AI on the Grid

An NI4AI Workshop

October 21, 2020

Course Overview

- Day 1 of 2 day course
  - Day 1: PMU Fundamentals
  - Day 2: Intro to AI
- Logistics
  - Day 2 will use the NI4AI platform
  - Sign up for a login ni4ai.org
  - Q&A on www.slido.com
  - Event code #M053

Opening Remarks

This course is put on by an initiative called NI4AI

A **N**ational **I**nfrastructure for **AI** on the Grid

In addition to this workshop, NI4AI provides ...

- A data platform
- Open access data
- Skills development
- Collaboration opportunities
- Research ideas
- Panel discussions
- Coding challenges
- Hackathons
- Research talks
- Blog posts

Subscribe for updates http://eepurl.com/he8jtj

Agenda

Day 1

Understanding PMU Data

Alexandra "Sascha" von Meier

(UC Berkeley)

Case Studies & Lessons Learned

Kevin Jones

(Dominion Energy)

Get Practice and Learn More

Laurel Dunn

(NI4AI)

Day 2

Big Data & Prediction

Sean Patrick Murphy

(PingThings)

Interfacing with Sensor Data

Chris Ryan

(PingThings)

Use Cases & Analytics

Mohini Bariya and Miles Rusch

(UC Berkeley)

Understanding PMU data

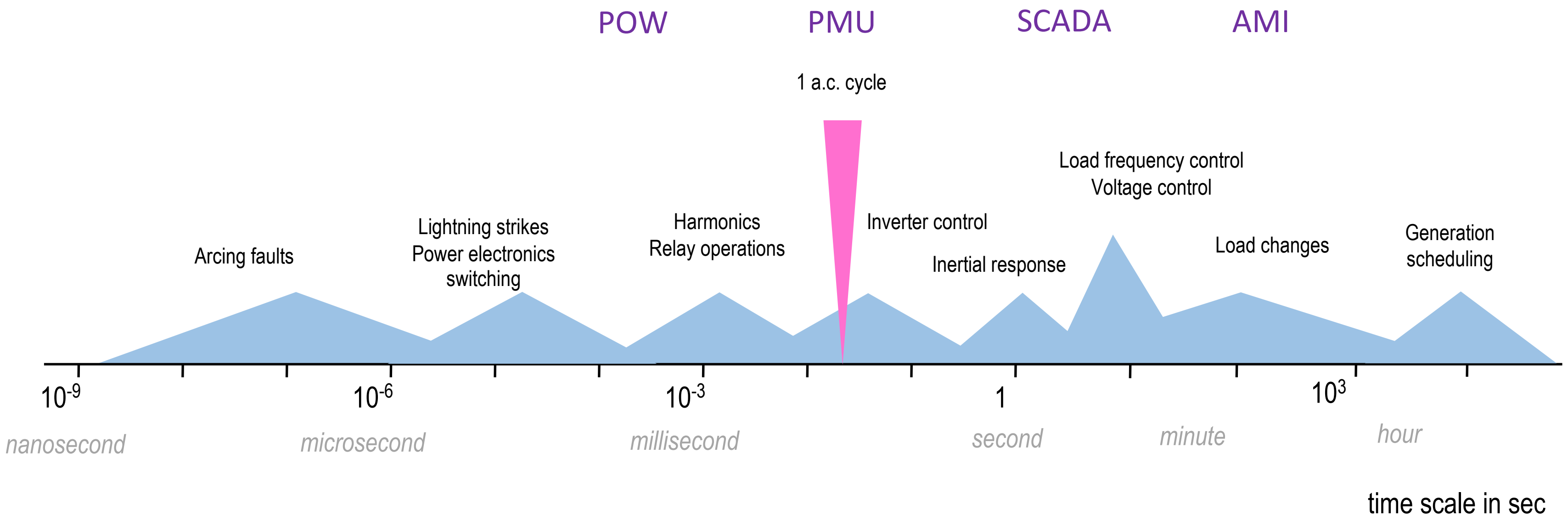
Alexandra "Sascha" von Meier
UC Berkeley

Types of grid measurement data

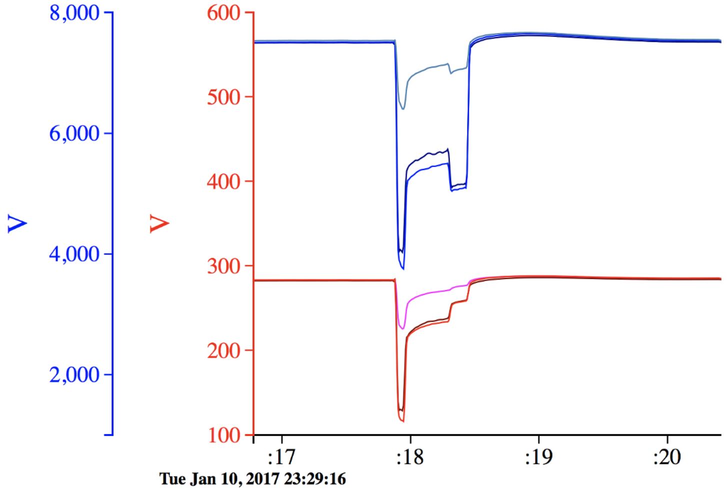
Advanced Metering Infrastructure (AMI)	*kW and kWh consumption at customer meters, typically reported at 15-min resolution*
Supervisory Control and Data Acquisition (SCADA)	*Voltage or current magnitudes, reported at resolution on the order of several seconds*
Phasor Measurement Units (PMUs)	*Voltage or current magnitudes and phase angles, frequency and derivative quantities, reported roughly each cycle (25-120 Hz)*
Event-triggered Point-on-Wave (POW) Continuous Point-on-Wave (CPOW)	*256 to 1 million samples/sec of voltage or current waveform, reported for a short duration or on a continuous monitoring basis*

For more, see: A. Silverstein and J. Follum: High-Resolution, Time-Synchronized Grid Monitoring Devices
https://naspi.org/sites/default/files/reference_documents/pnnl_29770_naspi_hires_synch_grid_devices_20200320.pdf

Time scales for electric grid events and control



Example: High-resolution voltage magnitude measurements in distribution systems



Voltage magnitudes on three phases, reported by micro-PMUs at 120 Hz
Blue: Berkeley, CA, Red: Alameda, CA
(ca. 20 km away via 115kV transmission)

Use case examples

Identify high-impedance faults

Diagnose PV inverter trips

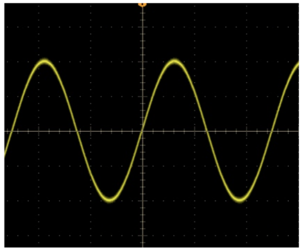
Determine connectivity by correlation:

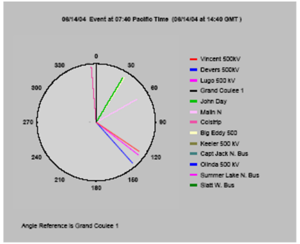
- *ABC phase*
- *open/closed switch status*

Phasor Measurement Data
a.k.a. Synchrophasors

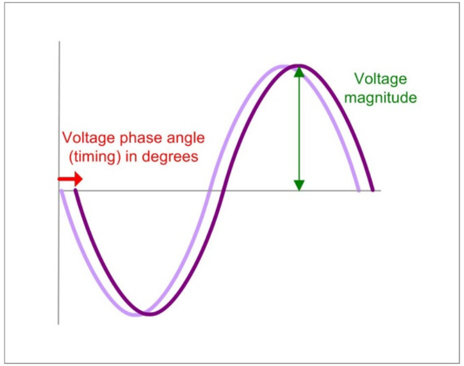
Phasor measurements of alternating current or voltage quantities give an abstract image of what is happening physically, based on an implicit model.

The phasor representation is synthesized from (many) raw analog measurements in a lossy compression algorithm.





Time Domain vs. Phasor Domain

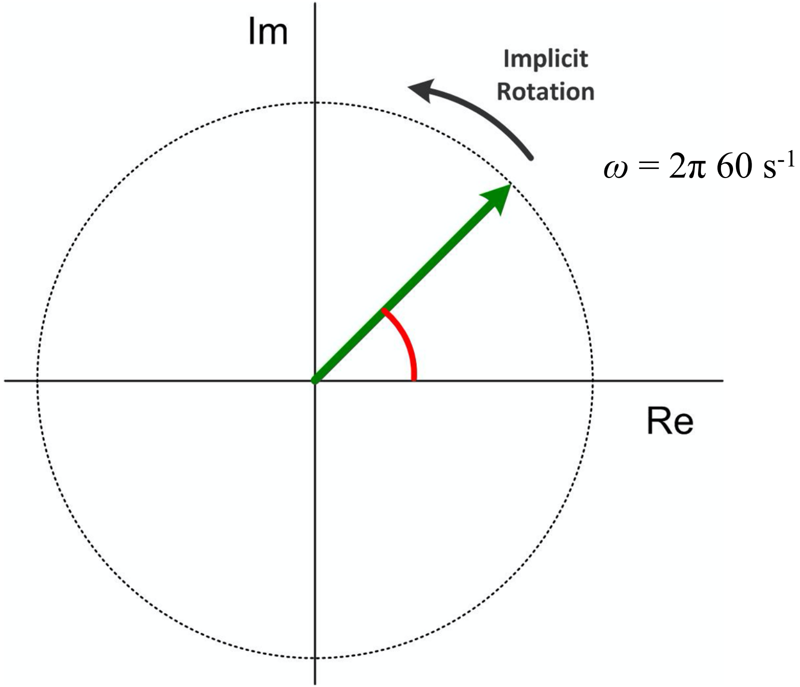


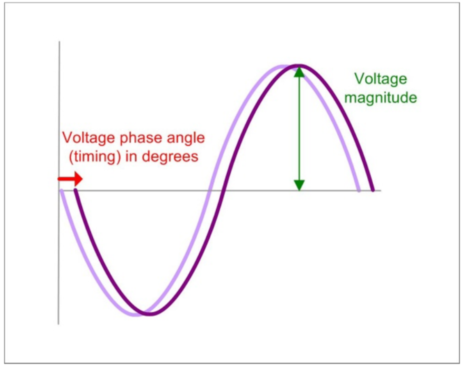
The sinusoidal function in the time domain

$$v(t) = V_{max} \cos (\omega t + \phi)$$

is written as the phasor

$$\boldsymbol{V} = |V|\, e^{j\phi}$$





Getting to Phasor Notation

We assume a waveform is represented by a pure sinusoid:

$$v(t) = V_{max} \cos\ (\omega t + \phi)$$

Now we imagine that we are looking at the real part of a complex quantity

$$v(t) = Re\{\mathbf{v}(t)\}$$

where

$$\mathbf{v}(t) = \cos(\omega t + \phi) + j\sin(\omega t + \phi)$$

$$e^{jx} = \cos x + j \sin x$$

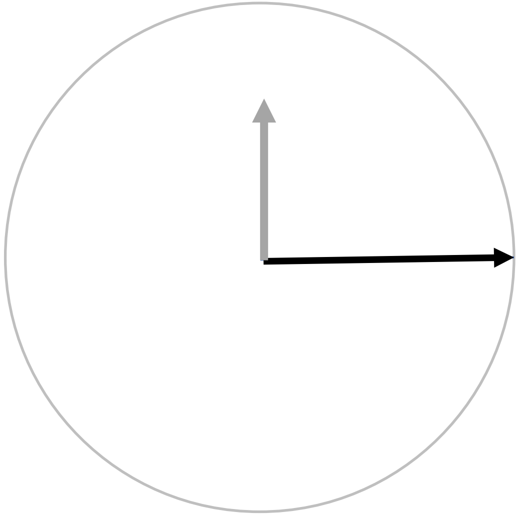
Using Euler's equation,
we format this as a complex exponential:

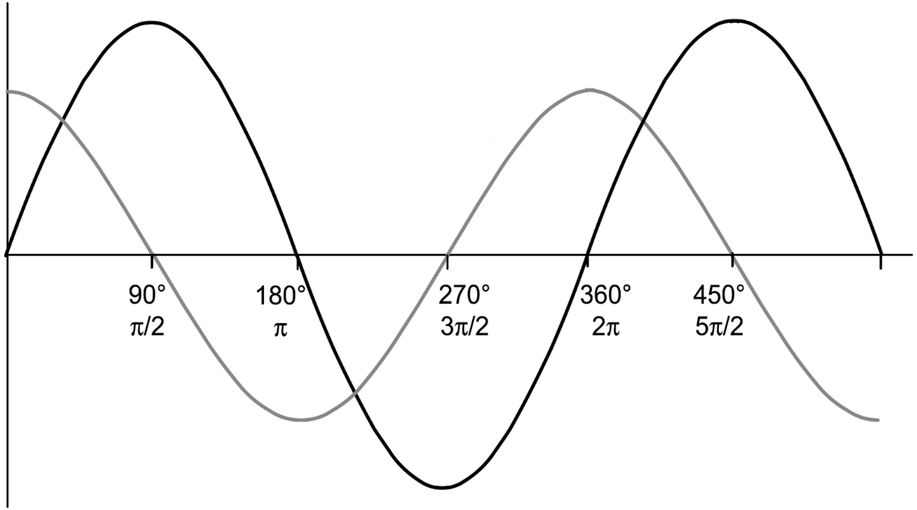
$$v(t) = Re\{V_{max}\ e^{j(\omega t+\phi)}\} = Re\{V_{max}\ e^{j\omega t} e^{j\phi}\}$$

For steady-state analysis, assuming we already know everything about frequency, we discard the "rotating phasor" and keep only the "stationary" exponential term with the phase angle:

$$v(t) = \cos(\omega t + \phi) \Rightarrow \mathbf{V} = V_{rms}\ e^{j\phi} = V_{rms} \angle \phi$$

Finally, in power engineering convention, we use the root-mean-square (rms) magnitude instead of the amplitude.

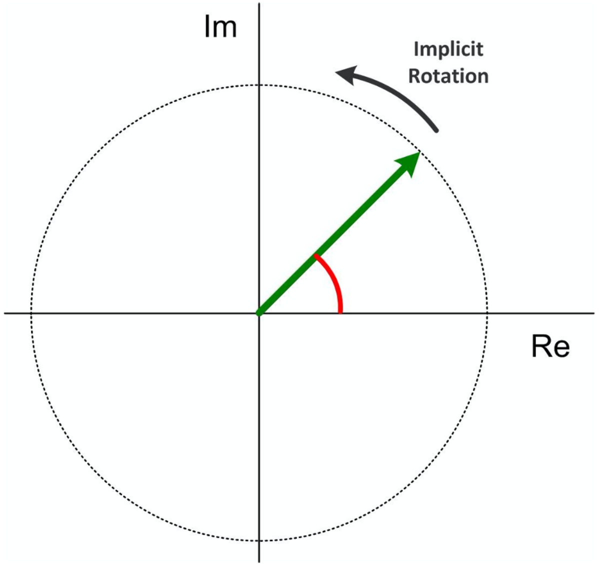




Displaying waves as a phasor snapshot in time allows easy comparison – assuming everything is at the same frequency!

$$v_1(t) \;=\; V_{1,max}\;\cos(\omega t + \phi_1)$$

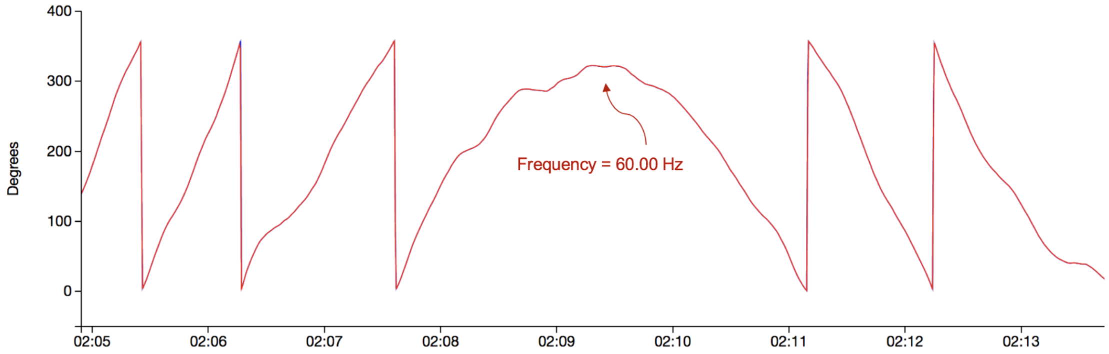
$$v_2(t) \;=\; V_{2,max}\;\cos(\omega t + \phi_2)$$

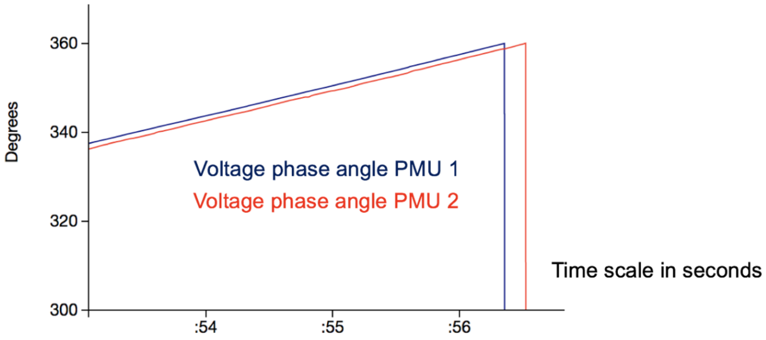


Measuring relative to a GPS clock, if the a.c. frequency is not exactly constant at 60.000 Hz, we will see the phase angle from a single measurement increasing and decreasing over time, wrapping around from +360 or -360 to 0^o

In the steady state, phasors have physical meaning only as a difference between two locations.

Phasors on time-series display

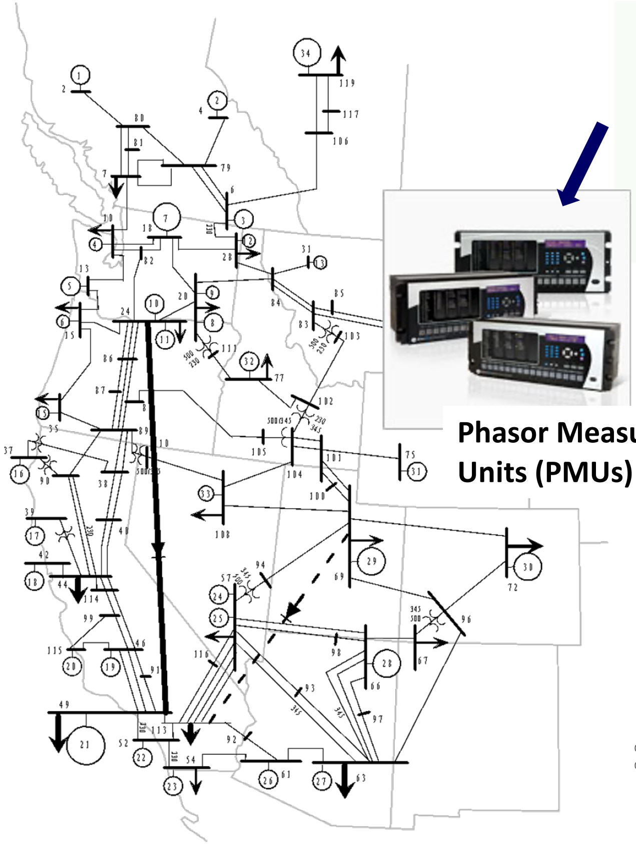




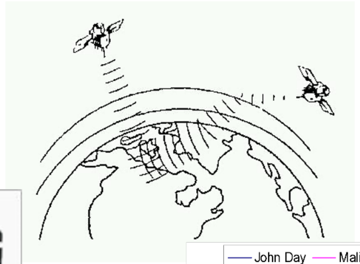
Measuring relative to a GPS clock, if the a.c. frequency is not exactly constant at 60.000 Hz, we will see the phase angle from a single measurement increasing and decreasing over time, wrapping around from +360 or -360 to 0°

In the steady state, phasors have physical meaning only as a difference between two locations.

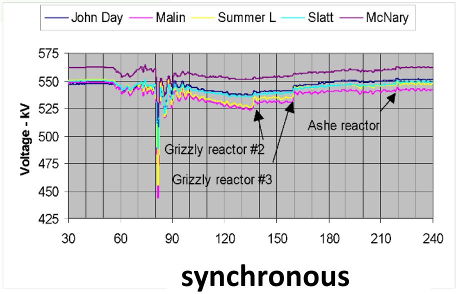
The need for synchronization



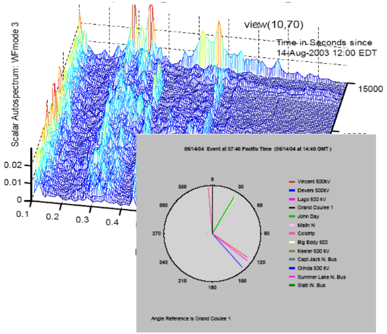
Phasor Measurement Units (PMUs)



Crucial piece of technology: shared time reference

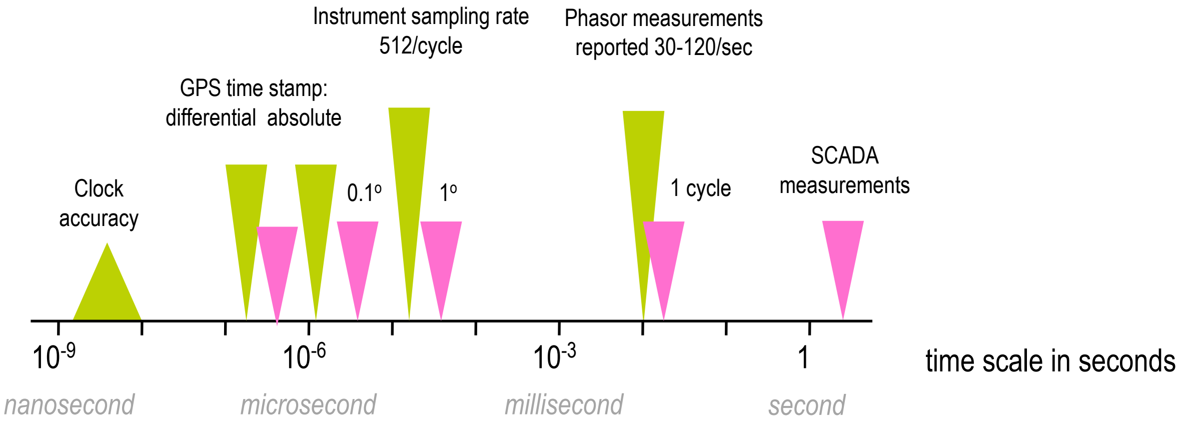


synchronous data



useful real-time information for system operators

Time resolution for PMU measurements



at 60 Hz *1 cycle ≈ 0.016 sec*

0.1° ≈ 4.6 μs

Describing phasor accuracy (or precision)

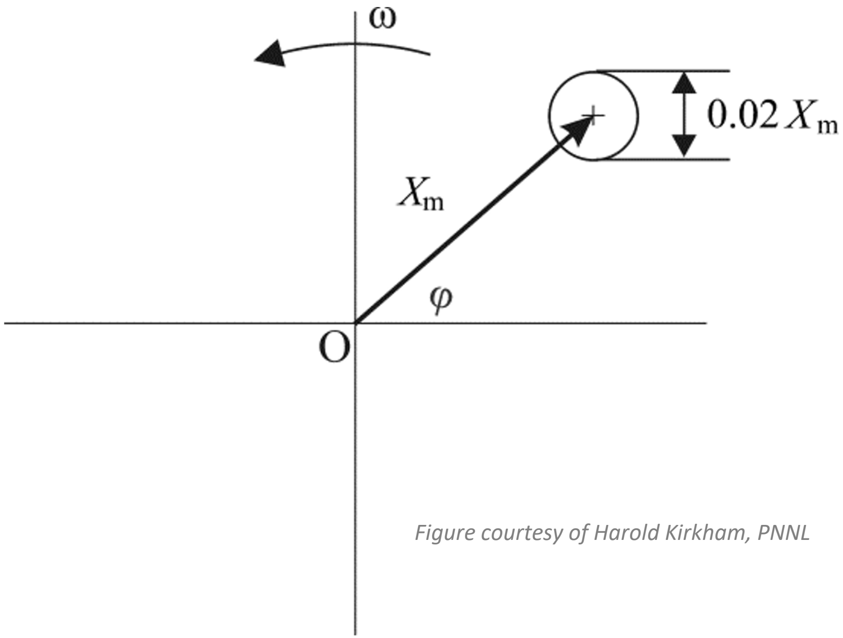


Figure courtesy of Harold Kirkham, PNNL

Standard performance criterion for PMUs in the transmission system:

Total Vector Error (TVE)

±1% of magnitude, projected as the radius of a circle

Total Vector Error: A Closer Look

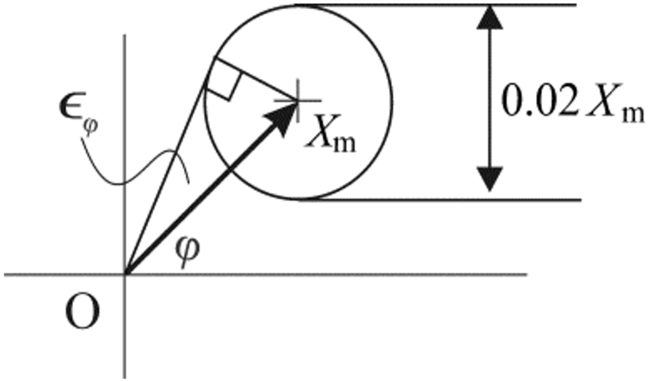


Figure courtesy of Harold Kirkham, PNNL

Standard performance criterion for PMUs in the transmission system:

±1% of magnitude, projected as the radius of a circle

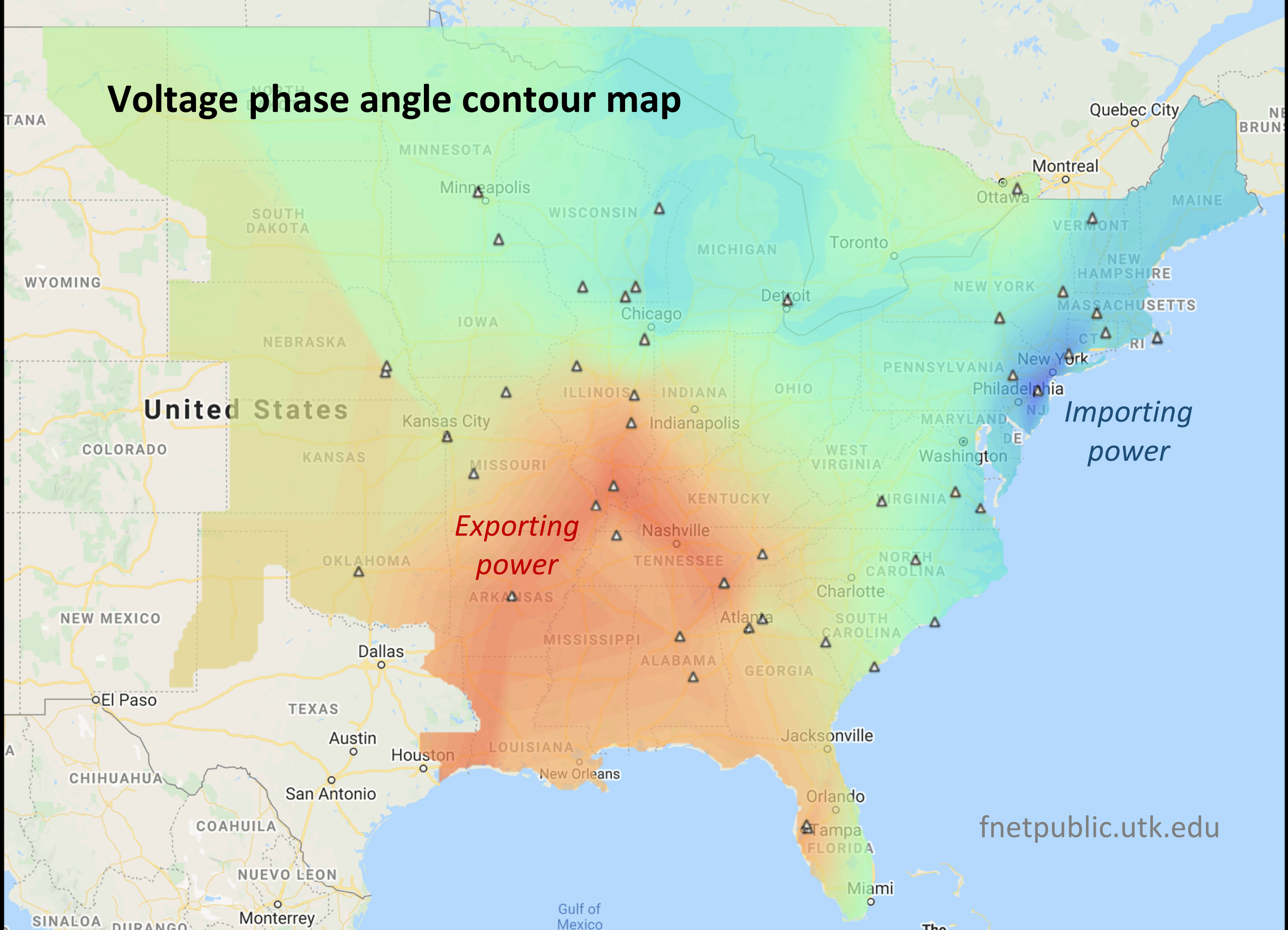
$$\epsilon_\varphi = \sin^{-1}\left(\frac{1}{100}\right) = 0.573°$$

Note: transmission-grade PMUs cannot resolve steady-state voltage phase angle differences in small distribution systems.

Building some physical intuition

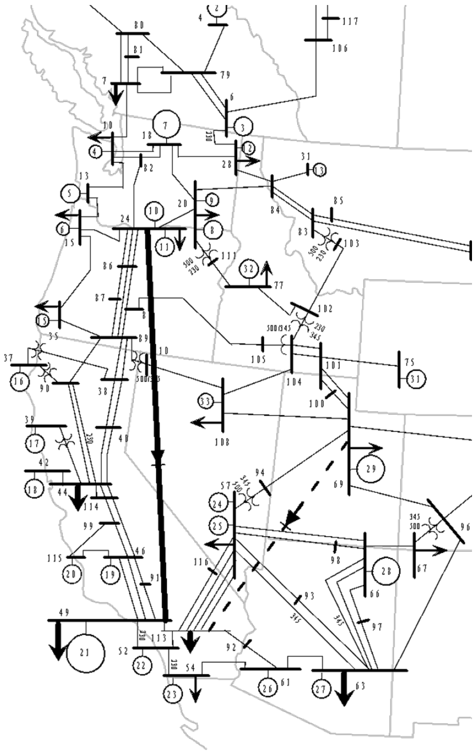
- AC frequency is (approximately) the same everywhere across a synchronous grid
- Synchronicity comes from rotating machines, electromagnetically coupled
- Imbalances in power generation vs. load make system frequency increase or decrease
- Local power injection or withdrawal can be visualized like a twist on a common rotating shaft
- Torque or twist drives power across the common shaft, analogous to voltage phase angle

Voltage phasor differences drive power flow across the grid



Voltage phase angle contour map
Exporting power
Importing power
fnetpublic.utk.edu
MINNESOTA
Minneapolis
WISCONSIN
SOUTH DAKOTA
MICHIGAN
Toronto
Ottawa
Montreal
Quebec City
MAINE
VERMONT
NEW HAMPSHIRE
NEW YORK
MASSACHUSETTS
CT
RI
New York
PENNSYLVANIA
Philadelphia
NJ
MARYLAND
DE
Washington
WYOMING
NEBRASKA
IOWA
Chicago
Detroit
United States
ILLINOIS
INDIANA
OHIO
Indianapolis
Kansas City
COLORADO
KANSAS
MISSOURI
WEST VIRGINIA
KENTUCKY
VIRGINIA
Nashville
TENNESSEE
NORTH CAROLINA
OKLAHOMA
ARKANSAS
Charlotte
NEW MEXICO
Atlanta
SOUTH CAROLINA
MISSISSIPPI
ALABAMA
GEORGIA
Dallas
El Paso
TEXAS
Austin
Houston
LOUISIANA
New Orleans
Jacksonville
CHIHUAHUA
San Antonio
Orlando
Tampa
FLORIDA
COAHUILA
NUEVO LEON
Miami
SINALOA
DURANGO
Monterrey
Gulf of Mexico

Voltage phasors are the state variables for the power network



Real and reactive power P_i and Q_i at the i^{th} bus are determined by all the V's and δ's

$$P_i = \sum_{k=1}^{n} |V_i||V_k|[g_{ik}\cos(\delta_i - \delta_k) + b_{ik}\sin(\delta_i - \delta_k)]$$

conductance and susceptance of each branch

$$Q_i = \sum_{k=1}^{n} |V_i||V_k|[g_{ik}\sin(\delta_i - \delta_k) - b_{ik}\underbrace{\cos(\delta_i - \delta_k)}_{\text{voltage phase angle difference } \delta_{ik}}]$$

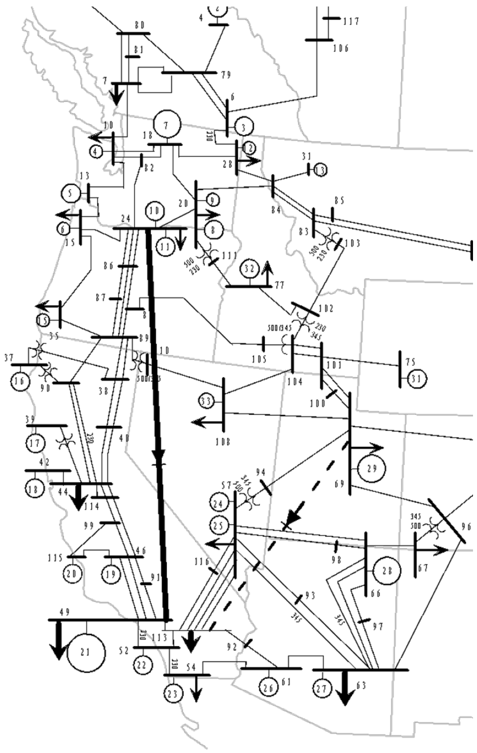
voltage magnitudes

voltage phase angle difference δ_{ik}

Power flow across the network is described by a profile of voltage phasors

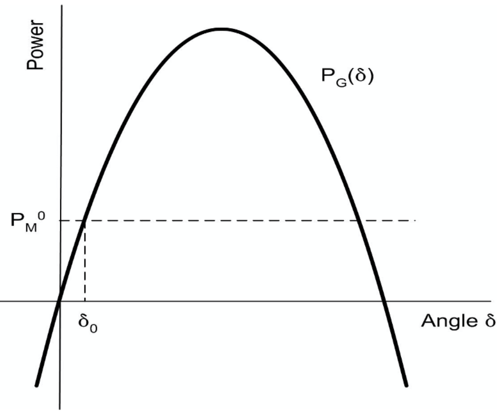
P depends more on δ , Q more on V

Voltage phasor differences drive power flow across the grid

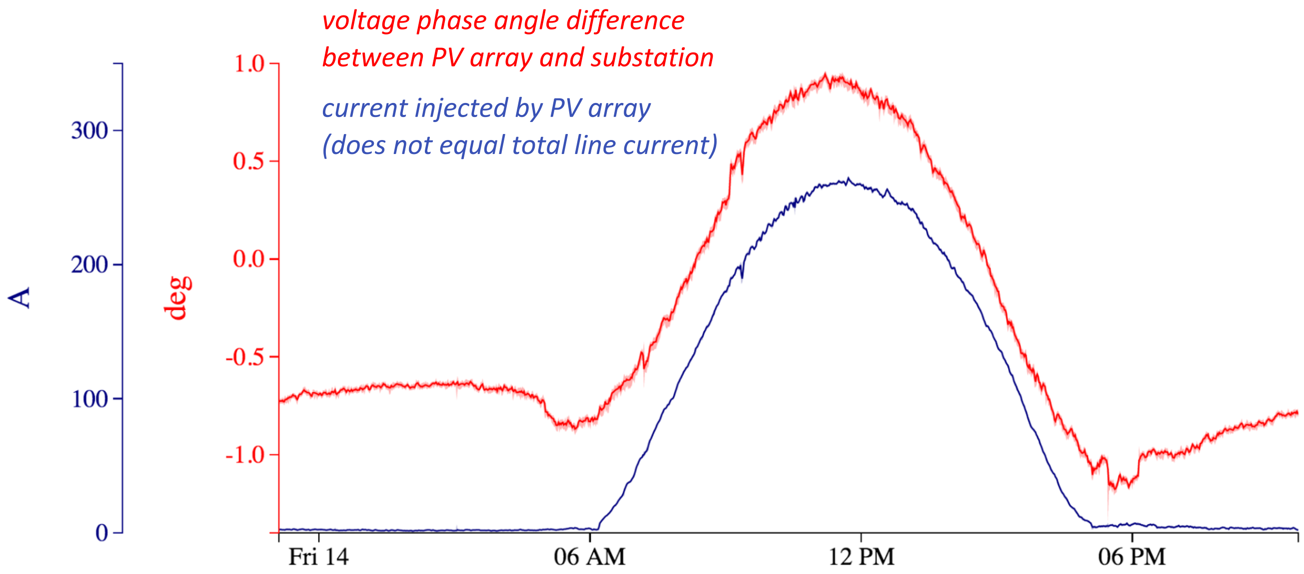


$$P_{12} \approx \frac{V_1 V_2}{X} \sin \delta_{12}$$

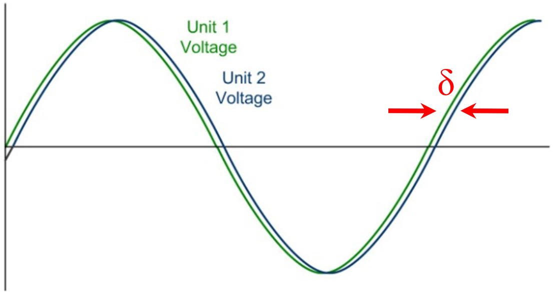
Distance (impedance) matters:
the farther you transmit a.c. power, the larger the voltage phase angle difference, and the more wobbly



Small-scale example: Voltage phase angle shift along a 12kV distribution circuit

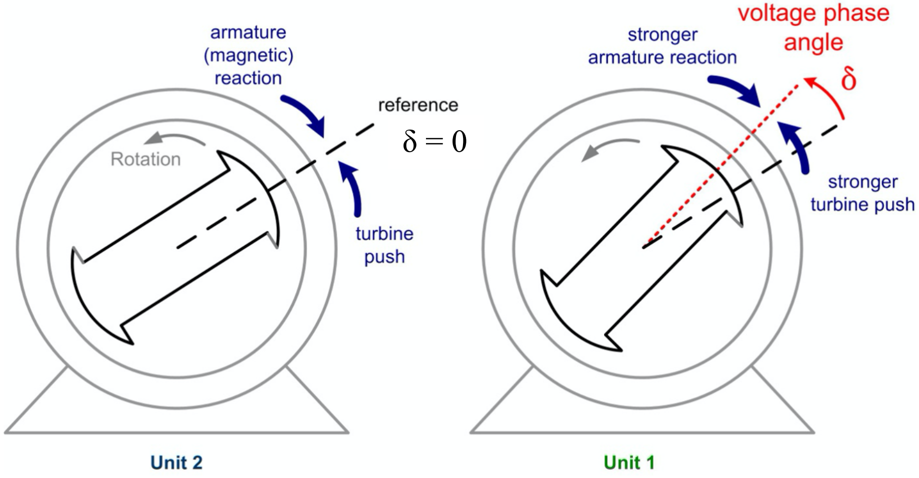


Voltage phasor differences drive power flow across the grid



The phase angle difference δ between locations drives a.c. power flow

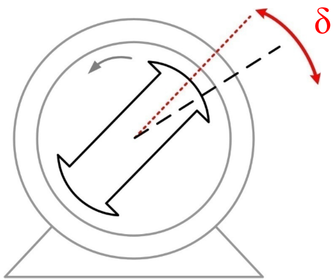
$$P_{12} \approx \frac{V_1 V_2}{X} \sin \delta_{12}$$

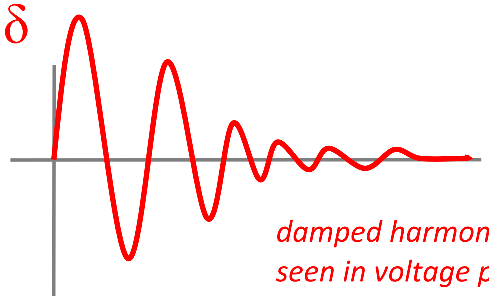


Power flows from Unit 1 toward Unit 2

Thinking about the physics of angle stability

- Power imbalance manifests as a change in angle δ and frequency ω
- Electromagnetic coupling provides negative feedback on rotor position: Power injected to the grid by a generator P_e is a function of δ
- Rotational inertia tends to hold ω steady



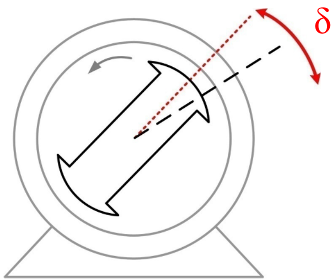


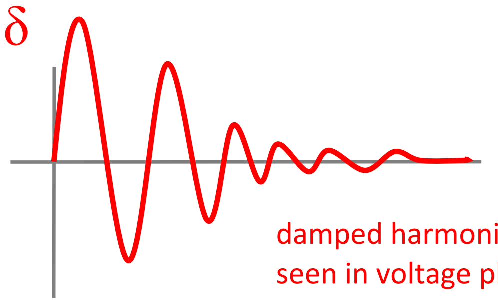
Generator swing equation

$$M\,\ddot{\delta} + D\,\dot{\delta} = P_m - P_e(\delta)$$

Thinking about the physics of angle stability

Voltage angle is a key variable, but it was not directly observable without PMUs!



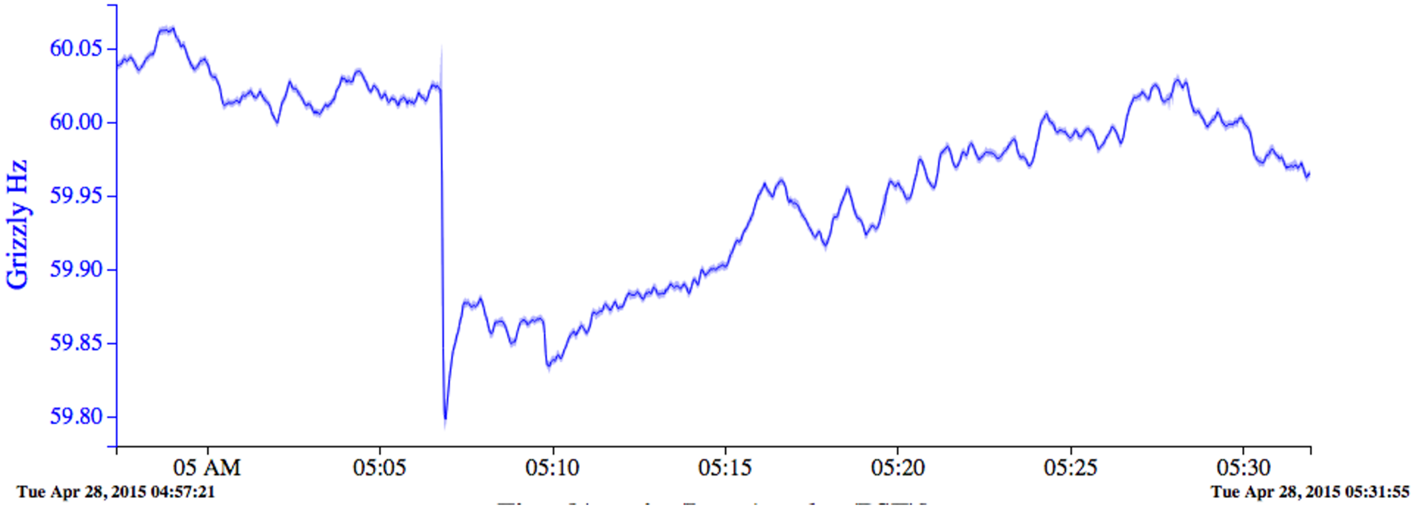


damped harmonic oscillation
seen in voltage phase angle

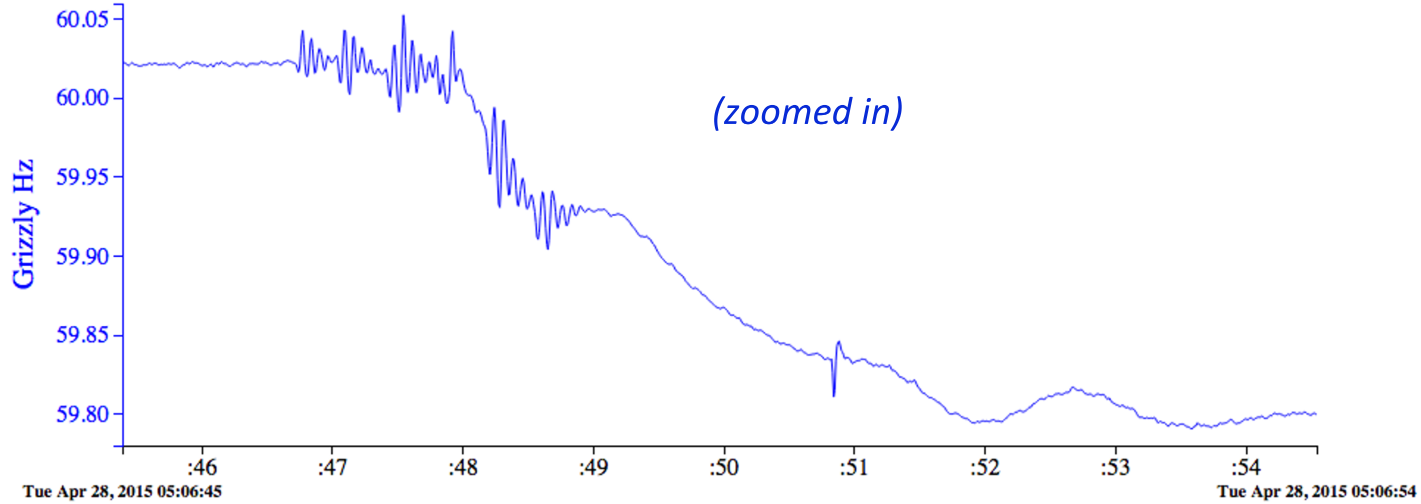
Generator swing equation

$$M\,\ddot{\delta} + D\,\dot{\delta} = P_m - P_e(\delta)$$

Example: Generator and transmission line trip event

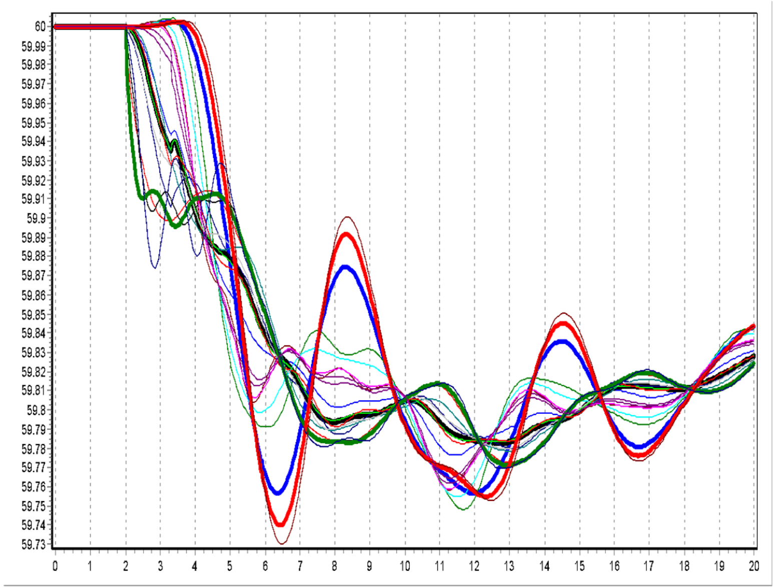


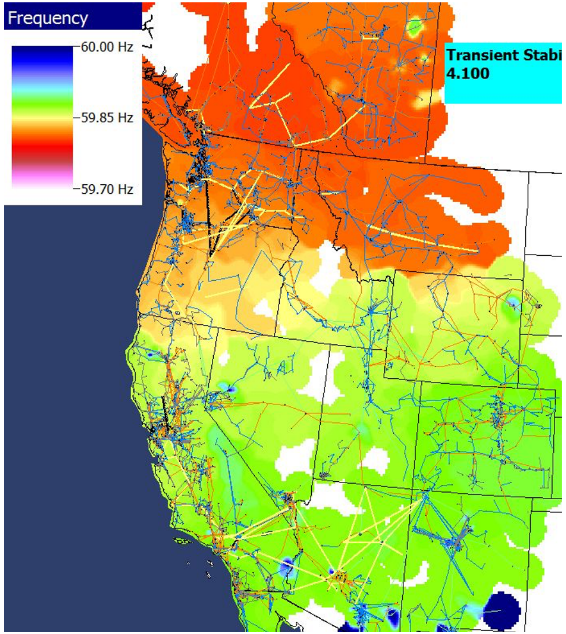
Example: Generator and transmission line trip event



Example: Frequency oscillations after a sudden loss of generation

green: Southern California, near lost generator
black: Washington State
blue: Alberta, Canada
red: Alberta, Canada



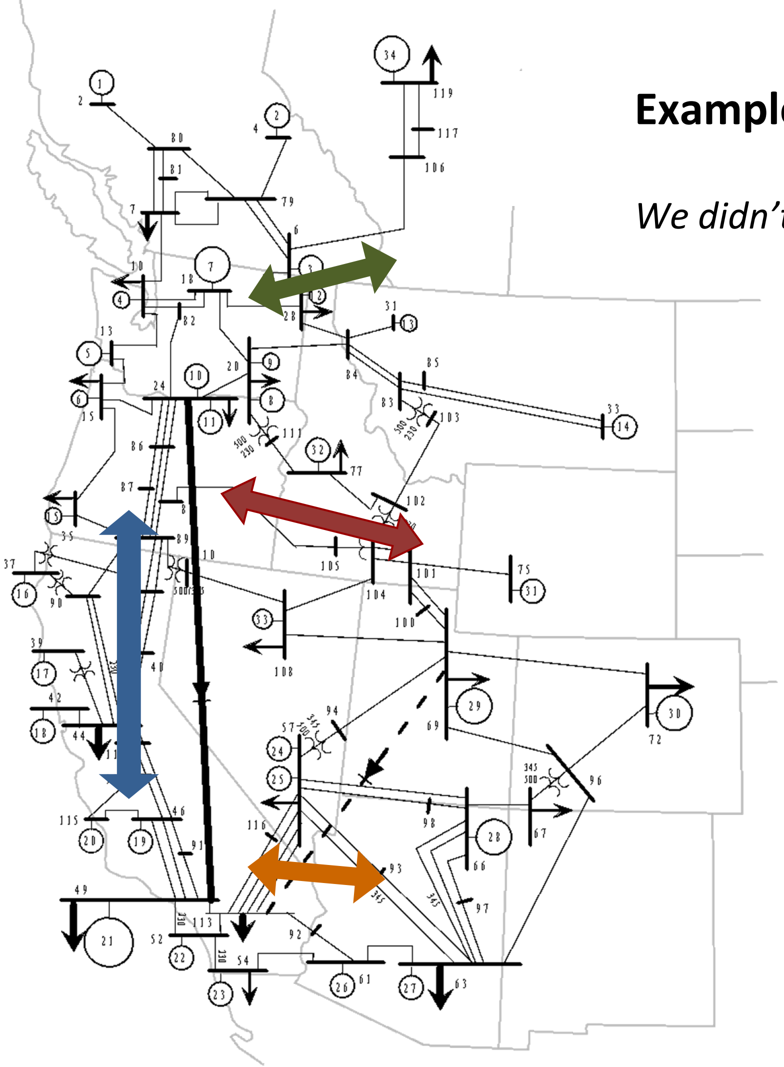


time in seconds

frequency contour

Example: Characteristic oscillation modes

We didn't know about these before PMUs...



Alberta
0.4 Hz

East-West
0.6 Hz

North-South
0.25 Hz

California-Desert
Southwest 0.5 Hz

What if the signal is not strictly a cosine?

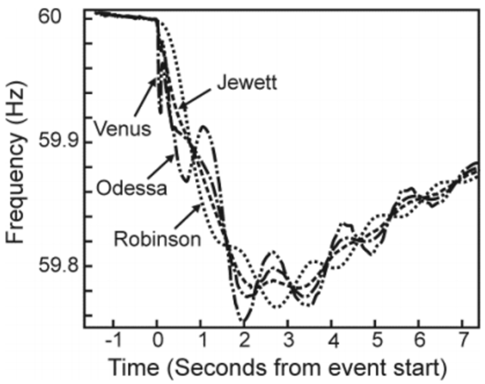


Figure 1 Observed frequency following generator loss

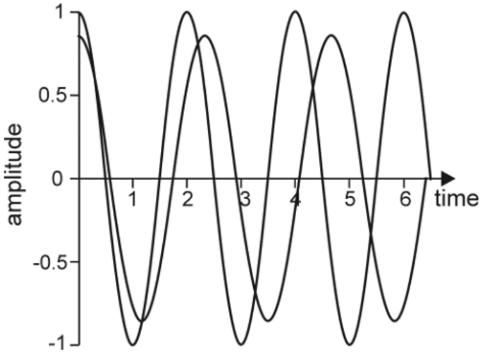
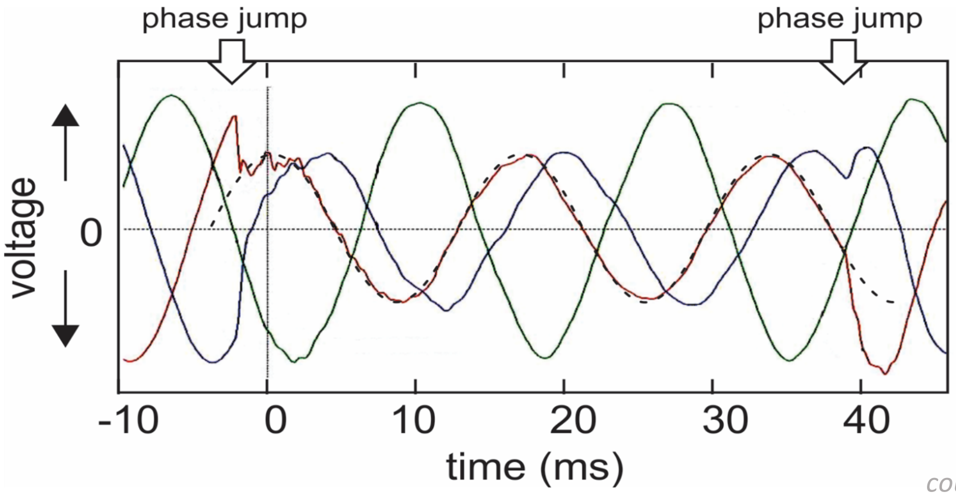


Figure 2. Two sine waves

Harold Kirkham, PNNL: "The Measurand: The Problem of Frequency."

PMUs still give valuable insight, but their outputs are not obvious to define.

What if the signal is not strictly a cosine?



courtesy of Harold Kirkham

The PMU answers the question,
"If this signal were a cosine, what would its amplitude, frequency and phase be?"

What if the signal is not strictly a cosine?

$$x(t) = X_{\mathrm{m}} \cos(\omega t + \varphi)$$

$$x(t) = X_{\mathrm{m}} \cos\left\{\left(\omega' + \frac{C_\omega}{2}t\right)t + \left(\varphi' + \frac{C_\varphi}{2}t\right)\right\}$$

Allowing for ω and φ to vary in time

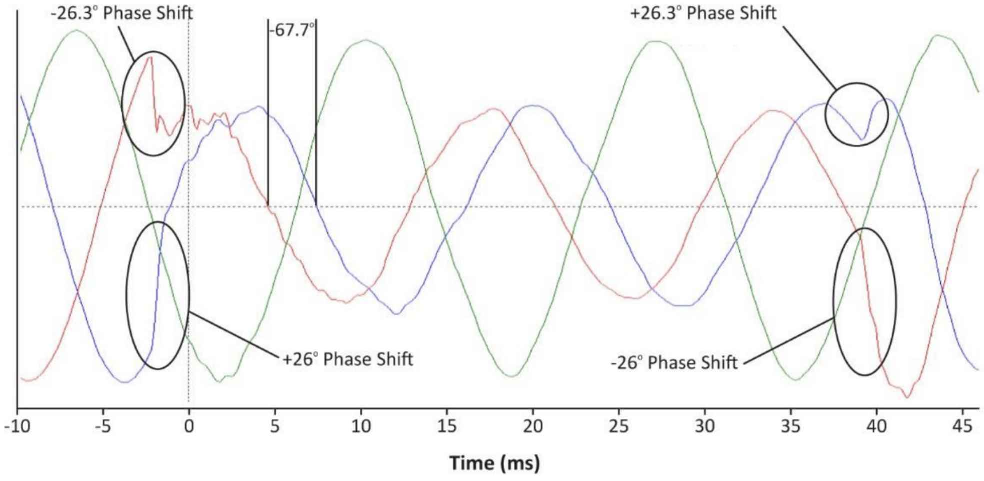
$$x(t) = X_{\mathrm{m}} \cos\left\{\left(\omega' + \frac{C_\varphi}{2} + \frac{C_\omega}{2}t\right)t + \varphi'\right\}$$

Grouping terms

Harold Kirkham, PNNL: "The Measurand: The Problem of Frequency."

There is more than one way to define frequency, phase, and rate of change of frequency (ROCOF).

Interesting times...



Blue Cut Fire Incident, 2016: Inverters calculated frequency differently than might have been expected, and tripped offline.

NERC, "1,200 MW Fault Induced Solar Photovoltaic Resource Interruption Report," June 2017

Observing and understanding the electric grid at increasingly higher resolution in space and time is increasingly important.

Case Studies & Lessons Learned

Kevin Jones, PhD
Dominion Energy

Oct. '09 – Oct. '20

Looking Back Over 10+ Years

- **2009** – Kicked off synchrophasor initiative; DOE SGIG Kickoff
- **2012** – Began standardized Relay-PMU sensor deployment
- **2013** – DOE SGIG Demonstration
  - Linear State Estimator v1.0 released as OSS
- **2014** – CERTS Synchrophasor Data Conditioning and Validation Project
- **2015** – DOE FOA970 Kickoff
- **2017** – DOE FOA970 Demonstration
  - Linear State Estimator v2.0
- **2017** – DFR PMU Conversion Begins
  - Towards total transmission system coverage
- **2018** – Analytics Journey Begins
  - High performance sandbox for use case development
- **2019** – Go-Live of Cloud-Hosted PingThings' Platform
- **2020** – Leaning into Data Analytics

2018

Hitting the Wall

2018-2019

A Path Forward for Synchrophasors

We must drive down the cost of working with data!

THE RIGHT TOOL FOR THE JOB

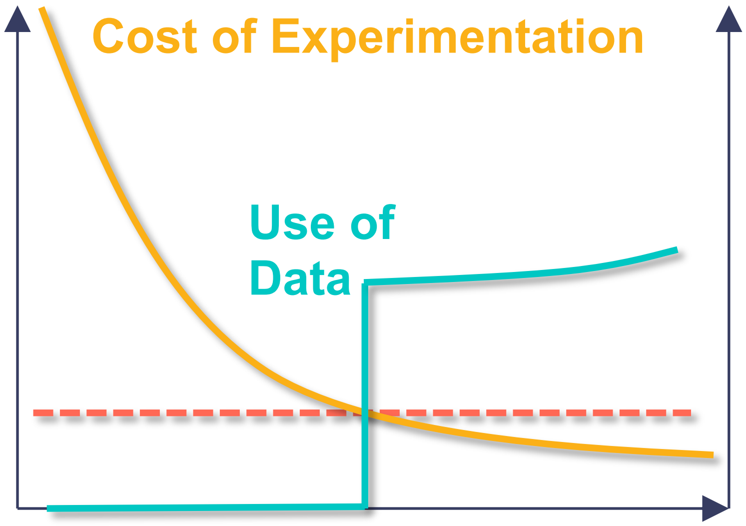
High resolution time series (e.g. synchrophasors) is a special comp. sci problem • Big Data technologies evolved towards specialization • Not all time-series DBs are equal • Historians make data history • Data at rest stays at rest

NO SINGULAR "KILLER APP"; ENSEMBLE INSTEAD

The literature is full (10^3s) of proposed applications • Each utility may have niche use cases • Value prop. of individual use cases is myopic

ANALYTIC EXPERIMENTATION >> A PRIORI "GUESSES"

We need to use lean methodologies, not guesses that play out over years, to arrive at our highest valued use cases



2018-2019

A Fork in the Road. . .

Technology

- First-Principles Approach
- Platform vs Siloed Applications
- Cloud vs On-Prem

Engineering vs Real-time Operations

- Rapid prototyping & integration
- Quicker ROI for synchrophasors

Capital vs O&M

- Larger company/societal impact

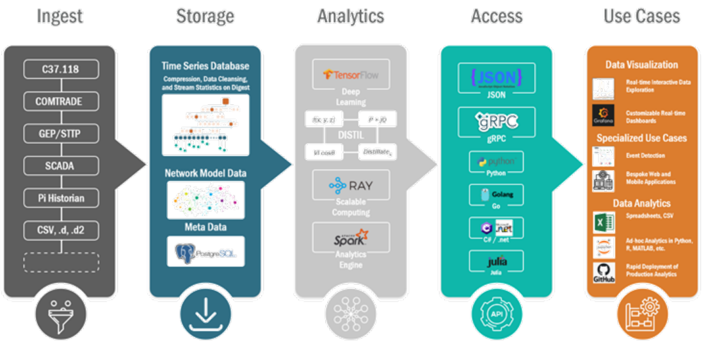
PingThings` PredictiveGrid Platform

PREDICTIVEGRID IS A PLATFORM-AS-A-SERVICE

This means we pay an annual subscription as an *all-in-cost* for:

- All Platform Features
- Infrastructure
- Maintenance
- Scheduled Upgrades
- Security
- Services

The combination of best-in-class tech, hosted in the cloud, and supported by a world-class team allows us to achieve at a scale and pace that would be otherwise impossible.



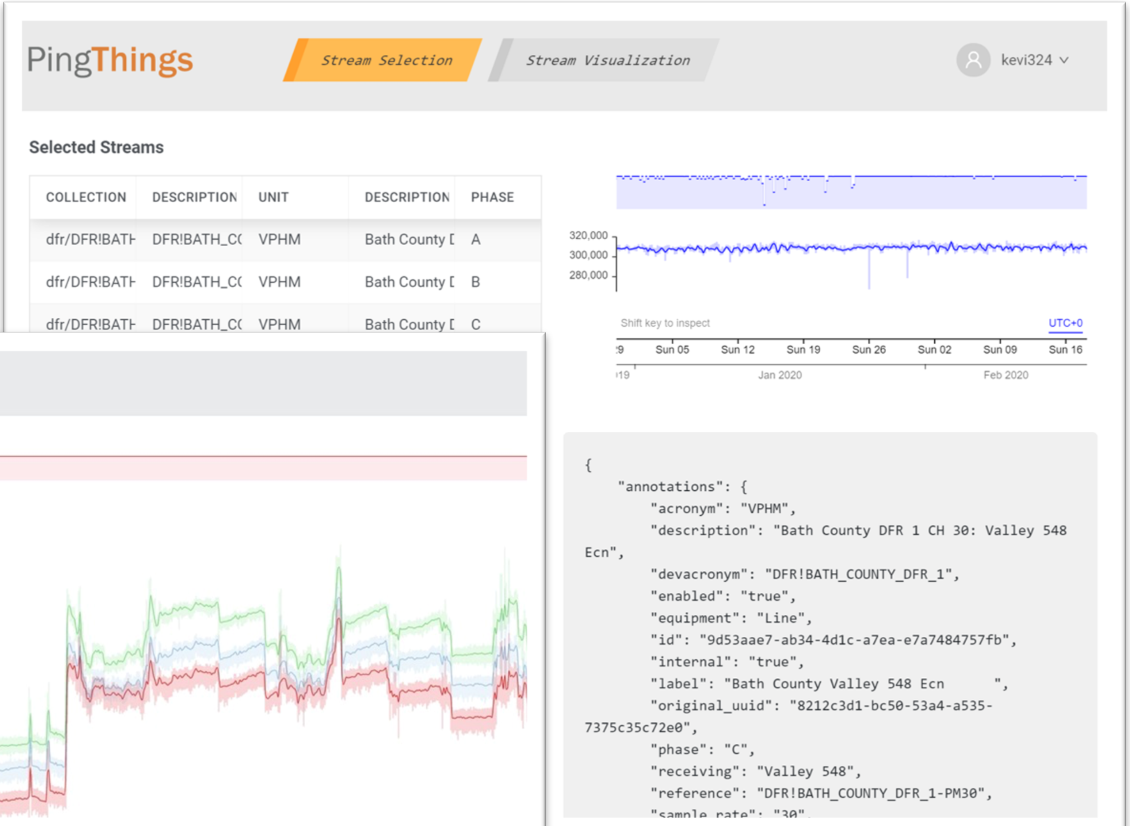
Zero to streaming data in under 4 months.

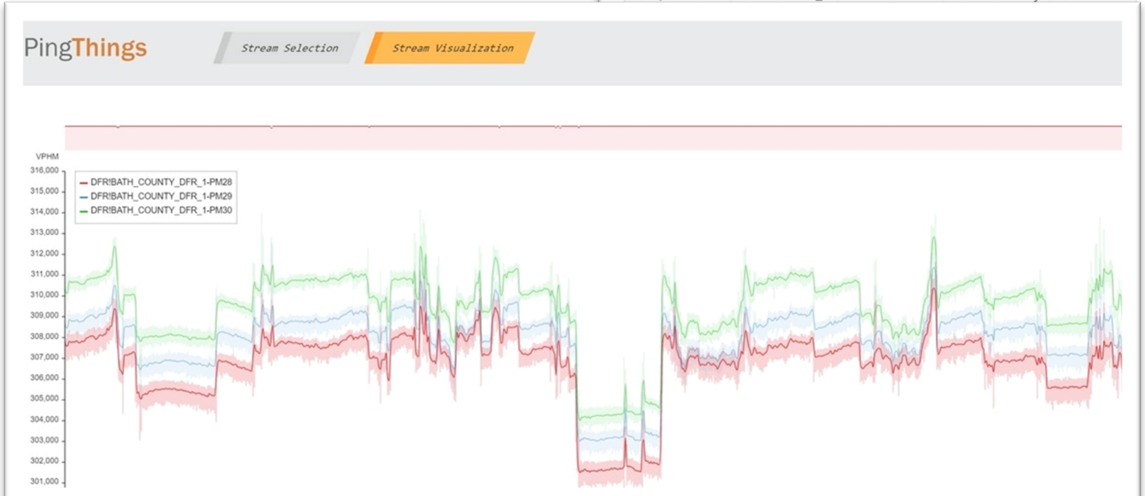
We can do more with less [people, time, and resources] with PingThings & PredictiveGrid.

Human-Scale Data Exploration

YOU MUST LOOK AT YOUR DATA!

Any data,
at your fingertips,
instantly, fluidly.





Data Exploration: A Case Study

Fault Analysis is a heavy user of Mr. Plotter.

RAPID EVENT ANALYSIS

Problem: Event analysis is tedious and time consuming – delaying restoration time. 45-60 minutes per event to visualize and analyze the data.

Solution: Mr. Plotter makes this instantaneous and flexible (multiple locations at once) saving critical time and answer key questions during critical restoration activities.

Opportunity: 87 events in the last 365 days

EVENT DATA REQUESTS

Problem: Generation often waits 45+ days to ask for event data but DFRs only store data for 30 days.

Solution: PredictiveGrid saves data forever and Mr. Plotter makes event data exports trivial.

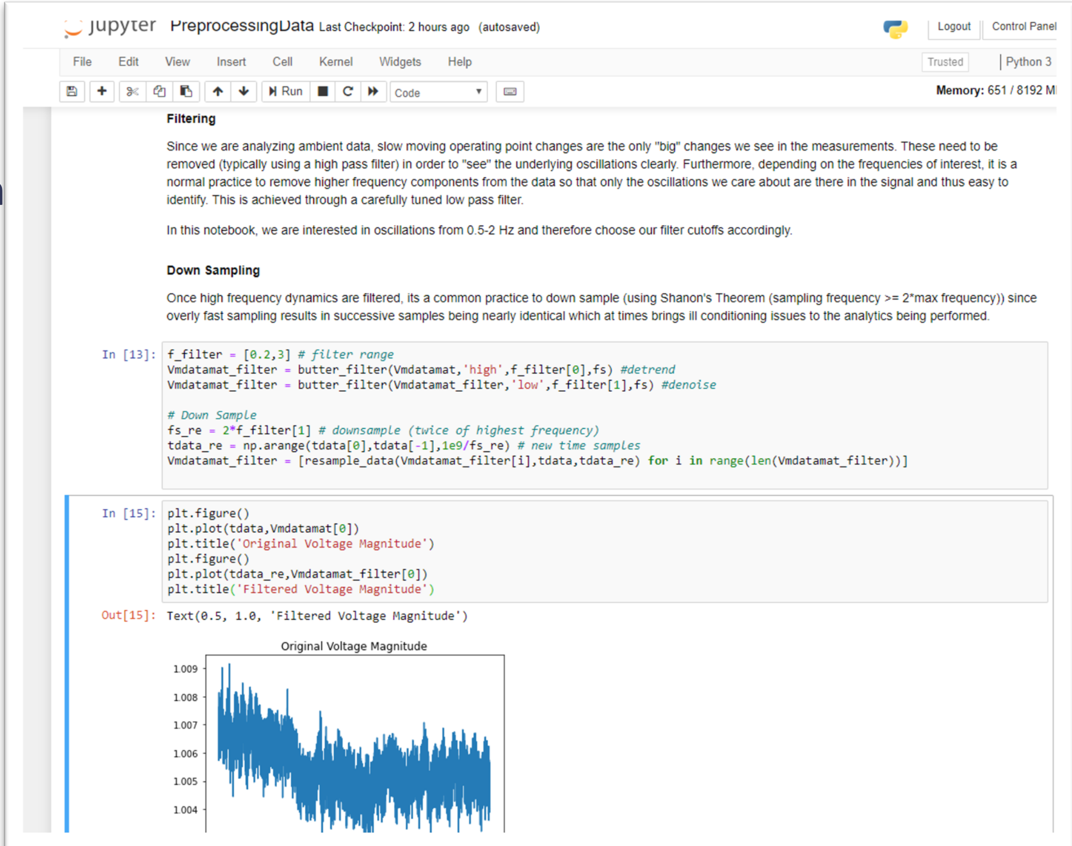
Opportunity: ~20 events each year – mostly storm season for critical locations like Surry, North Anna, Greensville.

"The plotter was worth the cost of admission … because it makes the data real." -Brian Starling

Rich, Programmatic Access

PREDICTIVEGRID DRIVES DOWN THE COST OF ANALYTIC DEVELOPMENT

- Ad-hoc Analytics & Experimentation
  - *Exploration*
- Rapid & Targeted Use Case Development
  - *Exploitation*
- Great for Exploration and Exploitation.
- Great for beginner, intermediate, and advanced users.



Our Team

Chetan Mishra, Ph.D.
Data Analytics Lead

Chen Wang, Ph.D.
Data Analytics, Data Eng.

Hesen Liu, Ph.D.
Data Analytics, Data Eng.

Duotong Yang, Ph.D.
Modeling

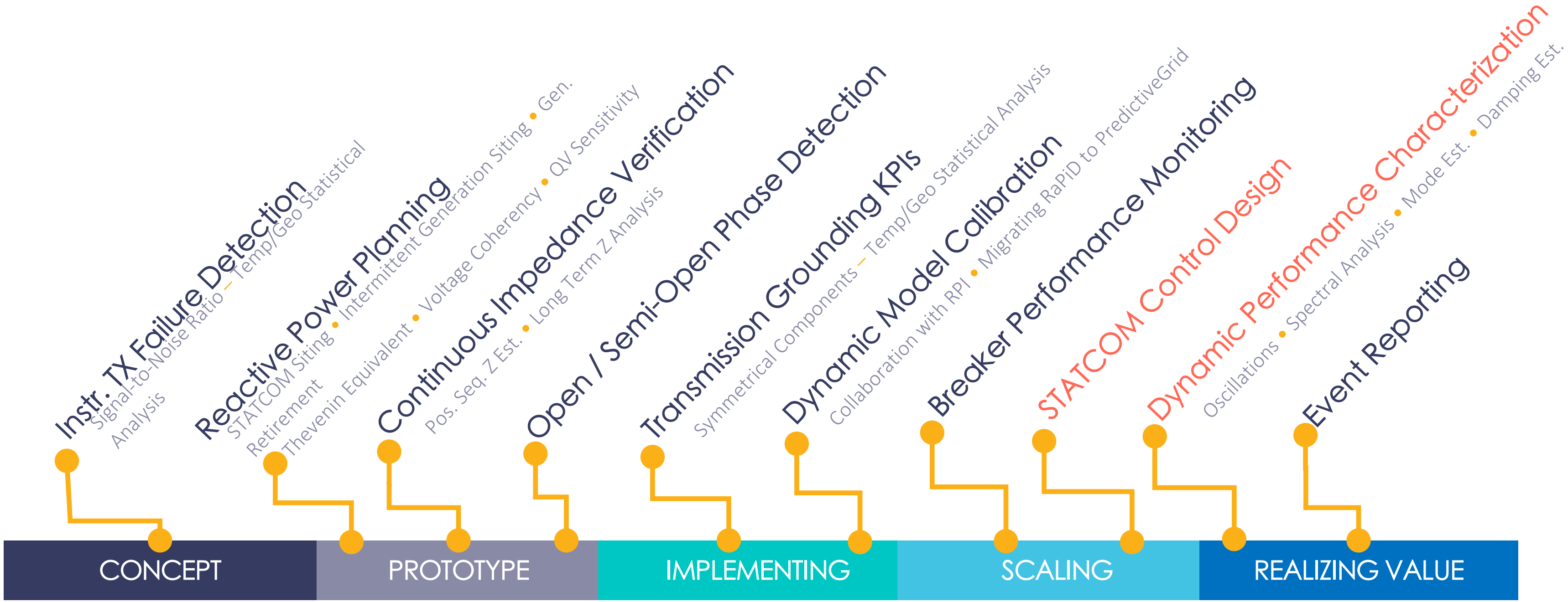
Benjamin Diller
Technology, Data Eng. (Joining Soon)

Xin Xu
Data Analytics (Joining Soon)

Marcelo de Castro Fernandes
Data Analytics Intern, Summer 2020

Xianda Deng
Data Analytics Intern, Summer 2020

Promising Use Cases



Beyond Synchrophasors

- Upload from UI
- Automated uploads from Sixth Man

COMTRADE Event Files

DFR PMU Data

Relay PMU Data

- Bulk historical uploads
- Synchronous updates
- From PI

Historical SCADA

- 10 Minute Network Snapshots from ANODE

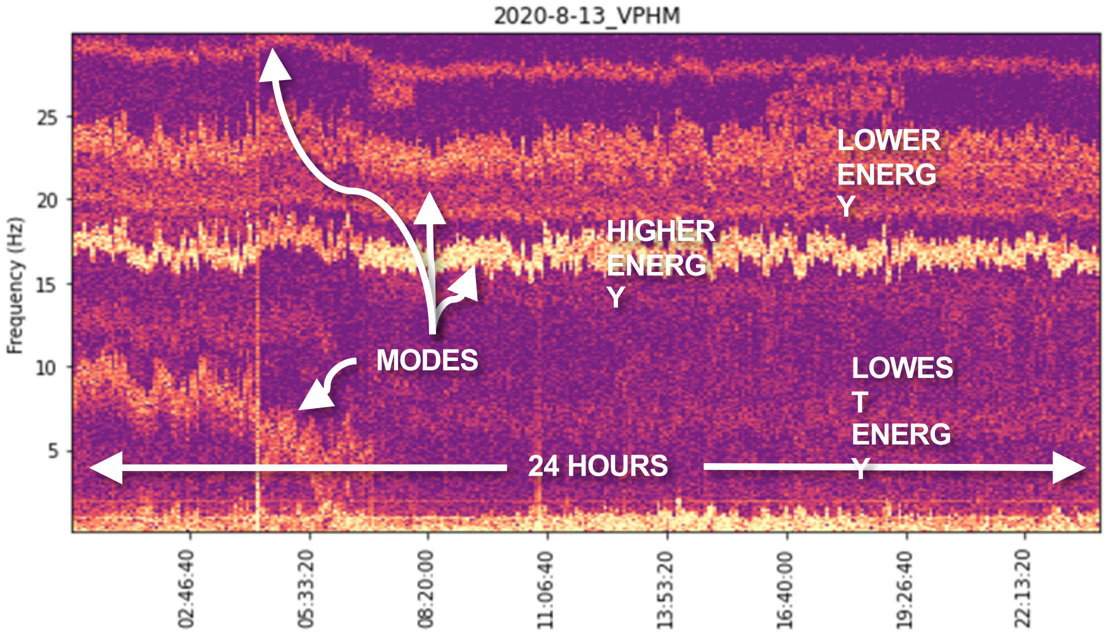
Network Model / Snapshots

Future??

PingThings' Predictive Grid

Today: Small Signal Analysis Case Studies

- Richness of ambient data
- Our homegrown toolbox is growing; dozens of techniques
- Must consider system level behaviors under all operating conditions across months of history
- This analysis requires working at a scale only made possible by PingThings` PredictiveGrid



Recent Case Studies

And what they mean to Dominion and the industry…

1: Regional Industrial Dynamics

Case Study: The Need to Improve Grid Models

MOTIVATION

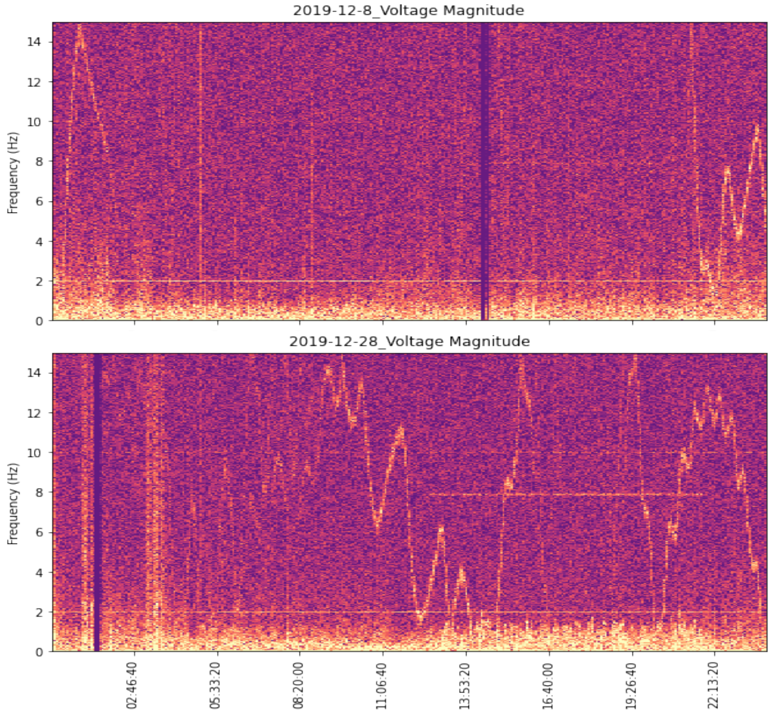
Distribution no longer passive • Regional dynamics influence integration of new devices • Avoid unwanted interactions • Solar and industrial use power electronics • Existing modeling practices overlook such dynamics

OBSERVATIONS

"Stumbled" onto interesting dynamics in voltage magnitude • Found poorly damped modes varying rapidly between 0-15 Hz • Nearby polymer plant and pet food plant have frequent customer complaints

TAKEAWAYS

Dynamics not reflected in models • Stumbling onto this implies many other locations with unaccounted dynamics • Matters when connecting other power electronic devices like solar



2: Regional Solar Dynamics

Case Study: The Need to Improve Grid Models & Analyses

MOTIVATION

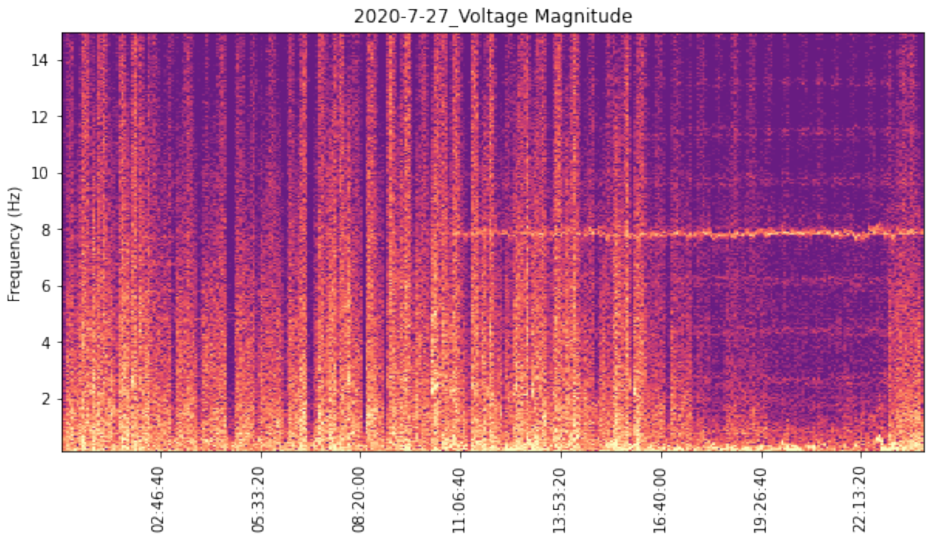
Distribution no longer passive • Regional dynamics influence integration of new devices • Avoid unwanted interactions • Solar and industrial use power electronics • Existing modeling practices overlook such dynamics

OBSERVATIONS

Sustained 8Hz oscillations observed at multiple locations • Invariant with operating conditions • From sunrise to sunset…solar! • Source identification through mode shape analysis of multiple locations • Confirmed solar plant

TAKEAWAYS

Dynamics not reflected in models • Solar interconnections will grow, exponentially increasing the likelihood of interactions • Needs to be accounted for during interconnection process



3: STATCOM Controller Dynamics Pt. 1

Case Study: Performance Assessment of FACTS

MOTIVATION

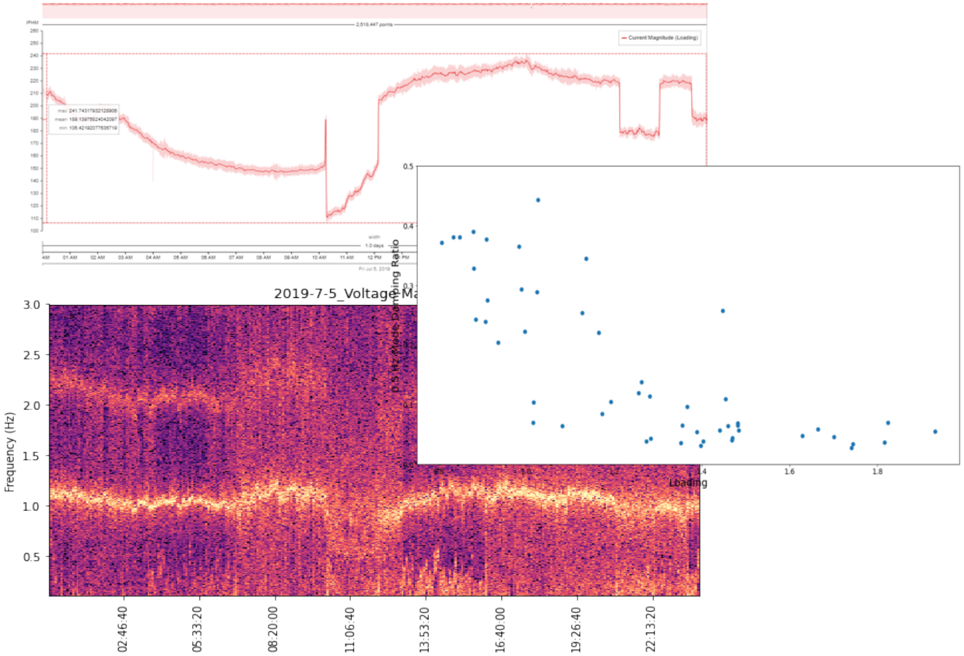
Investment in FACTS • Our duty to validate performance, suggest fixes, and influence future design • Feb 2019: topology change led to sustained oscillation • Found to be due to NSC • Deenergize control during low system strength.

OBSERVATIONS

Spectral analysis shows 2-3 modes from 0-3Hz • Modes become poorly damped under certain conditions • Damping estimated over many days showing negative correlation with system loading

TAKEAWAYS

Controller design didn't account for these system conditions • Need for adaptive gain adjustment hypothesized • Desire to validate hypothesis in the field



4: STATCOM Controller Dynamics Pt. 2

Case Study: Performance Assessment of FACTS

MOTIVATION

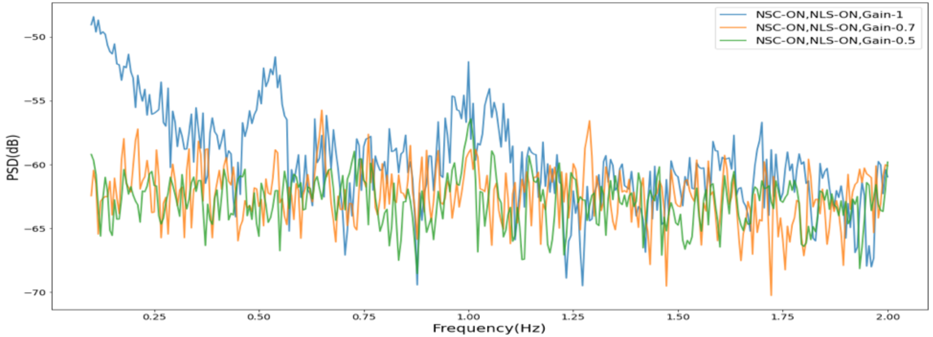
Investment in FACTS • Our duty to validate performance, suggest fixes, and influence future design • Sep 2020: STATCOM tested for NSC and NLS and multiple gain settings (100-70-50%) • Perfect *in-vivo* experiment to validate our observations.

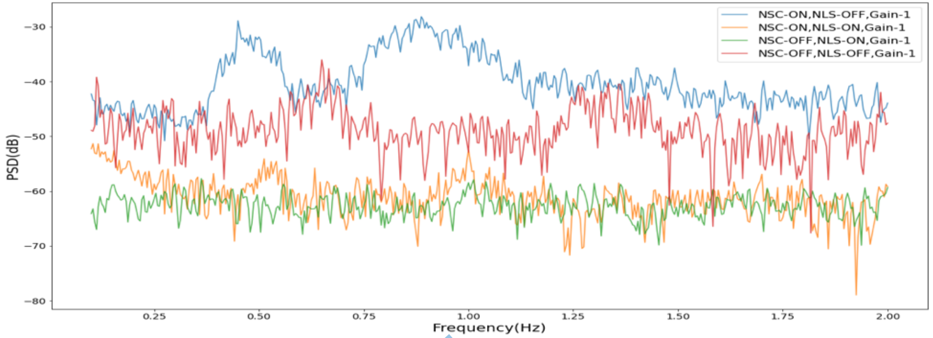
OBSERVATIONS

Poorly damped modes at 100% gain virtually gone at lower gains • NLS can be observed as a limiting factor for effective regulation during ambient conditions

TAKEAWAYS

Confirms the need for adaptive gain • Confirms the need to validate performance of FACTS assets





5: STATCOM Controller Interactions

Case Study: Performance Assessment of FACTS

MOTIVATION

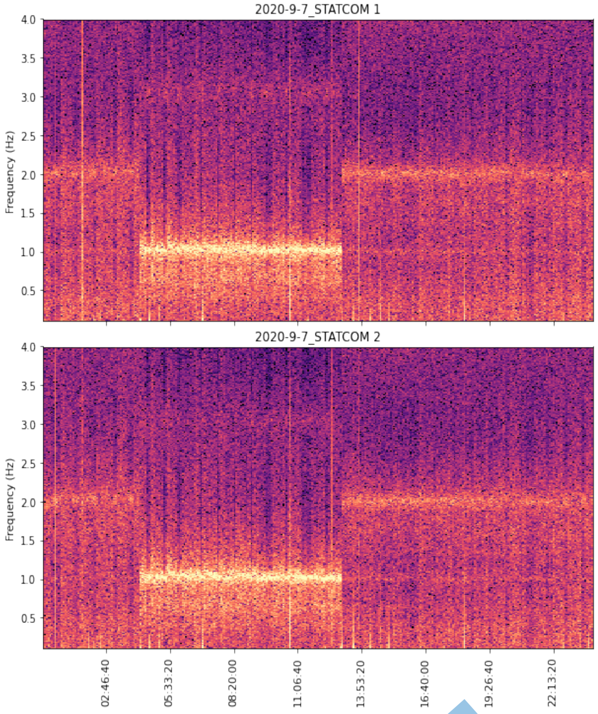
Investment in FACTS • Our duty to validate performance, suggest fixes, and influence future design • Neighboring STATCOMs may interact

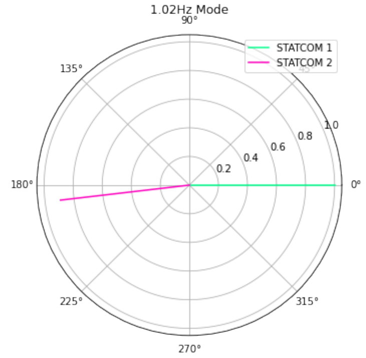
OBSERVATIONS

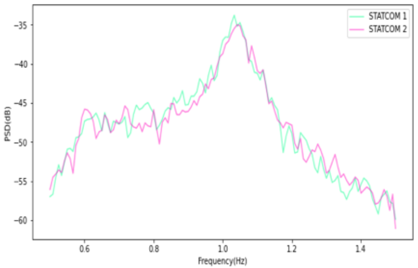
"Stumbled" onto poorly damped 1Hz V&I mode while baselining a region preparing for wind integration • Mode shape shows two STATCOMs participating 150deg+ out of phase

TAKEAWAYS

STATCOMs can interact • Need for coordinated control
• There are 4 STATCOMs, not 2 so need to expand study
• Study still ongoing







6: SVC Dynamics

Case Study: Performance Assessment of FACTS

MOTIVATION

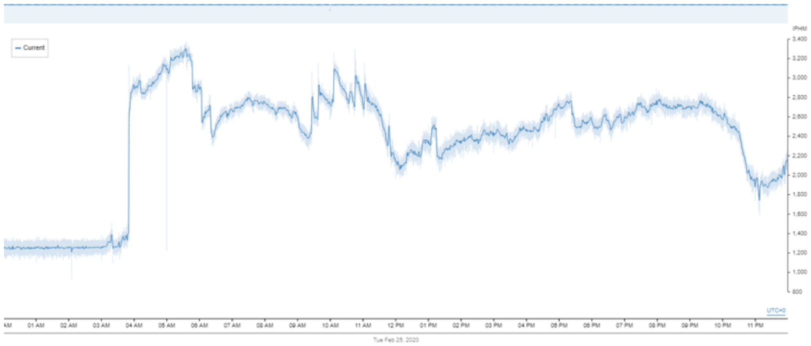
Investment in FACTS • Our duty to validate performance, suggest fixes, and influence future design

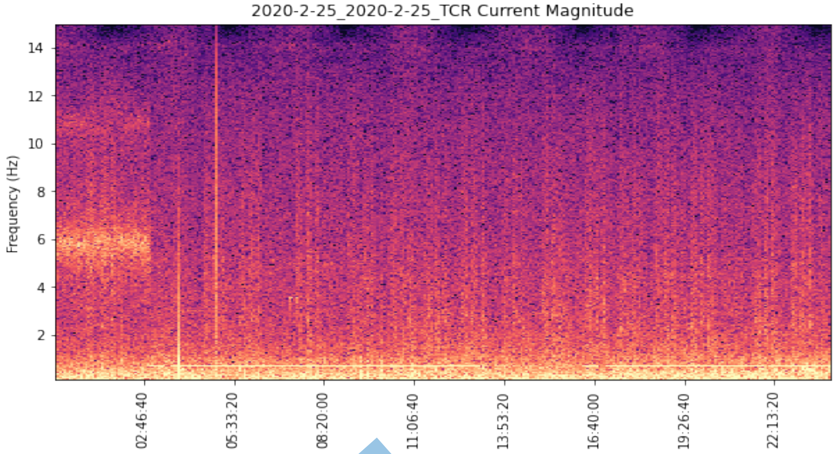
OBSERVATIONS

6Hz poorly damped modes observed • Randomly vanish throughout the day • Showed to be characteristic of Q control mode of SVC • Local generation setpoint change pushed voltage out of bounds of SVC, activating V control mode and eliminating oscillation

TAKEAWAYS

Interactions with other diverse, local assets can create unexpected interactions



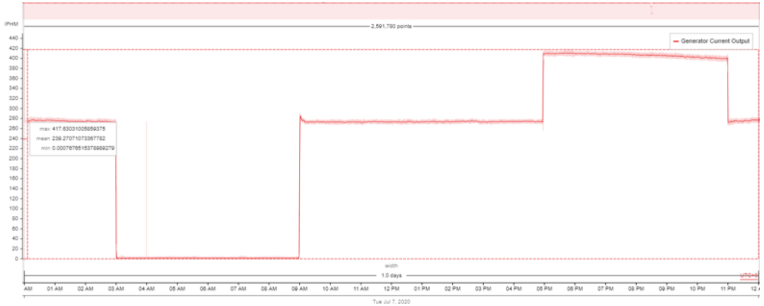


7: Hydro Plant Dynamics

Case Study: Data + Models for Diagnostic Analyses

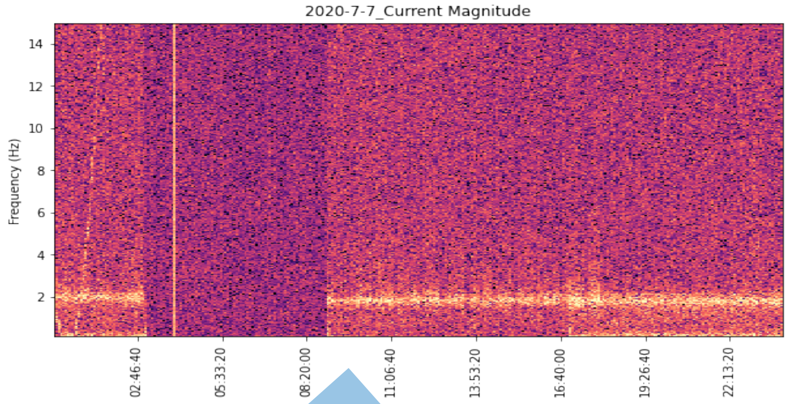
MOTIVATION

How to mitigate oscillator behavior observed in data? • For local issues, usually a controller design issue • Data alone insufficient to create new control • Recreate phenomena in simulation • Use data to improve models • Use models to identify mitigation



OBSERVATIONS

During plant operation, a poorly damped 2Hz mode is present • A modified model reproduces the oscillation in simulation • Sensitivity analysis then yields the appropriate control parameters to change

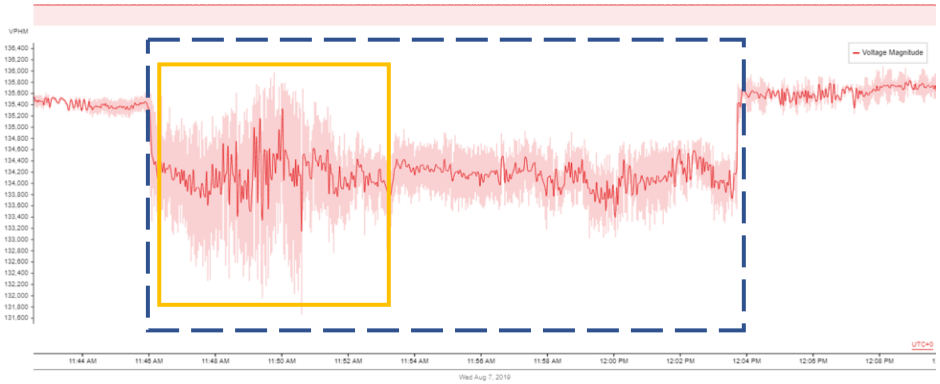


TAKEAWAYS

Gain of derivative block found to be most effective • Models can be manipulated to reproduce, diagnose, and identify suggested changes to mitigate observations from data • Implies a deeper synergy between data + models

8: Impacts of Arc Furnace

Case Study: Working with Real Data

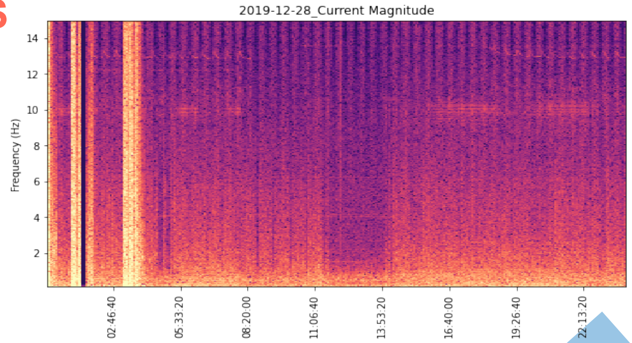


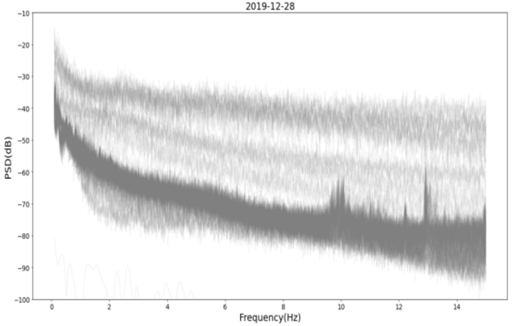
ABOUT

Arc Furnace (1) melts (orange box – higher variance, non-homogenous metal, varying Z), and (2) refines (blue box outside of orange box - less variance, constant Z

OBSERVATIONS + TAKEAWAYS

Impacts of Arc Furnace can be observed daily across the system • Aggravates FACTS devices • Cannot assume linearity • Must be compensated for in analysis of other dynamics





9: Nuclear Gen & Gas Gen Dynamics

Case Study: Going Beyond Synchrophasor Data

MOTIVATION

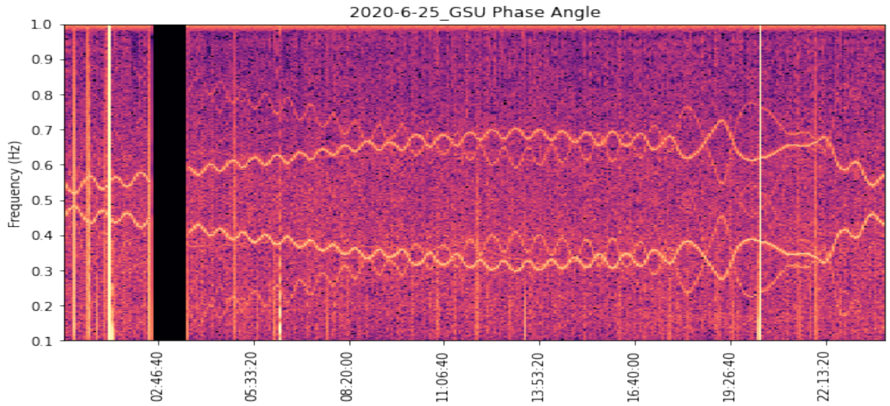
Observations in synchrophasor data are sometimes insufficient for diagnosis • How to leverage increased phasor reporting rates and waveform data to dive deeper?

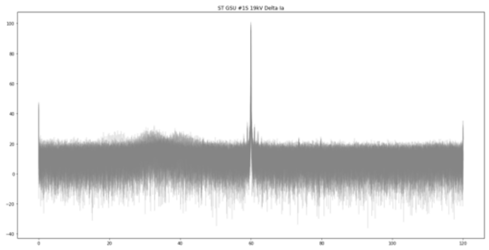
OBSERVATIONS

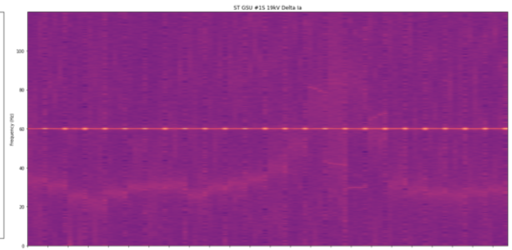
Original observation as <1Hz modes at nuclear plant GSU in phase angle w/r/t system • More prominent during summer • Hypothesized subsynchronous resonance/shaft dynamics • Triggered by combination of plant setpoint + grid condition • Strange symmetry • Similar observations at gas plant • 60Hz phasor data and waveform data imply hypothesis is correct because of higher frequency oscillations

TAKEAWAYS

Sampling minutes of waveform data over days can help dive deeper when lower res data suggests the need • Study still ongoing to learn vs modes and grid state + plant setpoints • Will resume once we have mechanical measurements







Metabolizing the Results

- Yes – it still takes time to turn these observations into business outcomes

- Yes – We’re just getting started. Lots of left to explore/exploit.
  This will keep my team employed for 10+ years ;)

- But – there is now be no question of the value of synchrophasors, the right data analytics tools, and investing in these competencies.

Why Does This Matter?

Consider a future where. . .

INCREASED RENEWABLES

Exponentially increases the likelihood of undesirable device interactions.

INCREASED DYNAMIC COMPENSATION DEVICES

As a key enabler of renewable integration, design must consider actual small signal characteristics.

LIMITATIONS ON TRADITIONAL SOLUTIONS

New technologies will be required, data analytics can compensate for uncertainty.

NEED FOR MULTI-MODAL INVESTMENT JUSTIFICATION

Data will become a necessary part of the simulation/model-based investment proposal process.

GROWING WORKFORCE OF TECH-SAVVY ENGINEERS

Talent will be available to build data teams

More Specifically. . .

MODELING

Data and models are deeply synergistic. Data can be used to improve models and models can be used in a diagnostic fashion when field observations are made.

DESIGN

Design of our assets will need to take into consideration actual system conditions observed at their planned installation location.

PLANNING

Data greatly augments our ability to identify and refine proposals for improving the grid.

INTERCONNECTIONS

Data driven small-signal analysis will need to become part of the interconnection analysis process.

A New Competitive Advantage

GROWTH OPPORTUNITIES

Competencies in grid data analytics such as those at Dominion Energy will become a competitive advantage for utility companies: improving regulatory approval and access to affordable capital.

PANDORA'S BOX

Pandora's box is now open – now that it is known what is possible, it won't be long until it becomes a de-facto standard, perhaps even a requirement.

A New Utility

- Unification of Physics + Data
  - Data Flows • Power Flows
- More Capital Efficient
  - Financial Capital • Human Capital
- Greater Adaptability

A Fork in Your Road. . .

- The path is clear – start today.
- Questions?
  - kevin.d.jones@dominionenergy.com
- NASPI: naspi.org
  - Virtual Conference Nov 3-5
- NI4AI: ni4ai.org

Graduate Student Internship Program

- Dominion hires graduate student interns each summer to work on exciting and challenging projects.
- Dozens have come in through the program, many are now full-time engineers at Dominion.
- The program has been active for over 10 years.
- Currently, we take ~10 students across all of T&D per summer.
- Applications for next summer are currently posted soon on the Dominion Careers website.

Get Practice and Learn More

Laurel Dunn
NI4AI

About NI4AI

Short for: **N**ational **I**nfrastructure for **AI** on the grid

About: 3-year ARPA-E project funded under Open Innovation 2018

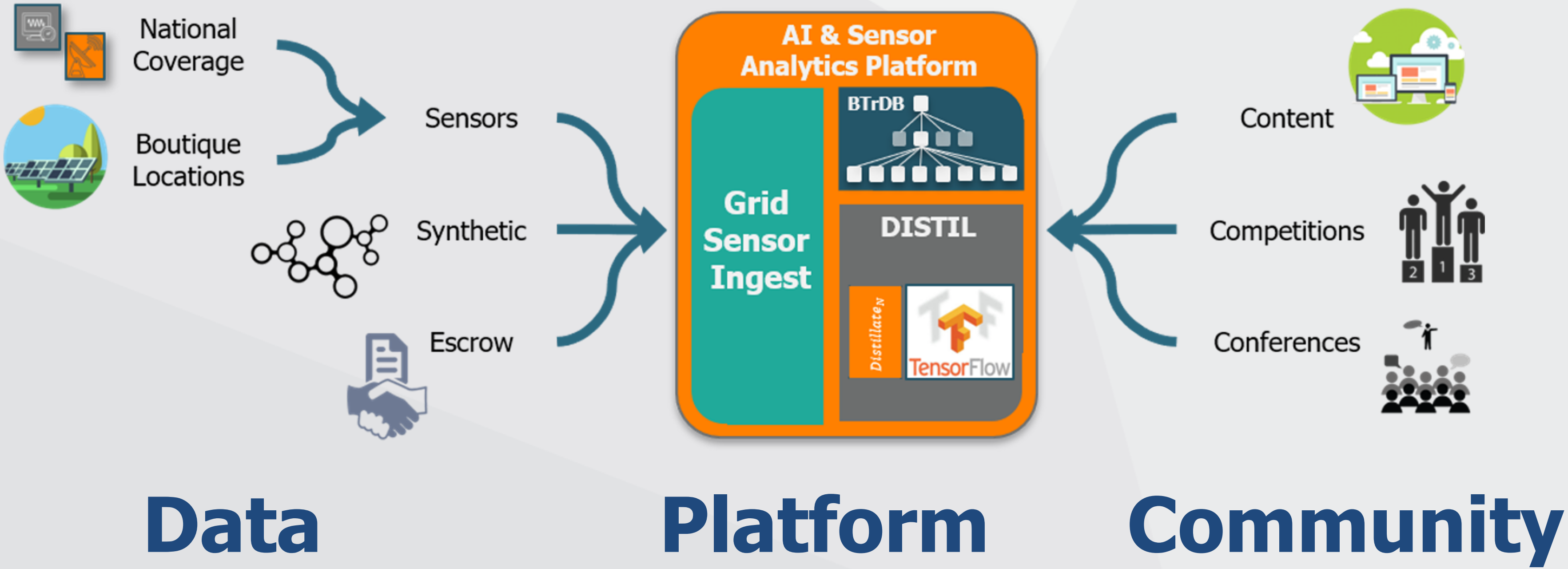
Our goal: Advance the use of AI in the industry

Approach: Eliminate barriers to analyzing grid data

Project pillars:

1. Provide access to a state-of-the-art data **PLATFORM**
2. Create **DATA** that analysts can readily use
3. Build **COMMUNITY** committed to developing new analytics

Project Pillars



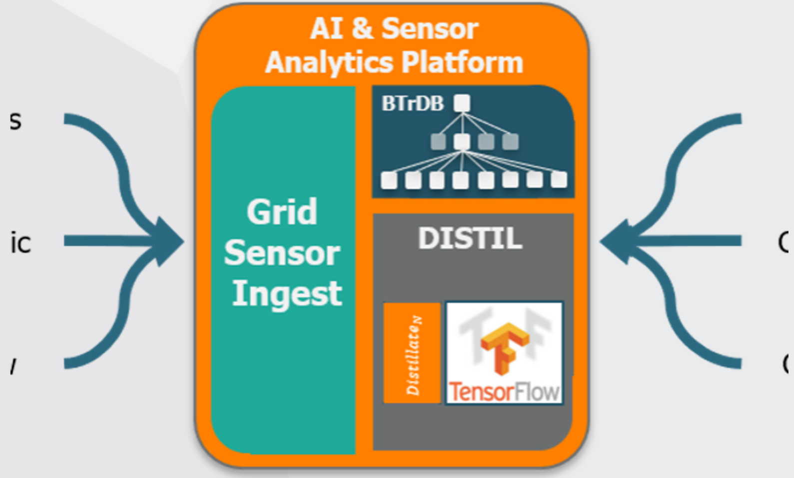
The Platform

PingThings' PredictiveGrid™

- Cloud-based platform
- Optimized for time series data
- Built for utilities
- Available to NI4AI users

Provides

- Data visualization
- API access (Python & Julia)
- Collaboration tools



Demo of Platform

https://www.youtube.com/watch?v=cqnaSlqPuGU

Learn more about the platform

Day 2 of this workshop

Python API documentation

https://btrdb.readthedocs.io/en/latest/

Blog posts tagged “set-up”

https://blog.ni4ai.org/tags/set-up/

Blog posts tagged “analytics” include code you can use

https://blog.ni4ai.org/tags/analytics/

The Data

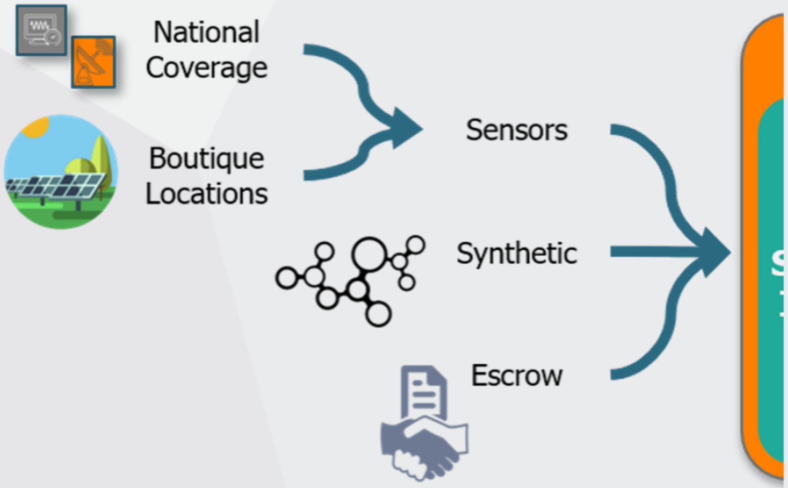
Open access data

Collected by **real sensors**

National coverage of the grid

Captures **interesting dynamics** relevant to users & stakeholders

- Experimental data
- Pilot projects
- Anonymized industry data



Have data you want analyzed?

Contact info@ni4ai.org

Datasets currently available to you

	Collections	Sensors	Duration	Features of interest
Real-time	ni4ai/ texas_pmus/	5	April-now	Real-time streaming data
Point on Wave	epfl/	3	6 events	Battery charging & discharging
Wide Area Events	transmission_events/	23	3 events	Switching events Oscillation
Archive	sunshine/	6	18 months	Distribution feeder with a PV array

plot.ni4ai.org

The Community

Made up of …

- Practitioners
- Researchers
- Students
- Utilities
- Vendors
- Hardware/sensor providers
- Anyone interested in grid data

The Community

How to engage

1. Use the platform
2. Attend workshops
3. Follow the blog
4. Do the exercises
5. Participate in competitions
6. Ask questions
7. Build your network
8. Make new collaborations
9. INSERT YOUR IDEA HERE

Attend workshops

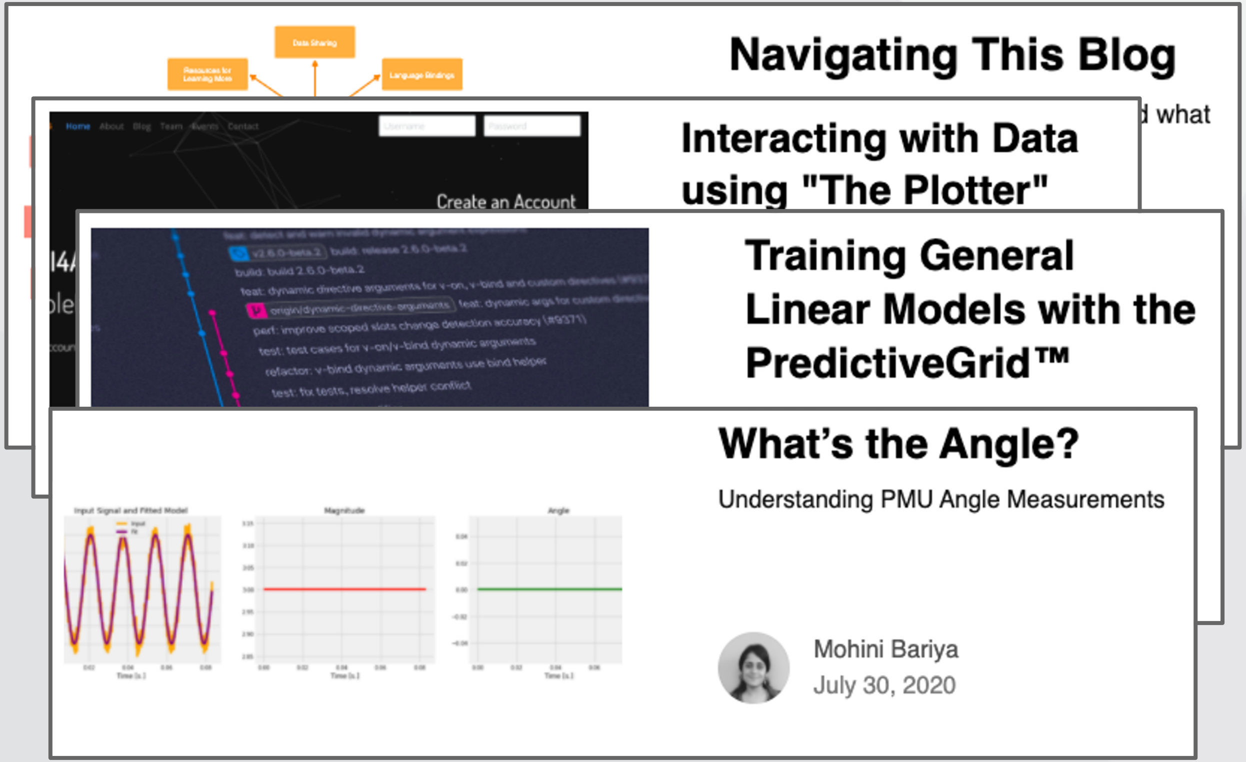
2020 Event & Conference Listing

Show 10 entries   Search:

Event	Dates	Location	Website
CIGRE Academy Webinar: PMU Fundamentals	October 21, 2020	Virtual	
CIGRE Academy Webinar: Intro to AI	October 28, 2020	Virtual	
NASPI Fall Working Group Meeting	November 3, 2020	Virtual	https://www.naspi.org/node/794
IEEE SmartGridConn	November 11-13, 2020	Virtual	https://sgc2020.ieee-smartgridcomm.org/

ni4ai.org/events

Follow the blog



blog.ni4ai.org

- Tutorials
- Exercises
- Code
- Research highlights
- New ideas
- Thought leadership
- Event information

Do the exercises

"Do-it-yourself" exercises are designed for you to get practice asking questions of data

- Assess data quality
- Monitor asset utilization
- Analyze grid frequency
- Quantify phase imbalance
- Locate disturbances

https://blog.ni4ai.org/tags/do-it-yourself

Where you can go to learn more

Follow developments in industry & research

- NASPI www.naspi.org
- CIGRE https://cigre-usnc.org/
- IEEE PES https://www.ieee-pes.org/
- PSERC https://pserc.wisc.edu
- PowerGlobe http://listserv.nodak.edu/archives/Power-Globe.html

Follow NI4AI

Subscribe to the newsletter http://eepurl.com/he8jtj

Read the blog blog.ni4ai.org

Look for announcements in PowerGlobe

Thank you!

Contact us

info@ni4ai.org

Subscribe

http://eepurl.com/he8jtj

Upcoming Events

Oct 28 **Intro to AI**

Nov 3-4 **NASPI working group meeting**

Nov 11-13 **IEEE SmartGridComm**