

# Synchrophasors Data Analytics at Dominion Energy

*Presented by*

Kevin D. Jones, Ph.D.

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# 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

# A Path Forward for Synchrophasors

*We must drive down the cost of working with data!*

## THE RIGHT TOOL FOR THE JOB

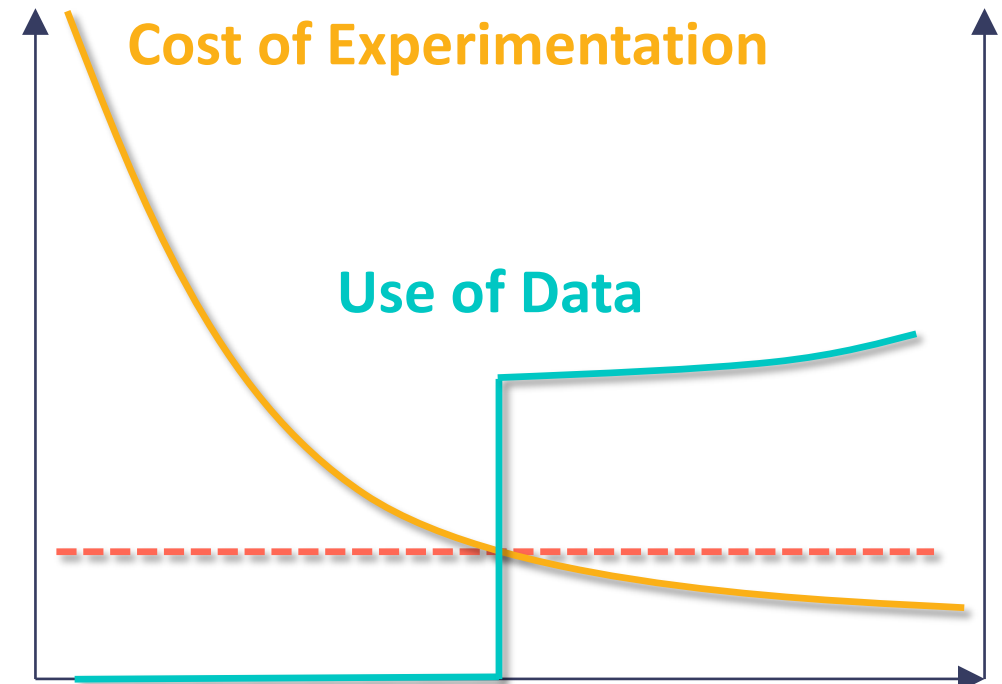
High resolution time series (e.g. synchrophasors) is a special comp. sci problem • Big Data technologies evolved towards specialization • Not all time-series DBs are equal • Historians make data history • Data at rest stays at rest

## NO SINGULAR “KILLER APP”; ENSEMBLE INSTEAD

The literature is full (10<sup>3</sup>s) 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



# 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

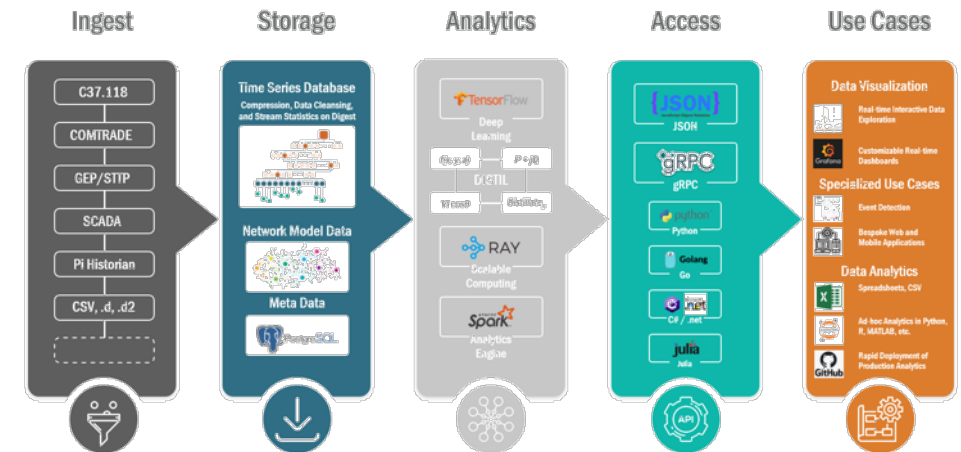


## PREDICTIVEGRID IS A PLATFORM-AS-A-SERVICE

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.

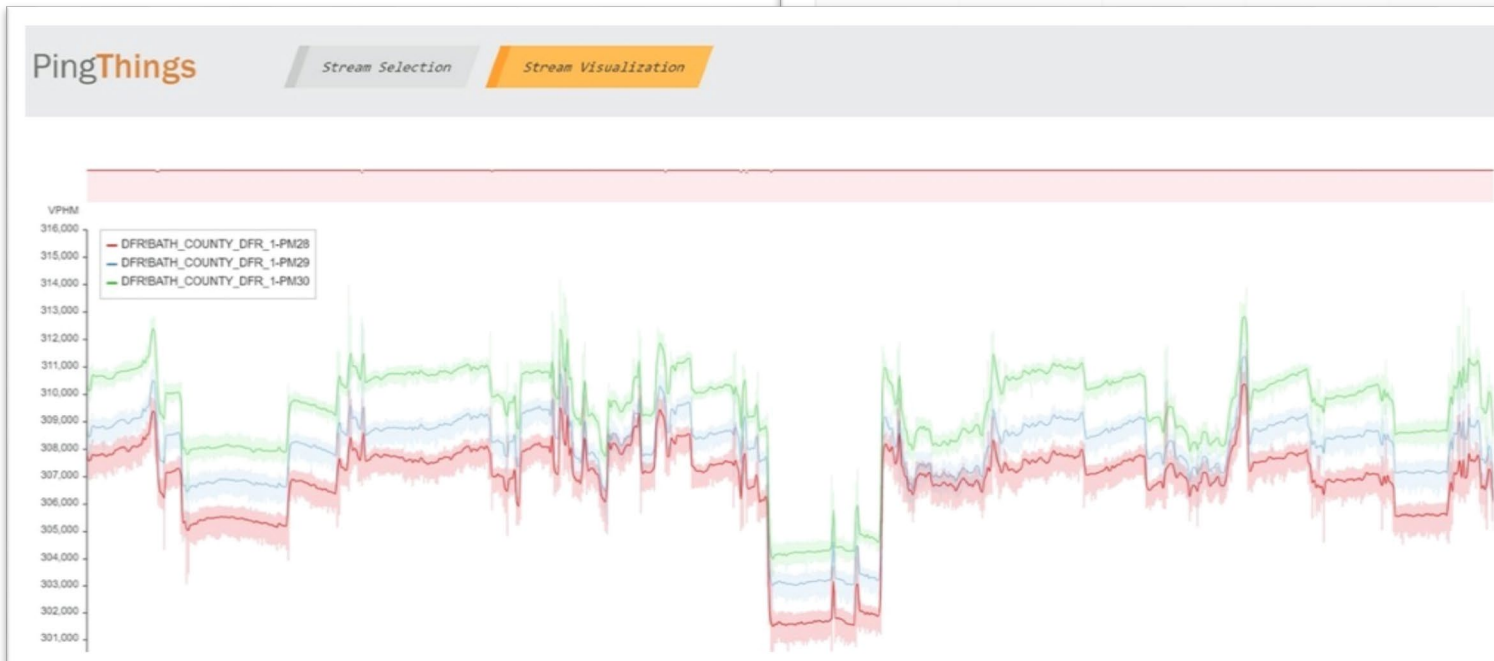
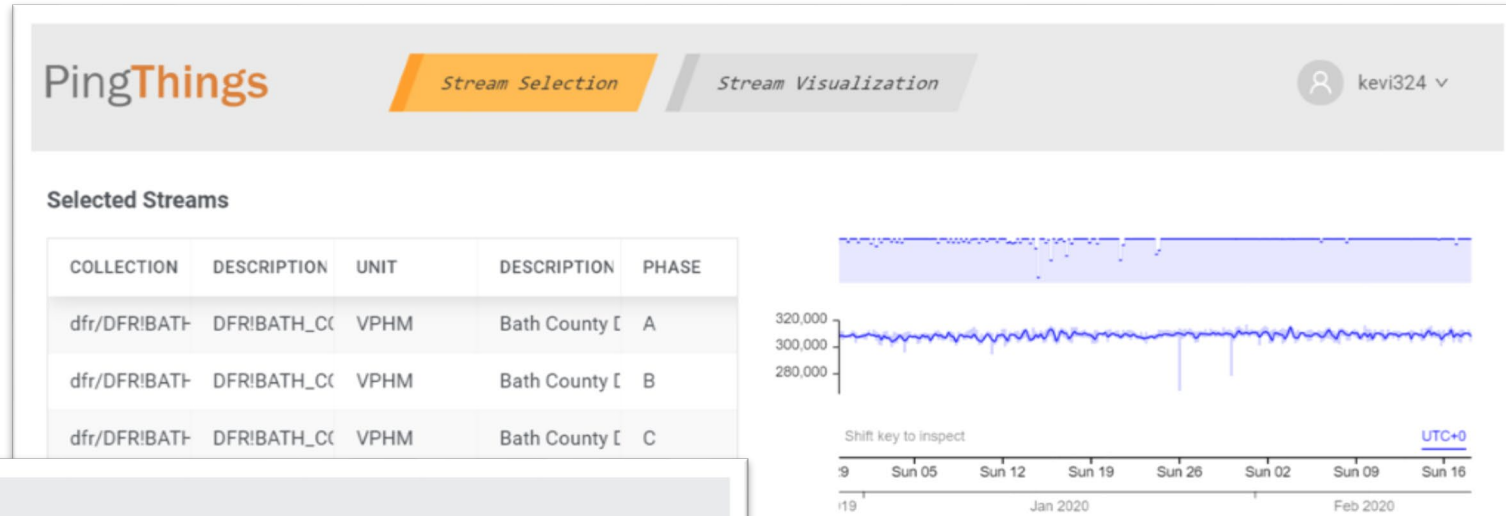


*Zero to streaming data in under 4 months. We can do more with less [people, time, and resources] with PingThings & PredictiveGrid.*

# Human-Scale Data Exploration

YOU MUST LOOK AT YOUR DATA!

Any data,  
at your fingertips,  
instantly, fluidly.

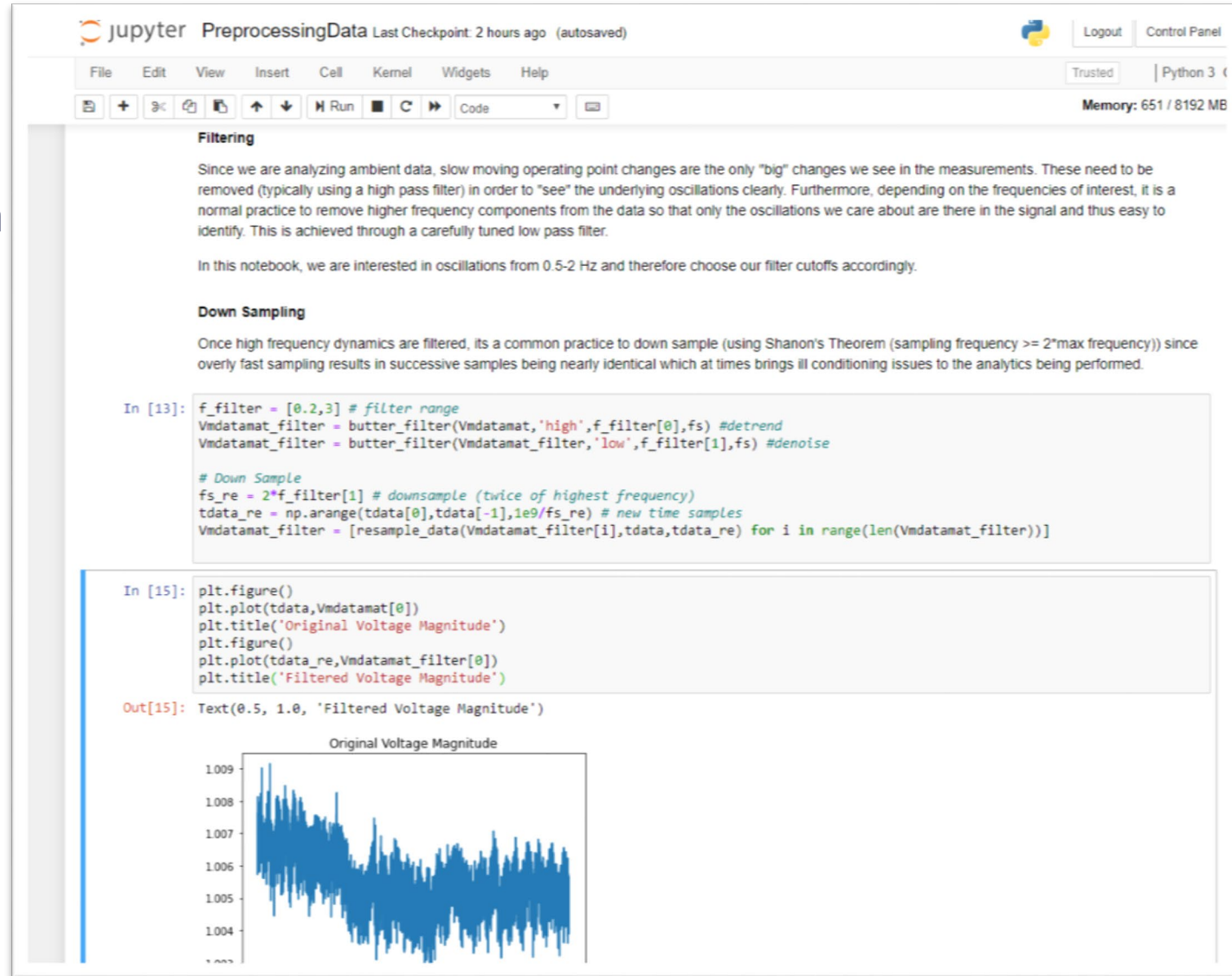


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# Rich, Programmatic Access

## 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.



The screenshot shows a Jupyter Notebook interface with the following content:

**Filtering**

Since we are analyzing ambient data, slow moving operating point changes are the only "big" changes we see in the measurements. These need to be removed (typically using a high pass filter) in order to "see" the underlying oscillations clearly. Furthermore, depending on the frequencies of interest, it is a normal practice to remove higher frequency components from the data so that only the oscillations we care about are there in the signal and thus easy to identify. This is achieved through a carefully tuned low pass filter.

In this notebook, we are interested in oscillations from 0.5-2 Hz and therefore choose our filter cutoffs accordingly.

**Down Sampling**

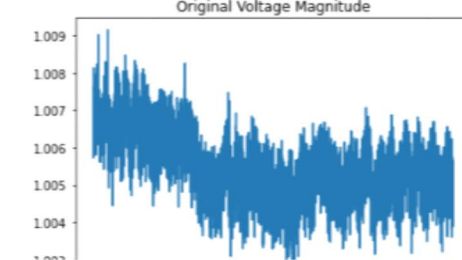
Once high frequency dynamics are filtered, its a common practice to down sample (using Shanon's Theorem (sampling frequency  $\geq 2 \times \text{max frequency}$ )) since overly fast sampling results in successive samples being nearly identical which at times brings ill conditioning issues to the analytics being performed.

```
In [13]: f_filter = [0.2,3] # filter range
Vmdatamat_filter = butter_filter(Vmdatamat,'high',f_filter[0],fs) #detrrend
Vmdatamat_filter = butter_filter(Vmdatamat_filter,'low',f_filter[1],fs) #denoise

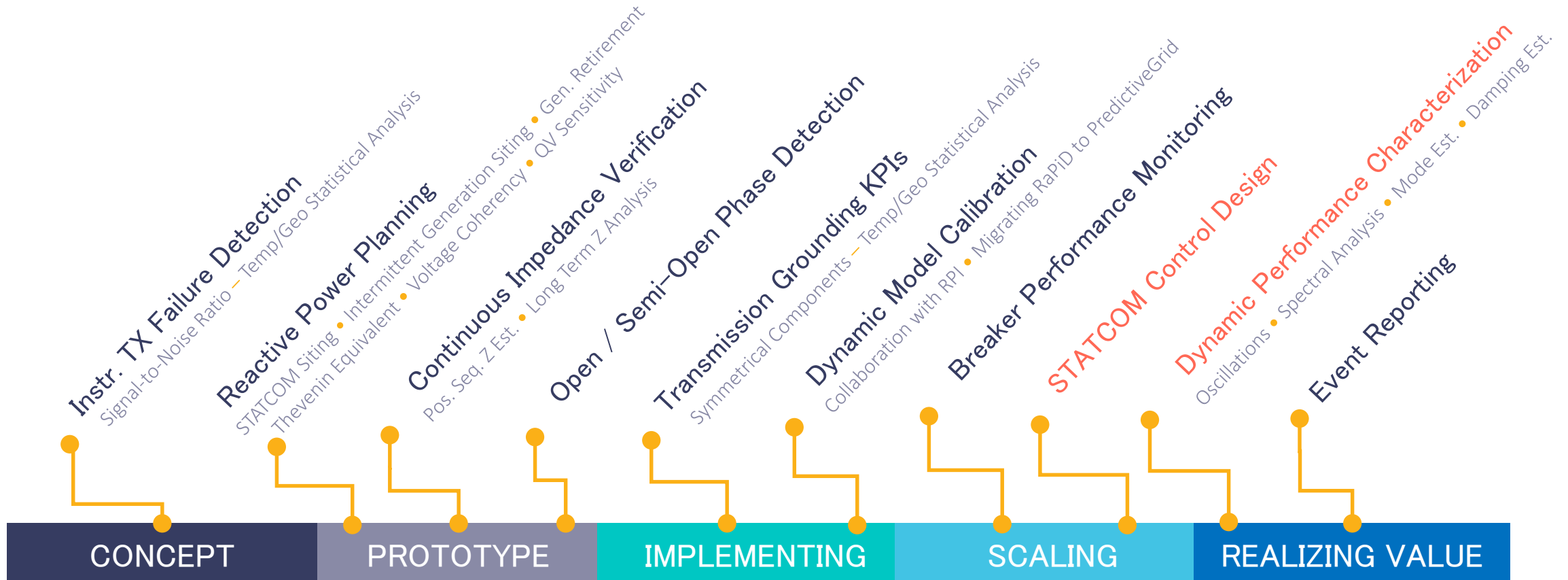
# Down Sample
fs_re = 2*f_filter[1] # downsample (twice of highest frequency)
tdata_re = np.arange(tdata[0],tdata[-1],1e9/fs_re) # new time samples
Vmdatamat_filter = [resample_data(Vmdatamat_filter[i],tdata,tdata_re) for i in range(len(Vmdatamat_filter))]
```

```
In [15]: plt.figure()
plt.plot(tdata,Vmdatamat[0])
plt.title('Original Voltage Magnitude')
plt.figure()
plt.plot(tdata_re,Vmdatamat_filter[0])
plt.title('Filtered Voltage Magnitude')
```

Out[15]: Text(0.5, 1.0, 'Filtered Voltage Magnitude')



# 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

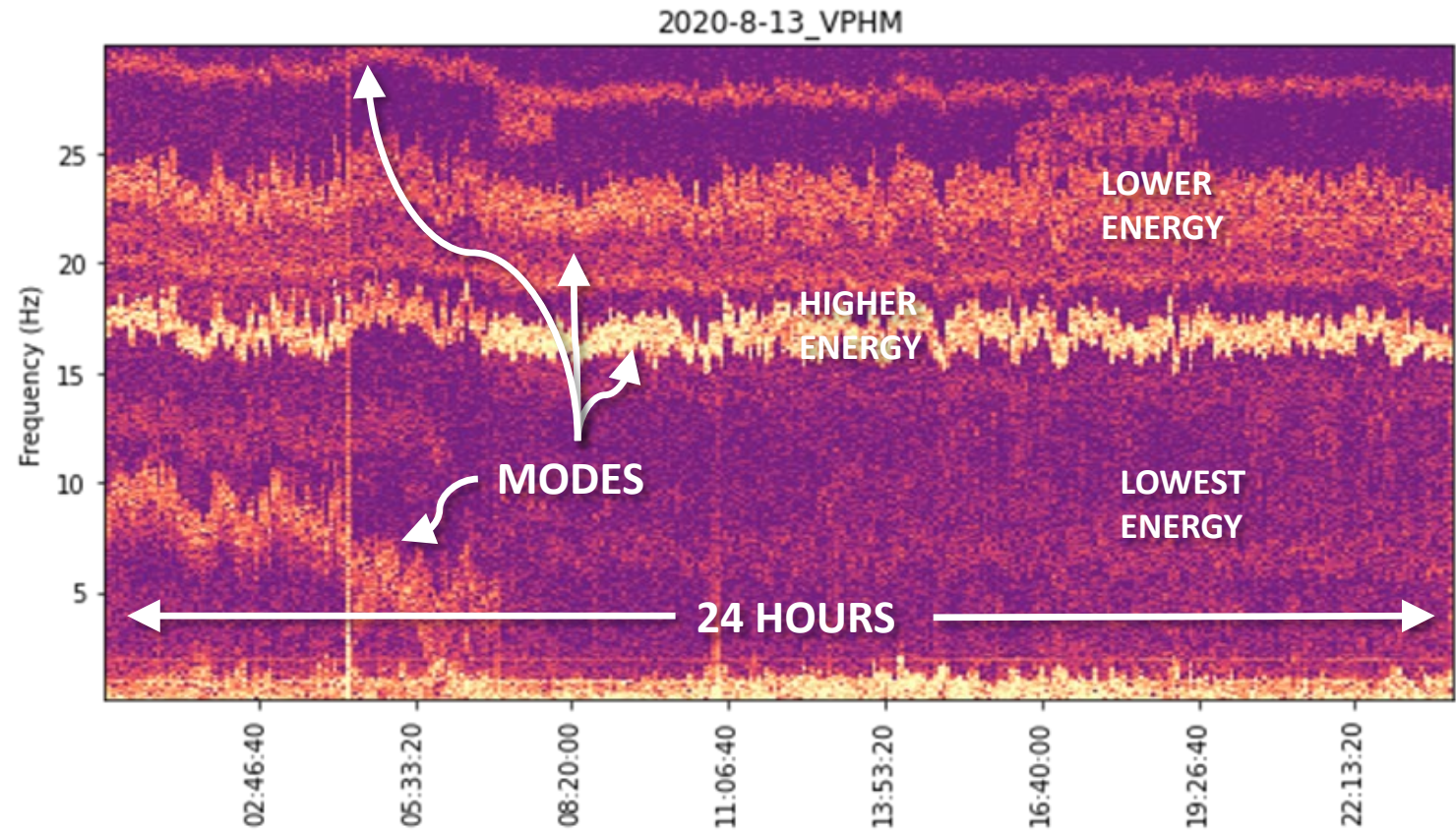
Network  
Model /  
Snapshots

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



# Today: Small Signal Analysis Case Studies

1. Regional Industrial Load Dynamics ← *Improving Grid Models*
2. Regional Solar Dynamics ← *Improving Grid Models & Interconnection Analyses*
3. STATCOM Controller Dynamics ← *Improving Existing Controller Design*
4. STATCOM Controller Testing ← *In-Vivo Testing of Controller Changes*
5. STATCOM Controller Interactions ← *Improving Existing Controller Design*
6. SVC Dynamics ← *Performance Assessment of FACTS*
7. Hydro Plant Dynamics ← *Data + Models for Diagnostics*
8. Impacts of Arc Furnace ← *Data Wrangling & Power Quality*
9. Nuclear & Gas Gen Dynamics ← *Beyond Synchrophasors: Point-on-Wave*

# 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

# Thank you!

Kevin D. Jones, Ph.D.

[kevin.d.jones@dominionenergy.com](mailto:kevin.d.jones@dominionenergy.com)