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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

The 9th Annual Monitoring and Situational Awareness Technical Conference – Session 3

New Normal in Energy Management Systems

NERC EMS Working Group

October 28, 2021

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RELIABILITY CORPORATION

Today's Agenda

- Session Theme: Technique and Workforce Challenges
- EMS Staffing Challenges
  - Stacen Tyskiewicz, BPA
- Cloud-based Power System Elastic Computing and Wide-Area Monitoring
  - Song Zhang, ISO New England
- **10-minute Break**
- Enhancing Grid Resilience Monitoring and Situational Awareness by Intelligent Analytics Integrated with Digital Twin Simulation
  - Hongming Zhang, NREL
  - Seong Choi, NREL
  - Yilu Liu, University of Tennessee
- Session Summary
  - Matt Lewis, NERC

Stacen Tyskiewicz

Stacen Tyskiewicz manages the Energy Management Systems group at Bonneville Power Administration (BPA). She has been providing technology support to System Operations for over 25 years.

Stacen is a member of the NERC EMS Workgroup, WECC Data-Exchange & EMS Workgroup, and a member and current Chair of the WECC Situational Awareness and Security Monitoring Subcommittee.

Stacen earned her BSEE from Mississippi State University with an emphasis in industrial control systems.

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B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

EMS Staffing Challenges

Stacen Tyskiewicz

October 28, 2021

Discussion Topics

- Introduction to BPA
- What is an EMS Engineer?
- Why is EMS staffing a challenge?
- How can we address the challenge?
- How is BPA addressing the challenge?


BONNEVILLE POWER ADMINISTRATION
BPA
OVERVIEW

PROFILE

- BPA (a component of the U.S. Department of Energy) is a nonprofit and self-funded federal power marketing administration in the Pacific Northwest.
- Congress created BPA in 1937 to deliver and sell the power from Bonneville Dam.
- BPA now markets wholesale electrical power from 31 federal hydroelectric dams in the Northwest, one nonfederal nuclear plant and several small nonfederal power plants.

TRANSMISSION SERVICES

15K+
CIRCUIT MILES

TRANSMISSION

- BPA operates and owns one of the nation's largest high-voltage transmission systems.
- It operates and maintains about three-fourths of the high-voltage transmission in its service territory, which includes Idaho, Oregon, Washington, western Montana and small parts of eastern Montana, California, Nevada, Utah and Wyoming.
- BPA provides transmission to direct-service industries and public and private utilities.

POWER SERVICES

total generation

8,000+ aMW

The Columbia Generating Station is the third-largest generator of electricity in Washington state, producing enough clean, carbon-free energy to power a city the size of Seattle.

1 GRAND COULEE

2 CHIEF JOSEPH

3 COLUMBIA

POWER SERVICES

- Hydropower generated by the Columbia River is sold at cost by BPA.
- This power is an important energy resource that fuels daily life and businesses of the Northwest.
- BPA provides about 28 percent of the electric power used in the Northwest. Its resources — primarily hydroelectric — make BPA power nearly carbon free.

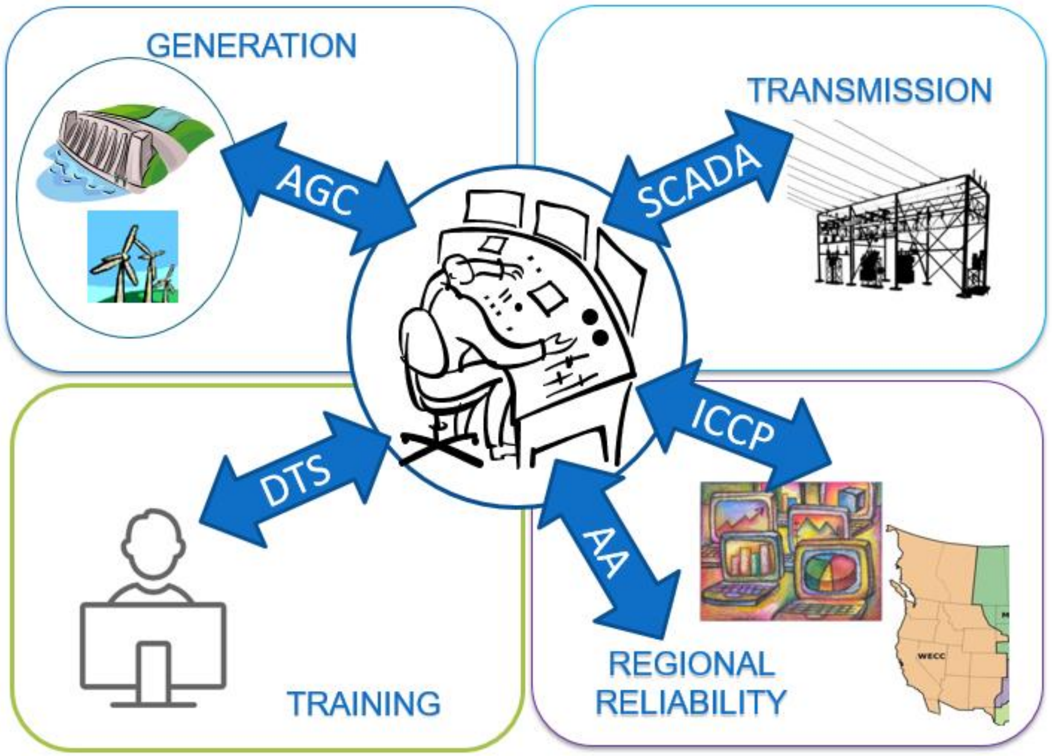
What is an EMS Engineer?

EMS Engineers are responsible for the life-cycle support for the Energy Management Systems (EMS) used by Power System Dispatchers/Operators to monitor, control, and optimize the Power Grid.

Responsibilities include analysis, engineering, design, implementation, operations and maintenance support and technical leadership for those systems required to support the operation of an interconnected utility.

What is an EMS Engineer?

For a large utility, these systems likely include Supervisory Control and Data Acquisition (SCADA), Automatic Generation Control (AGC), on-line power flow and state estimation (Adv Apps), real-time inter-control center data exchange (ICCP) , and systems which simulate the real world to provide real-time operational data and dispatcher training environments (DTS). Responsibilities may also include applicable cyber security functions and supplemental project support.



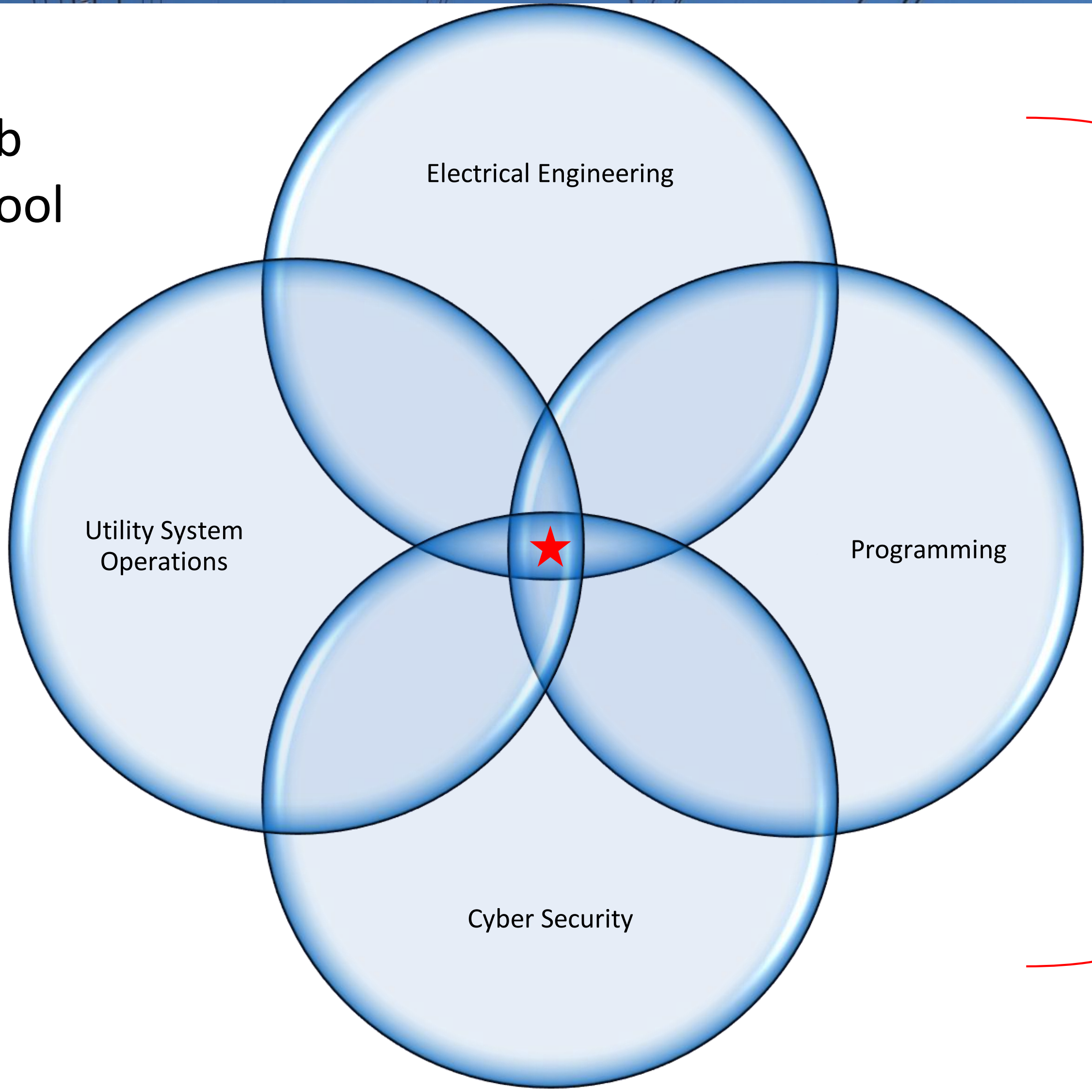
What is an EMS Engineer?

Beyond understanding Electrical Engineering as it applies to Electric Power Systems, an EMS Engineer also requires the following knowledge, skills, and abilities:

- Programming (high-availability)
- Cyber Security/NERC-CIP
- Utility System Operations
- EMS vendor’s implementation
- Database structures
- Any unique requirements and challenges of their utility’s transmission service area and/or Balancing Authority Area
- An understanding and appreciation of the complexities of testing real-time control systems in a high-availability power system control environment
- Grace under pressure

Why is EMS staffing a challenge?

★ It's a highly specialized job with a very small talent pool to choose from



Even if you find a candidate with this skillset, you will still likely need to train them on:

- Your EMS vendor's implementation
- Any unique requirements and challenges of your utility's transmission service area and/or Balancing Authority Area

Why is Staffing a Challenge?

Recruiting a trained EMS Engineer seems to be about as likely as buying the winning lottery ticket.

So… if you can't hire a trained EMS Engineer, what can you do?

How can we address the challenge?

If you're in a must-hire-now situation:

- **Double-Up** – Hire a Power Systems EE plus a skilled Programmer; pair them up.
- **Pilfer** – If your EMS vendor employs skilled EE/programmers, try to recruit from that talent pool (but don't tell them it was my idea).
- **Outsource** – Skilled EMS Engineers are available through several consulting firms.
- **Beg** – If you have recently retired EMS Engineers, do what you need to do to entice them back to give you time to hire/train.

How can we address the challenge?

If you're in a must-hire-now situation:

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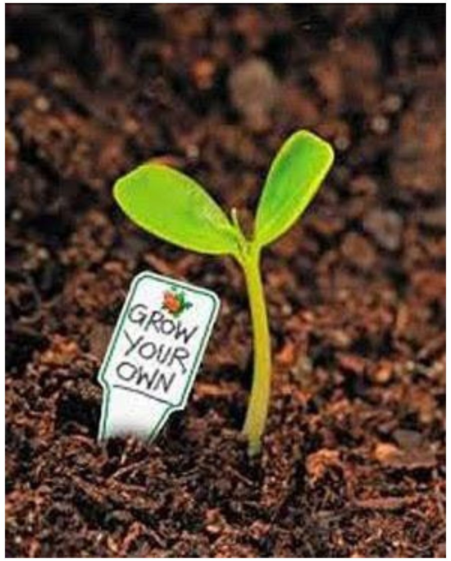
- **Beg** … t you need to do to …

When not in this urgent situation, what are some longer term approaches to EMS Staffing?

How can we address the challenge?

1. Hire Electrical Engineers with some of the needed skills; train to address gaps. Good options for recruiting include:
    - Industry Conferences
    - Your EMS vendor's Users Group Conference
    - Other organizations within your utility
2. Offload non-EE work from your EMS Engineer positions and augment EMS staff as needed with:
    - Cybersecurity Specialists
    - Technical Writers
    - Business Analysts
    - Programmers
3. Use retention bonuses or other tools available to retain the EMS Engineers you currently employ until you can train new hires.

How can we address the challenge?



Ultimately, if you can't find the talent you need, you'll have to grow your own. This takes **TIME** and **SUPPORT** from executives.

One way to accomplish this, is with a documented **EMS STAFFING STRATEGY** that details the challenges and your long-term plan for addressing them.

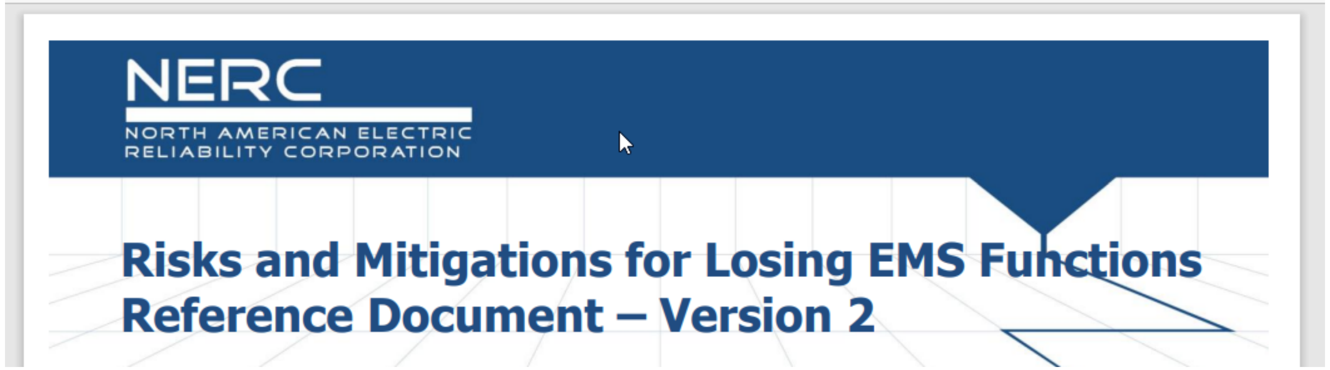
How can we address the challenge?

EMS STAFFING STRATEGY – Needs to include details that clearly define the problem and the solution. A good staffing strategy document will likely include:

- Justification of the size of EMS team your utility needs
- Details about the scarcity of trained resources
- Examples of how EMS Engineers are required for grid reliability
- Explanation of the time needed to fully train EMS Engineers
- Benefits of hiring early enough to allow mentoring before a retirement
- Potential impacts of inadequate EMS Engineer staffing

How can we address the challenge?

EMS STAFFING STRATEGY – Use references!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Risks and Mitigations for Losing EMS Functions
Reference Document – Version 2

"It is essential to develop dedicated and skilled in-house personnel who can troubleshoot and correct issues…"

"…more skilled in-house personnel who can troubleshoot and correct these issues can lead to shorter EMS outage durations…"

How can we address the challenge?

EMS STAFFING STRATEGY – Needs to include details that clearly define the problem and the solution. A good staffing strategy document will likely include:

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Let's look more closely at this before me move on.

How can we address the challenge?

An informal study was recently conducted that determined the industry average for total EMS staff is:

Staff/10,000 points	Staff/100 Displays	Staff/Load GW	Adv Apps Staff /1000 Busses
1.59	2.79	5.63	1.74

The above data shows the number of full time equivalents (Total EMS staff) measured against metrics that are related to field modifications, maintenance, and support. The data was collected from 8 utilities of various sizes. Different EMS support functions in some utilities were spread across different groups. In this case, the total staff working directly on the EMS were included even if they were not on the EMS team. For example, in some utilities, display builders worked directly for the Transmission System Operators.

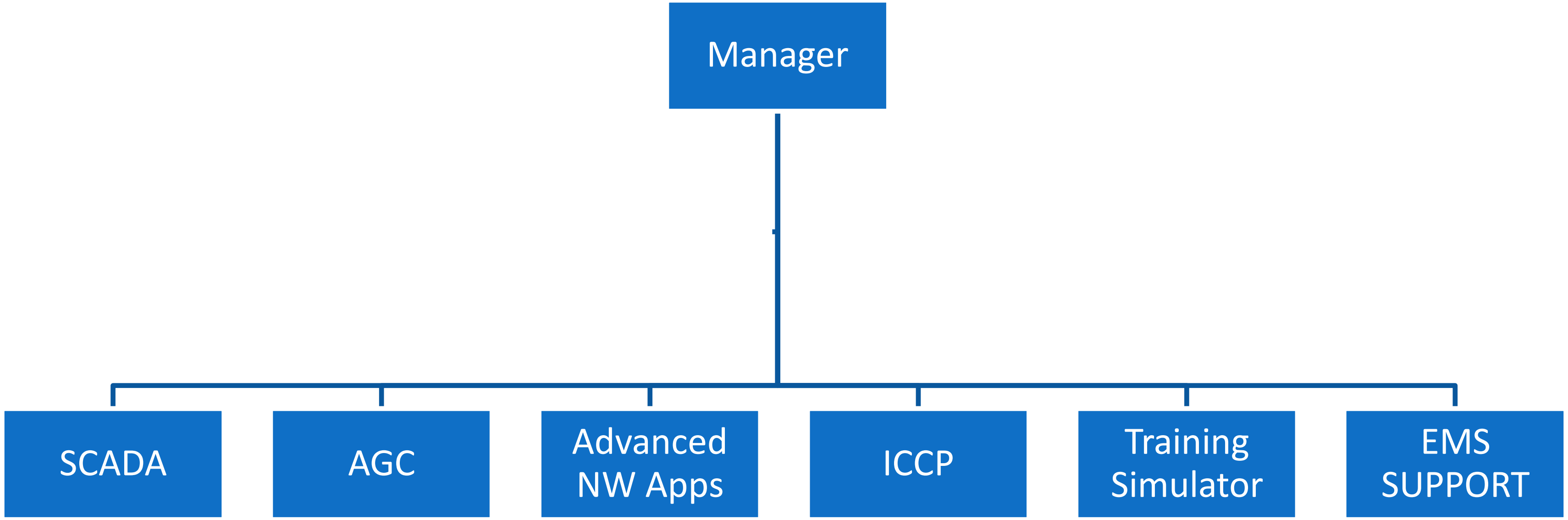
Would it be beneficial to conduct a larger, more in-depth nationwide study?

How is BPA addressing the challenge?

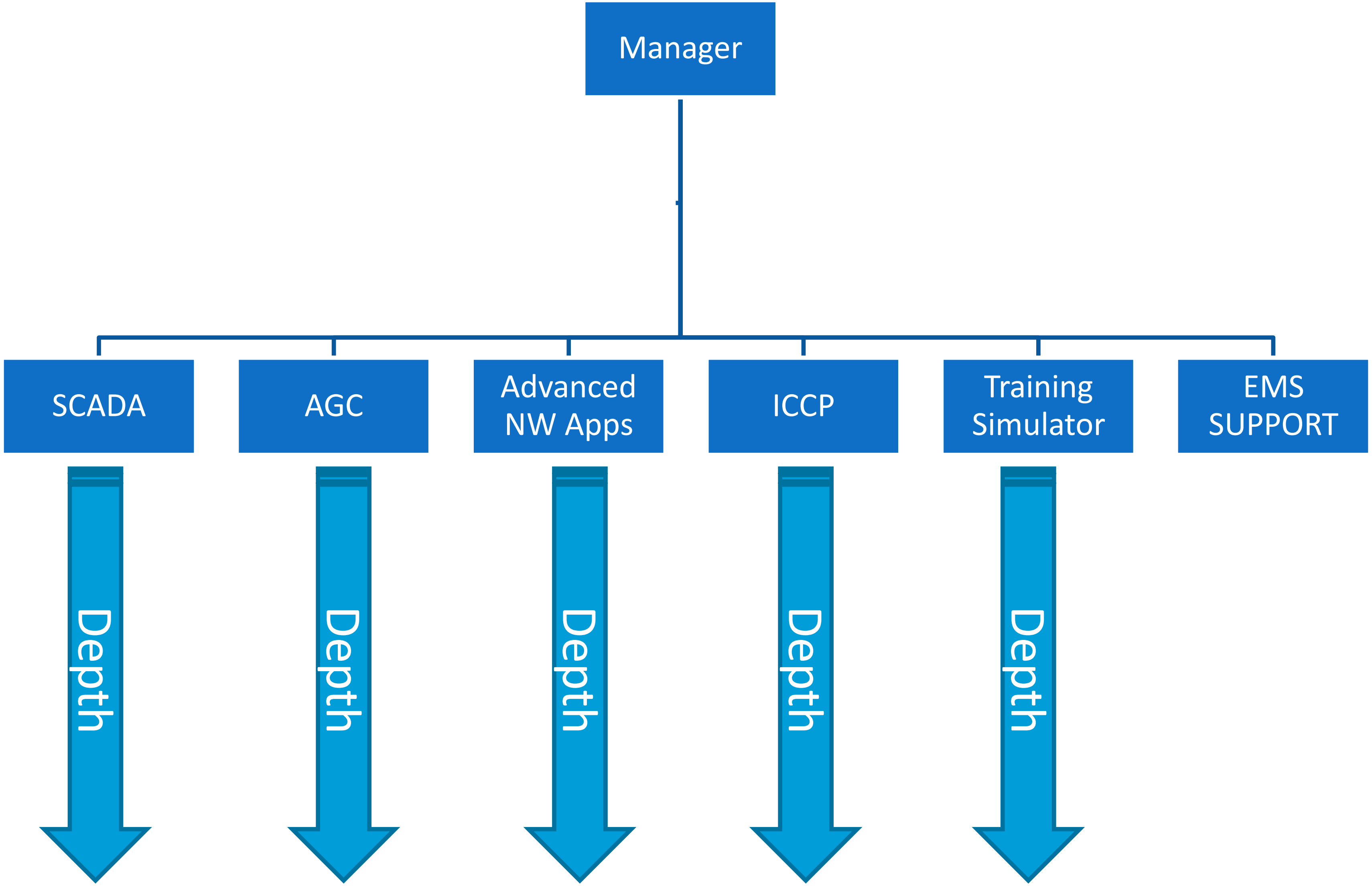
BPA’s EMS Staffing Strategy:

- Relies heavily on BPA’s Pathways (student/recent grad) Program
- Incorporates a training and career path to ensure successful development of EMS Engineers
- Offloads non-engineering workload from engineers
- As necessary, allows for the use of retention pay to retain Senior EMS Engineers and/or the re-hiring of retired EMS Engineers to provide mentoring
- When needed, fills gaps with expert consultants

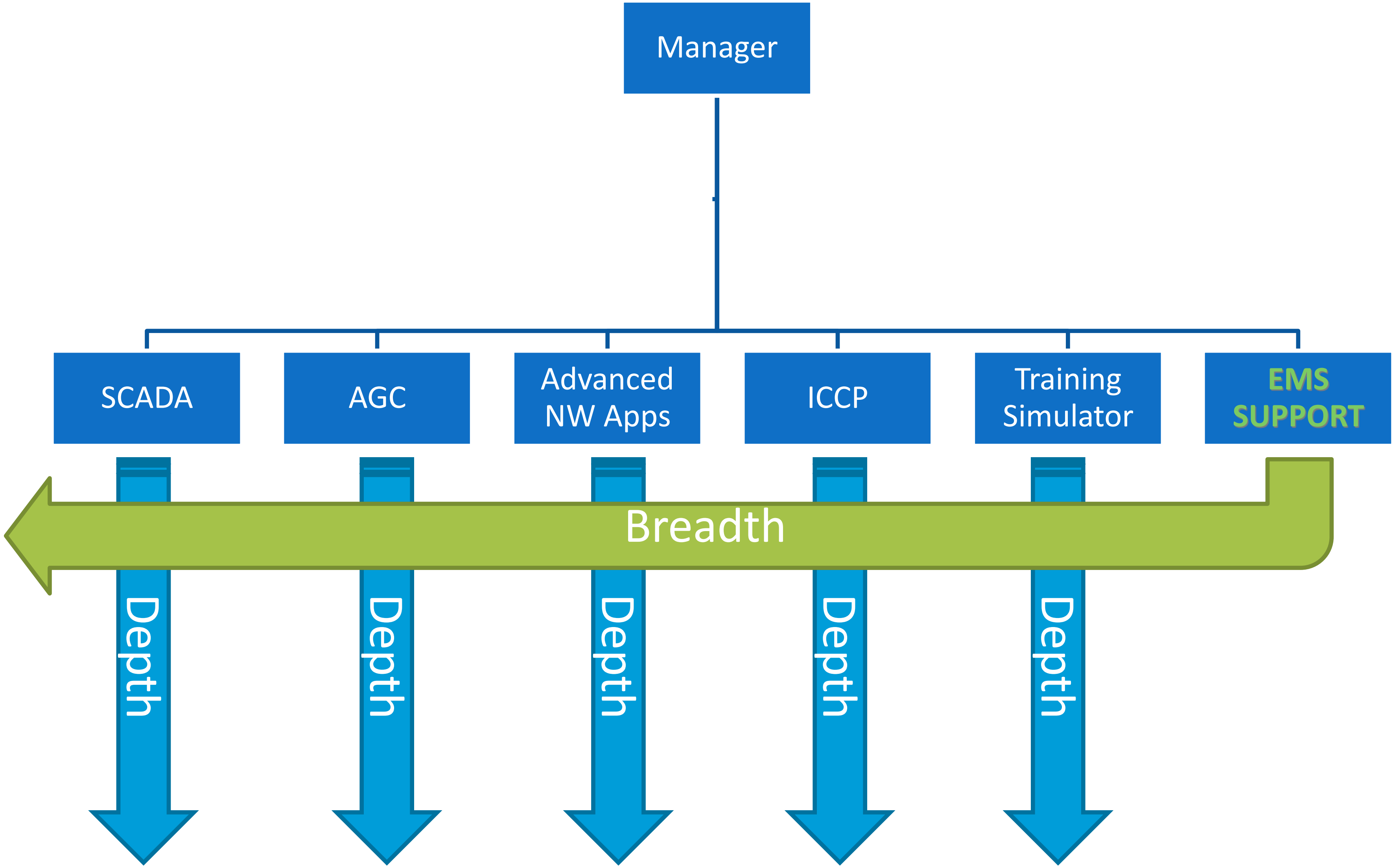
How is BPA addressing the challenge?



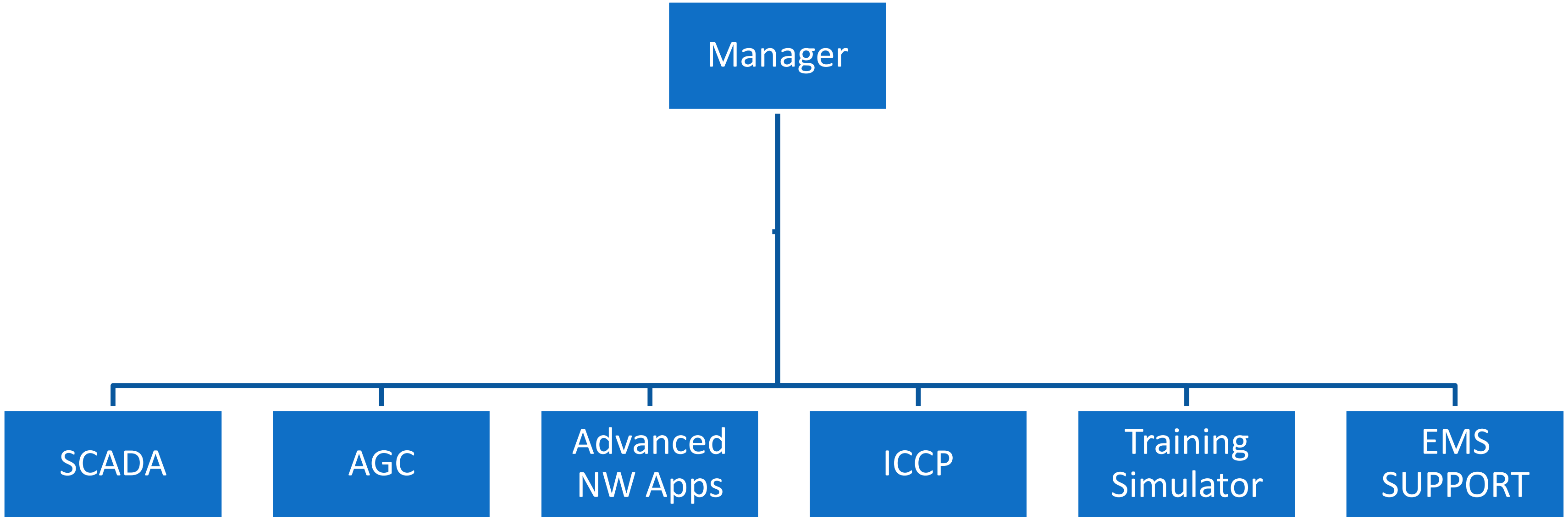
How is BPA addressing the challenge?



How is BPA addressing the challenge?

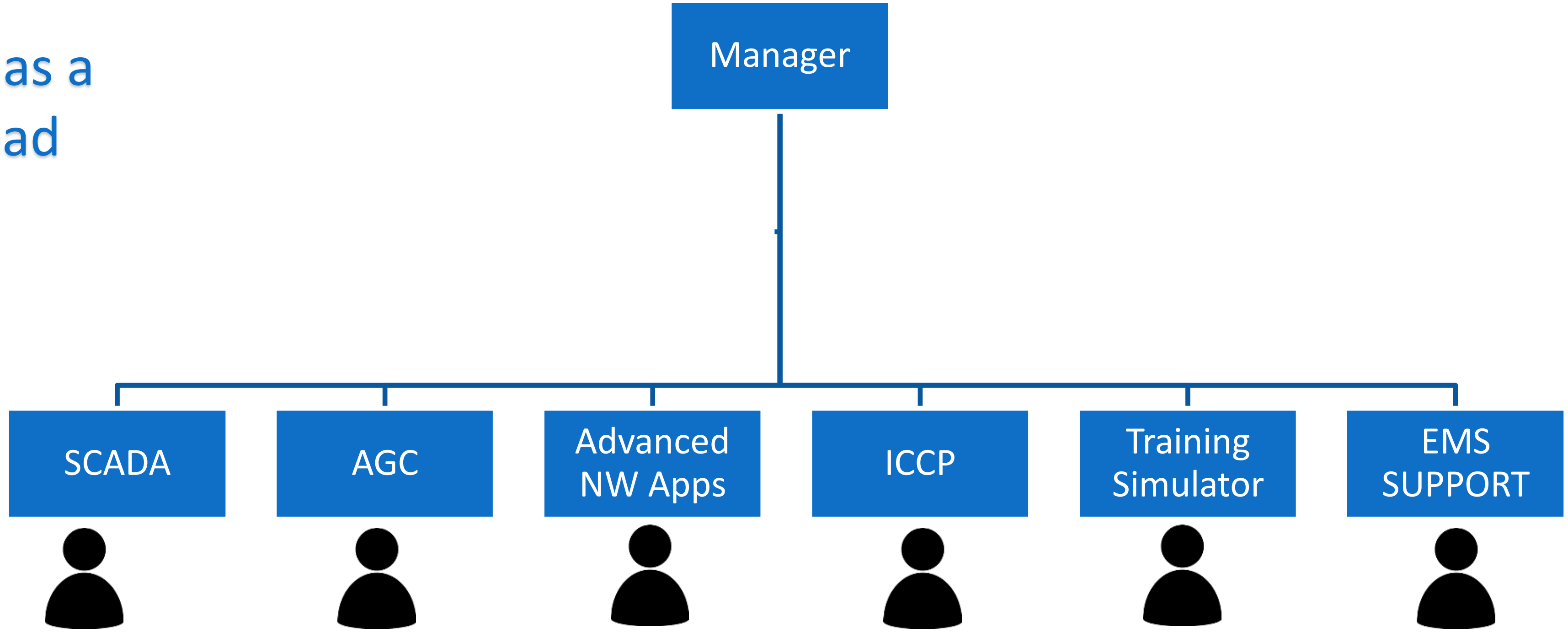


How is BPA addressing the challenge?



How is BPA addressing the challenge?

Each team has a dedicated lead



How is BPA addressing the challenge?

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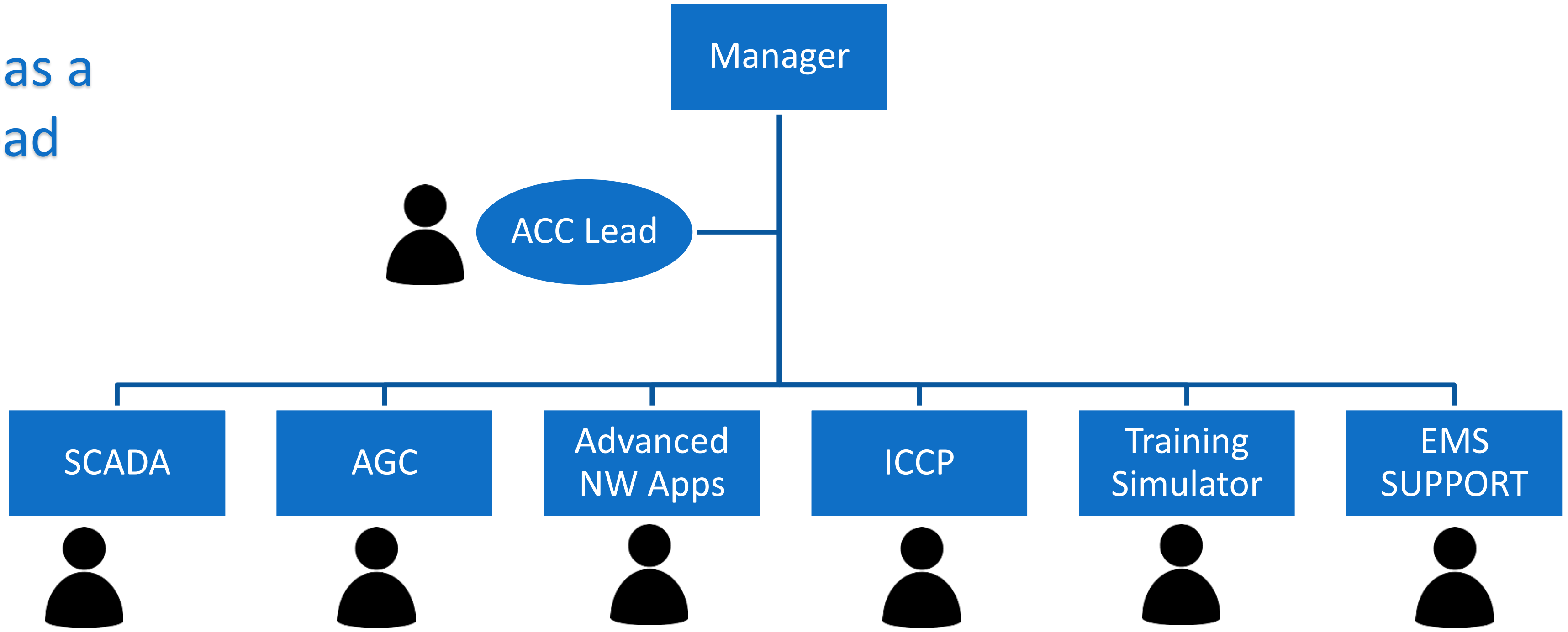
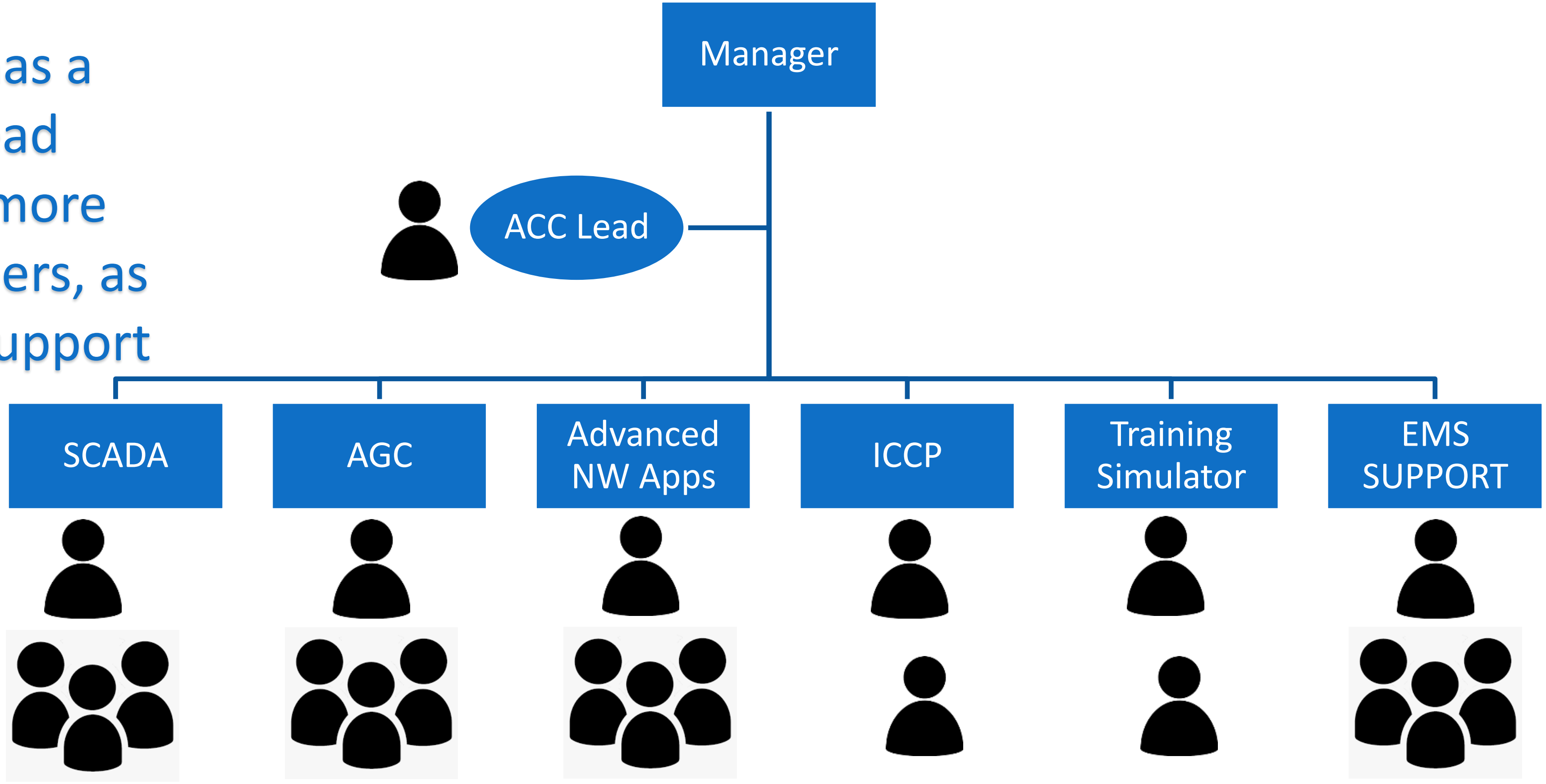
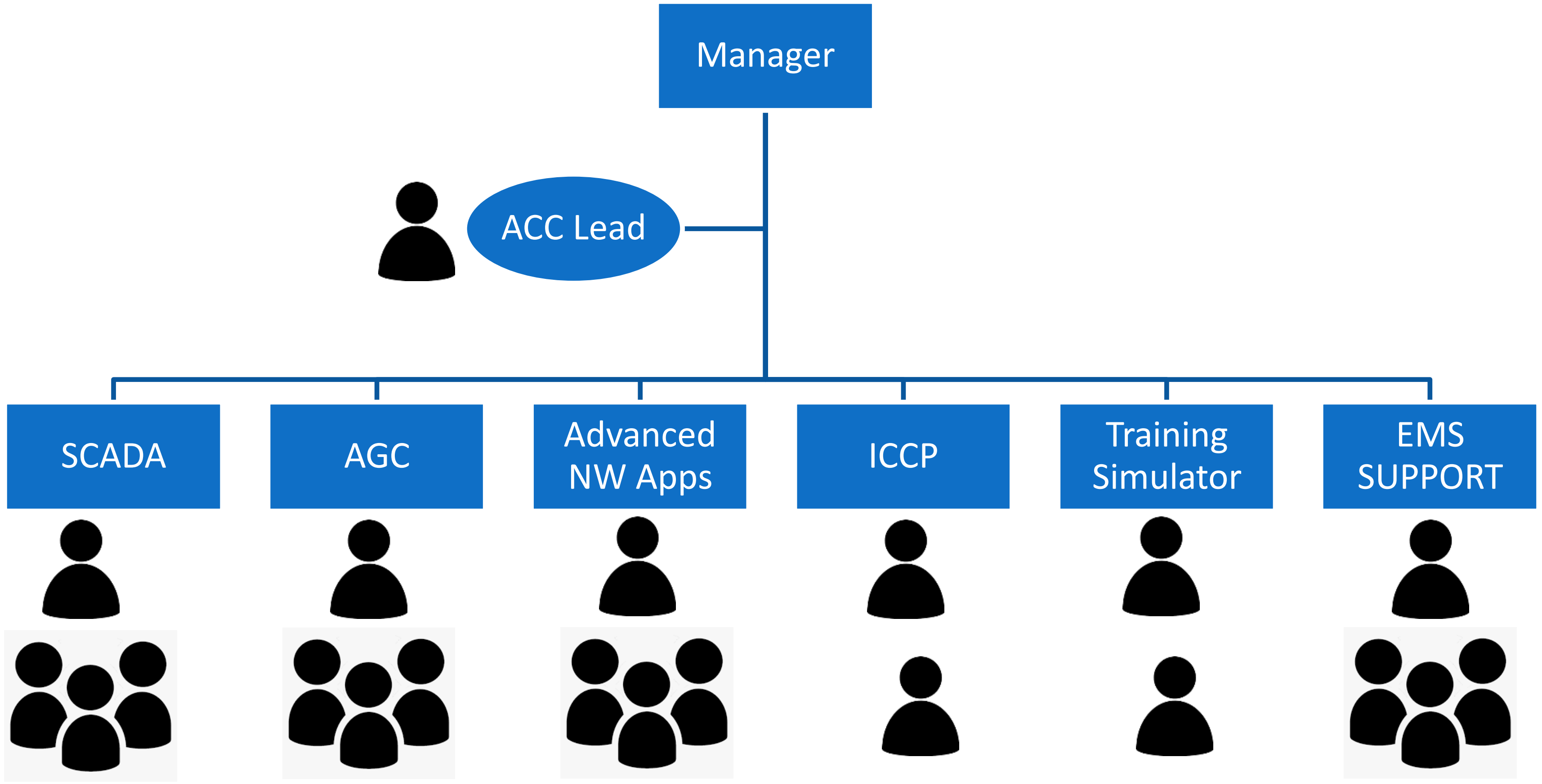


How is BPA addressing the challenge?

Each team has a dedicated lead and one or more team members, as needed to support typical workload.

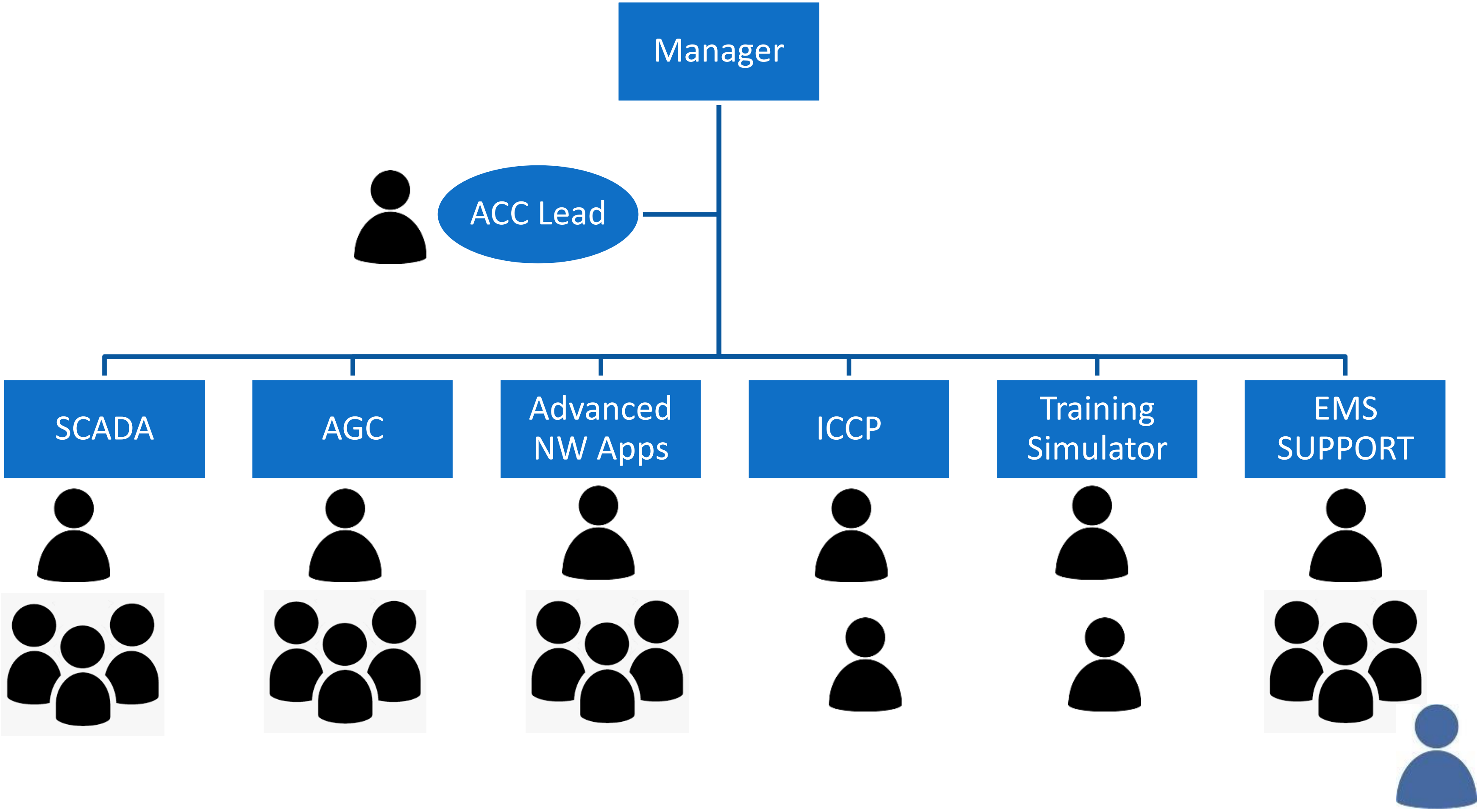


How is BPA addressing the challenge?



Each Team Lead is responsible for providing needed training to ensure adequate "bench strength" for every function performed by their team.

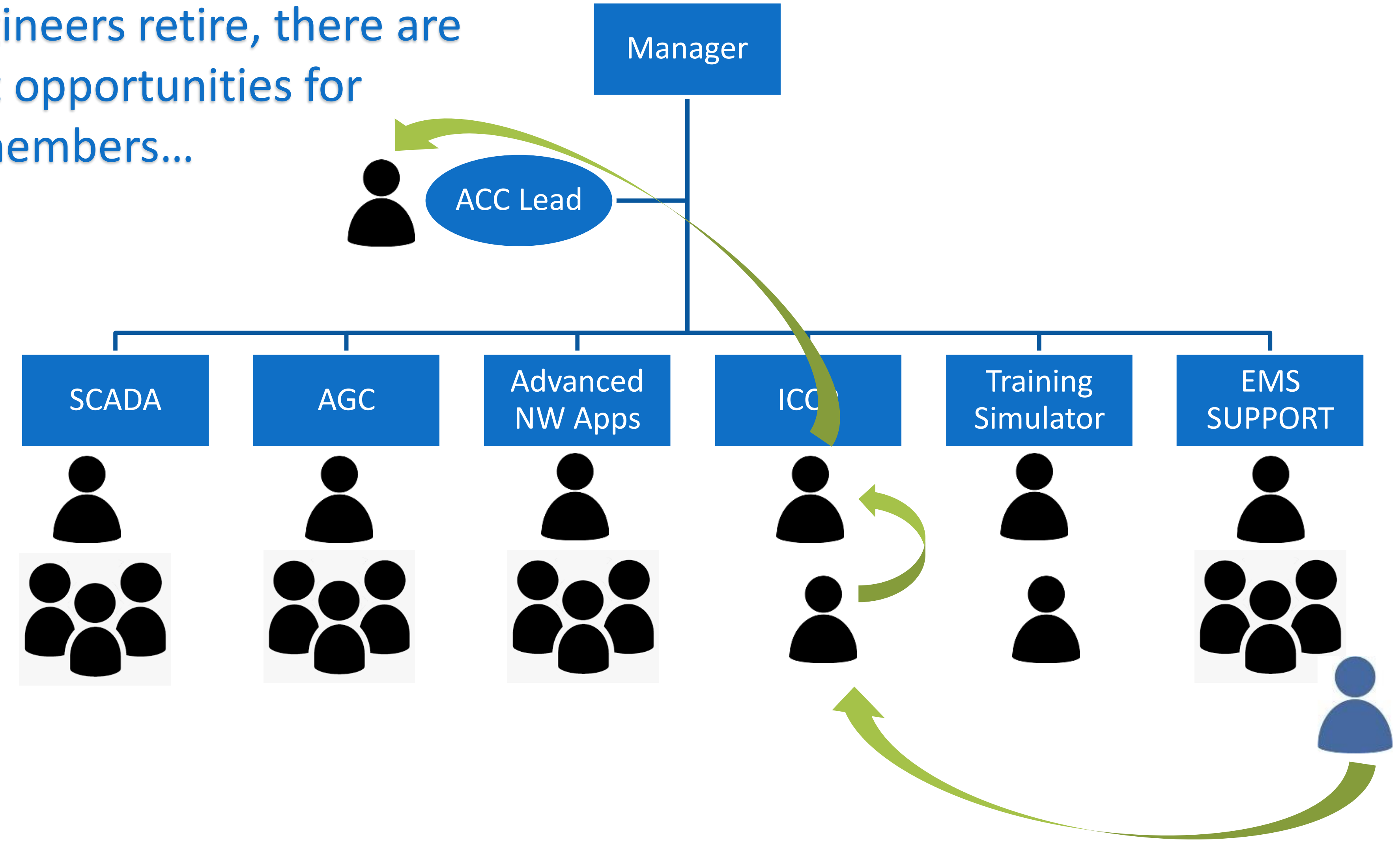
How is BPA addressing the challenge?



Ideally, new hires (including Pathways participants) are assigned to the EMS Support team initially to gain a foundational understanding of EMS.

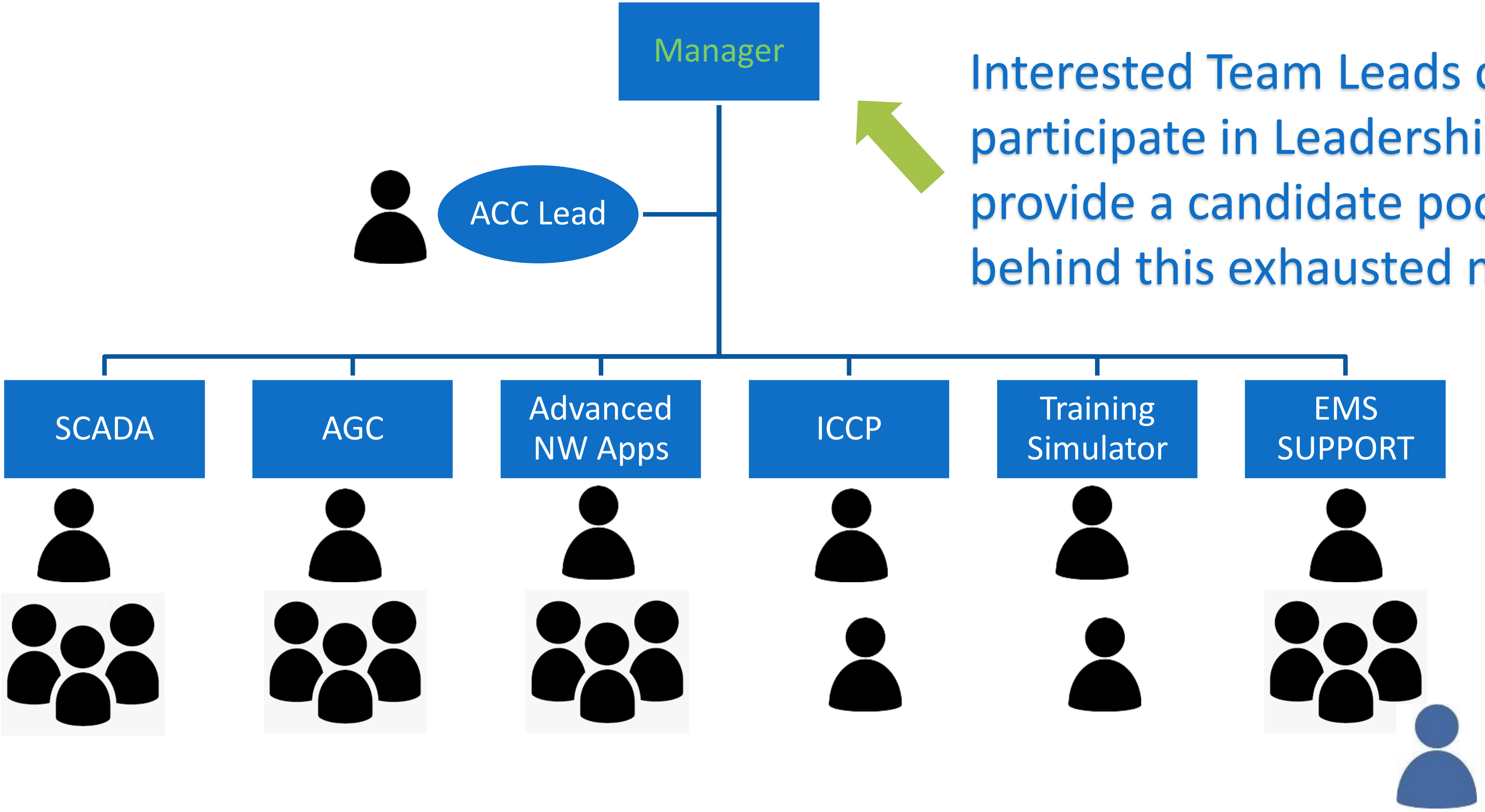
How is BPA addressing the challenge?

As Senior Engineers retire, there are advancement opportunities for other team members…



… and then it's time to recruit again!

How is BPA addressing the challenge?



Interested Team Leads can also participate in Leadership Training to provide a candidate pool for filling behind this exhausted manager.

BPA's Transmission Pathways Program

Before closing, I'd like to share a little information about BPA's Student Intern/Recent Graduate Program…

The purpose of The Transmission Student Development Program is to proactively attract, develop and retain the technical talent needed for the coming 3 years.

It is compromised of two tracks:

- Student Interns
- Recent Graduates

Student Interns:

- Must complete 640 hours (minimum)
- Usually 2 consecutive summer rotation
- Can also work during school year (P/T)

Recent Graduates:

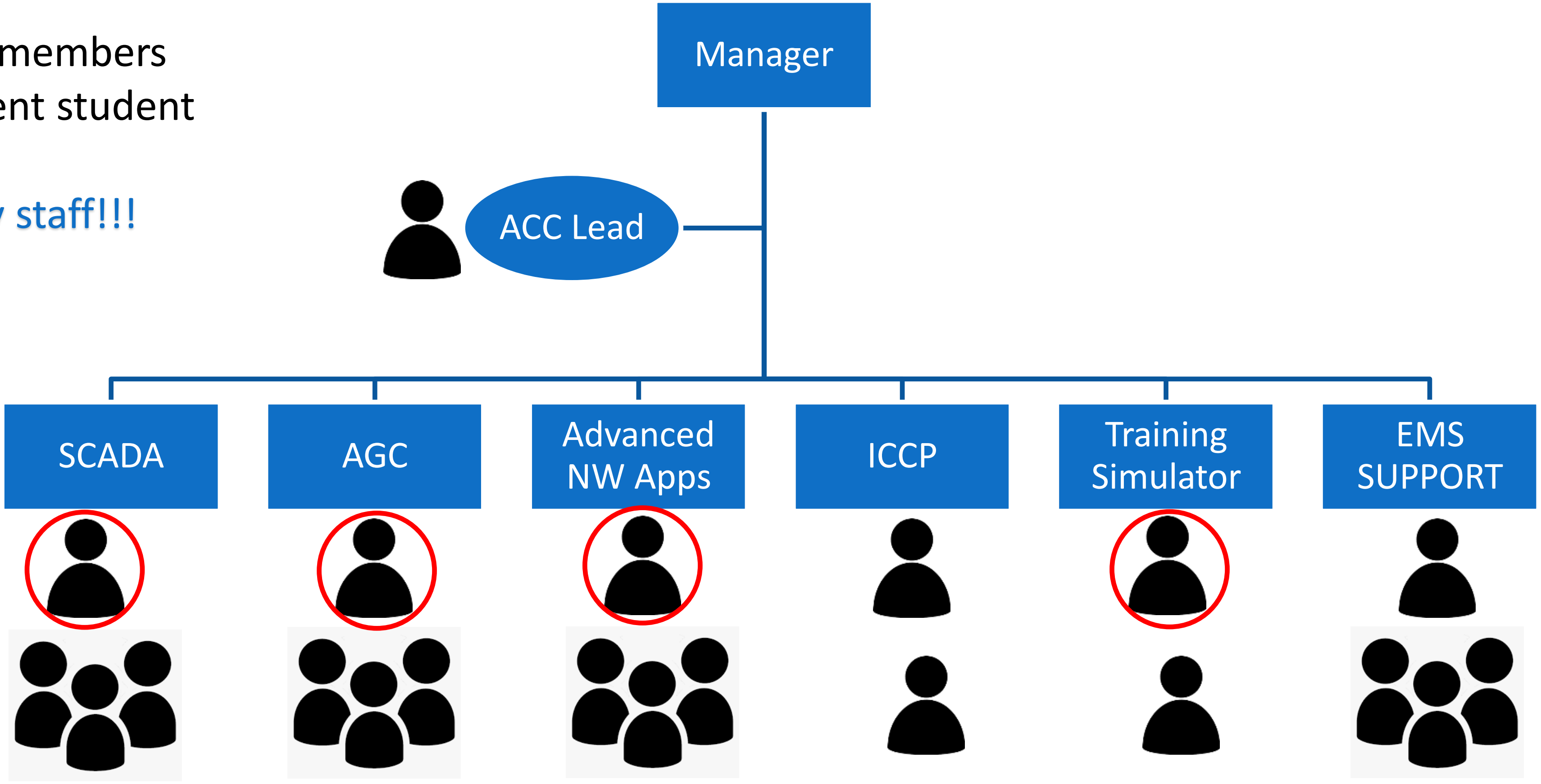
- Must complete two 6 month rotations

BPA's Transmission Pathways Program

Former interns currently on BPA's EMS Team:

- 4 Team Leads
- 3 other team members
- Plus one current student

Almost 25% of my staff!!!



EMS Staffing Challenges

Questions?

Song Zhang is an R&D Lead Analyst at ISO New England and a senior member of the IEEE. He is a certified AWS Solution Architect and the lead of multiple cloud computing projects at ISO New England. He is also Chair of IEEE PES Task Force on Cloud Computing for Power Grid and Chair of IEEE PES Springfield Chapter. Before joining the ISO, he was a Power System Engineer at GE Grid Solutions from 2014 to 2017.

Dr. Zhang received his Ph.D. degree in Electrical Engineering from Arizona State University. His research interest includes power system operation, power system analysis, power system stability and control, cloud computing, big data and synchro phasor technology.

OCTOBER 28, 2021

Cloud-based elastic computing and wide-area monitoring for power systems

9th Annual Monitoring and Situational Awareness Conference

Song Zhang

R&D LEAD ANALYST

ISO NEW ENGLAND

Cloud For Power Grid

- "Cloud for Power Grid" is a task force proposed by a variety of power industry members and approved by IEEE PES Big Data & Analytics Subcommittee and Analytic Methods for Power Systems (AMPS) Technical Committee
- **Team** – we have a large team diversity, with delegates from various leading users in utilities/ISOs, cloud providers/partners, power system software vendors, DoE Labs and NERC
- **Mission** – promote cloud computing in electric energy sector, facilitate the industry with use of this mature, well-proven and state-of-the-art technology in power systems reliably and securely, with the focus on operation, planning, monitoring and control

Motivation & Key Drivers

- FERC's Directive
  - FERC held a technical conference in June 2019 to extensively discuss use of emerging technologies such as cloud computing and virtualization for Bulk Power System (BES) services
  - FERC issued Notice of Inquiry in February 2020 to continue seeking comments and suggestions regarding potential benefits and risks associated with use of cloud technology for BES operation
  - FERC ordered NERC to submit an informational filing that evaluates possible modifications to the Critical Infrastructure Protection (CIP) Reliability Standards to facilitate the voluntary use of cloud computing to perform BES operations by the end of 2021
- Industry's Growing Interest
  - Quite a few power industry members have been aware of how their non-CIP, low-impact business needs can be better met by means of cloud. They are highly interested in when and how to start a journey on cloud
- External Factors
  - DoD JWCC Project (JEDI was cancelled)
  - NSA $10B cloud contract

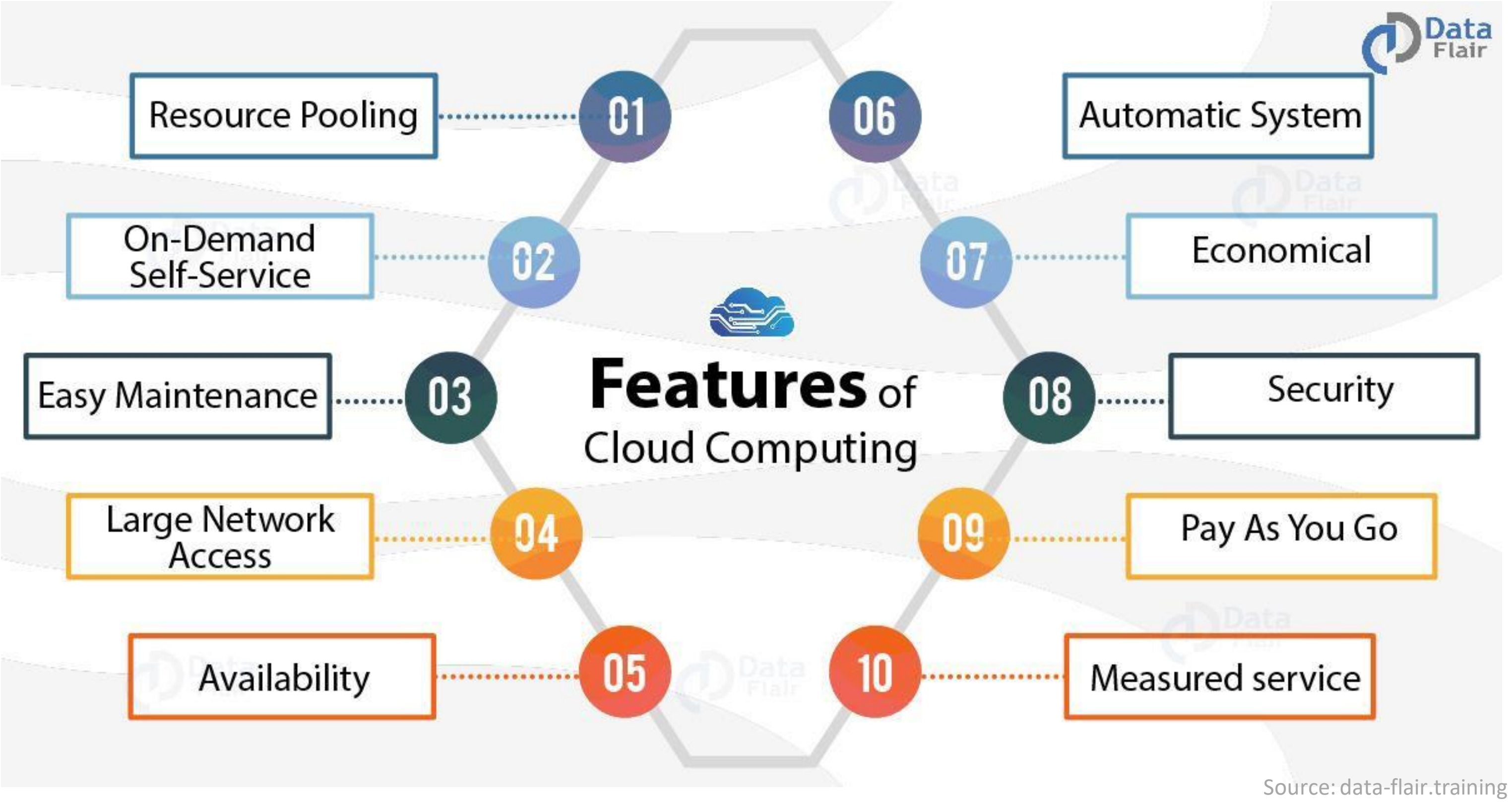
Info about Our Task Force

- Website
  - https://sites.google.com/view/cloud4powergrid
- Emails
  - cloud4powergrid@listserv.ieee.org
  - sozhang@iso-ne.com
  - xluo@iso-ne.com

Stay tuned with latest real-world cloud adoption cases!

CLOUD COMPUTING BASICS

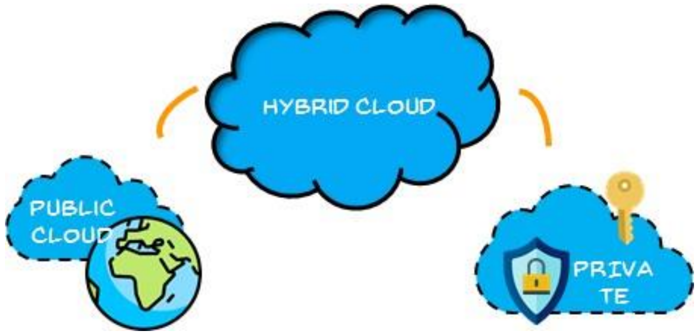
Key Features



Source: data-flair.training

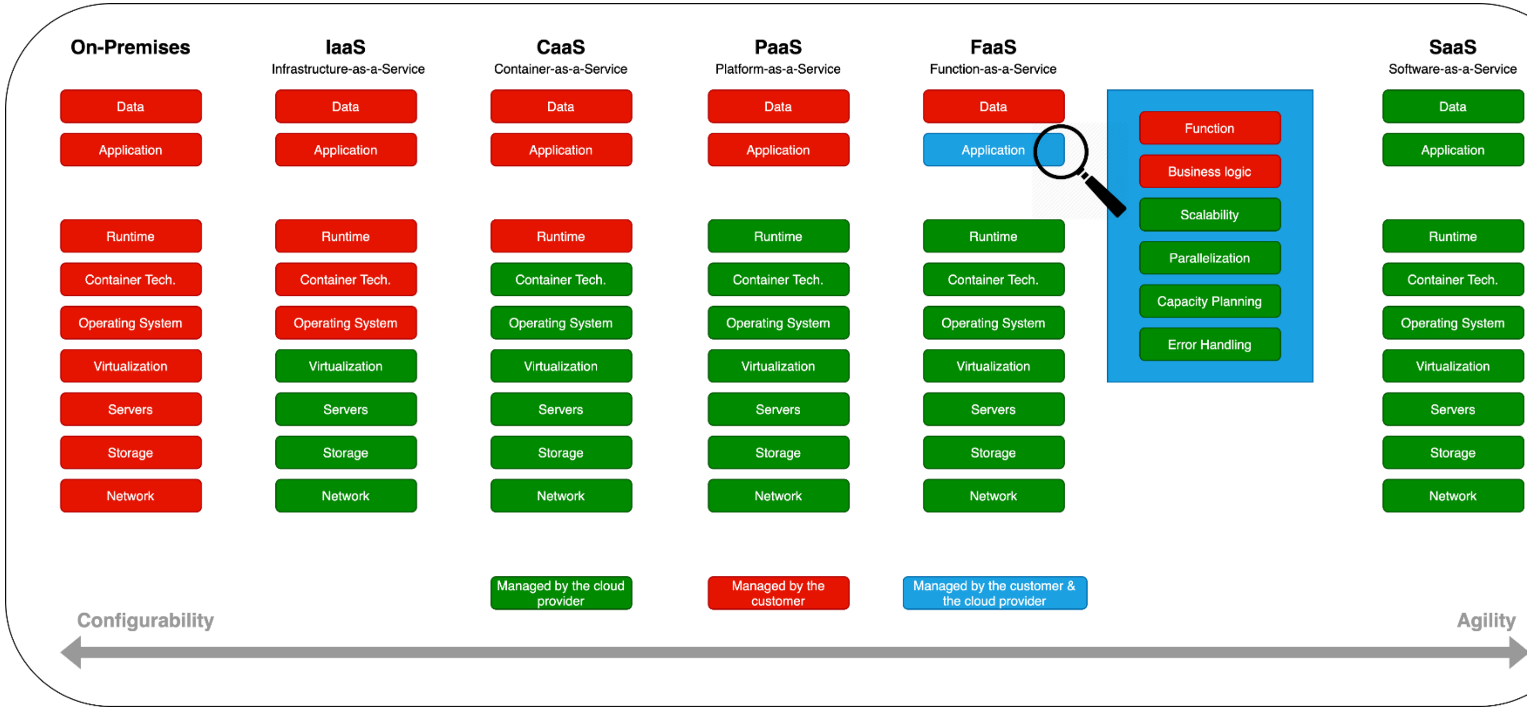
Cloud Computing Types

- **Private Cloud**
  - Designed for particular needs
  - Corporate data centers, taking care of security and privacy concerns
  - Needs persistent investment to keep the infrastructure up to date
- **Public Cloud**
  - Offer a variety of cloud services
  - Higher scalability and lower prices
  - Big players: Amazon, Microsoft, Google, IBM, Oracle, Alibaba
- **Hybrid Cloud**
  - A combination of the two above (“1 + 1 ≠ 2”)



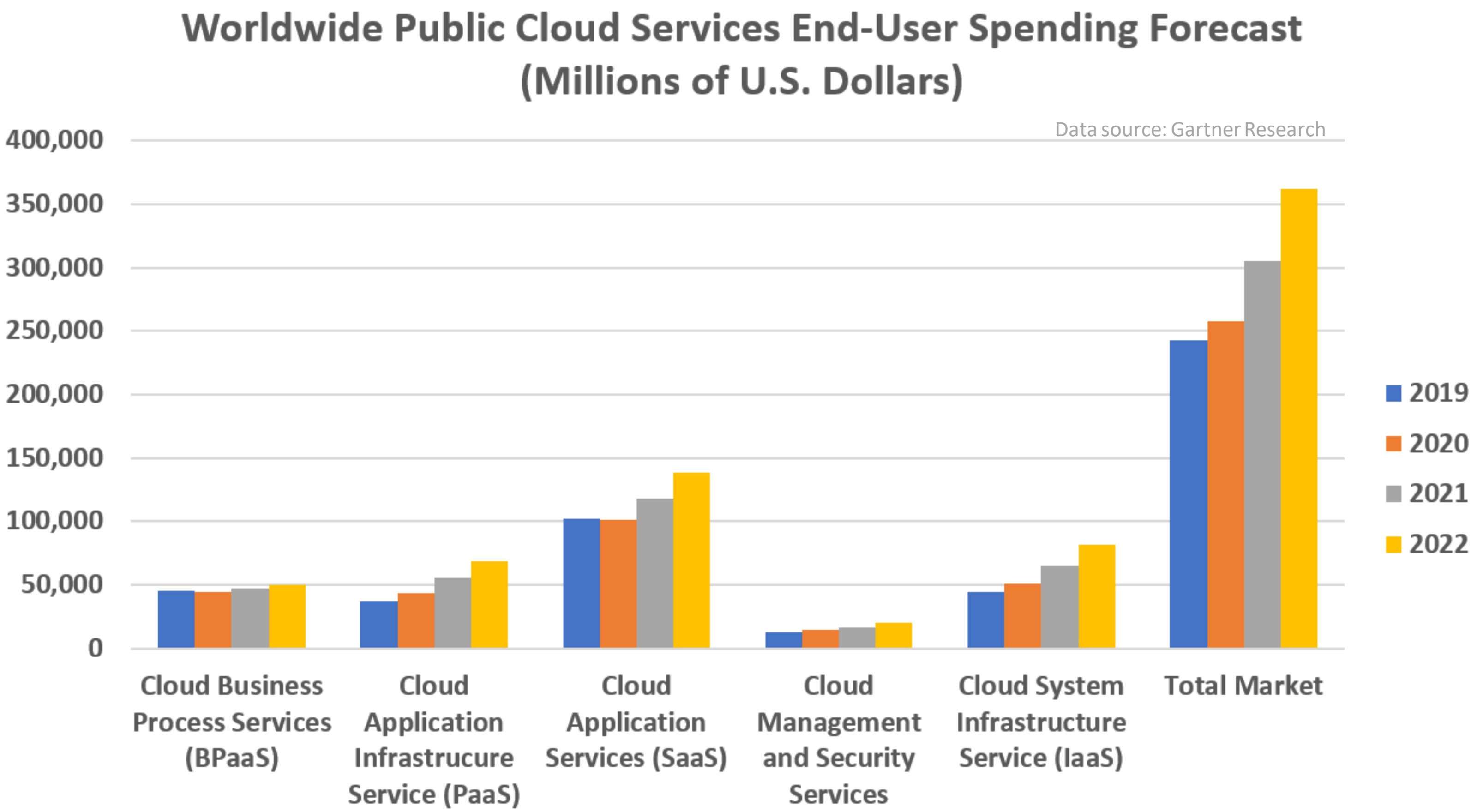
Bonus question: which one is more infrastructure secure, private cloud or public cloud?

Cloud Service Models



Source: medium.com

Cloud is the Future

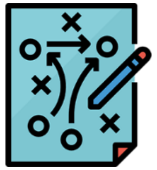


WHY DO WE NEED CLOUD COMPUTING IN POWER SYSTEMS?

Needs for Cloud in Power Systems

Resources

Vast, scalable resources in the cloud, including cost-effective storage, computing, analytics and networking



Solutions

A great deal of new solution frameworks and advanced algorithms and tools, e.g., ML/AI, are unlocked by the cloud

Infrastructure

Cloud provides resilient global Infrastructure to support IT/OT convergence

HPC Needs in Power System Analysis

- Increasing network size and system complexity
  - Nonlinear, non-convex functions
  - Discrete and integer variables
  - Ill-behaved characteristics
  - Hundreds of Thousands of differential and algebraic equations
- Large volume of data
  - PMU, AMI, IoT
- Complexity of the power grid today and in the nearest future
  - Distributed, Invert-based resources
  - High volatility and uncertainty
  - Continuous and discrete controls
- More scenarios to run and simulation takes longer time

Calls for high performance computing techniques and scalable computing resources

EI MMWG Power Flow Case in 2013

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS®E TUE, JUN 11 2013 10:08

	BUSES	PLANTS	MACHINES	WIND MACHINES	MACHINE OWNERS
TOTAL	64287	6736	8466	23	8616
MAXIMUM	150000	26840	33050	560	66100

	S H U N T S			MULTI-SECTION LINE	
	FIXED	SWITCHED	LOADS	GROUPINGS	SECTIONS
TOTAL	2268	5785	34984	39	82
MAXIMUM	150000	10580	300000	3710	9260

		T R A N S F O R M E R S			
	BRANCHES	TWO-WINDING	THREE-WINDING	ZERO IMPEDANCE	BRANCH OWNERS
TOTAL	82427	23941	1955	3016	90824
MAXIMUM	300000	60000	15000	7500	600000

	AREAS	ZONES	OWNERS	TRANSFERS	MUTUALS
TOTAL	139	832	340	0	0
MAXIMUM	1200	9999	1200	2000	4000

	2-TERM. DC	N-TERM. DC	VSC DC	FACTS DEVICES	GNE DEVICES
TOTAL	38	0	0	1	0
MAXIMUM	50	20	40	250	40

EI MMWG Power Flow Case in 2019

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS(R)E WED, MAR 13 2019 15:29

	BUSES	PLANTS	MACHINES	WIND MACHINES	MACHINE OWNERS
TOTAL	84015	7609	9269	858	9408
MAXIMUM	150000	26840	33050	2880	66100

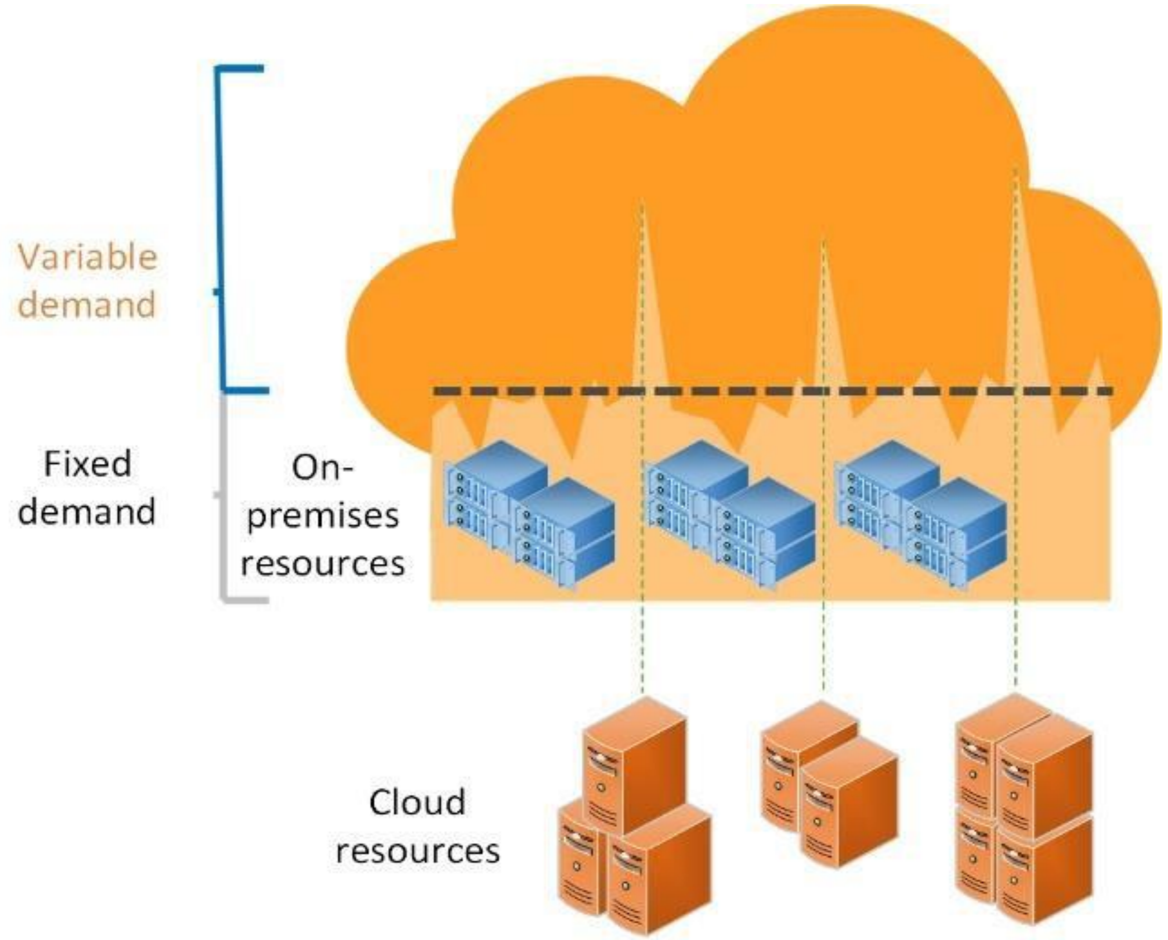
	S H U N T S			INDUCTION
	FIXED	SWITCHED	LOADS	MACHINES
TOTAL	3089	7556	48501	0
MAXIMUM	150000	10580	300000	560

		T R A N S F O R M E R S				
	BRANCHES	TWO-WINDING	THREE-WINDING	ZERO IMPEDANCE	BRANCH OWNERS	MUTUALS
TOTAL	105917	30228	2935	5215	110586	0
MAXIMUM	300000	60000	15000	75000	600000	13890

	MULTI-SECTION LINE					
	GROUPINGS	SECTIONS	AREAS	ZONES	OWNERS	TRANSFERS
TOTAL	40	91	138	930	391	0
MAXIMUM	3710	9260	1200	9999	1200	2000

	2-TERM. DC	N-TERM. DC	VSC DC	FACTS DEVICES	GNE DEVICES
TOTAL	40	0	1	13	0
MAXIMUM	100	20	40	250	40

Use On-prem and Cloud Resources Collectively



A PEEK AT ISO-NE ELASTIC COMPUTING PLATFORM

Milestones reached by ISO-NE on the Cloud

2013
PoC (Cycle Computing, PaaS)

2013-2015
Pilot w/ Axceleon, Home-grown tools built

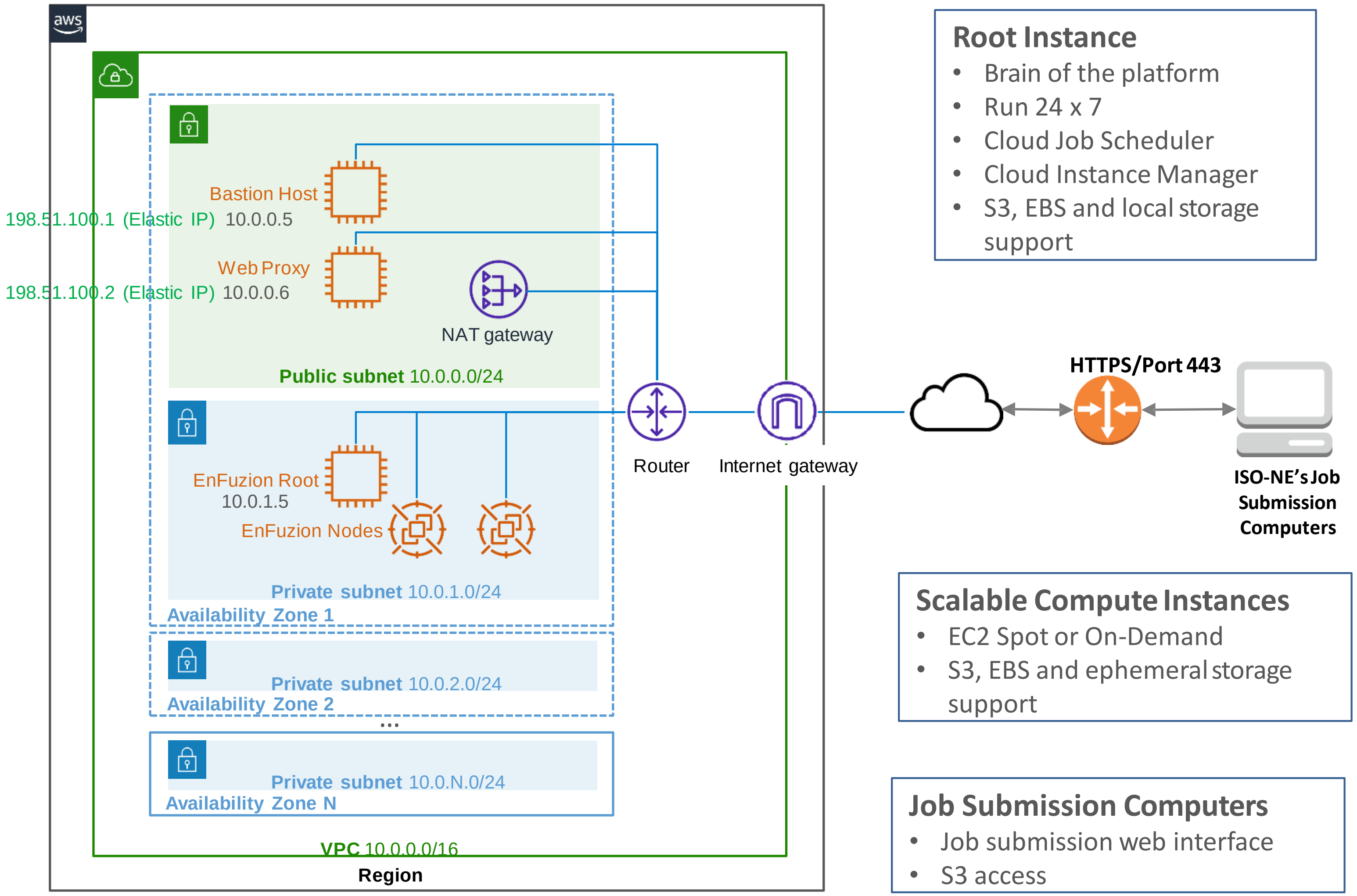
2017
CloudFuzion in production

2018
Research use (data mining, machine learning, etc.)

2019
Forward Capacity Auction(FCA) delist study began running on cloud

2021
Cloud Foundation project

Cloud-hosted Elastic Computing Platform @ ISO-NE



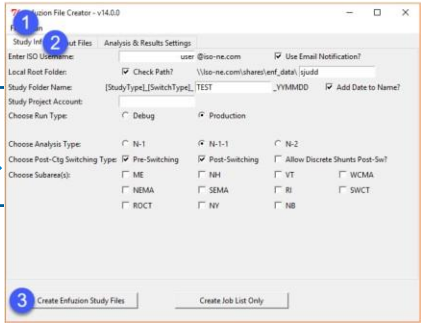
Root Instance
- Brain of the platform
- Run 24 x 7
- Cloud Job Scheduler
- Cloud Instance Manager
- S3, EBS and local storage support

Scalable Compute Instances
- EC2 Spot or On-Demand
- S3, EBS and ephemeral storage support

Job Submission Computers
- Job submission web interface
- S3 access

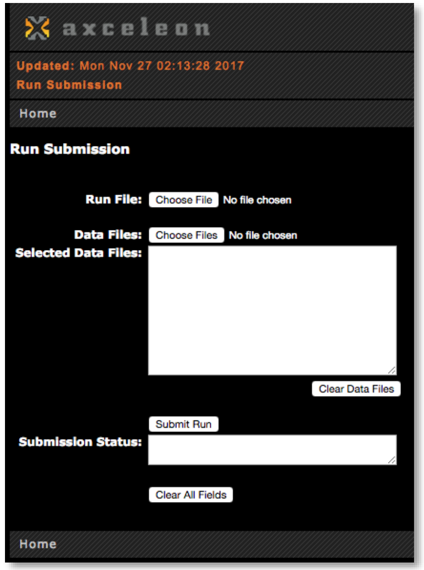
ISO-NE's Cloud Platform - User Workflow

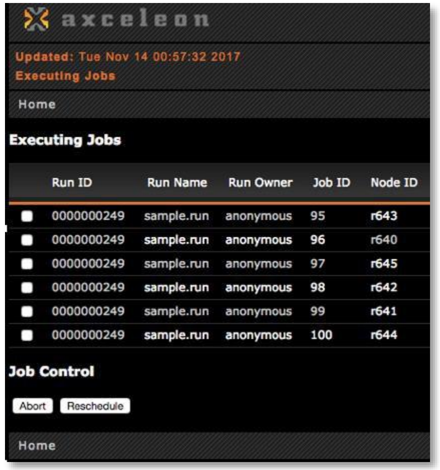
Users prepare it through a home-grown tool



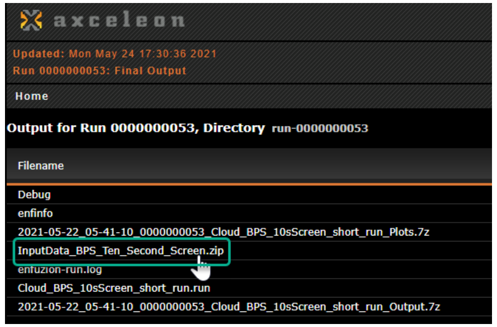
Run File

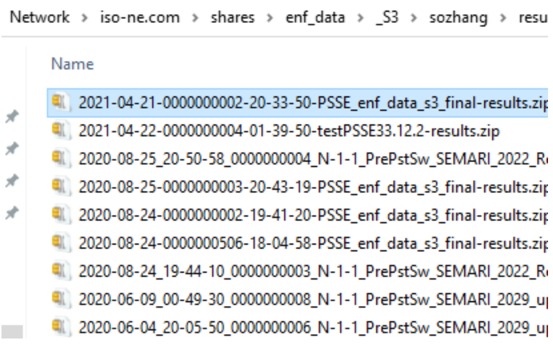
Program Input (optional)





(a) Download results directly from webpage

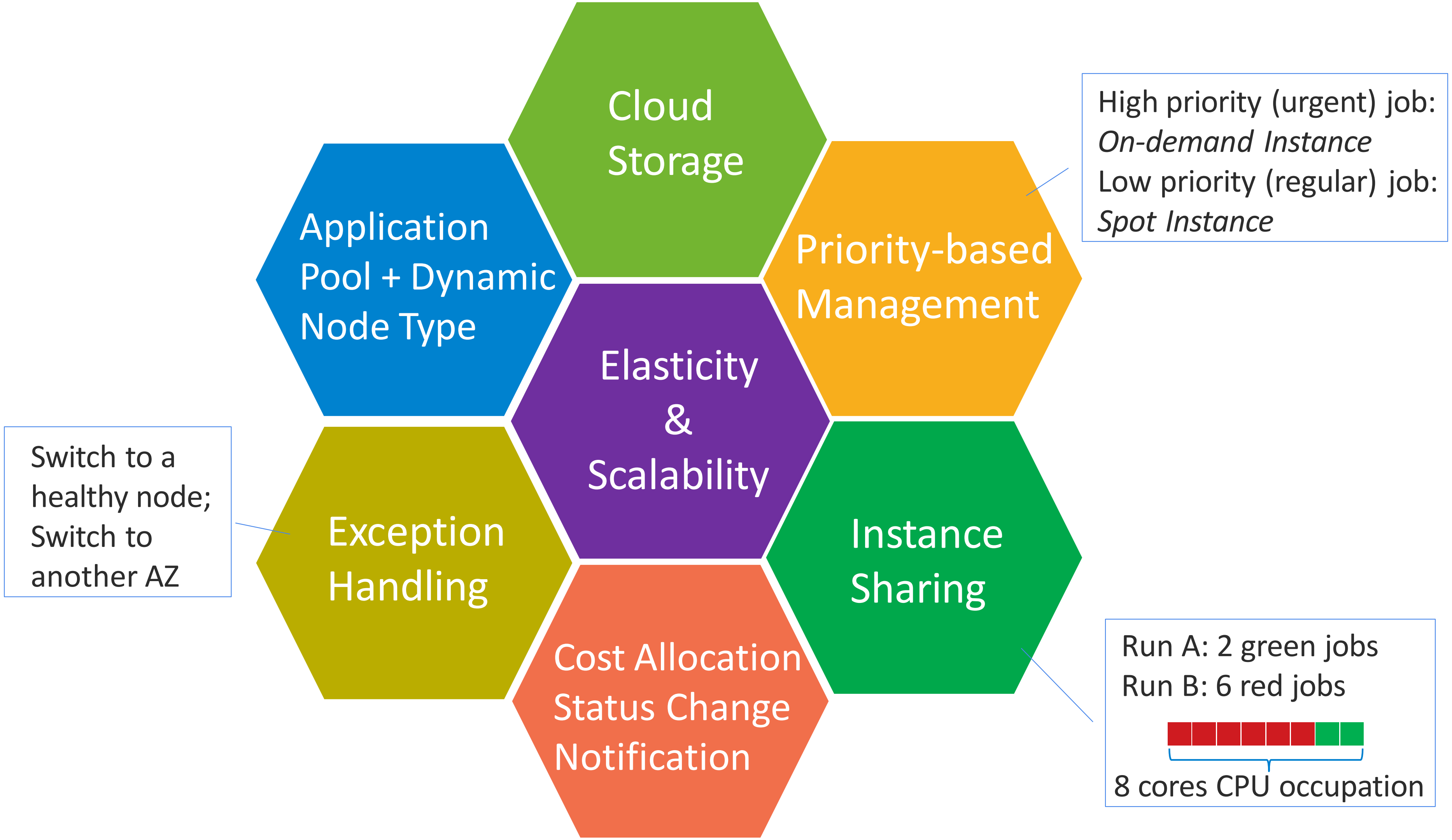




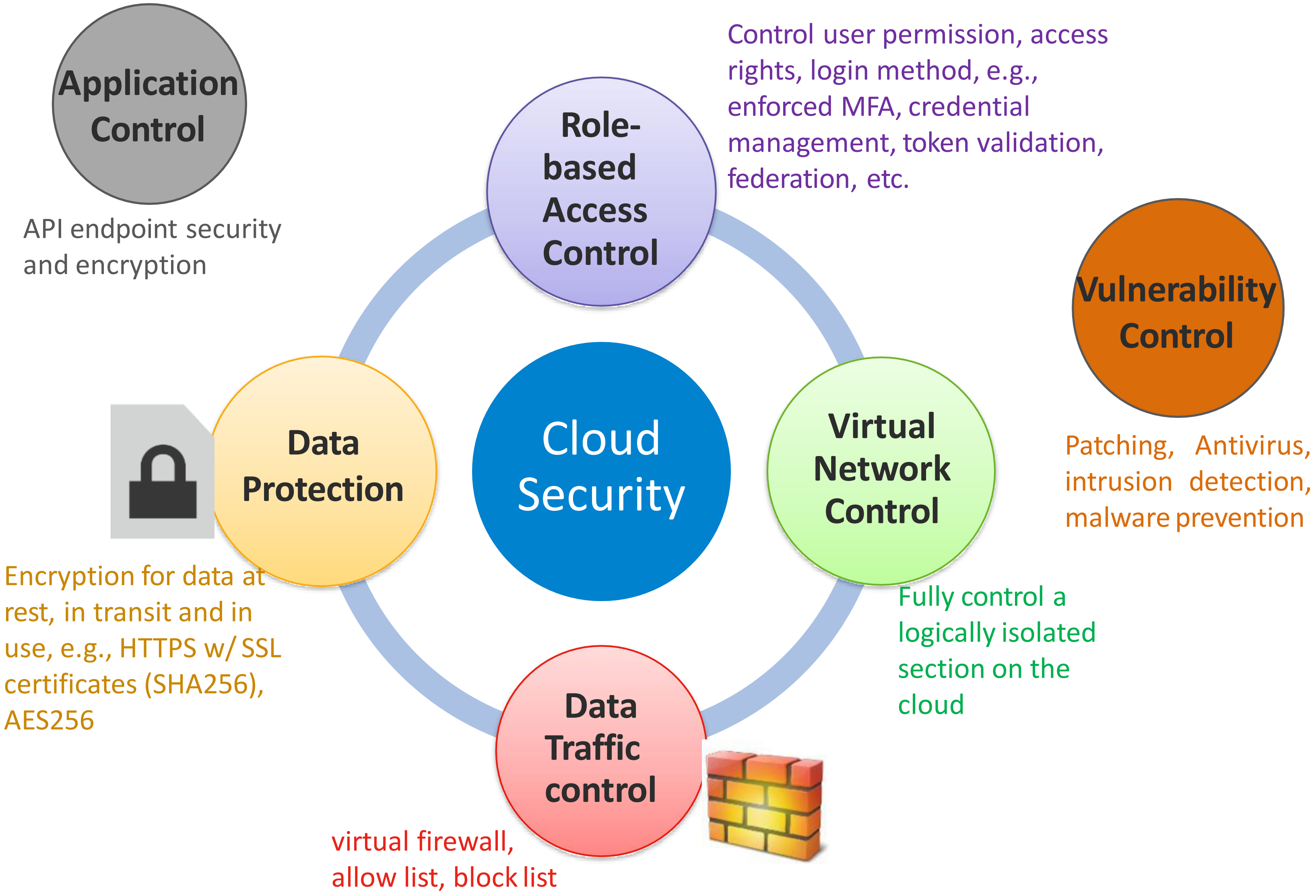
(b) Access results from network drive sync with clou

Create Preparation → Submit Run → Monitor Progress → Retrieve Results

Features of Cloud-hosted HPC Platform



Security Control Schemes on the Cloud



Security Compliance

CIP Workloads

- Current requirements are silent on Cloud
- Revisions are underway for BCSI & Virtualization
- Regulatory opportunities – FERC filing; NERC Engagements

Non-CIP Workloads

No CIP, but CEII* data involved in cloud adoption pursuant to section 215A(d) of the Federal Power Act

* CEII – Critical Energy Infrastructure Information, please see https://www.ferc.gov/enforcement-legal/ceii

Internal Compliance

- Security Framework
- Documents classification
- Data retention and destruction
- Cyber security training
- Others

OFFLINE STUDIES RUN ON THE PLATFORM

Use Cases of Elastic Computing Platform

Source: ref [5]

Data / Study Case	No. of jobs	No. of Nodes Used	Nodes Uptime	Cost ($)	Time spent on cloud	
					vs. PC	vs. on-prem cluster†
N-1-1 contingency analysis	$10^2 \sim 10^4$	10 ~ 20	1h ~ 6h	$10^1 \sim 10^2$	~ 30 times faster	~ 10 times faster
FCA Delist study	$10^3 \sim 10^4$	100	< 1h*	100 ~ 200	N/A*	N/A*
NPCC BPS Test	$10^3 \sim 10^4$	10 ~ 20	1h ~ 12h	$10^1 \sim 10^2$	~ 30 times faster	~ 10 times faster
Demand Curve Study	$10^2 \sim 10^3$	5 ~ 20	3h ~ 5h	$10^1 \sim 10^2$	~ 40 times faster	~ 5 times faster
Tie Benefit Study	$50 \sim 10^3$	5 ~ 20	1h ~ 5h	5 ~ 50	12 times faster	N/A*

* Highly time-constrained study. N/A means no data since it was never run locally

† On-prem cluster used to have 80 cores, now has 432 cores

Case Study (1) – TARA N-1-1 Planning Study

- Typical transmission planning study
  - N-1-1 TARA simulations with 14,812 jobs for SWCT Needs Assessment
    - 30 *c3.2xlarge* Compute Instances (8 vCPUs, 15 GB memory, 2 × 80 GB

      SSD, Intel Xeon E5-2680 v2 @ 2.8 Ghz)
    - **6 hours 20 minutes**, at a cost about **$80**;
    - **Approximately 68 hours** on the internal clusters;
    - **55 days** on PC

axceleon

EnFuzion® 17

Updated: Mon Nov 20 13:57:49 2017
Results

Root: ip-10-0-0-247.ec2.internal:10102
User: anonymous

Home | Cluster | Nodes | Runs | Accounting | Execution | Submit | Results

Results

	Run ID	Name	Status	User	Account	Submitted	Completed	Uptime	Total Time	Jobs Waiting	Jobs Done	Jobs Failed	Jobs Rescheduled	Job Length	Data Jobs Done	Data Job Length	Nodes
☐	0000000025	TARA_N-1-1_PrePstSw_Cloud_NA_N-1-1_1117.run	done	anonymous	None	Fri Nov 17 21:41:27 2017	Sat Nov 18 04:02:41 2017	06:21:14	55d,17:40:10	0	14812	0	0	00:05:25	0	0.000	30
☐	0000000010	TARA_N-1-1_PrePstSw_Cloud_TEST_SWCT_N11_1117_Sample.run	done	anonymous	None	Fri Nov 17 19:27:13 2017	Fri Nov 17 19:32:25 2017	00:05:12	00:36:00	0	8	0	0	00:04:30	0	0.000	1
☐	0000000001	TARA_N-1-1_PrePstSw_Cloud_NANC_N11.run	done	anonymous	None	Fri Nov 17 14:31:49 2017	Fri Nov 17 18:08:40 2017	03:36:51	20d,21:28:45	0	1418	0	8	00:21:13	0	0.000	31
☐	0000000002	TARA_N-1-1_PrePstSw_Cloud_ARNC_N11.run	done	anonymous	None	Fri Nov 17 14:32:11 2017	Fri Nov 17 17:06:42 2017	02:34:31	10d,10:15:41	0	715	0	0	00:21:00	0	0.000	16
☐	0000000043	aws-run-64-save-on-root.run	done	anonymous	None	Tue Nov 14 21:03:35 2017	Tue Nov 14 21:14:11 2017	00:10:36	00:20:36	0	4	0	0	00:05:09	0	0.000	1
☐	0000000042	aws-run-64-save-on-root.run	done	anonymous	None	Tue Nov 14 21:03:00 2017	Tue Nov 14 21:12:21 2017	00:09:21	00:20:31	0	4	0	0	00:05:07	0	0.000	1

Run Details

Output | Log | Completed Jobs | Used Nodes

Run Control

Reschedule | Delete

Home | Cluster | Nodes | Runs | Accounting | Execution | Submit | Results

Case Study (2) – Forward Capacity Auction (FCA) Dynamic Delist Study

- Perform annually since 2019
- Run L+G N-1-1 contingency analysis w/ unit de-list bids considered.
- Must finish within a tight time window: 1:30 – 6:30 PM; on-premises computing infrastructure could not meet the time constraints
- 200 cloud instances were requested before 1:30 PM in the 1st round, which became available within a few minutes
- Another 137 nodes were spun up in the 2nd round
- Total cost: $413

Case Study (3) – PSS/E Dynamic Study

❑ NPCC Bulk Power System Test

- Apply permanent fault on each element of the bulk power system (115kV and above), inspect whether an event at a specific location on the transmission system would have a significant adverse impact outside of the local area.
- NPCC mandates a BPS test across the entire New England system in case of any transfer limit increase on the interfaces.
- A recent re-assessment tied to transfer limit increase in northern New England involves **7,000+** PSS/E fault simulations
- ISO-NE relies on external consultants to help complete the BPS tests in the past.

Case Study (3) - Con't

- 100 BPS transient stability study
- simulation length = 20 seconds

	Personal Laptop	On-premises Cluster	Cloud Cluster
Total completion time (min)	1,500	189	61
Number of cores used	4	80	100
Cost ($)	N/A	*	8.82

* on-premises server maintenance cost is prorated

Case Study (4) – GE MARS Resource Adequacy

❑ Installed Capacity Requirement (ICR)

- Objective: to determine the system installed capacity requirement for next three years.
- Software: GE MARS
- Study approach: Monte Carlo simulation

No. of jobs (demand curves)	Replication years	Total time (hrs)	
		Cloud	PC
500 ~ 600	5,000 ~ 10,000	0.5 ~ 0.7	18

Case Study (5) – GE MARS Resource Adequacy

❑ Tie Benefit Study

- Objective: find out how much power we can get from neighboring control areas for emergency assistance.
- Stop criterion: **Loss-of-load Expectation (LOLE) ≤ once in ten years**
- Approach: probability based methodology – (Monte Carlo Simulation)

No. of jobs (demand curves)	Replication years	Total time (hr)	
		Cloud	PC
1	1,000	0.5	6

EMT Simulations?

1. Deploy software for EMT simulations

↓

2. Bring your own license (BYOL) to the cloud

↓

3. Prepare your run file to orchestrate the workflow

↓

4. Bring back your simulation results from cloud storage

Moving large-scale EMT simulations to the cloud is on the ISO-NE's roadmap (on corporate scorecard)

Key Findings

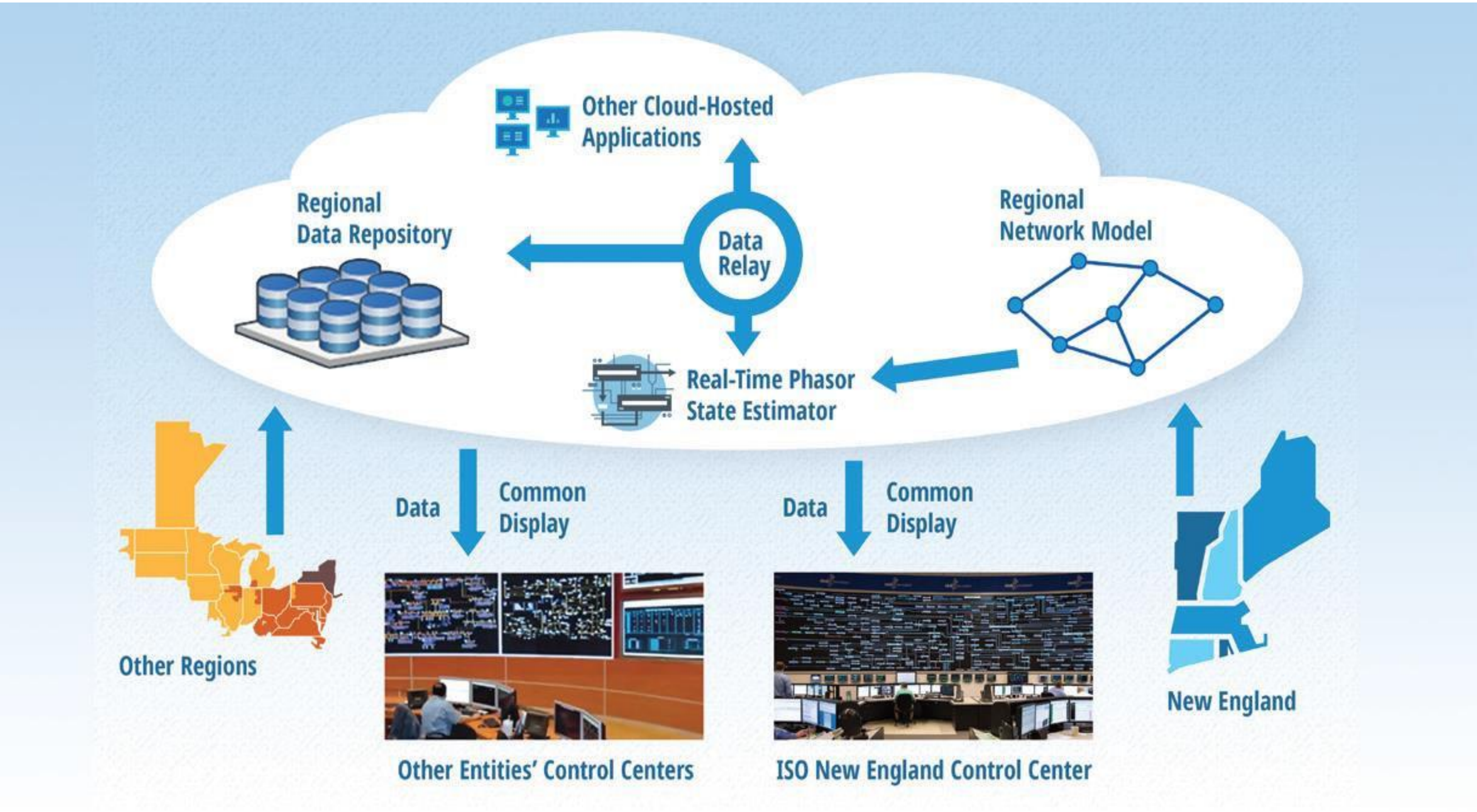
- ❑ Necessary conditions for power system simulations to run on cloud
  - ✓ **Parallelizable**
    - Software support multithread or multicore computing
  - ✓ **Parameterizable**
    - Simulation scenario definition can be parameterized
    - Simulation workflow can be controlled by parameters
  - ✓ **Replication Independent**
    - Each simulation is independent from each other; not a series of sequential runs
  - ✓ **Licensing option support**
    - Simulations are run on VMs, license cannot be dongle, node-locked or single-user

Lessons Learned and Challenges

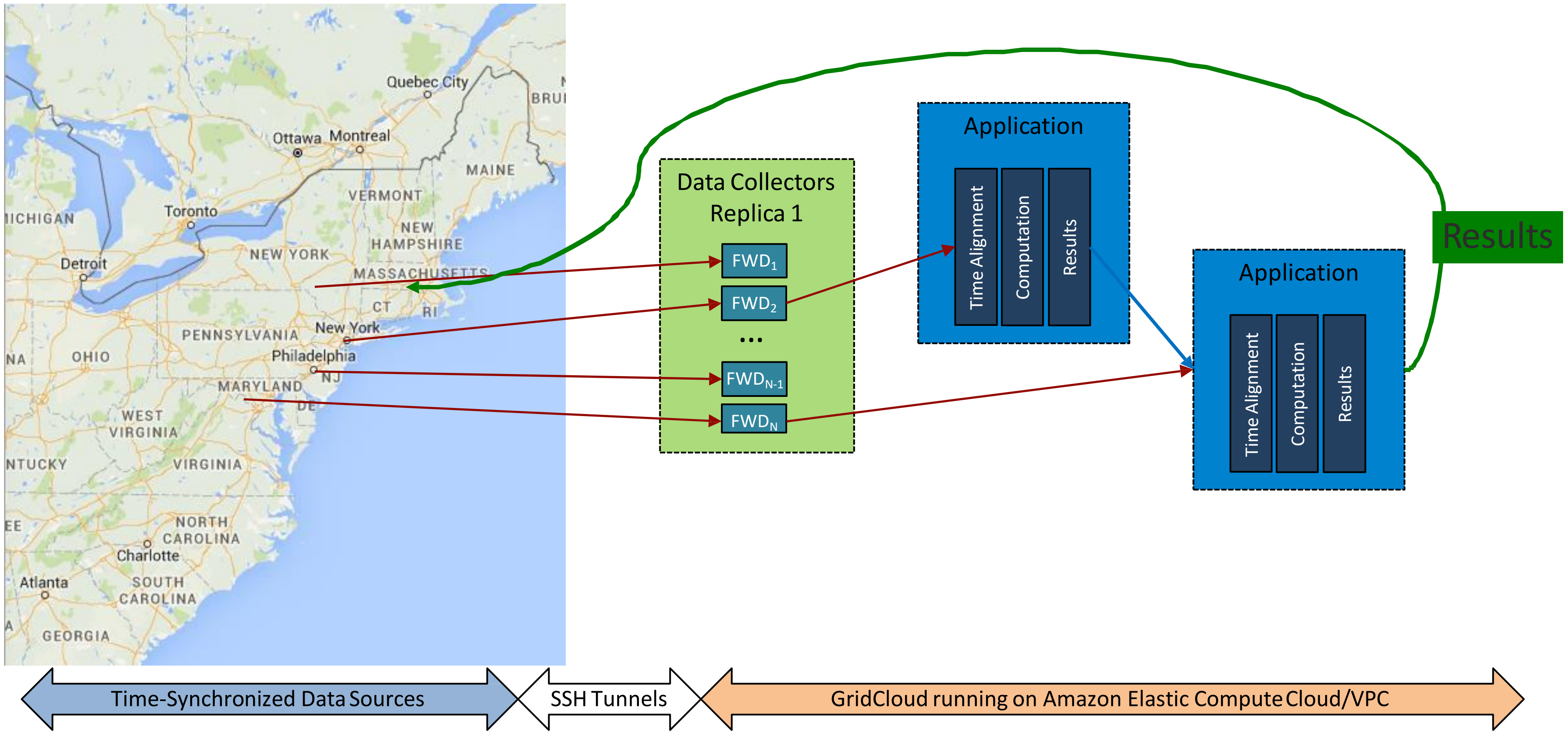
- Design an intelligent and flexible platform is the key of our innovation and the success
  - On-demand cloud resource access
  - Priority based job scheduling
  - Fully automated cloud resource management
- Application independent cloud platform is essential. IaaS is a good fit for this need.
- Software challenges
  - Licensing
  - Pricing
  - Design pattern: monolithic vs. microservices architecture

A PEEK AT GRIDCLOUD: A CLOUD-BASED DATA SHARING AND SYSTEM MONITORING PLATFORM

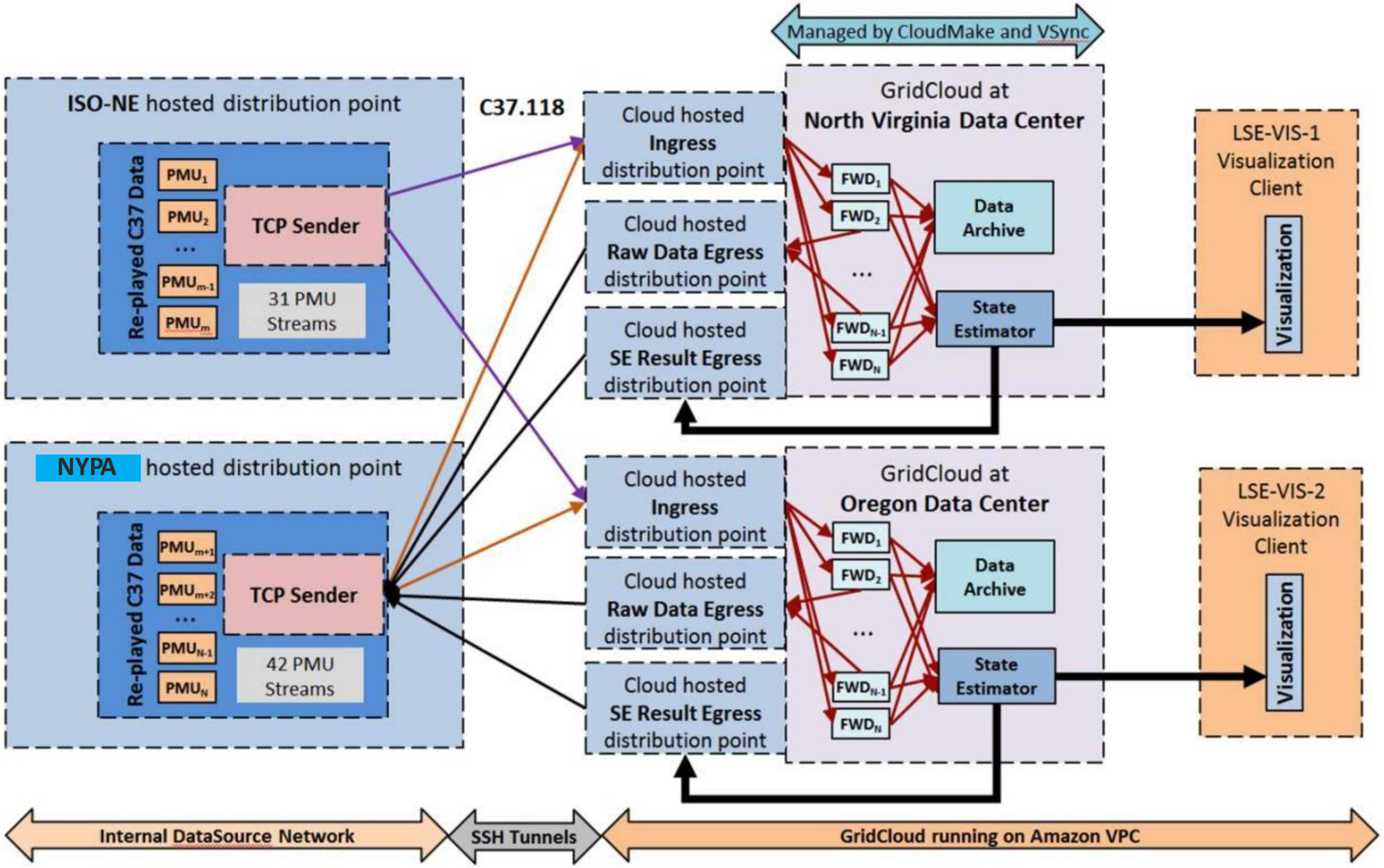
Overview of GridCloud



GridCloud Data Flow



Cloud Hosted WAMS Deployment



Project Objectives

- Share PMU data
  - Between ISO-NE and NYISO, PJM, etc.
  - Multilateral data exchange
    - As opposed to multiple bilateral data exchange
  - "Centralized" PMU Registry management
  - "Centralized" historical PMU data storage
- Shared online application
  - Runs on PMU data from different regions
  - Real-time grid operator collaboration
  - Potentially eliminates the need for raw data sharing
- Assess the **security, latency**, **fault-tolerance** and **consistency** of cloud-based processing of real-time PMU data streams
  - Measure round-trip latencies from ISO-NE and NYPA to Amazon cloud data centers in North Virginia and Oregon
  - Run linear state estimator in two AWS data centers and assess consistency of results

Security

- VPN over SSH tunnel for data streaming
- ISO-NE data source
  - Historical data playback w/ simulated real-time timestamps
  - Inside firewall
  - Data publishing
  - No data subscription
- Cloud Data Storage
  - Encrypted using a **key**
    - Generated by and stored in Amazon AWS
    - Managed by users

Cost

- As configured for testing:
  - 13 instances total per datacenter
    - Vizualizer, CloudRelay, CloudMakeLeader, StateEstimator, 3xRawArchiver, 4xSEArchiver, 2xForwader
  - $2.47/hr to run per datacenter
- Optimizing cost was not an objective for PoC
  - Tailored for convenience and repeatability
  - In a deployment for actual use would tailor the resources to the needs of the actual problem

Performance

- Latency
  - Average RTT w/o SE compute time = 261ms
  - SE compute time = 75ms ~ 100ms
  - SSH tunneling added less than 2ms to RTT
- Fault Tolerance
  - Two parallel systems
  - Independent
    - Manual redundancy
  - Restarting a data center
    - Needs ~500 s
- Consistency
  - No raw data loss
  - Few SE data loss
    - Due to replay wrapping
  - Within ~100 ms
    - End users have consistent data/results from both data centers

Lesson Learned

- The available cloud infrastructure is generally reliable and very fast, even across the continent
- The security risks are totally manageable via IaaS
- Latencies satisfy the needs for wide-area monitoring
  - Data encryption and SSH tunneling add negligible latencies

Cloud Adoption Use Cases in the Industry

Grid/Market Operators	Utilities	Market Participants	Software Vendors	Other Solution Providers
New York ISO (1) ISO New England (4) California ISO (1) AEMO (2) Midcontinent ISO (1)	Portland General Electric (3) OPPD (1)	Centrica (1) AutoGrid (1)	Itron (1) Energy Exemplar (1)	LineVision (1) NRECA (1) Incsys (1)

Use cases cover the following business needs

- **Planning studies**
- **Data driven modeling and analytics**
- **Load Forecast**
- **Wide-area monitoring and data sharing**
- **Backup control and emergency dispatch**
- **Anomaly detection**
- **Operational efficiency and custom experience improvement**
- **DER aggregation and management**
- **Market settlement**
- **Collaborative system modeling and hybrid simulation**

The Future Direction of Using Cloud in the Industry

- More non-critical, low-impact workloads will be migrated to the cloud or backed up in the cloud
- IaaS and SaaS will be the two major service models for power industry cloud adoption
- Deeper investigation on how to meet the security and service reliability objectives needs to be conducted
- Power system software vendors will have their attempt in the cloud
- Modifications of relevant compliances possibly will be performed by regulatory bodies to allow cloud adoption for BES services

References

- [1] B. Bhattarai, et.al, “Big data analytics in smart grids: state-of-the-art, challenges, opportunities , and future directions,” IET Smart Grid, vol. 2, no. 2, pp. 141-154, Feb. 2019
- [2] S. Vidich, “NERC CIP Standards and Cloud Computing”, Microsoft Azure, Jul. 2019
- [3] S. Zhang, X. Luo, et. al, “Big data analytics platform and its application to frequency excursion analysis,” IEEE PES General Meeting, Portland, 2018
- [4] J. Duan, D. Shi, et. al, “Deep-Reinforcement-Learning-Based Autonomous Voltage Control for Power Grid Operations,” IEEE Trans. Power Syst., vol. 35, no. 1, Jan. 2020
- [5] X. Luo, S. Zhang, et. al, “Practical design and implementation of cloud computing for power system planning studies,” IEEE Trans. Smart Grid, vol. 10, no. 2, pp. 2301-2311, Aug. 2018
- [6] S. Zhang, X. Luo, et. al, “Serverless computing for cloud-based power grid emergency generation dispatch,” Intl. Journal of Electrical Power & Energy Systems, vol. 124, Jul. 2020
- [7] D. Anderson, K. Birman, et. al, “GridCloud: Infrastructure for cloud-based wide area monitoring for bulk electric power grids,” IEEE Trans. Smart Grid, vol. 10, no. 2, pp. 2170-2179, Mar. 2019

Questions

10 minute Break

Hongming Zhang

Hongming Zhang is currently Chief Engineer at National Renewable Energy Laboratory. Accomplished EMS Engineer and Manager with 20 years of experience in the utility industry.

Demonstrated success leading EMS Network Applications (State Estimator, Real-Time Contingency Analysis or RTCA, Real-time Voltage Stability Analysis Tool, online Transient Security Analysis Tool et al) and Dispatcher Training System (DTS) teams to maintain and tune tools and implement new software enhancements or upgrades. Implemented new Synchrophasor technology tools and developed use cases for Peak RC control rooms.

Seong Chio

Seong Choi is the Lead Engineer of the Power Systems Engineering Center at the National Renewable Energy Laboratory (NREL) where he is responsible for Bulk Electric System (BES) Energy Management System support.

Mr. Choi received his BS in Electrical Engineering from Korea Advanced Institute of Science and Technology (KAIST), South Korea and MS in Technology and Human Affairs from Washington University, St. Louis, MO, respectively

Yilu Liu

Yilu Liu received her M.S. and Ph.D. degrees from the Ohio State University, Columbus, in 1986 and 1989. She received the B.S. degree from Xian Jiaotong University, China.

Dr. Liu is currently the UT-ORNL Governor’s Chair at the University of Tennessee and Oak Ridge National Laboratory. She is also the deputy director of the DOE/NSF engineering research center CURENT (curent.utk.edu). She led the effort to create the North American power grid Frequency Monitoring Network FNET/GridEye (fnetpublic.utk.edu, powerit.utk.edu). Dr. Liu is also an expert in large grid dynamic modeling, simulations, and monitoring.

Dr. Liu is a member of National Academy of Engineering, a member of the National Academy of inventors, a fellow of IEEE.

Enhancing Grid Resilience Monitoring and Situational Awareness by Intelligent Analytics Integrated with Digital Twin Simulation

for 2021 NERC Monitoring and Situational Awareness Conference

By Hongming Zhang and Seong Choi (NREL), Yilu Liu and Jenny Dong (UTK)

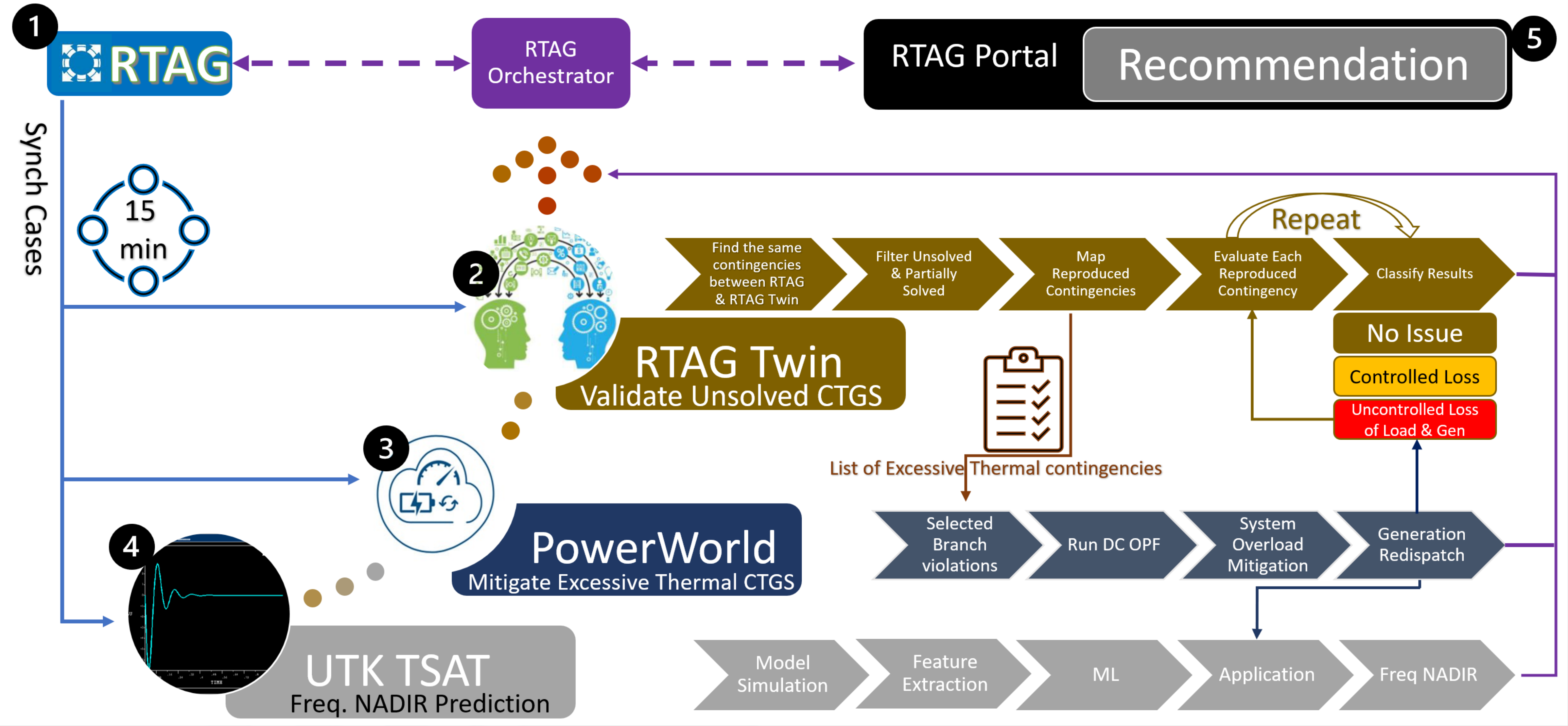
October 28 2021

*This material is based upon work supported by the U.S. Department of Energy, Office of Electricity, Advanced Grid Modeling (AGM) research program under Award Number TE1103000-05300-3123785.

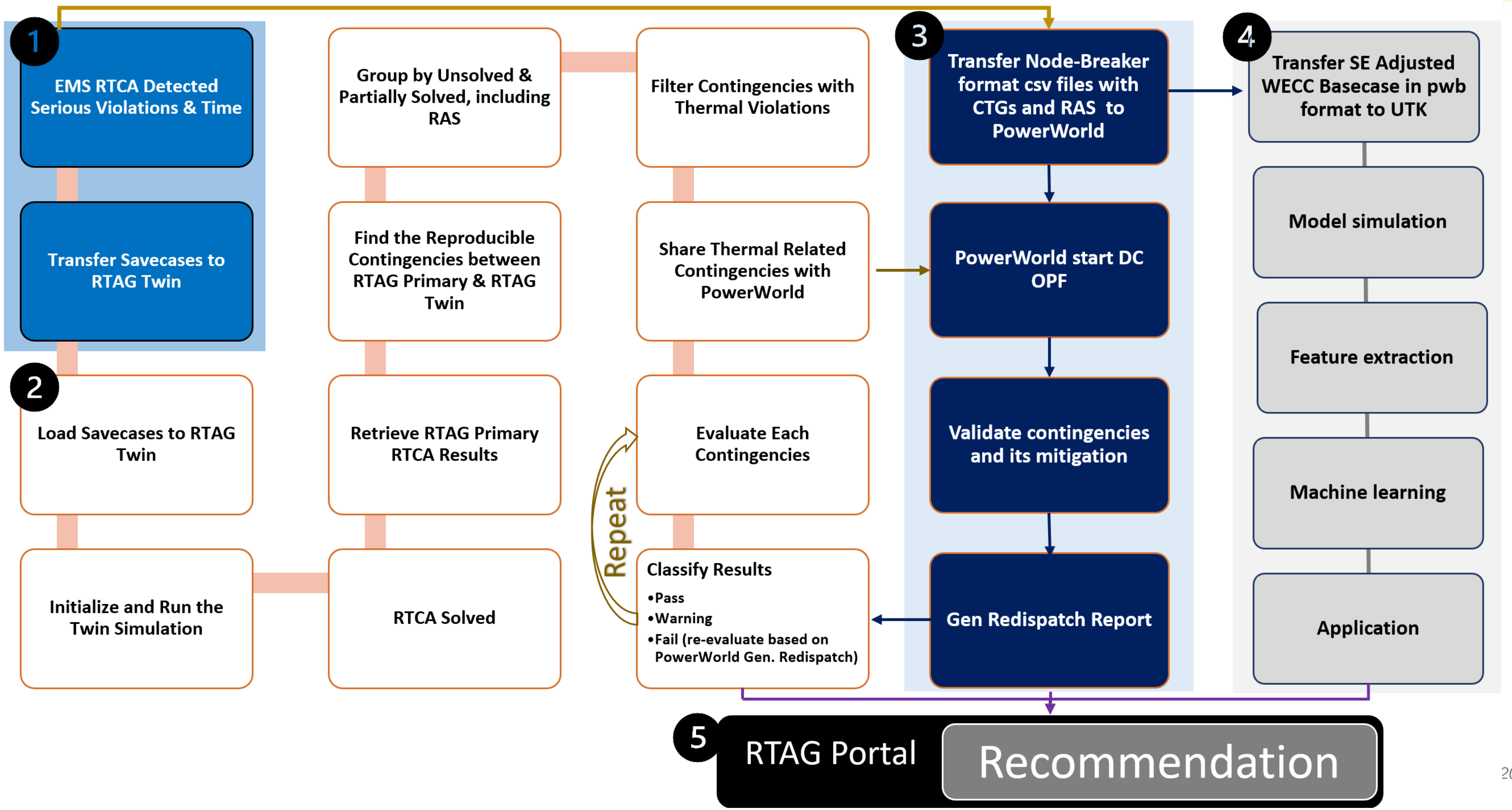
DOE AGM funded Virtual Operator Assistant (VOA) Project

- NREL and ORNL/UTK collaborate on development of human in the loop AI modules to improve operator decisions under increased renewable penetration and BES-Gas interdependency
- Two AI Agents are initially developed to address two of major reliability risks identified by NERC:
  - Governor Frequency Response i.e., Palo Verde N-2 NADIR predication
  - Situational Awareness i.e., RTCA monitoring and validation
- Digital Twin driven simulation is applied to “Verify” and “Validate” RTCA potential IROL violations automatically
- DTS ride-through simulation for N-k cascading risk evaluation

VOA System & Real-Time Analytics for Grid (RTAG)

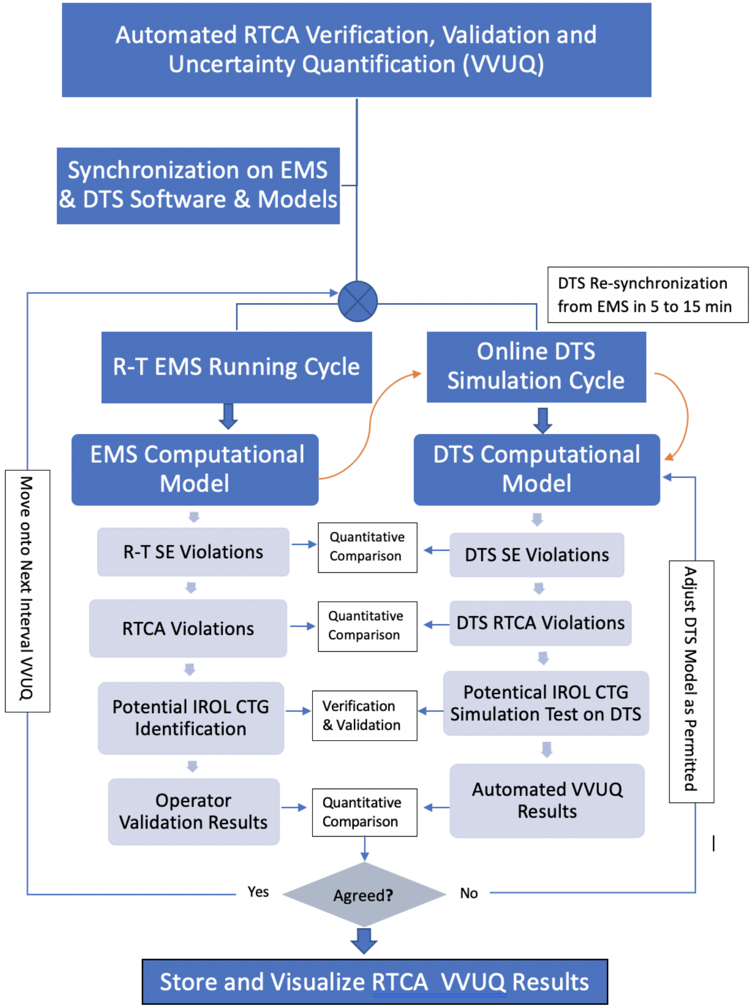


VOA System Workflow Highlight



RTCA VVUQ Agent Workflow

- "Verification, Validation and Uncertainty Quantification" (VVUQ), was promoted by ASME for Computational Modeling and Simulation in Mechanical Engineering
- VOA adopts the VVUQ approach shown on the right to automate RTCA validations for potential IROL violations:
  - Unsolved Contingency
  - Partially Unsolved Contingency
  - Branch Overload Contingency (exceeding 125% emergency thermal limit)
- RTCA VVUQ results are presented to Operators by:
  - **Pass** (i.e., no issue)
  - **Fail** (i.e., uncontrolled loss of gen and load) and
  - **Warn** (controlled loss of gen and load).



DTS Ride Through Simulation vs Traditional CA Study

Advantages of DTS dynamic simulation over Post-Contingency Power Flow

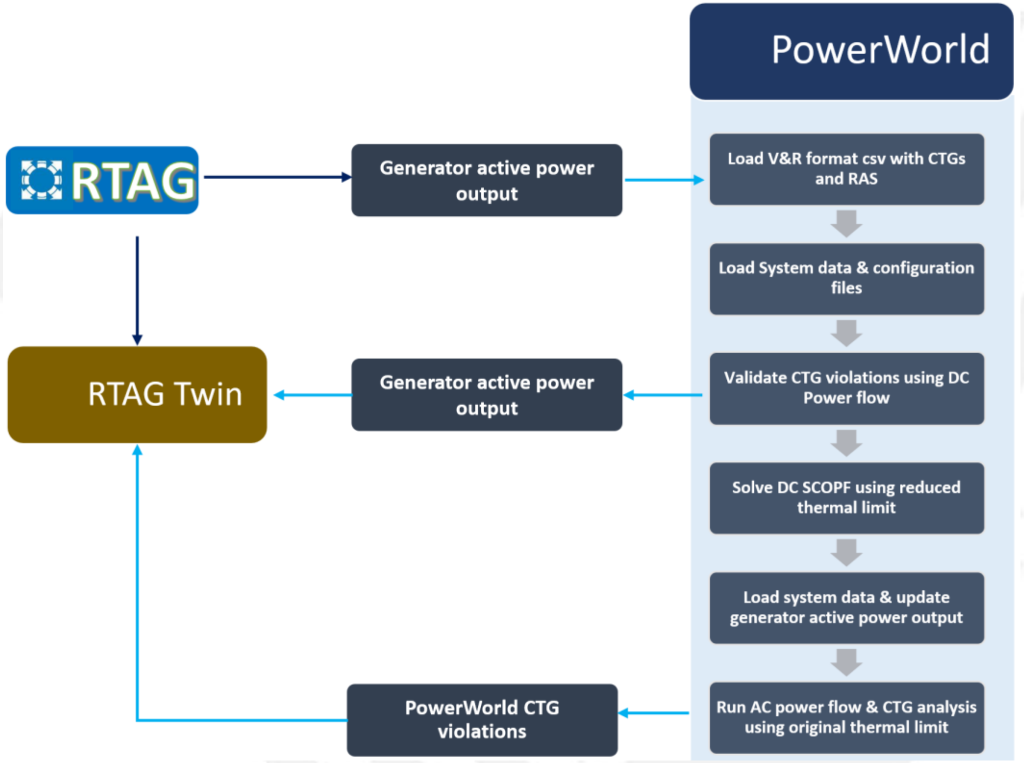
- More accurate models on unit governor and excitation device and frequency dynamics
- Equipment outages and protection control actions can be simulated in good order to mimic actual system response properly
- A subset of units and islands with a poor voltage issue and/or bad frequency issue will be removed automatically to keep simulation running with the main island solution with no interruption
- 4 quantities i.e., gen loss, load loss, frequency deviation and simulation status are included for RTCA VVUQ consideration

Ex. RTCA VVUQ Validation Sim Results

CTG ID	DTS-Values	Pre-Contingency	Post-Contingency	Diff	Status	Validation
BCT5X004	Generation [MW]	95936	95932	4	TRUE	PASS
	Load [MW]	93502	93498	4	TRUE	
	Freq [Hz]	60.093	60.094	0.0004	TRUE	
	Status	RUNNING	RUNNING	0	TRUE	
BCT5L005	Generation [MW]	95936	95805.87	130.13	FALSE	Warn
	Load [MW]	93502	93389.87	112.13	FALSE	
	Freq [Hz]	60.091	60.09	0.0002	TRUE	
	Status	RUNNING	RUNNING	0	TRUE	

Thermal Overload Validation and Mitigation

Use PowerWorld SCOPF to mitigate thermal contingency violations. No voltage violations are considered at the current phase of VOA development. To relieve computational burden, DC approximation is employed to optimize generator output. 95% Branch MVA limit will be used in DCOPF to compensate the error caused by DC approximation



DC SCOPF error is acceptable

	Number of thermal violations (base case)	Maximum interface thermal violation (%)	Number of thermal violations (after SCOPF)	Maximum interface thermal violation after SCOPF (%)
DC SCOPF	4	118.40 (PATH 15)	1	101.18 (PATH 15)
AC	2	112.21 (PATH 15)	2	101.44 (PATH 15)

DC approximation uses reduced thermal limit, thus base case has more violations

1. One branch has high violation because of excessive reactive load, which cannot be resolved using DC SCOPF
2. Interface (PATH 15) violation has been successfully reduced

	Category	Value	Limit	Percent
1	Branch MVA	71.46	54.00	132.34
2	Interface MW	3116.08	2777.00	112.21
3	Bus High Volts	1.089	1.065	102.24

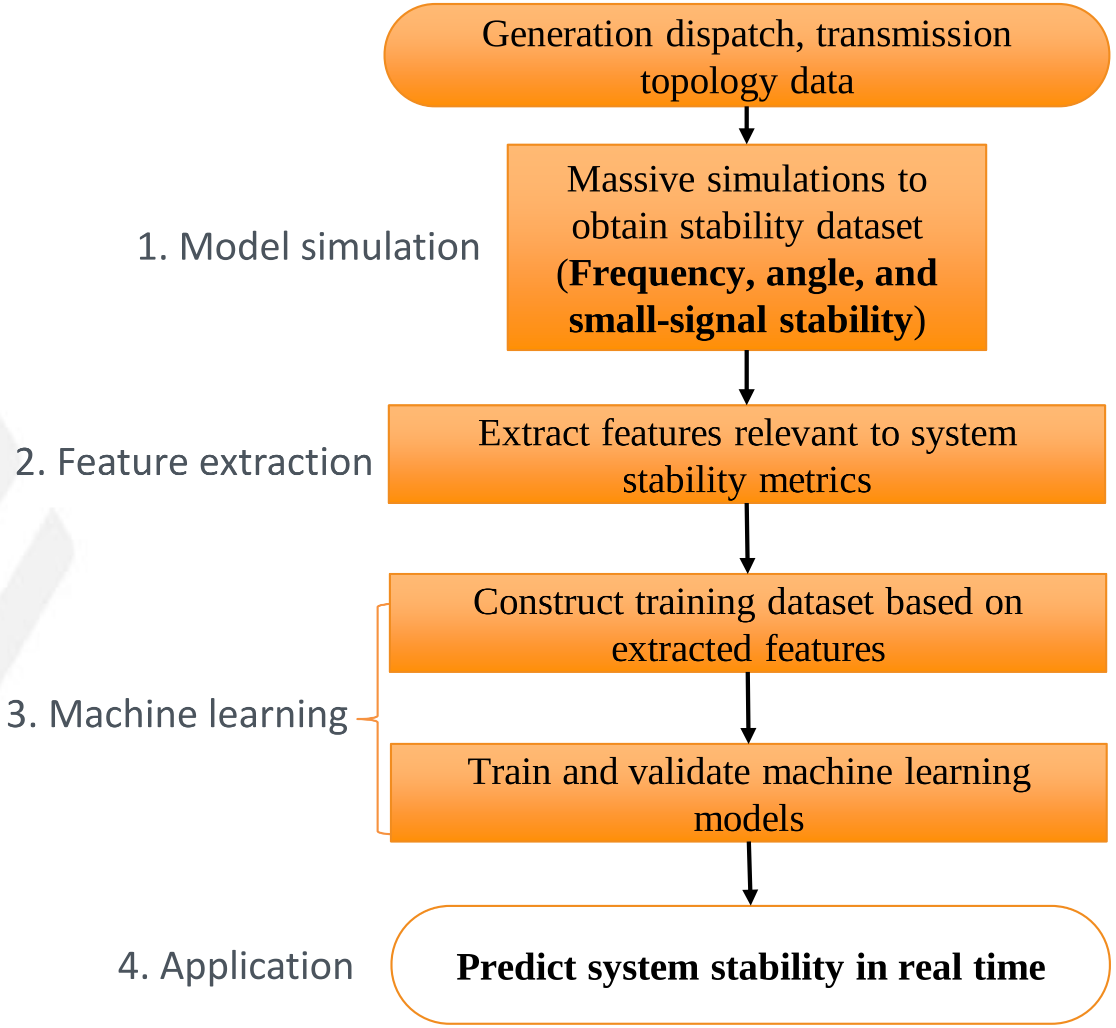
Base case (AC)

	Category	Value	Limit	Percent
1	Branch MVA	71.46	54.00	132.34
2	Bus High Volts	1.086	1.065	102.01
3	Interface MW	2817.11	2777.00	101.44

After SCOPF (AC)

AI Agent for Frequency Stability Assessment: Overview

- **Objective:**
  - Develop an AI agent for online evaluation of the system stability (angle, frequency and small-signal stability) for a large system model
  - Validate the AI agent performance using historical dispatch cases of full WECC system
  - Focus on frequency stability prediction currently

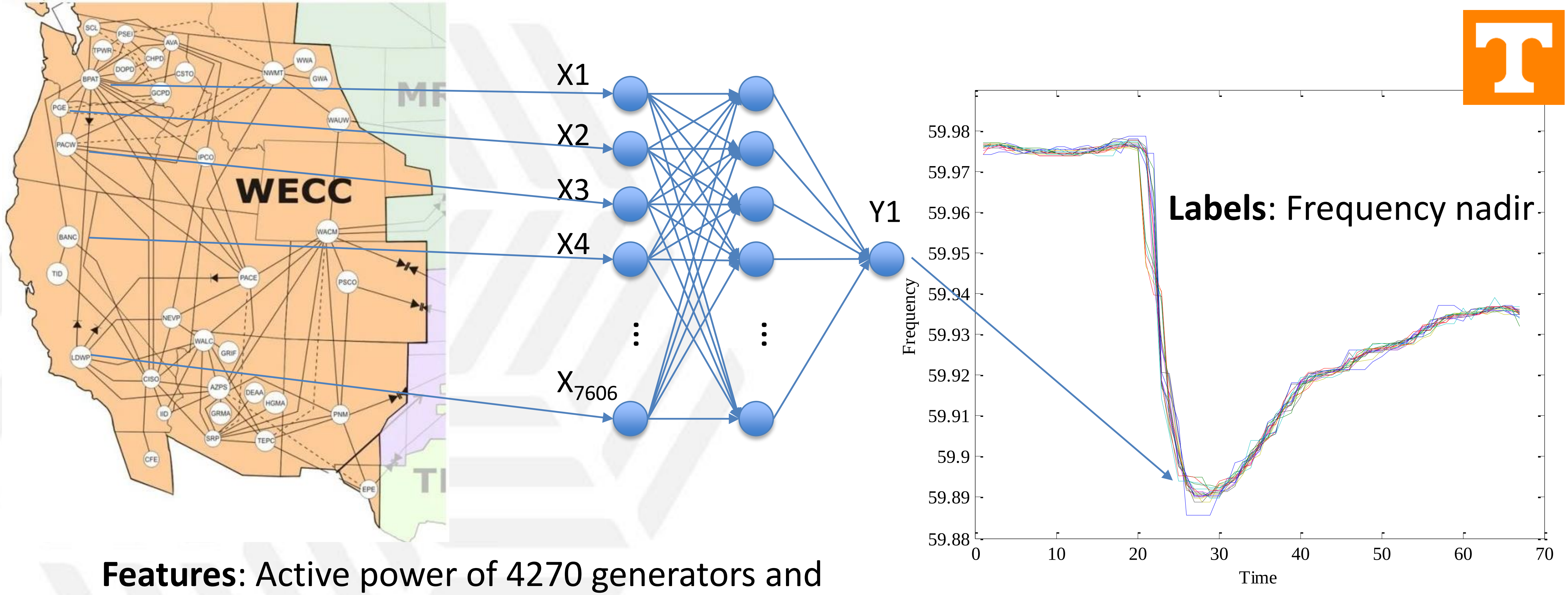


Framework of AI-based system stability prediction

AI Agent for Frequency Stability Assessment: Approach

- **Step 1**: Generation of Historical WECC Dispatch Cases
  - Create 138 dynamic cases from historical dispatch data on 03/19/2019
- **Step 2**: Massive Simulation
  - Perform massive simulations offline to obtain frequency nadir data
  - Generator trip events: PALOVRD1 & PALOVRD2, 1.37GW & 1.37GW
- **Step 3**: Feature Extraction (7606 inputs in total)
  - Active power of 4270 generators and inertia of 3336 non-PV generators
- **Step 4**: Machine Learning
  - Construct training dataset based on extracted features
  - Train the AI agent using a Neural Network model and a Random Forest model
- **Step 5**: Application
  - Predict system stability in real time

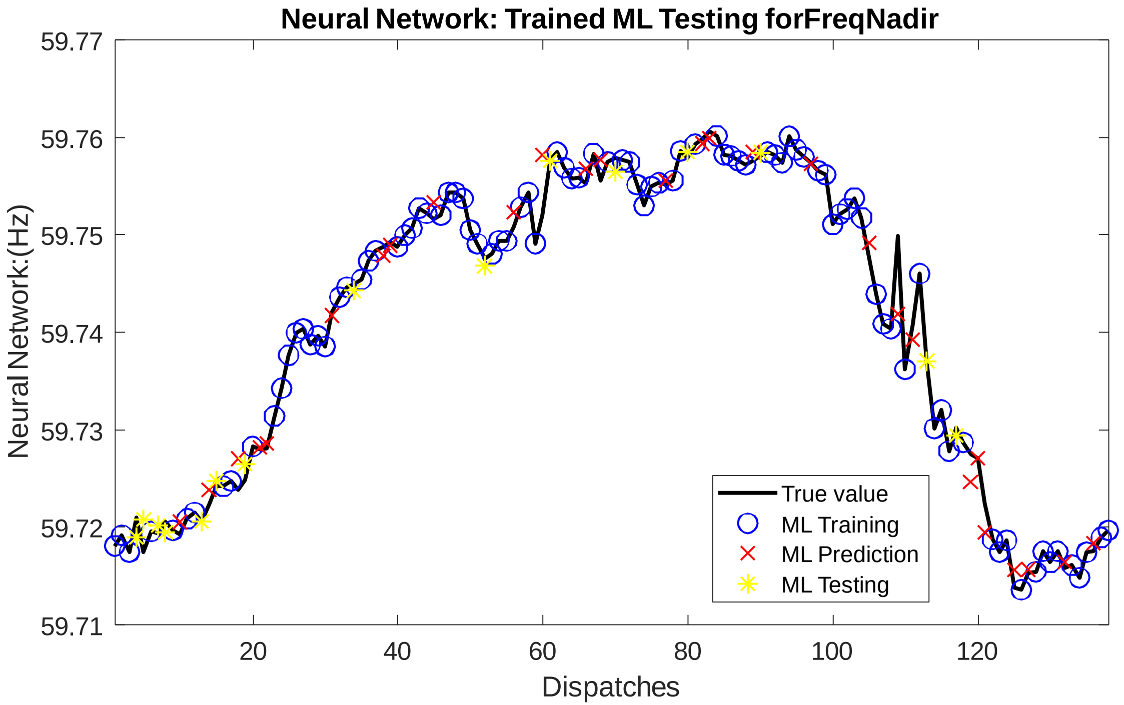
AI Agent for Frequency Stability Assessment: Illustration

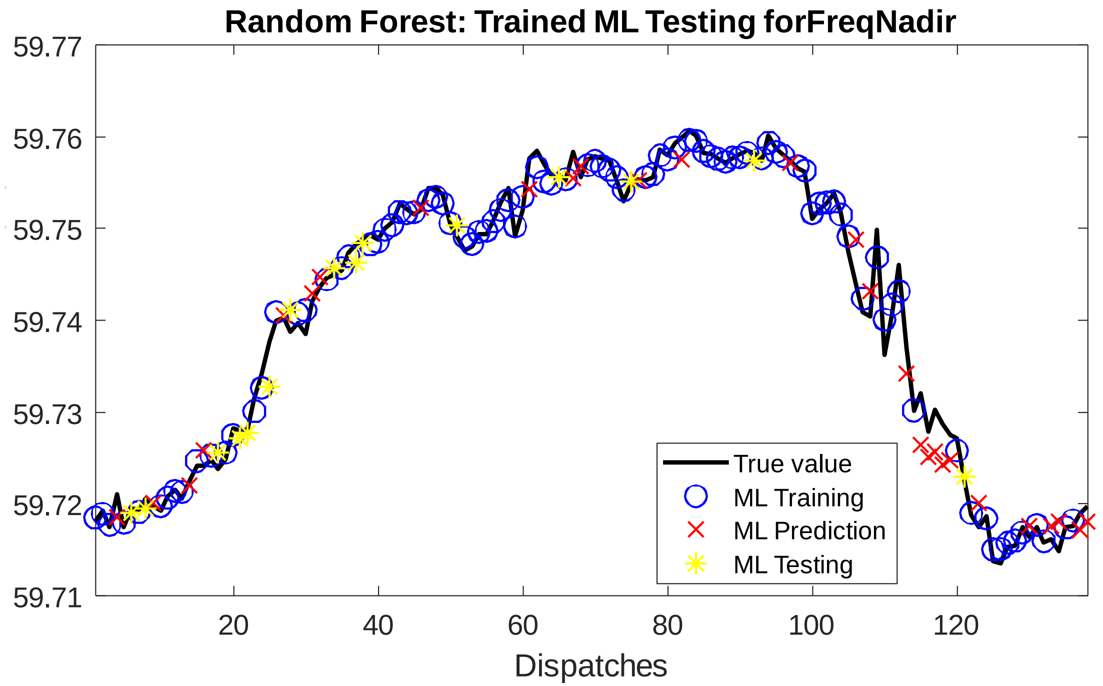


Features: Active power of 4270 generators and inertia of 3336 non-PV generators in WECC system (7606 inputs in total)

AI Agent for Frequency Stability Assessment: Results on Full WECC System

- Predicted frequency nadir using the developed AI agent
  - Dispatch data on 03/19/2019 every 6 minutes
  - Generator trip events: PALOVRD1 & PALOVRD2, 1.37GW & 1.37GW
  - Features: Active power of 4270 generators and inertia of 3336 non-PV generators
  - Labels: Frequency nadir

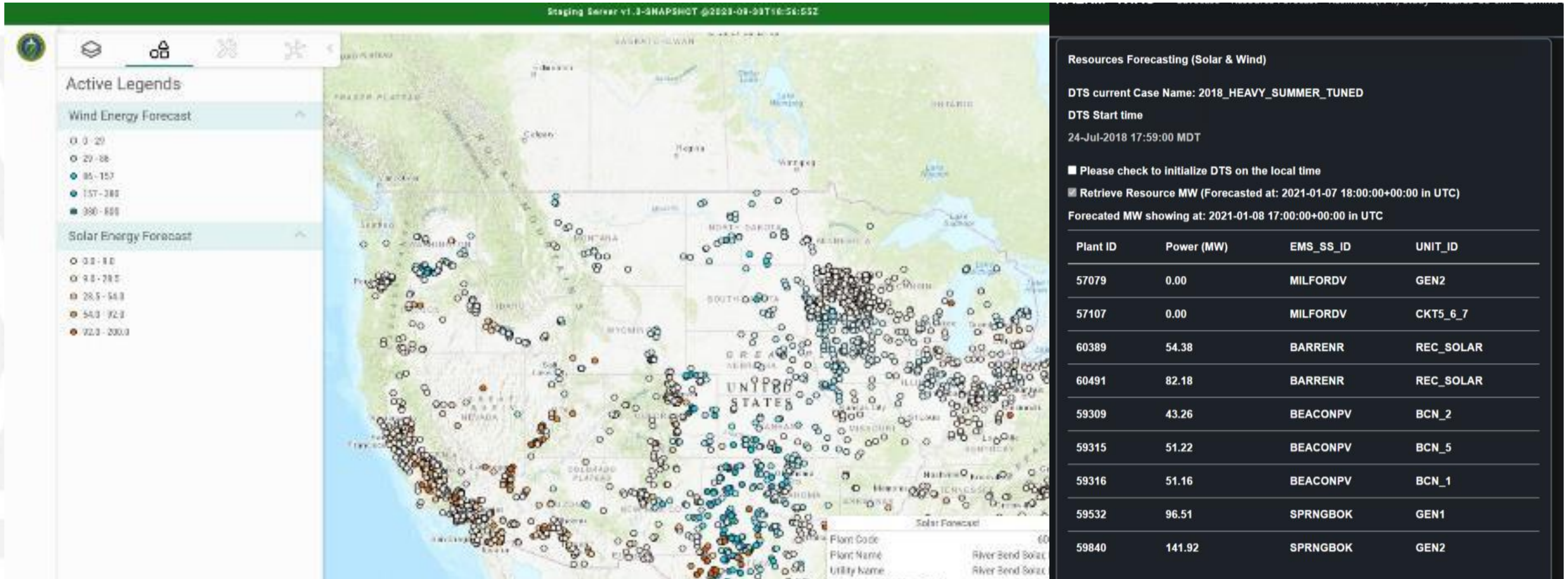


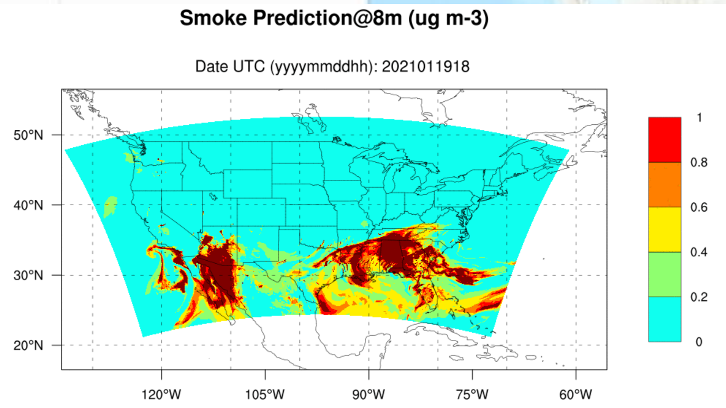


VOA N-k Co-Sim for Renewable Generation Curtailments

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

- Retrieves Wind & Solar forecast values in real-time.
- Runs DTS simulation with EMS real-time snapshots.
- Converts its SE solution into WECC planning case in real-time.

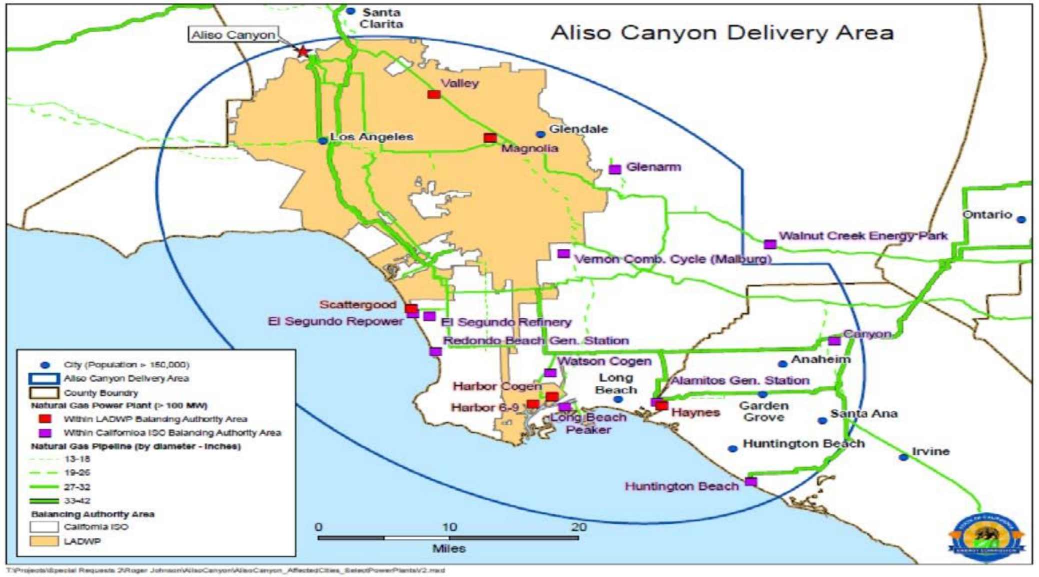


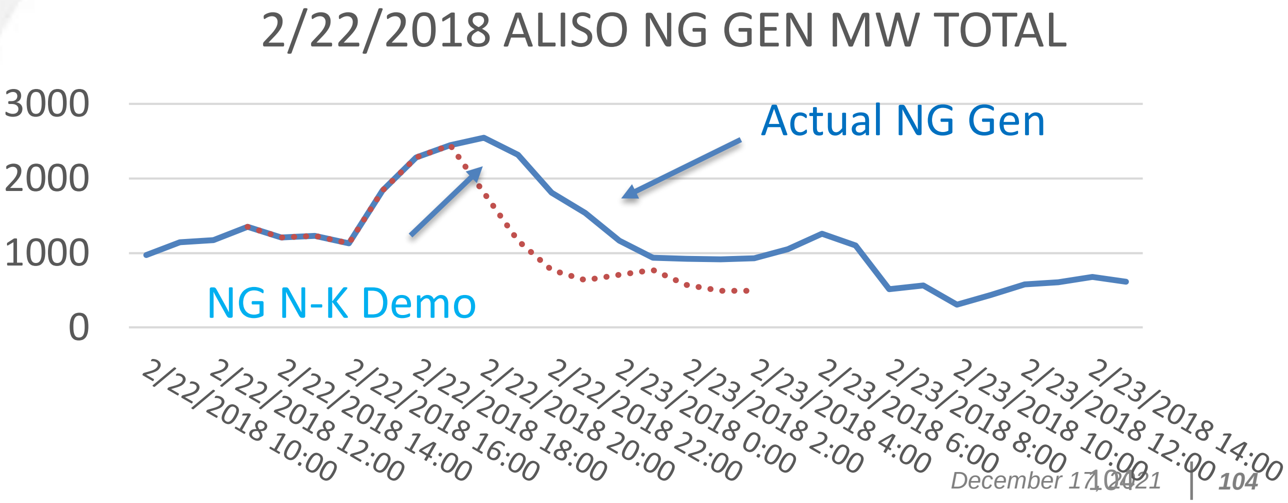


Near-surface smoke predicted from HRRR (3km resolution) from 18UTC 01/19/2021 to 06UTC 01/21/2021.

California NG N-k Resilience Risk Simulation

- When NG N-k curtailments in Aliso Canyon occurred in off-peak hours, there was no issue.
- What if the curtailments happened at the sunset?
  - CAISO load rose by 5,000 MW hourly and Solar PV generation was down by ~4,000 MW in an hour.
  - MW Import increased by 5,000 MW
  - **Could this N-k contingency be secured?**

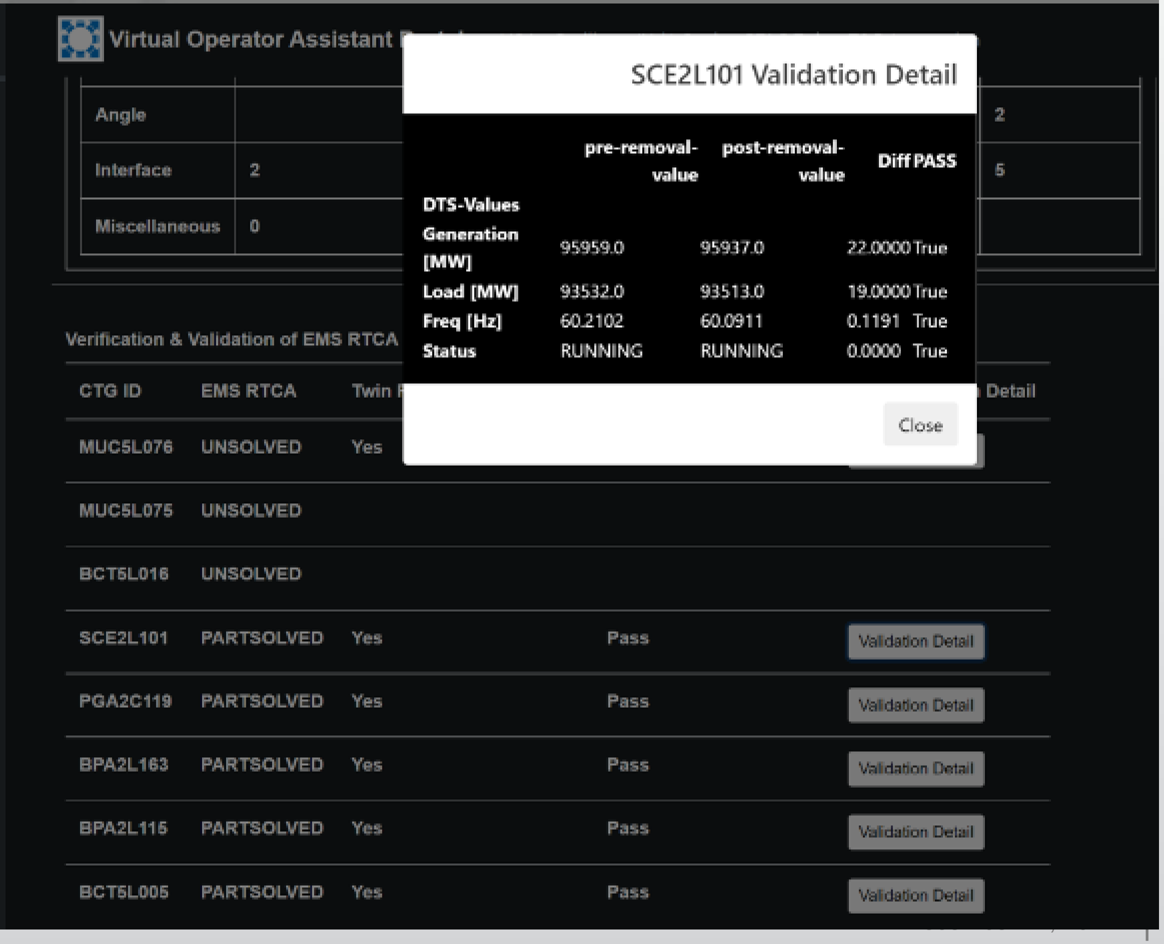




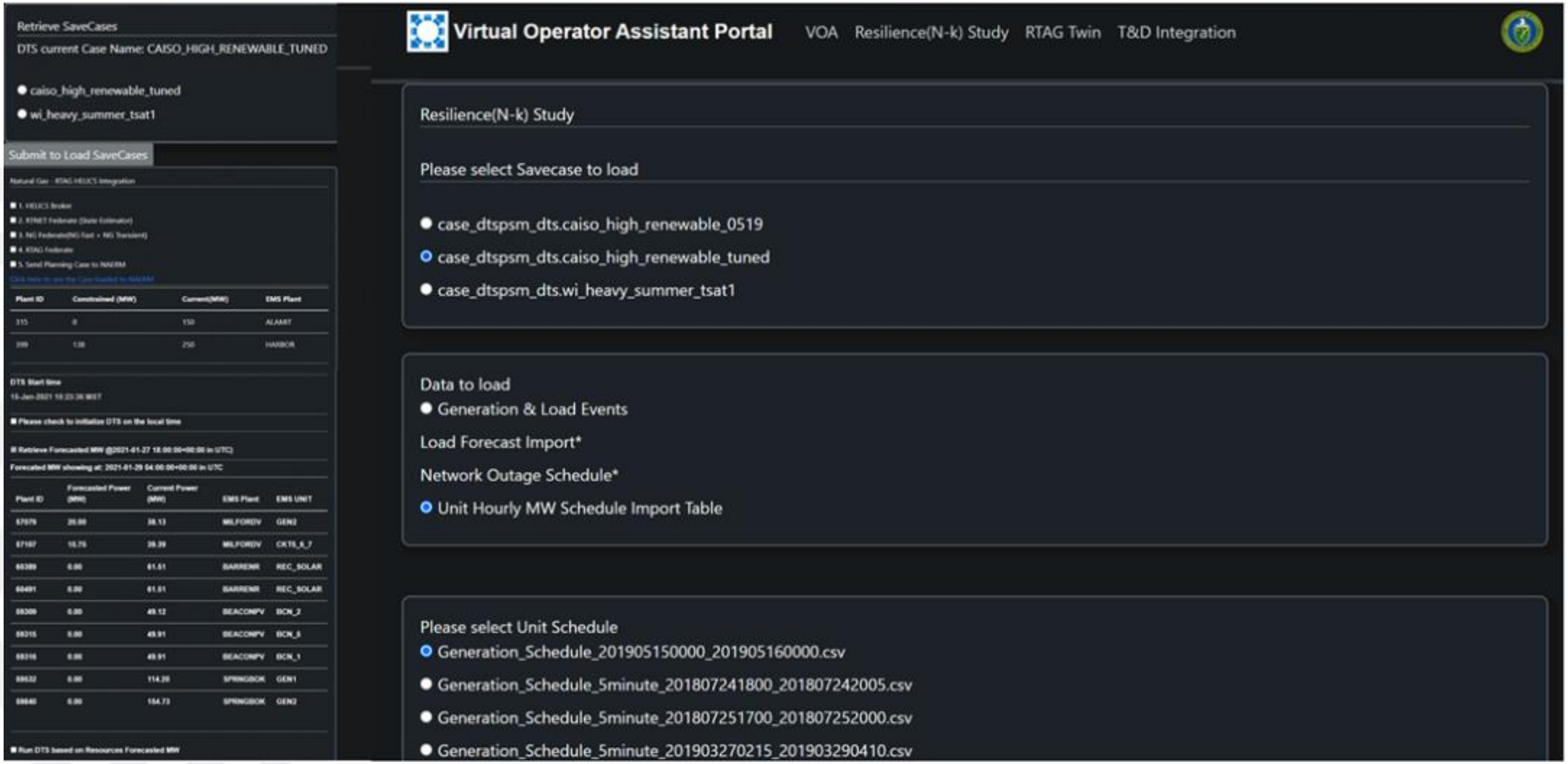
VOA Menu Display

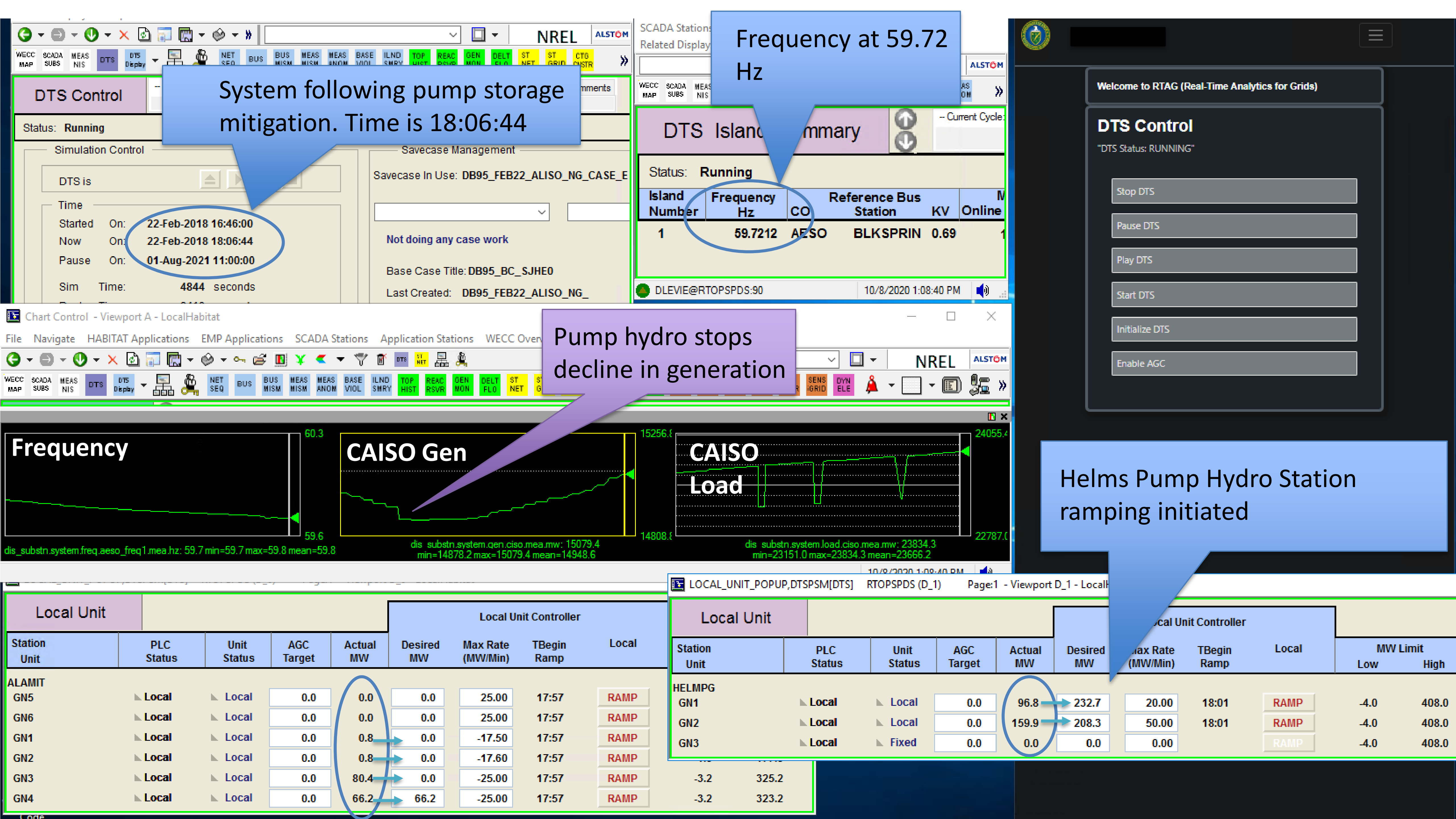
GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

- RTVA VVUQ Display
- Contingency Validation Page



VOA N-k Study Menu Display




System following pump storage mitigation. Time is 18:06:44
Frequency at 59.72 Hz
Pump hydro stops decline in generation
Helms Pump Hydro Station ramping initiated
DTS Control
Status: Running
Started On: 22-Feb-2018 16:46:00
Now On: 22-Feb-2018 18:06:44
Pause On: 01-Aug-2021 11:00:00
Sim Time: 4844 seconds
Savecase In Use: DB95_FEB22_ALISO_NG_CASE_E
Not doing any case work
Base Case Title: DB95_BC_SJHE0
DTS Island Summary
Island Number
Frequency Hz
Reference Bus Station
KV
1
59.7212
AESO
BLKSPRIN
0.69
Welcome to RTAG (Real-Time Analytics for Grids)
DTS Control
"DTS Status: RUNNING"
Stop DTS
Pause DTS
Play DTS
Start DTS
Initialize DTS
Enable AGC
Frequency
CAISO Gen
CAISO Load
dis_substn.system.freq.aeso_freq1.mea.hz: 59.7 min=59.7 max=59.8 mean=59.8
dis_substn.system.gen.ciso.mea.mw: 15079.4 min=14878.2 max=15079.4 mean=14948.6
dis_substn.system.load.ciso.mea.mw: 23834.3 min=23151.0 max=23834.3 mean=23666.2
Local Unit
Local Unit Controller
ALAMIT
HELMPG

Questions and Answers

Conference Summary (1/3)

- Session 3
  - Session Theme: Technique and Workforce Challenges
  - Date: 10/28/2021, 1:00 PM – 3:00 PM ET
  - EMS Staffing Challenges
    - Stacen Tyskiewicz, BPA
  - Cloud-Based Power System Elastic Computing and Wide-Area Monitoring
    - Song Zhang, ISO New England
  - Enhancing Grid Resilience Monitoring and Situational Awareness by Intelligent Analytics Integrated with Digital Twin Simulation
    - Hongming Zhang, NREL
    - Seong Choi, NREL
    - Yilu Liu, University of Tennessee

Conference Summary (2/3)

- Session 1
  - Session Theme: Overview
  - Date: 9/23/2021, 1:00 PM – 3:00 PM ET
  - Analysis of EMS Event Outages
    - Wei Qiu, NERC
  - NERC System Awareness --- Department Overview and PI Integration
    - Brent Kent, NERC
  - FERC and ERO Enterprise Joint Report on Real-time Assessments
    - Dwayne Fewless, ReliabilityFirst
    - Clayton Calhoun, NERC

Conference Summary (3/3)

- Session 2
  - Session Theme: Distributed Energy Resources (DER)
  - Date: 10/07/2021, 1:00 PM – 3:00 PM ET
  - Inverter-Based Resource Integration at Duke Energy
    - Adam Guinn, Duke
  - Distributed Energy Resources
    - Daniel Moscovitz, PJM
  - DER Order 2222
    - Kristin Swenson, MISO
  - Modeling Distributed Energy Resources in CAISO systems
    - Ankit Mishra, CAISO

Thank You and See you Next Year !