### Experiences with Synchrophasor Data Systems & Management

NASPI DNMTT Panel on *Success Stories & Lessons Learned of Utility* Synchrophasor Archive and Network Standups

Presented by

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### What We Have at Dominion

- Many Hundreds of PMUs: *40,000+ individual measured quantities*
- Critical and Non-Critical PMUs
- Substation PDCs
- Central PDC w/ Software PDC
- Gateway (Software PDC) to PJM and PredictiveGrid (PingThings) in AWS
- PredictiveGrid State-of-the-Art Data Mgmt & Analytics Platform in AWS
- Undergoing evaluation of new control room applications



### An Important Underlying Principle for Synchrophasor Networks & Archives

### We must drive down the cost of working with data! < Lesson Learned

#### THE RIGHT TOOL FOR THE JOB

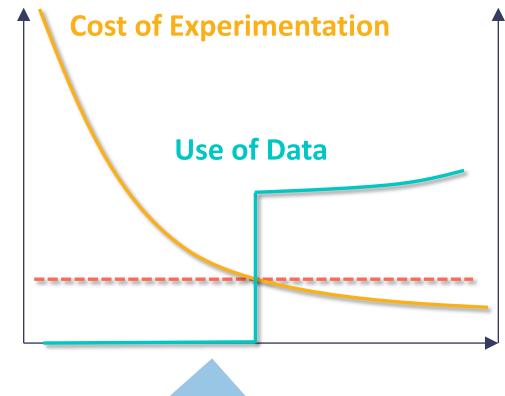
High resolution time series (e.g. synchrophasors) is a special comp. sci problem • Big Data technologies evolved towards specialization • Not all time-series DBs are equal • Historians make data history • Data at rest stays at rest

#### **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





### Data Transport

### • Firewalls

- Firewalls are the only real blockers we have experienced
- Substation PDC minimizes firewall rules Lesson learned
- Hire dedicated person to handle firewalls *← Lesson learned*

### Central PDC

- Use openPDC
- Use physical hardware, not virtual *← Lesson learned*
- Data quality monitoring

### Communication

- GEP (STTP) for aggregate streaming *← Lesson learned*
- VPN from Dom network to AWS
- Dedicated circuit to PJM
- Eventually dedicated circuit to AWS



# **Our "Archive"**





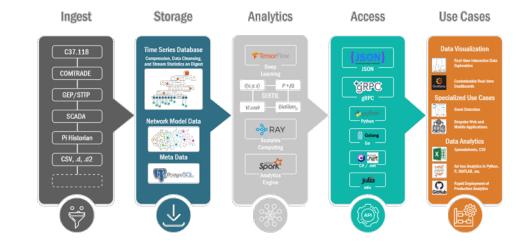
## **PingThings** PredictiveGrid Platform

#### **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 bestin-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. ← Success Story We can do more with less [people, time, and resources] with PingThings & PredictiveGrid.



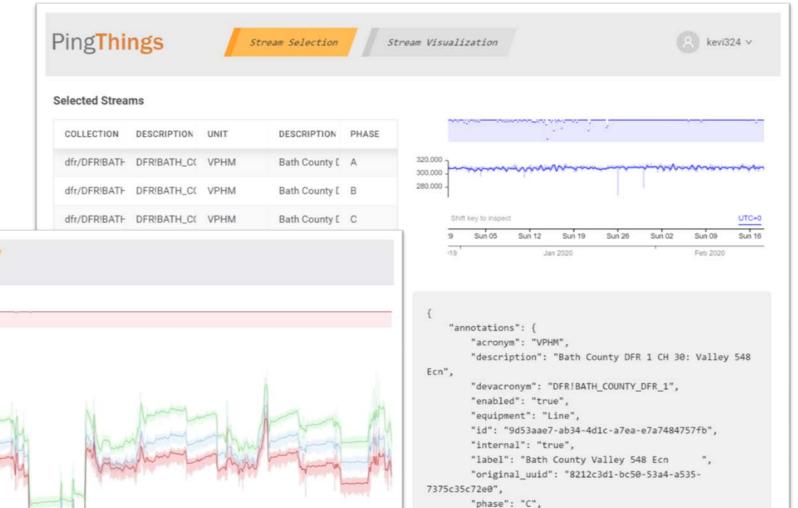
Dominion Energy<sup>®</sup>

Ping**Things** 

### **Human-Scale Data Exploration**

### YOU MUST LOOK AT YOUR DATA!

Any data, at your fingertips, instantly, fluidly.



"receiving": "Valley 548",

"sample rate": "30",

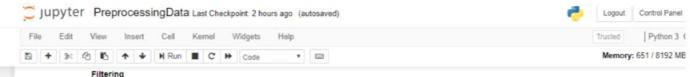
"reference": "DFR!BATH COUNTY DFR 1-PM30",

**PingThings** Stream Selection Stream Visualization VPH 316,000 - DFRIBATH COUNTY DFR 1-PM28 315,000 - DFRIBATH COUNTY DFR 1-PM29 - DFRIBATH\_COUNTY\_DFR\_1-PM30 314,000 313,000 312,000 311,000 310,000 309,000 308.000 307,000 306 000 305,000 304,000 303.000 302.000 301,000

## **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.



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.

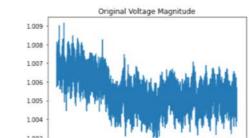
#### **Down Sampling**

Once high frequency dynamics are filtered, its a common practice to down sample (using Shanon's Theorem (sampling frequency >= 2\*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.

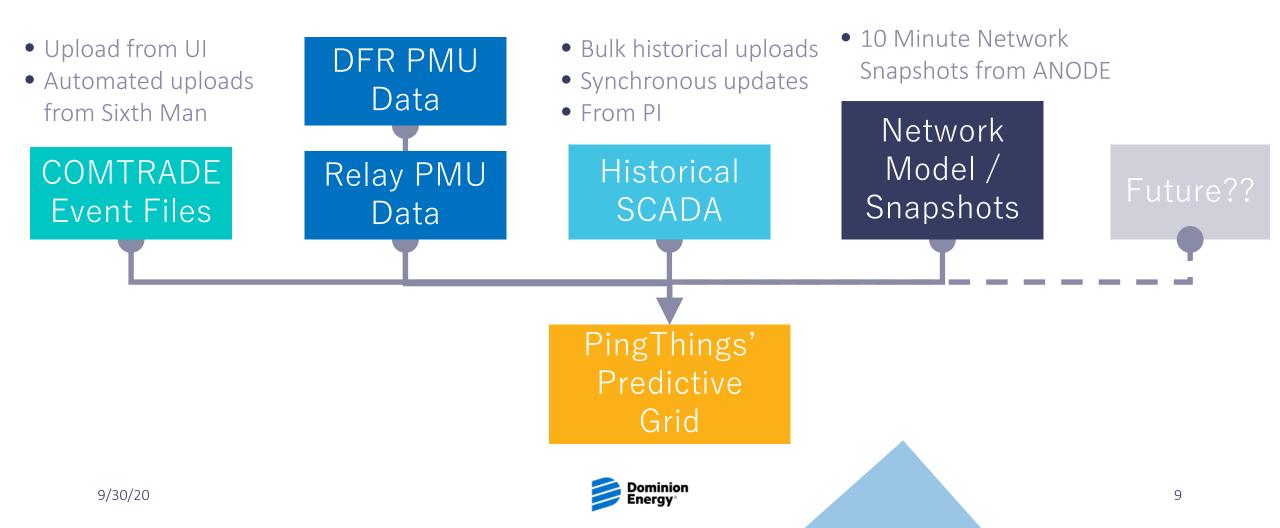
In [13]: f filter = [0.2,3] # filter range Vmdatamat filter = butter filter(Vmdatamat, 'high', f filter[0], fs) #detrend Vmdatamat\_filter = butter\_filter(Vmdatamat\_filter, 'low',f\_filter[1],fs) #denoise

# 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')



## Beyond Synchrophasors *← Success Story*



## Getting Help with the Cloud

- Cloud technologies and technology partners make all the difference for synchrophasors at scale *Success stories, Lesson learned*
- Cloud infrastructure makes the most sense as a:
  - Terminal node in a data system (i.e. archive/historian/data analytics platform)
  - A portal into a data system
  - NOT a router/PDC/streaming gateway
- PaaS/SaaS cloud solutions help limit IT bottlenecks and improve pace of innovation, flexibility of solutions, cost management, access to premier talent.
- Challenges:
  - Perception of security
  - Services/IT org feels their role is being taken from them
  - Cloud infrastructure is treated as O&M, not capital.



# Conclusion





## Key Takeaways

- Design data systems with a focus on cost of experimentation
- Consider post-synchrophasor use cases for data storage and retrieval
- Leverage the cloud whenever possible
- Don't limit solutions to internal Services/IT
- Find skilled collaborators



## **Other NASPI Talks to Check Out**

To get more of our story:

- Sep 30, 2020: Synchrophasors at Dominion Energy: Yesterday, Today, and Tomorrow
- October 30, 2019: Considerations for Working with Time Synchronized Measurements from Disparate Sources
- October 29, 2019: Zero to One: A Digital Transformation at Dominion Energy
- October 29, 2019: Architectural Influences on the Success of PredictiveGrid at Dominion Energy
- April 16, 2020: Turning 10: A Decade of Synchrophasor Technology at Dominion Energy
- April 15, 2019: Archiving Strategies for Synchrophasor Data
- October 24, 2018: Getting Beyond Base Camp: Scaling Your Synchrophasor Data Mountain
- April 24, 2018: The Role of a High-Performance Sandbox in Your Synchrophasor Analytics Pipeline



### Thank you!

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