Accelerating Data Access, Analytics, and Collaboration

Panel Presentation & Discussion

NASPI Work Group Meeting
November 3, 2020

NASPI North American SynchroPhasor Initiative

Today's Panelists

Mack Grady, Baylor University

Lessons Learned from the Texas Synchrophasor Network

Theo Laughner, PowerGrid-RX

The Need for PQ Analytics

Sascha von Meier, UC Berkeley
Panel Moderator

Kamron Tangney, Powerside
microPMU: From the lab to the grid

Laurel Dunn, UC Berkeley

A National Infrastructure for Artificial Intelligence on the Grid

Accelerating Data Access, Analytics and Collaboration Session
NASPI Work Group Virtual Meeting

"Lessons Learned from the Texas Synchrophasor Network"

Prof. Mack Grady
Prof. of ECE at Baylor, Prof. Emeritus of ECE at U.T. Austin

Supported by

Schweitzer Engineering Labs
DoD Defense Threat Reduction Agency
ERCOT

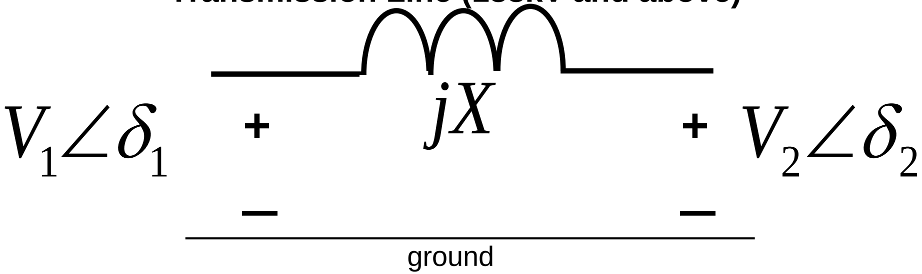
November 3, 2020

Why are Synchrophasors Important?

Power flow depends on angle difference. Stability depends on angle swings. We could always calculate angles with loadflows and stability programs, but there was no way to measure them remotely.

Then came synchrophasors!

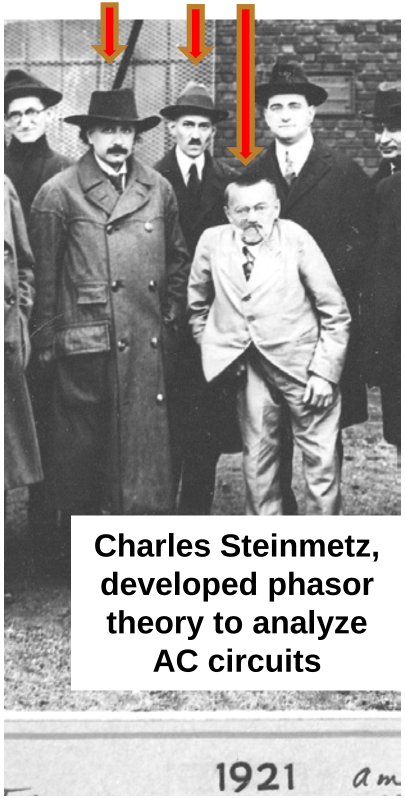
Average Power Flow P Through a Mostly Inductive Transmission Line (138kV and above)



These are about 1pu

For small x, sin(x) = x

$$P = \frac{V_1V_2}{X}\sin(\delta_1 - \delta_2)$$



Charles Steinmetz, developed phasor theory to analyze AC circuits

Because synchrophasors are phasors, we need not transmit sub-cycle measurements to concentrators. 30 measurements per second are adequate.

SEL donated and continues to donate all our equipment. Our first 1-minute of data came from the fire station at McDonald Observatory in far West Texas, in late November 2008. One student was with me out there, another was at U.T. Austin at the PMU concentrator that SEL donated.

The U.T. student sent me a one-minute screen shot of the relative voltage phase angle graph, and I didn't believe it – too noisy! Loadflows don't do that! Furthermore, how could we know the net 30 degree phase shift due to transformers?

Regarding the net 30, a former student at ERCOT was later check the system operators loadflow so I could determine the proper net 30. Still, power grids are nervous, the noise is normal, so one must learn how to deal with noise and net 30.

With data flowing in at 30 to 60 readings per second, PMU concentrators do not wait very long for data that is delayed by the internet, so one must learn how to deal with missing data (and do **not** treat the missing values as zero!).

One of the Best Uses for Synchrophasors: Observing Grid Response to Generator Trips

Classic Unit Trip. Curve-Fit 2nd Order Damped Response and Compute Normalized Damping Ratio

		Exponential Steady State Transition Curve				Damped Sinusoidal Term						Avg. Sum
Start Sec	Stop Sec	A	B	T1	Tau1	C	T2	Tau2	Tdamp	Fdamp	Zeta	Squared Error
5.5	11	17.05	18.58	5.91	0.24	1.73	6.18	4.64	1.59	0.628	0.055	0.0044
												Alpha
												0.215
												F0
												0.629

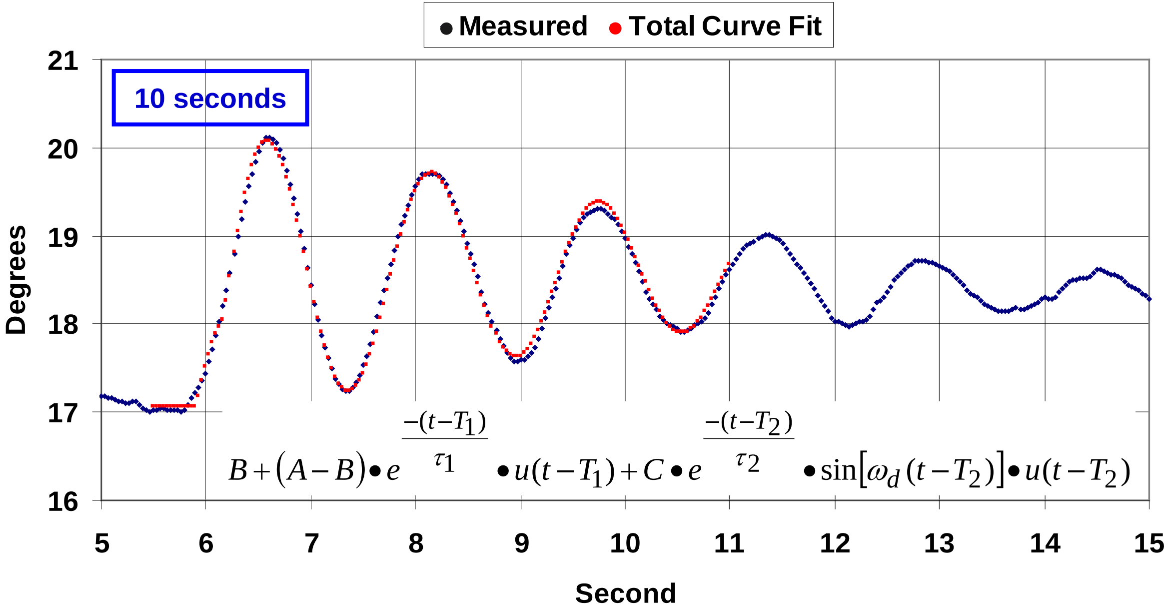
Steady-State Change = 18.58 – 17.05 = 1.53 degrees

Ring Magnitude, degrees

Damped Resonant Frequency, Hz

Normalized Damping Ratio

Unit Trip 2011/05/30 03:03:00 GMT. UT Pan Am Relative to U.T. Austin.

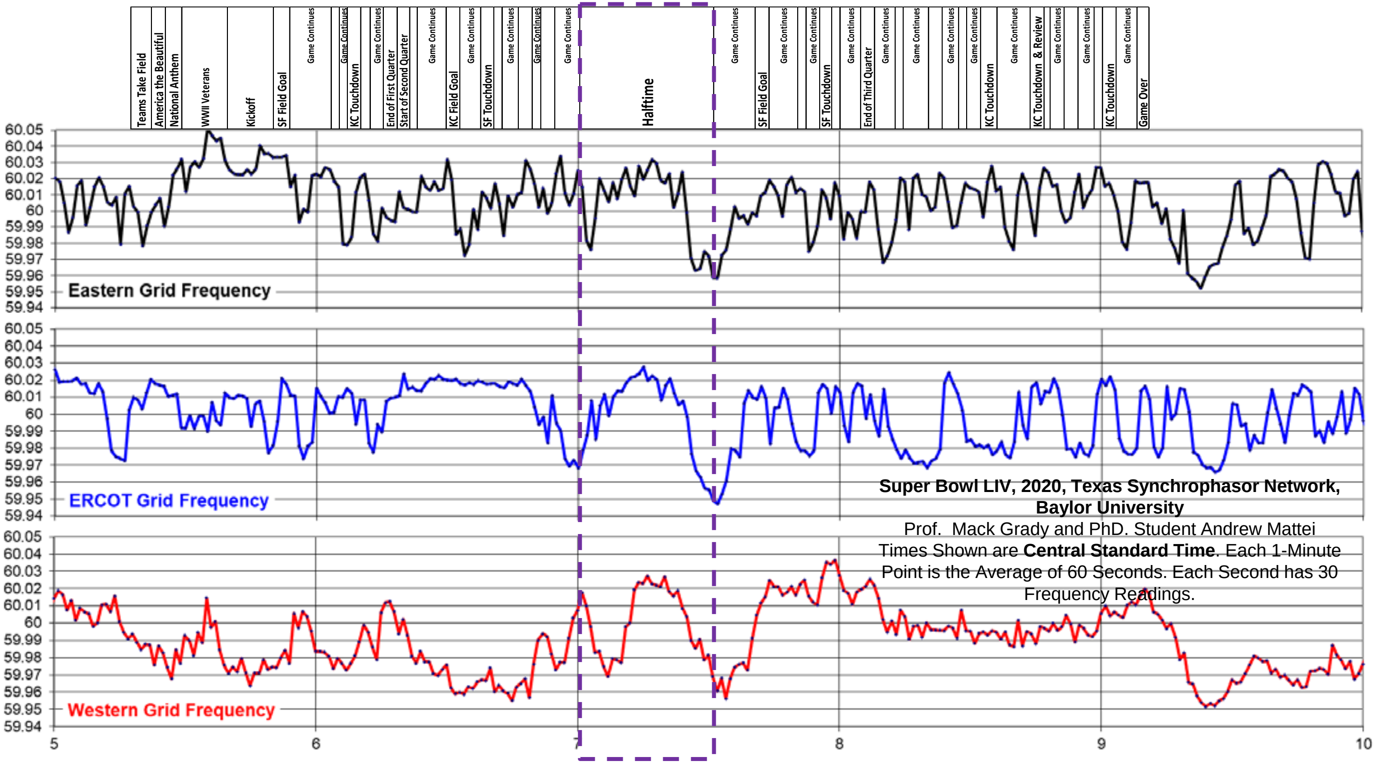


$$B+(A-B)\bullet e^{\frac{-(t-T_1)}{\tau_1}}\bullet u(t-T_1)+C\bullet e^{\frac{-(t-T_2)}{\tau_2}}\bullet \sin[\omega_d(t-T_2)]\bullet u(t-T_2)$$

Relative voltage phase angles within the same grid are extremely useful - but not useful between grids. Frequency, however, can spot national events.

(Eastern, ERCOT, and Western Grid Frequencies, 5-Hour Graph)

Super Bowl 2020 Half-Time



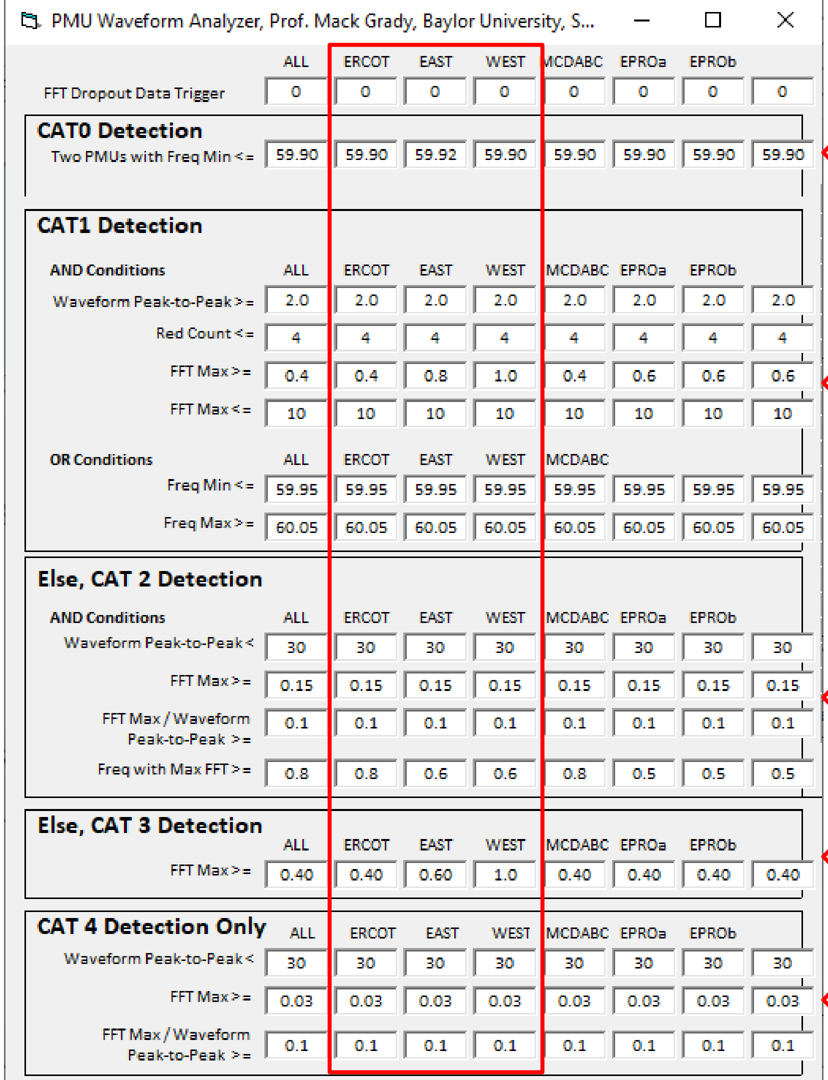
Screening the Data

- Synchrophasor data are extremely useful in studying events over seconds and minutes, but are also very useful for averaging frequency, voltage magnitudes, and phase angles over minutes, hours, days, and months. Average values are necessary to define "normal."

- It is essential to examine data very carefully BEFORE using it to search for events. Expect 1-2% of data to be missing. This means that you must develop methods to "skip over" the missing data, else you will trigger mostly on "false" alerts.

- It would be nice if we could view every minute of frequency, voltage magnitude, and voltage angle on a computer screen. Typically, each hour has at least one minute with "surprises." The solution is to develop a set of event triggers.

Triggers for the Three Grids



PMU Waveform Analyzer, Prof. Mack Grady, Baylor University, S...

	ALL	ERCOT	EAST	WEST	MCDABC	EPROa	EPROb	
FFT Dropout Data Trigger	0	0	0	0	0	0	0	0

CAT0 Detection

Two PMUs with Freq Min <=	59.90	59.90	59.92	59.90	59.90	59.90	59.90	59.90

CAT1 Detection

AND Conditions	ALL	ERCOT	EAST	WEST	MCDABC	EPROa	EPROb	
Waveform Peak-to-Peak >=	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Red Count <=	4	4	4	4	4	4	4	4
FFT Max >=	0.4	0.4	0.8	1.0	0.4	0.6	0.6	0.6
FFT Max <=	10	10	10	10	10	10	10	10

OR Conditions	ALL	ERCOT	EAST	WEST	MCDABC			
Freq Min <=	59.95	59.95	59.95	59.95	59.95	59.95	59.95	59.95
Freq Max >=	60.05	60.05	60.05	60.05	60.05	60.05	60.05	60.05

Else, CAT 2 Detection

AND Conditions	ALL	ERCOT	EAST	WEST	MCDABC	EPROa	EPROb	
Waveform Peak-to-Peak <	30	30	30	30	30	30	30	30
FFT Max >=	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
FFT Max / Waveform Peak-to-Peak >=	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Freq with Max FFT >=	0.8	0.8	0.6	0.6	0.8	0.5	0.5	0.5

Else, CAT 3 Detection

	ALL	ERCOT	EAST	WEST	MCDABC	EPROa	EPROb	
FFT Max >=	0.40	0.40	0.60	1.0	0.40	0.40	0.40	0.40

CAT 4 Detection Only

	ALL	ERCOT	EAST	WEST	MCDABC	EPROa	EPROb	
Waveform Peak-to-Peak <	30	30	30	30	30	30	30	30
FFT Max >=	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
FFT Max / Waveform Peak-to-Peak >=	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

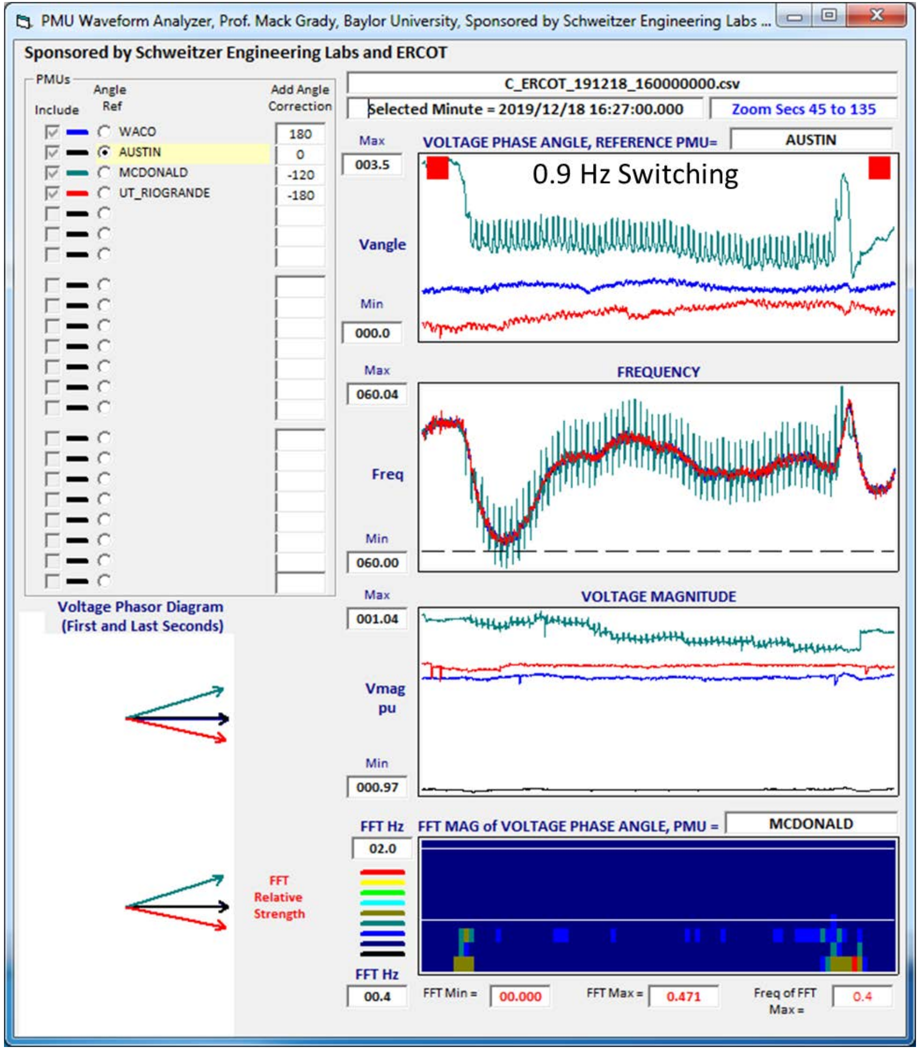
CAT0. Large unit trips

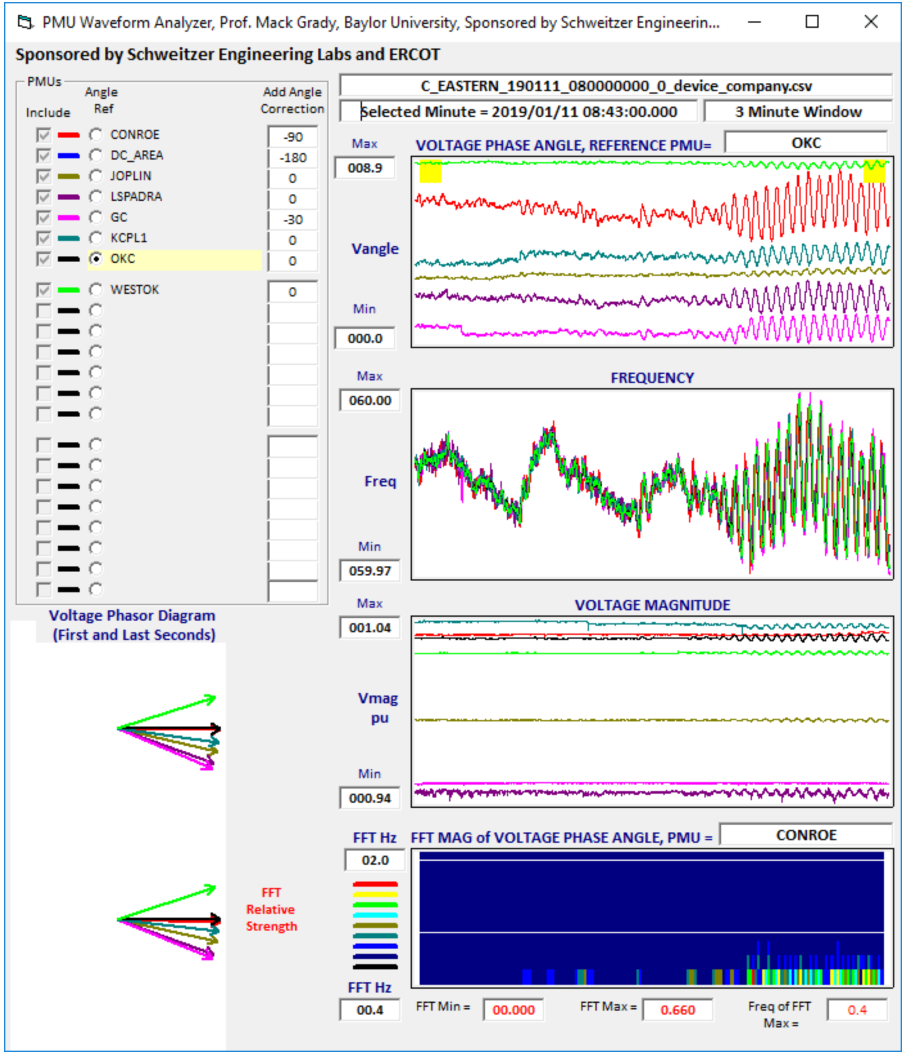
CAT1. Significant Ringing

CAT2. Less-Significant Ringing

CAT3. Slightly Higher-Freq. Ringing

CAT4. 2 – 8 Hz Ringing


PMU Waveform Analyzer, Prof. Mack Grady, Baylor University, Sponsored by Schweitzer Engineering Labs ...
Sponsored by Schweitzer Engineering Labs and ERCOT
PMUs
Include
Angle Ref
Add Angle Correction
WACO 180
AUSTIN 0
MCDONALD -120
UT_RIOGRANDE -180
C_ERCOT_191218_160000000.csv
Selected Minute = 2019/12/18 16:27:00.000
Zoom Secs 45 to 135
VOLTAGE PHASE ANGLE, REFERENCE PMU=
AUSTIN
0.9 Hz Switching
Max 003.5
Vangle
Min 000.0
FREQUENCY
Max 060.04
Freq
Min 060.00
VOLTAGE MAGNITUDE
Max 001.04
Vmag pu
Min 000.97
Voltage Phasor Diagram
(First and Last Seconds)
FFT Relative Strength
FFT Hz 02.0
FFT MAG of VOLTAGE PHASE ANGLE, PMU =
MCDONALD
FFT Hz 00.4
FFT Min = 00.000
FFT Max = 0.471
Freq of FFT Max = 0.4


PMU Waveform Analyzer, Prof. Mack Grady, Baylor University, Sponsored by Schweitzer Engineerin...
Sponsored by Schweitzer Engineering Labs and ERCOT
PMUs
Include
Angle Ref
Add Angle Correction
CONROE -90
DC_AREA -180
JOPLIN 0
LSPADRA 0
GC -30
KCPL1 0
OKC 0
WESTOK 0
C_EASTERN_190111_080000000_0_device_company.csv
Selected Minute = 2019/01/11 08:43:00.000
3 Minute Window
VOLTAGE PHASE ANGLE, REFERENCE PMU= OKC
Max 008.9
Vangle
Min 000.0
FREQUENCY
Max 060.00
Freq
Min 059.97
VOLTAGE MAGNITUDE
Max 001.04
Vmag pu
Min 000.94
Voltage Phasor Diagram (First and Last Seconds)
FFT Hz 02.0
FFT MAG of VOLTAGE PHASE ANGLE, PMU = CONROE
FFT Relative Strength
FFT Hz 00.4
FFT Min = 00.000
FFT Max = 0.660
Freq of FFT Max = 0.4

Thank you!

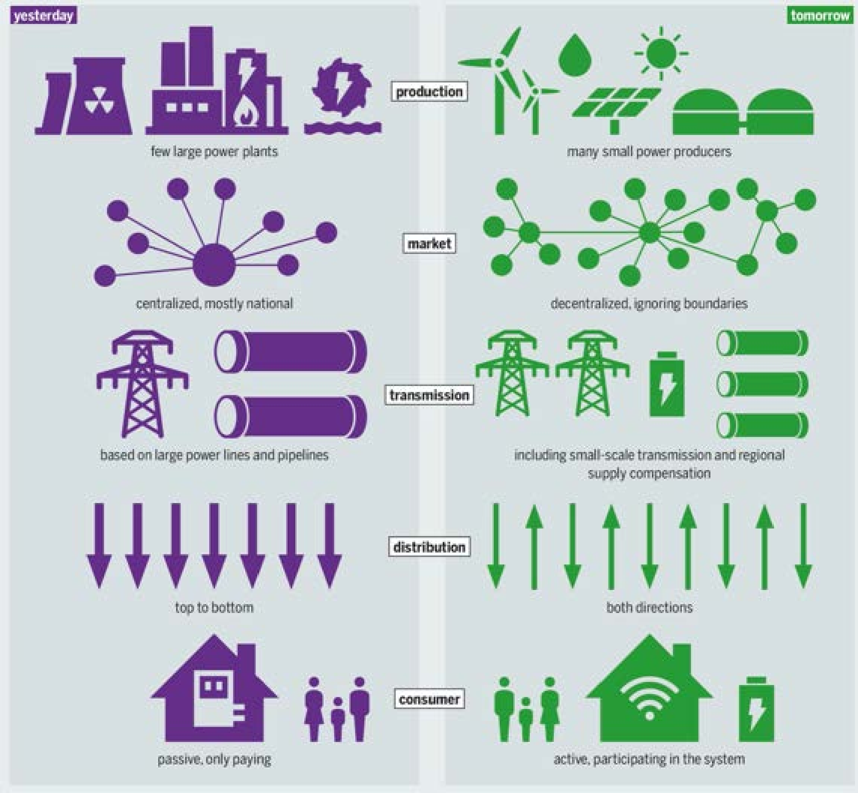
The Need for PQ Analytics

Theo Laughner, PE

Theo Laughner started PowerGrid-RX to help utilities maximize their investment in data for the contemporary grid. He started this endeavor after a 21-year career at TVA, where he was responsible for integrating data from over 1700 PQ monitors, DFRs, revenue meters, and microprocessor relays into an enterprise database system. His accomplishments at TVA garnered him the prestigious NSPE Top 10 of all Federal Engineers in 2017.

POWER QUALITY – A RETROSPECTIVE

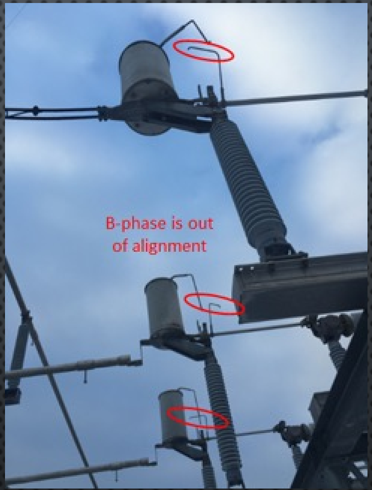
Historically –
End use "consumer"
phenomenon

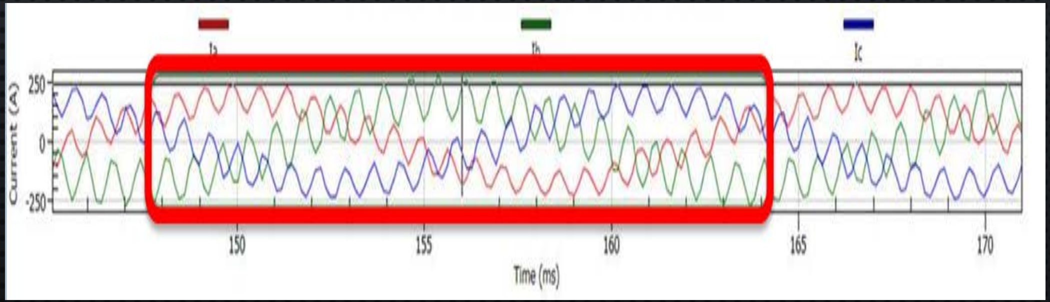


Who is the
consumer...

Generation?
Transmission?
Distribution?
Consumer?

INCREASING COMPLEXITY RESULTS IN UNFORESEEN CIRCUMSTANCES





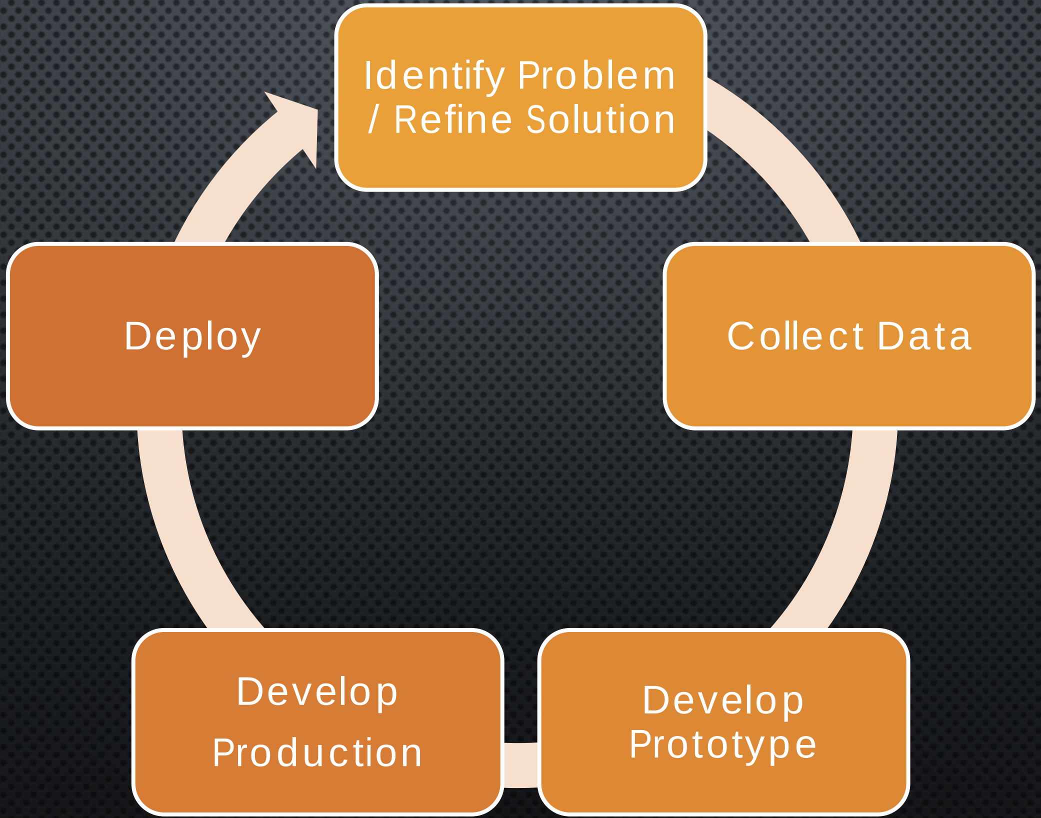
ASSET MANAGEMENT FUTURE STATE

VISION – MOVE FROM TIME-BASED TO CONDITION-BASED MAINTENANCE PROGRAMS. PREVENT CATASTROPHIC FAILURE OF ASSETS AND UNPLANNED INTERRUPTIONS TO CUSTOMERS.

Automatically Detect and Alert the Following:

- Capacitor Units with Shorted Elements or Blown Fuses
- Non or Mis-operation of Capacitor Unbalance Protection
- Control Circuit Element Failures
- Timing of Breakers and Circuit Switchers
- Alignment of Circuit Switcher and Pre-Insertion Inductors
- Breaker and Circuit Switcher Restrikes
- Bus PT Incipient Failure

DEVELOPMENT CYCLE – 3 YEARS



THE PROMISE - REDUCING DEVELOPMENT TIME

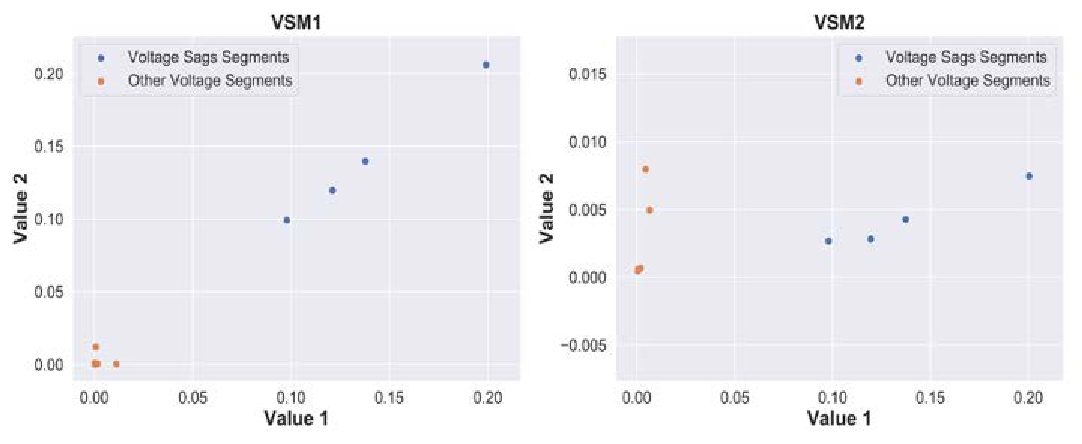
Data Exploration

Test out metrics on data samples

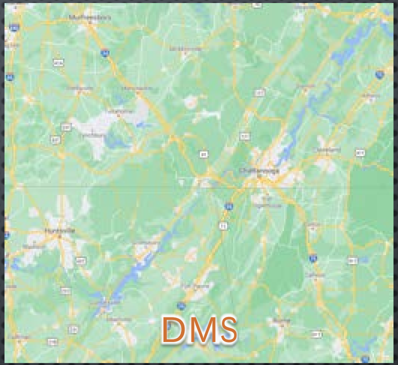
```
In [*]: def sagMetric(data, seconds=2):
            # data : window of measurement data in which to check for voltage sag
            # seconds : half the width of the voltage sag in seconds.
            T = np.size(data);
            # Find the minimum point of the data window. This is potentially the
            # center of the voltage sag
            minIdx = np.argmin(data);
            minVal = data[minIdx];
            meanVal = np.mean(data);

            n = seconds * 120;
            prevVal = data[max(0, minIdx - n)]; postVal = data[min(minIdx + n, T-1)];
            # Compute the values of the metric on this data
            t1 = (prevVal-minVal)/meanVal; t2 = (postVal-minVal)/meanVal;
            return [t1, t2]
```

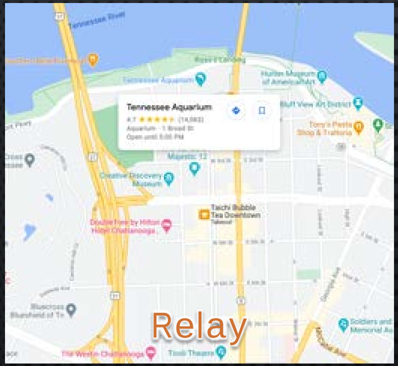
- Shareable
- Able to be vetted / improved by community
- Instantly deployable across data sets

- Worldwide community
- Development time – 1 week
- Device agnostic



GRID DATA SOURCES – A GEOGRAPHIC ANALOG





GRID DATA SOURCES – A GEOGRAPHIC ANALOG

- Combined
- Seamless
- Provides new ways of viewing data
- Allows crowd-sourced and model-based data

Thoughts

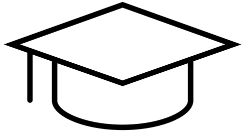
- The Grid is increasing in complexity
- We don't know what we don't know
- Measure everything let analytics sort it out

microPMU

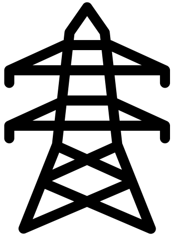
From the lab to the grid

POWERSIDE™

3 Major Customer Types



Universities

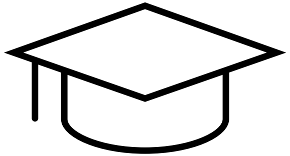


Utilities

Utility Product Providers

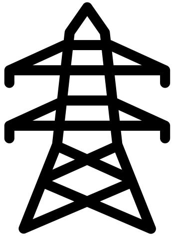
POWERSIDE

Most successful collaborations



University

+

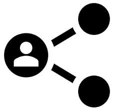


Local
Utility

Issues with current collab

Local Utility +
Local University

Limited Duration



No easy way to
share/transfer data

Objections to Data Sharing

Don't want to expose my issues

Grid security

Change from Status Quo

Benefits of data sharing

Larger pool of potential collaborators

Access to larger data set

Utilities don’t have time to spend on research projects

POWERSIDE™

Advancing Data Analytics for the Grid

How you can get more from your data

Laurel Dunn

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

PingThings

Berkeley
UNIVERSITY OF CALIFORNIA

Inaccessible data prevents progress

Asking questions of data is **too slow for every-day work**

New collaborations are challenging to establish

Big data warrants **new/different skills** and expertise

Analysts need **real data** to develop solutions that work

PingThings

Real solutions require real data

Algorithms are only as good as the data that train them

- **Robust solutions** require large training datasets
- Datasets must capture the **relevant dynamics**
- Real **systems are complicated**; data are messy

Analysts need your help

- To **understand the problems**
- To identify **viable solutions**
- To **get relevant data**

PingThings

Open data creates … more powerful tools

Promote discovery of **new use cases**

Compare solutions on basis of **predictive power**

Synthesize training data across utilities

Lowers barrier to **deploy solutions** developed by …

- Other utilities
- Top universities
- Research institutes
- Tech startups
- Students
- **Anyone else**

Open data creates … more skilled analysts

Promote discovery of **new use cases**

Student work **improves “data literacy”** of interns & hires

Students (usually) work for free and are willing/able to help

- Class projects & curriculum
- MS/PhD theses
- Student groups, hackathons, coding challenges, etc.

PingThings

How to create open access data

1. Install dedicated sensors
   - Substation
   - Distribution grid
   - Demonstration sites (campuses, microgrids, testbeds, etc.?)
2. Choose to remain anonymous
3. Remove locations
4. Remove sensitive data streams (e.g., power flow)

PingThings

Data streams that may be easier to share

1. Archived data from the distant past
2. Voltage magnitude & angle
3. DFR data
4. Power quality data
5. Experimental data
6. Other ideas? Let us know!

Support the advancement of analytical tools

A National Infrastructure for AI on the Grid

Three project pillars

1. Create training **DATA** analysts can readily use to build solutions
2. Provide access to PredictiveGrid, a state-of-the-art data **PLATFORM**
3. Build a **COMMUNITY** of analysts to share new ideas and insights

PingThings

Thank you!

Mack Grady, Baylor University

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