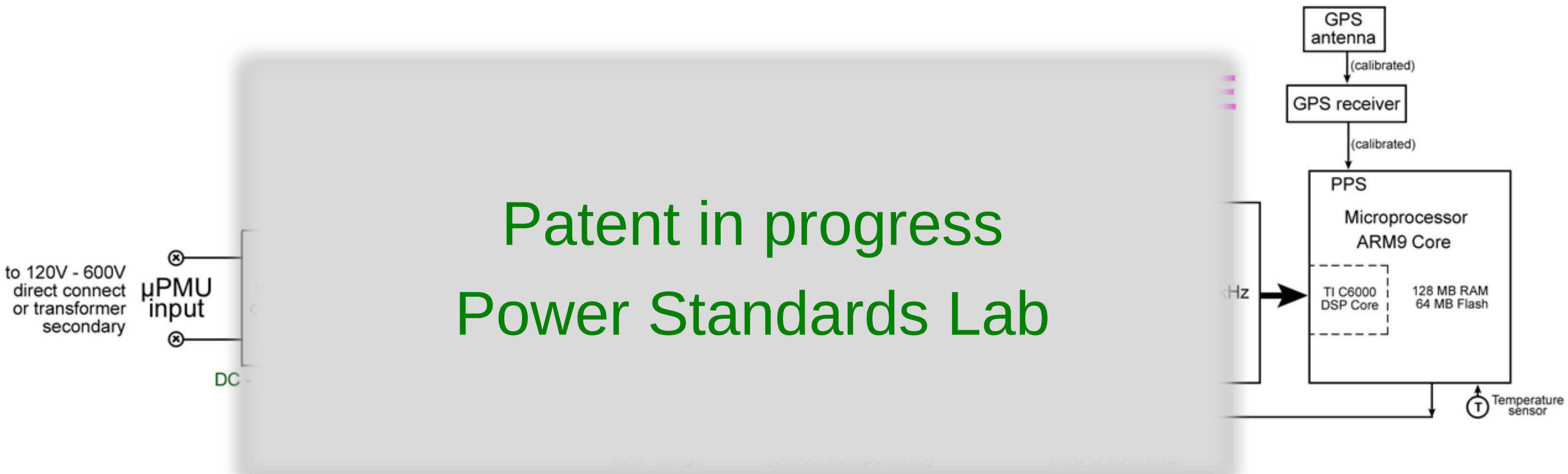
Traditional PMU, optimized for transmission system

Partial schematic, showing analog path for typical ±1° angle resolution



Proposed μPMU, optimized for distribution system

Partial schematic, showing analog path for precision ±0.01° angle resolution

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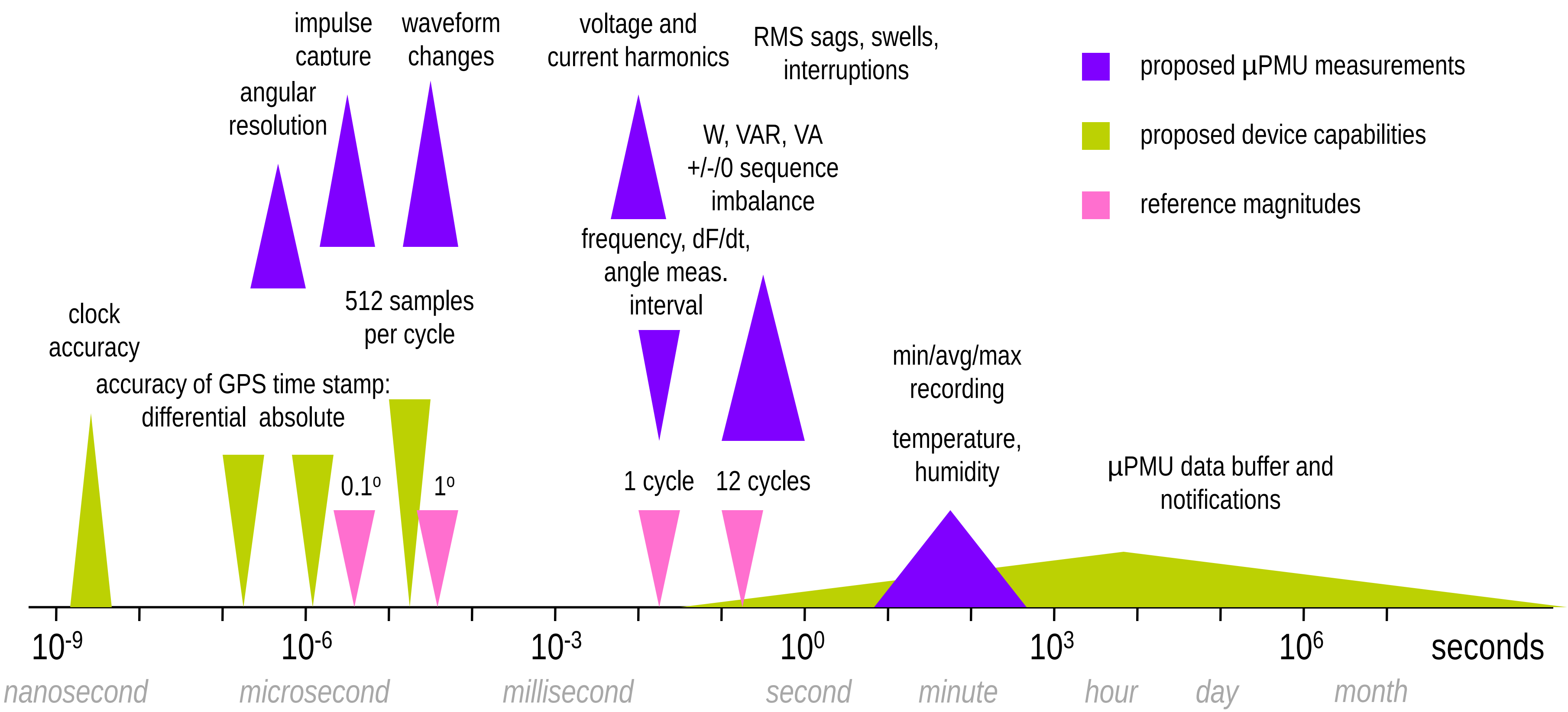
μPMU concept



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Some interesting problems at the micro-scale

- Need to separate signal from noise

  Combine phase angle and frequency with info about disturbances, harmonics, lightning strikes…

- Need sampling rate consistent with frequency of phenomena to be observed

  Find angular sampling rate required to observe relevant behavior on the scale of inverter control loops (> 10 kHz)

- How to define “frequency” and “phase angle” when signal < single cycle?
- Need to account for signal latencies everywhere
- What do you mean by “real time”?

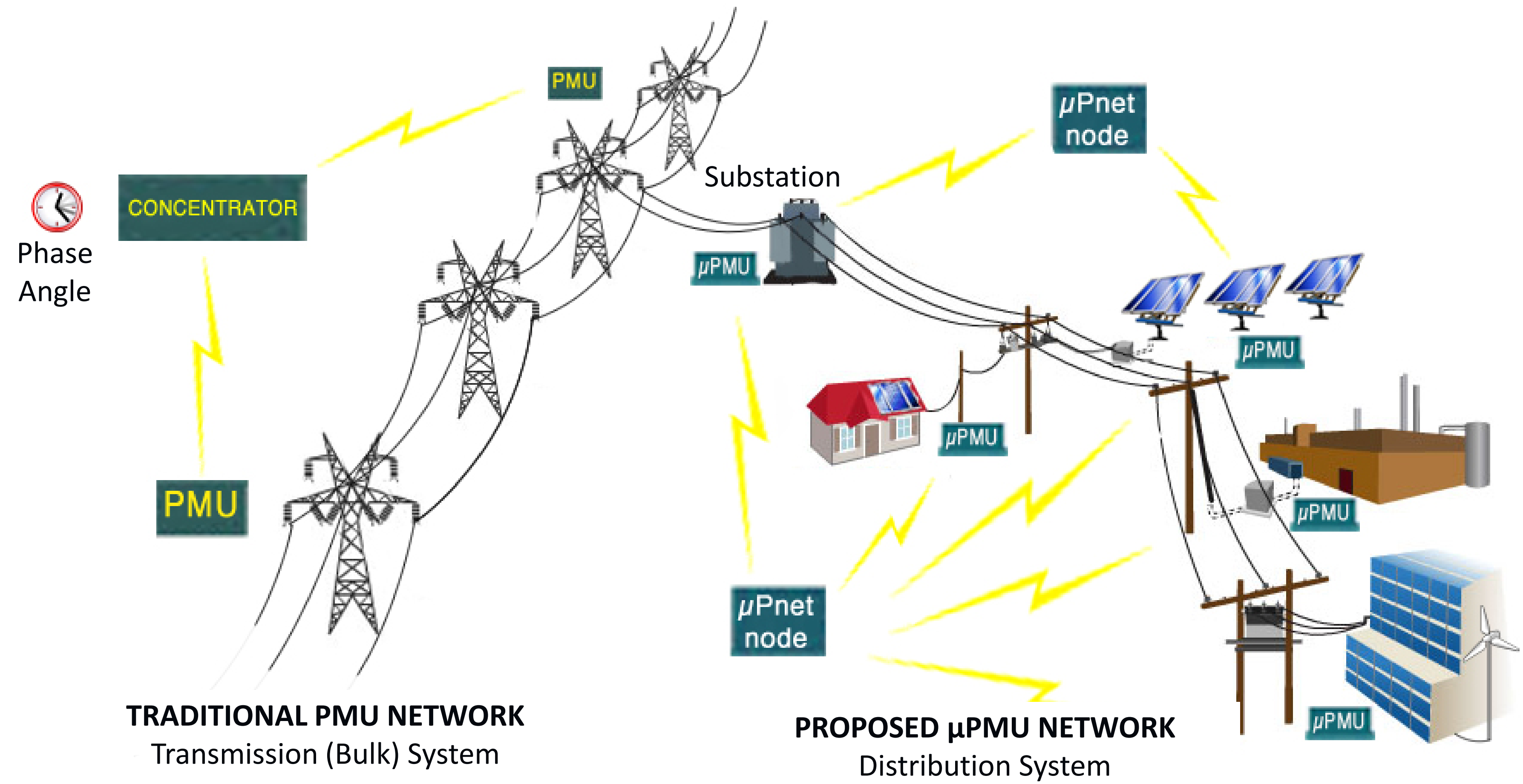
ARPA-E Research Project Plan

- Validate µPMU performance
- Develop µPnet:

  implement communications, data analysis based on sMAP

  (simple Measurement and Actuation Profile, developed by UC Berkeley)
- Install on selected distribution feeders to make first empirical observations of voltage angle at very high resolution
- Study the promise of voltage angle as a state variable
- Examine diagnostic and control applications for µPMU data

µPMU concept



Possible diagnostic applications for µPMU data:

- island detection
- oscillation detection
- characterization of inertia
- FIDVR diagnosis
- fault location, protective relaying

Possible control applications:

- Volt-VAR optimization
- microgrid coordination
- seamless intentional islanding and re-synchronization of microgrids
- creative recruitment of distributed resources for ancillary services

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Applications will have different requirements for

- **measurement accuracy**
- **communication speed**
- **data transfer rate**
- **data continuity**

We plan to identify these requirements

(and hope to meet them)

...but for starters,
we don't even know:

What are we
going to see?

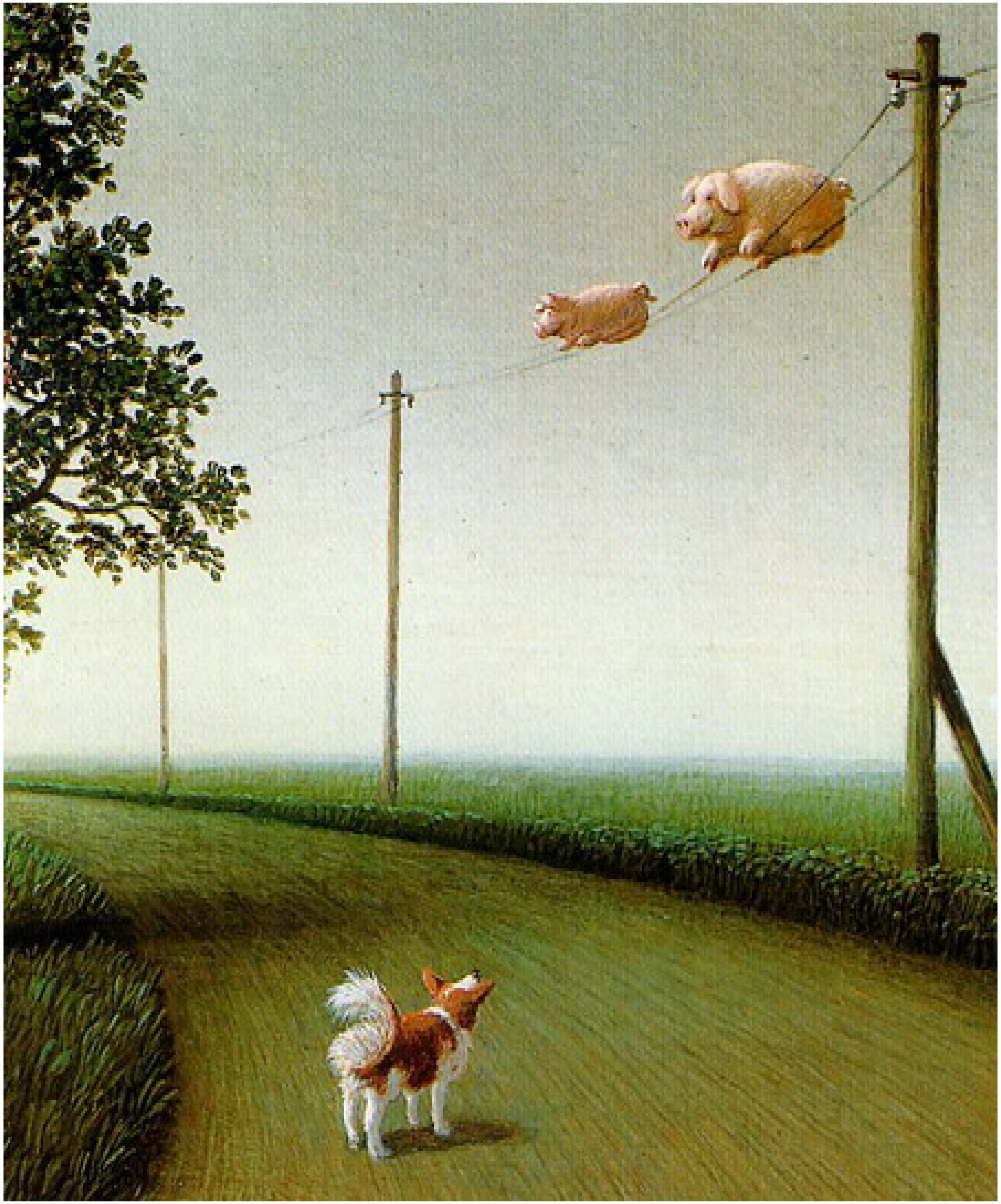


Illustration: Michael Sowa

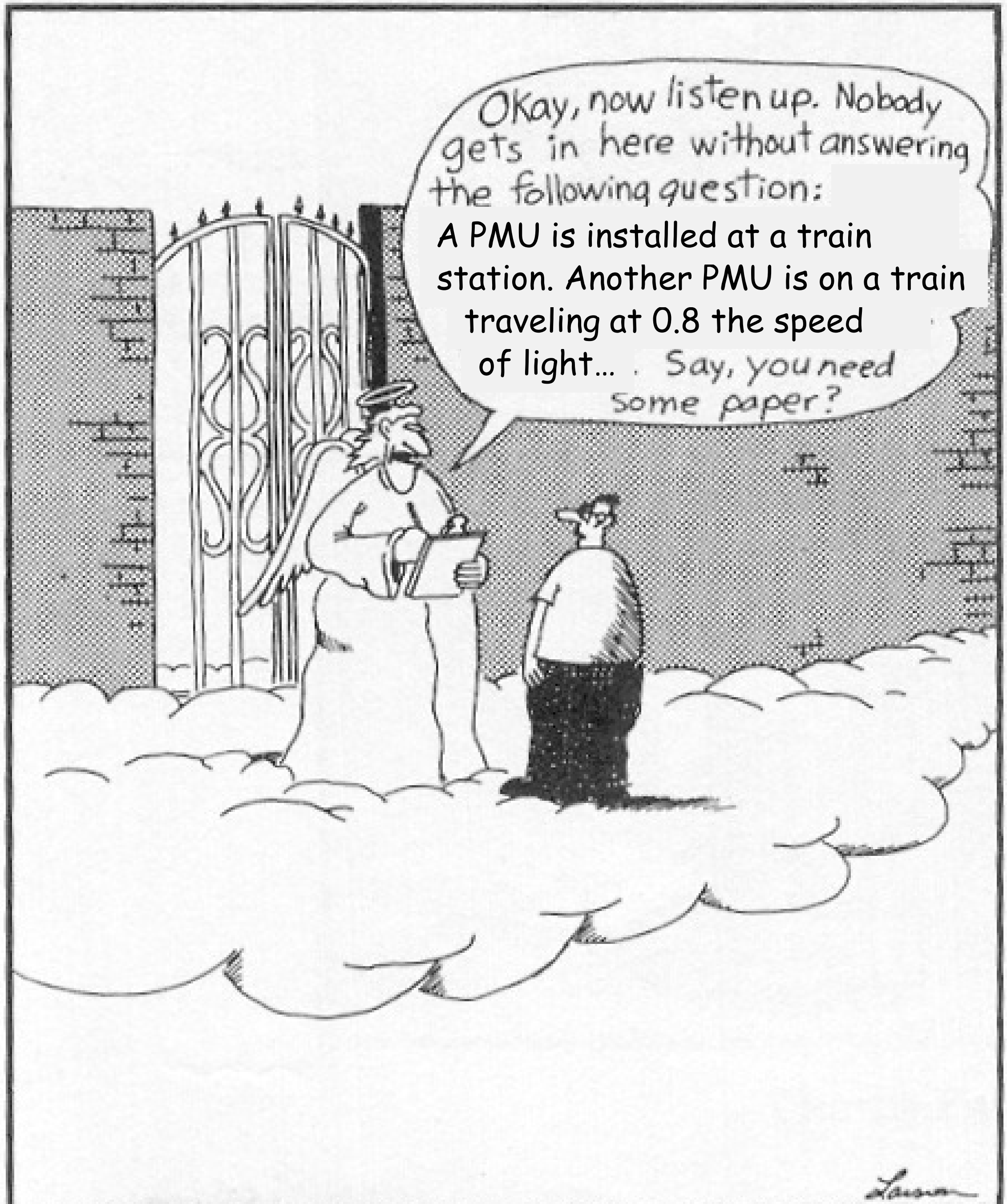
What are we going to see?

Things that matter in a world with lots of distributed resources? *(We think, probably yes.)*

- Power flow direction
- Rapid changes in voltage or power flow - transients
- Oscillations, stability issues?
- How inverters interact with the legacy grid?
- Nothing interesting?

"If we knew what we're doing,

it wouldn't be called research."



Math phobic's nightmare