NOVEMBER 16, 2022

Past, Present and Future of Power Grid
CAISO Moving to Community Data Sharing

Evolution of PI System in CAISO's Operations

Vincent Frey, ISO Lead Market Operator

Jim Hiebert, ISO Lead EMS Power Technology Engineer

CAISO/RC West - PI Architecture

- 4 Basic Environments
  - Production (32), Stage (11), Dev, Training, Simulation
  - > 56 Total Servers – 2 PI Admins (TW and JH)
- 2 Site Redundancy (both CCA and Non-CCA)
- HA Collectives
- Redundant SQL Servers for PI Vision (Always-On) and Asset Framework Databases
- More than 400 Internal Company PI Users
- Sharing PI Vision Displays with 68 External Companies using certificate-based connections
- 22+ Years of Data Archive
- 1.4M Points (1.2 million events/minute)

CAISO Facts

As a federally regulated nonprofit organization, the ISO manages the high-voltage electric grid in California and a portion of Nevada.

52,061 MW record peak demand
(Sept. 6, 2022)

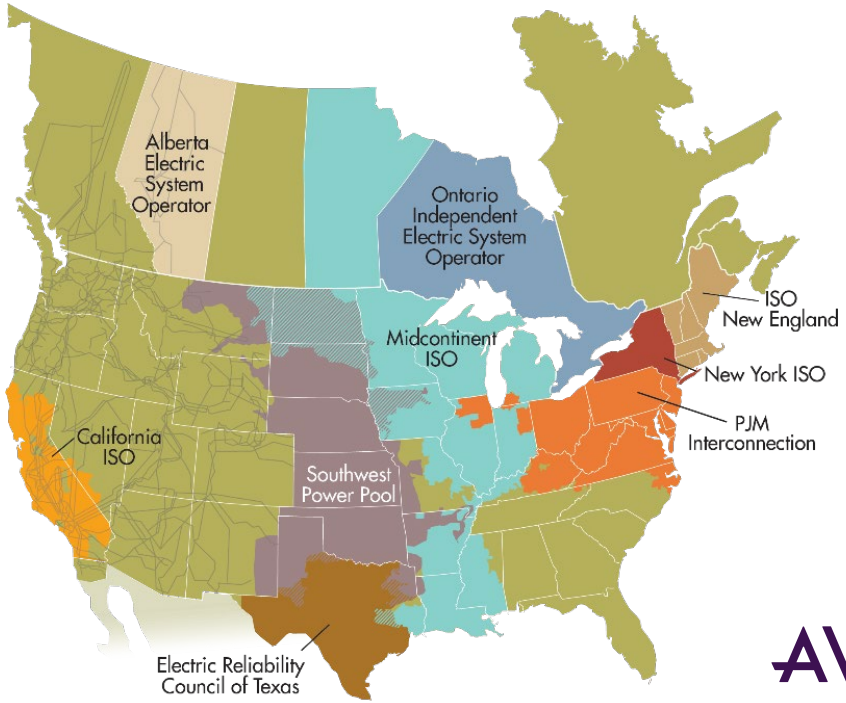
224.8 million megawatt-hours
of electricity delivered (2020)

75,747 MW power plant capacity
Source: California Energy Commission

1,119 power plants
Source: California Energy Commission

32 million people served

One of **9** ISO/RTOs in North America

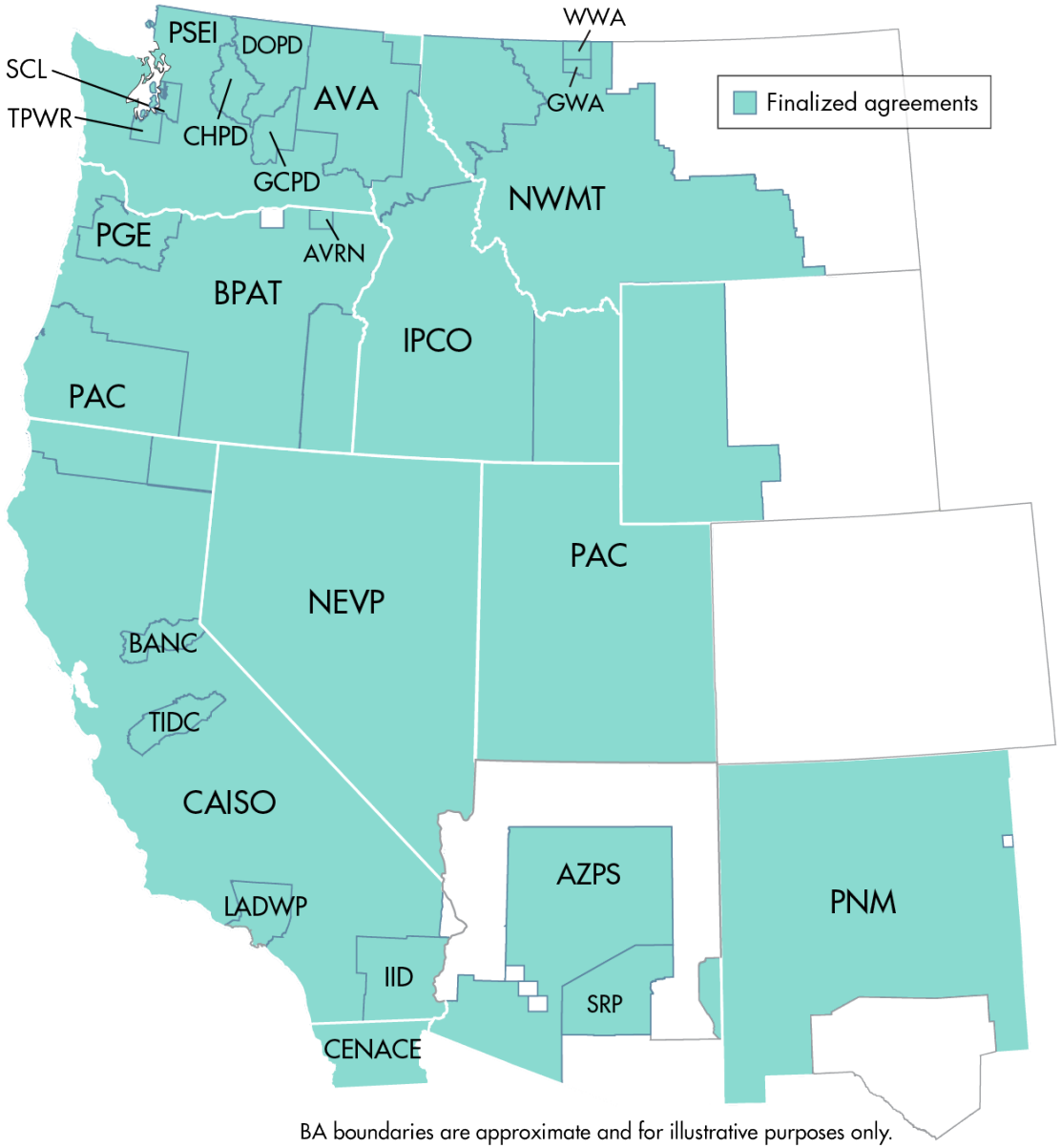


RC West

The ISO became the reliability coordinator for the majority of the Western Electricity Coordinating Council (WECC) in 2019.

130, 985 MW record peak demand

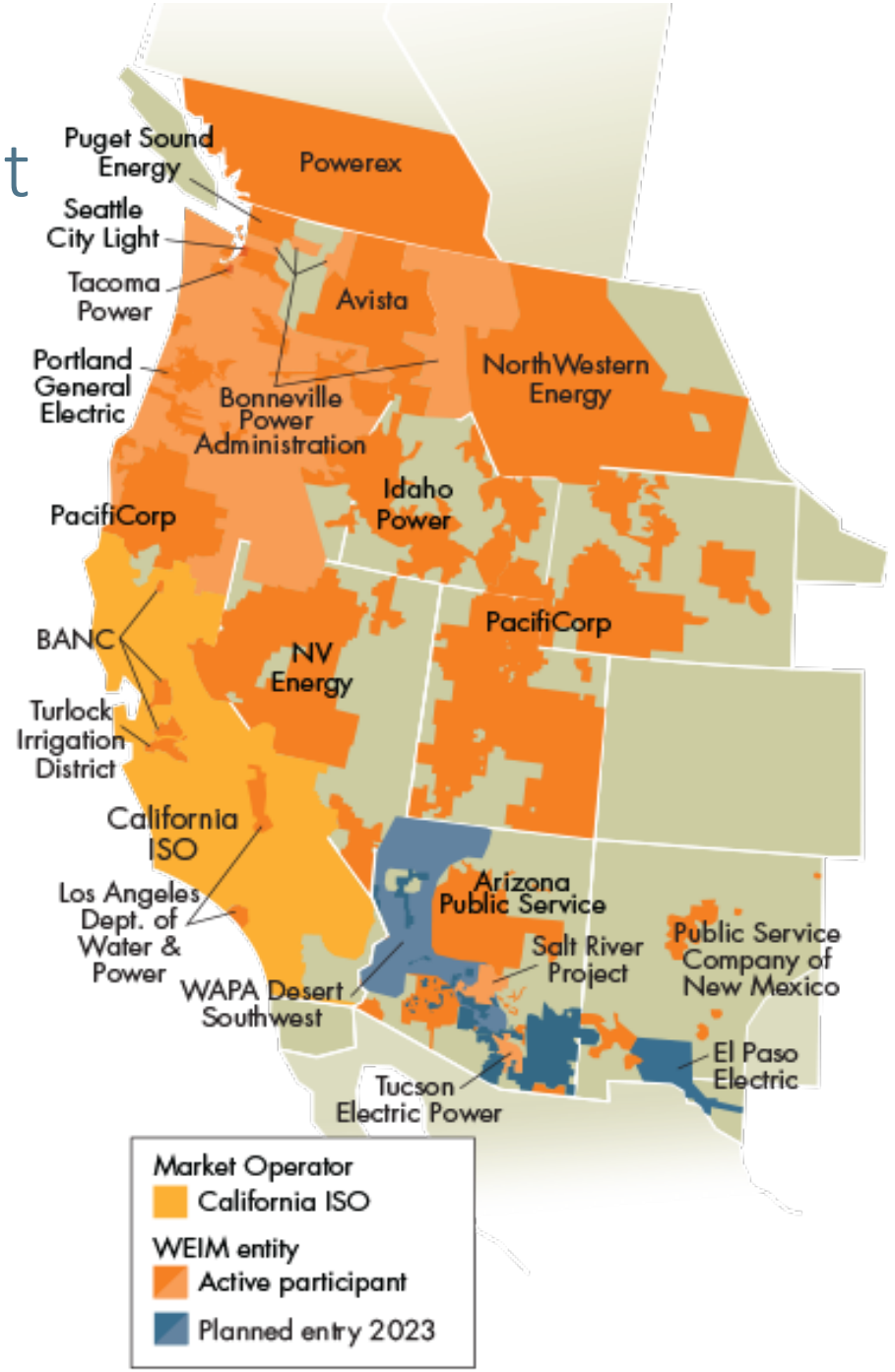
(Sept. 6, 2022)



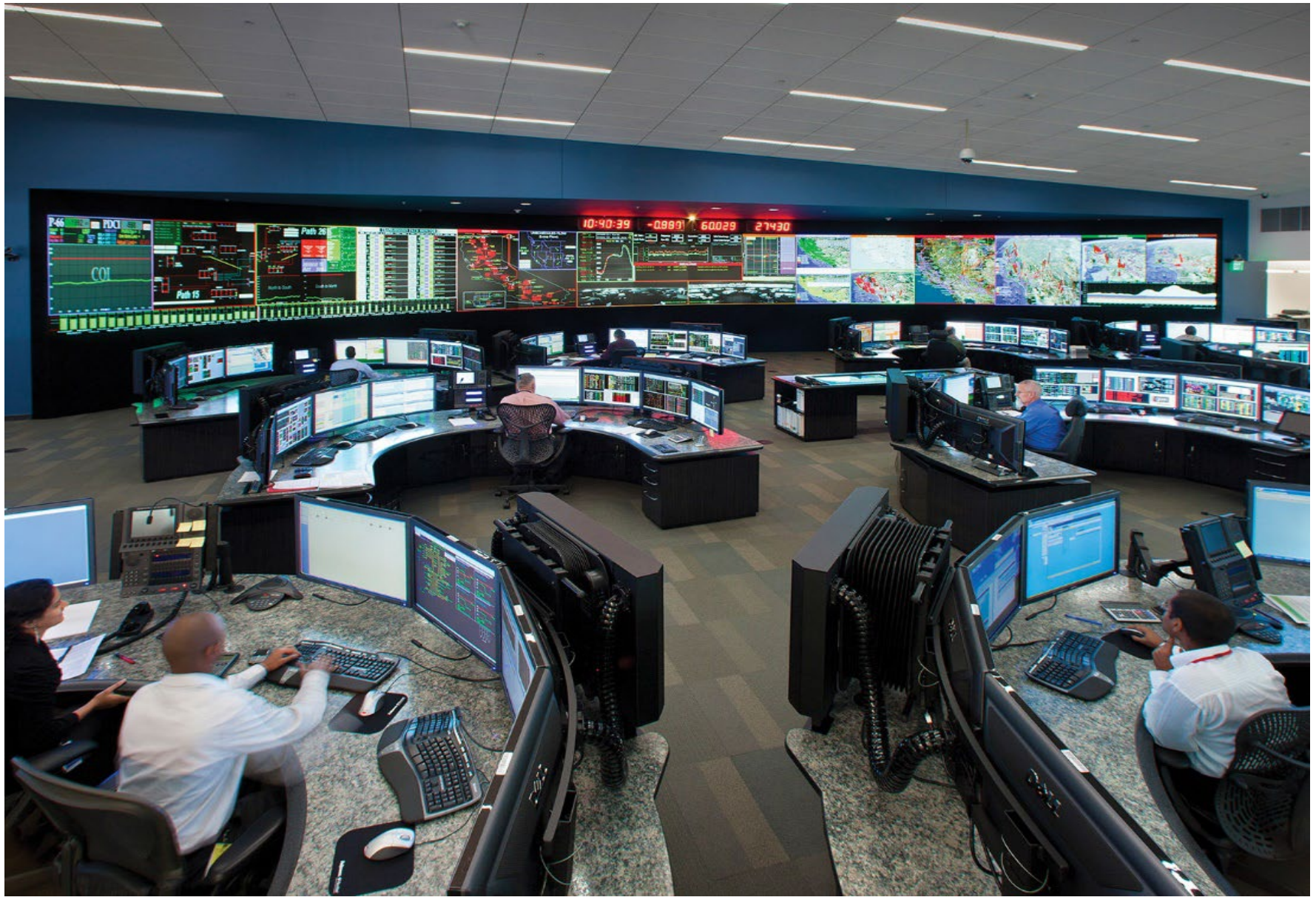
Western Energy Imbalance Market

- The ISO operates the WEIM
- Launched in 2014
- 20 Balancing Authorities are currently members
- 3 more entities are set to join in spring 2023
- 134,219 MW peak load

(Sept. 6, 2022)



CAISO Control Room

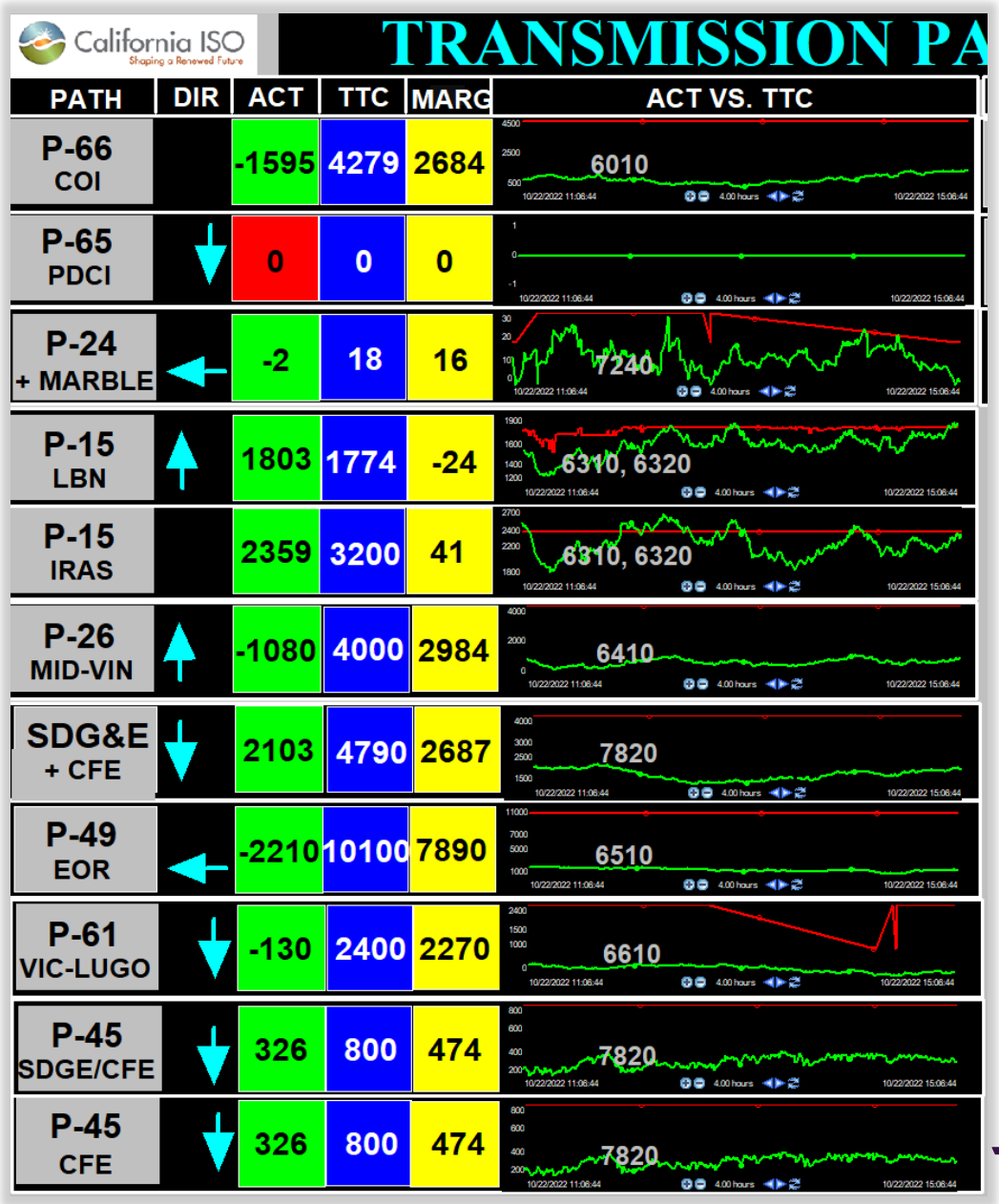


How CAISO Operations' Use of PI has Changed over the Years

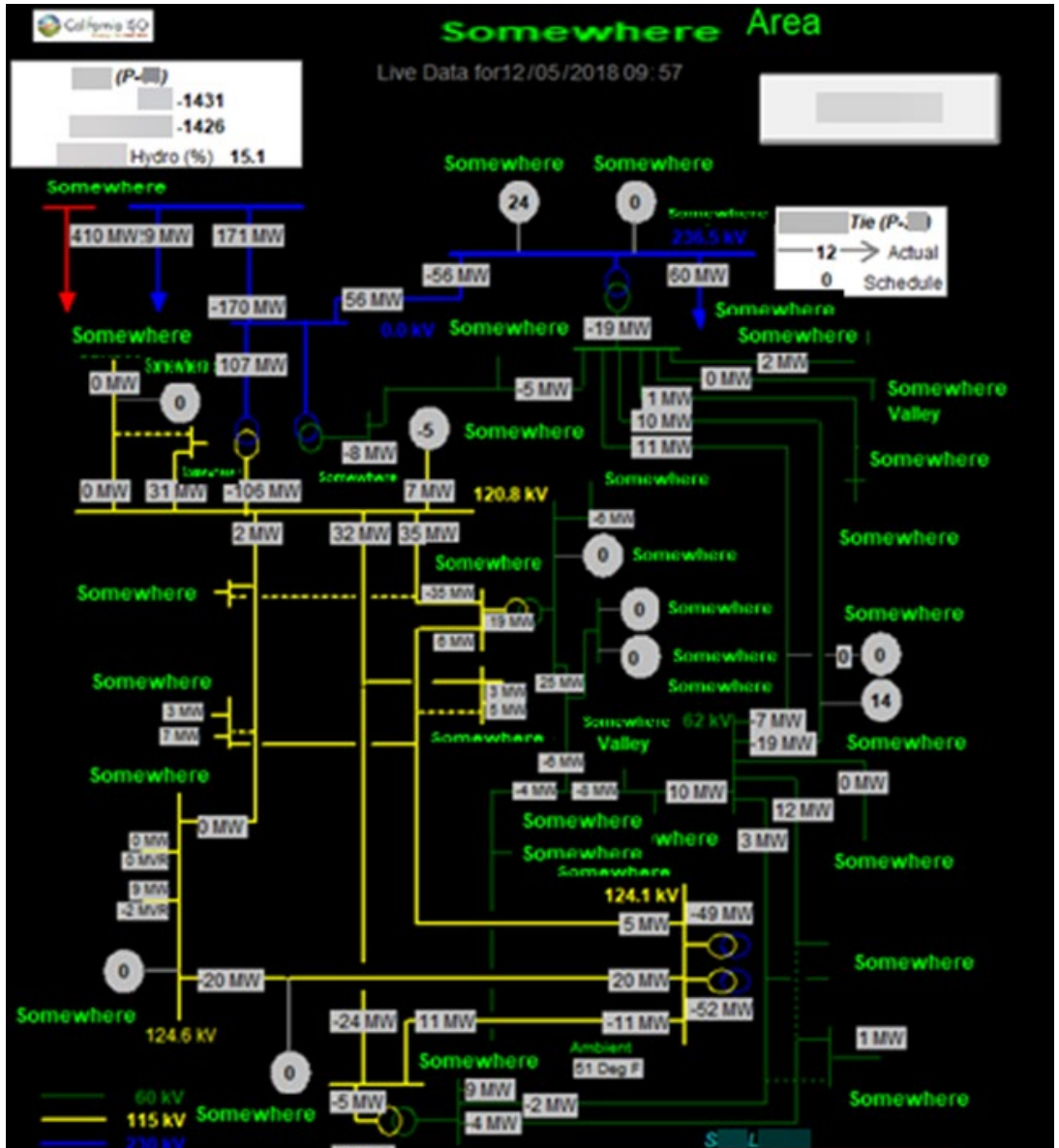
- Evolution of Overviews
- Evolution of Focusing Attention
- Evolution of Content Consolidation
- Evolution of PI Data Sharing with the "Community"

Evolution of Overviews
Tabular Overviews Circa 2010

- Tabular displays were often colorful
- There was multi-stating
  - Red and blinking were reserved for limits and alarming



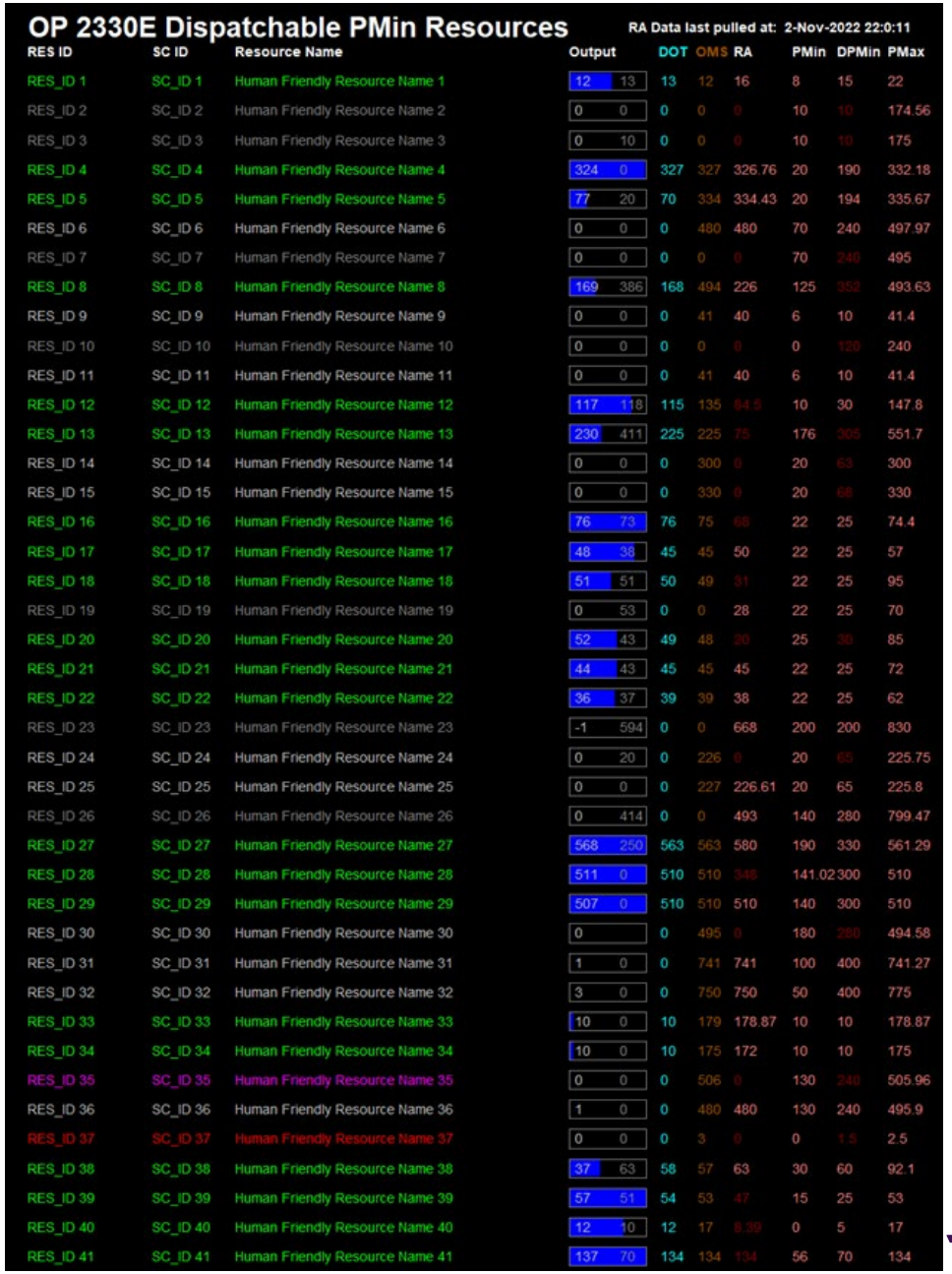
Transmission Overview Format Circa 2010



- Area Name
- Time Stamp
- Different colors for Voltage levels
- Station Names
- Bus kV
- Line flows
- Generation
- Miscellaneous Info
  - Links to Operating Procedures
  - Impacting Paths

Tabular Overviews Circa 2016

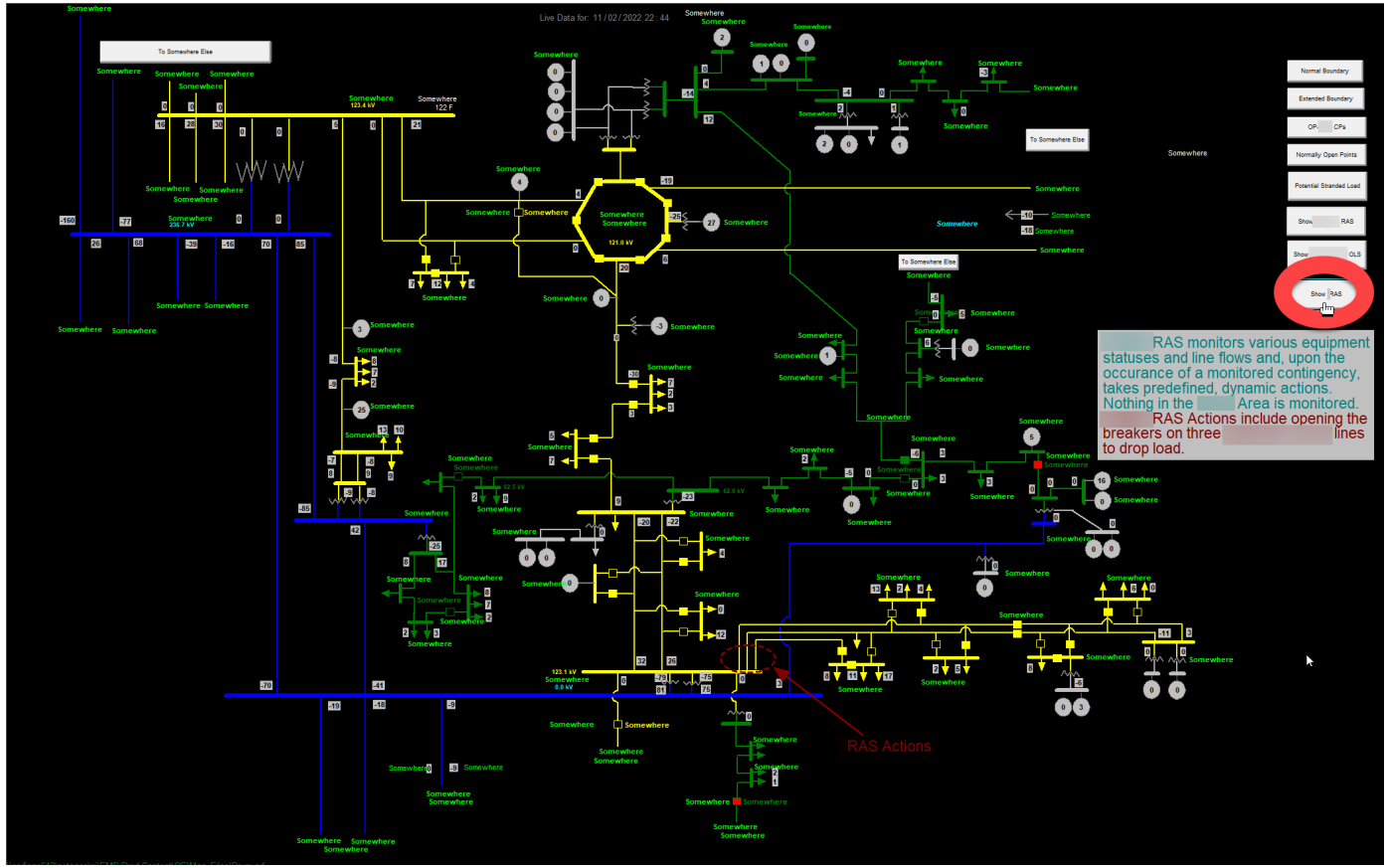
- Began making tabular displays self-update from databases
- Colors began getting more muted when not trying to garner attention
- The PB example to the right used Visual Basic to reference a spreadsheet and two different databases, then redraw and multi-state entire display



OP 2330E Dispatchable PMin Resources — RA Data last pulled at: 2-Nov-2022 22:0:11

RES ID	SC ID	Resource Name	Output		DOT	OMS	RA	PMin	DPMin	PMax
RES_ID 1	SC_ID 1	Human Friendly Resource Name 1	12	13	13	12	16	8	15	22
RES_ID 2	SC_ID 2	Human Friendly Resource Name 2	0	0	0	0	0	10	10	174.56
RES_ID 3	SC_ID 3	Human Friendly Resource Name 3	0	10	0	0	0	10	10	175
RES_ID 4	SC_ID 4	Human Friendly Resource Name 4	324	0	327	327	326.76	20	190	332.18
RES_ID 5	SC_ID 5	Human Friendly Resource Name 5	77	20	70	334	334.43	20	194	335.67
RES_ID 6	SC_ID 6	Human Friendly Resource Name 6	0	0	0	480	480	70	240	497.97
RES_ID 7	SC_ID 7	Human Friendly Resource Name 7	0	0	0	0	0	70	240	495
RES_ID 8	SC_ID 8	Human Friendly Resource Name 8	169	386	168	494	226	125	352	493.63
RES_ID 9	SC_ID 9	Human Friendly Resource Name 9	0	0	0	41	40	6	10	41.4
RES_ID 10	SC_ID 10	Human Friendly Resource Name 10	0	0	0	0	0	0	120	240
RES_ID 11	SC_ID 11	Human Friendly Resource Name 11	0	0	0	41	40	6	10	41.4
RES_ID 12	SC_ID 12	Human Friendly Resource Name 12	117	118	115	135	84.5	10	30	147.8
RES_ID 13	SC_ID 13	Human Friendly Resource Name 13	230	411	225	225	75	176	305	551.7
RES_ID 14	SC_ID 14	Human Friendly Resource Name 14	0	0	0	300	0	20	63	300
RES_ID 15	SC_ID 15	Human Friendly Resource Name 15	0	0	0	330	0	20	68	330
RES_ID 16	SC_ID 16	Human Friendly Resource Name 16	76	73	76	75	68	22	25	74.4
RES_ID 17	SC_ID 17	Human Friendly Resource Name 17	48	38	45	45	50	22	25	57
RES_ID 18	SC_ID 18	Human Friendly Resource Name 18	51	51	50	49	31	22	25	95
RES_ID 19	SC_ID 19	Human Friendly Resource Name 19	0	53	0	0	28	22	25	70
RES_ID 20	SC_ID 20	Human Friendly Resource Name 20	52	43	49	48	30	25	38	85
RES_ID 21	SC_ID 21	Human Friendly Resource Name 21	44	43	45	45	45	22	25	72
RES_ID 22	SC_ID 22	Human Friendly Resource Name 22	36	37	39	39	38	22	25	62
RES_ID 23	SC_ID 23	Human Friendly Resource Name 23	-1	594	0	0	668	200	200	830
RES_ID 24	SC_ID 24	Human Friendly Resource Name 24	0	20	0	226	0	20	65	225.75
RES_ID 25	SC_ID 25	Human Friendly Resource Name 25	0	0	0	227	226.61	20	65	225.8
RES_ID 26	SC_ID 26	Human Friendly Resource Name 26	0	414	0	0	493	140	280	799.47
RES_ID 27	SC_ID 27	Human Friendly Resource Name 27	568	250	563	563	580	190	330	561.29
RES_ID 28	SC_ID 28	Human Friendly Resource Name 28	511	0	510	510	348	141.02	300	510
RES_ID 29	SC_ID 29	Human Friendly Resource Name 29	507	0	510	510	510	140	300	510
RES_ID 30	SC_ID 30	Human Friendly Resource Name 30	0		0	495	0	180	280	494.58
RES_ID 31	SC_ID 31	Human Friendly Resource Name 31	1	0	0	741	741	100	400	741.27
RES_ID 32	SC_ID 32	Human Friendly Resource Name 32	3	0	0	750	750	50	400	775
RES_ID 33	SC_ID 33	Human Friendly Resource Name 33	10	0	10	179	178.87	10	10	178.87
RES_ID 34	SC_ID 34	Human Friendly Resource Name 34	10	0	10	175	172	10	10	175
RES_ID 35	SC_ID 35	Human Friendly Resource Name 35	0	0	0	506	0	130	240	505.96
RES_ID 36	SC_ID 36	Human Friendly Resource Name 36	1	0	0	480	480	130	240	495.9
RES_ID 37	SC_ID 37	Human Friendly Resource Name 37	0	0	0	3	0	0	1.5	2.5
RES_ID 38	SC_ID 38	Human Friendly Resource Name 38	37	63	58	57	63	30	60	92.1
RES_ID 39	SC_ID 39	Human Friendly Resource Name 39	57	51	54	53	47	15	25	53
RES_ID 40	SC_ID 40	Human Friendly Resource Name 40	12	10	12	17	8.39	0	5	17
RES_ID 41	SC_ID 41	Human Friendly Resource Name 41	137	70	134	134	134	56	70	134

Transmission Overviews Circa 2016



- Added multi-stated breakers where relevant
- Started adding locally-specific, dynamically-visible details to lessen tribal knowledge transfer burdens

Overview of RC West Expansion Needs (2019)

We also had a planned Energy Management System replacement at six months later

PI displays were used to bridge the change

Problem Statements:

1. Needed to build a lot of displays with a standard format
2. Needed ability to move between related/neighboring displays
   - Simple push buttons, sometimes hidden
3. Needed ability to see transmission statuses at a glance
4. Needed transmission status changes to be accentuated

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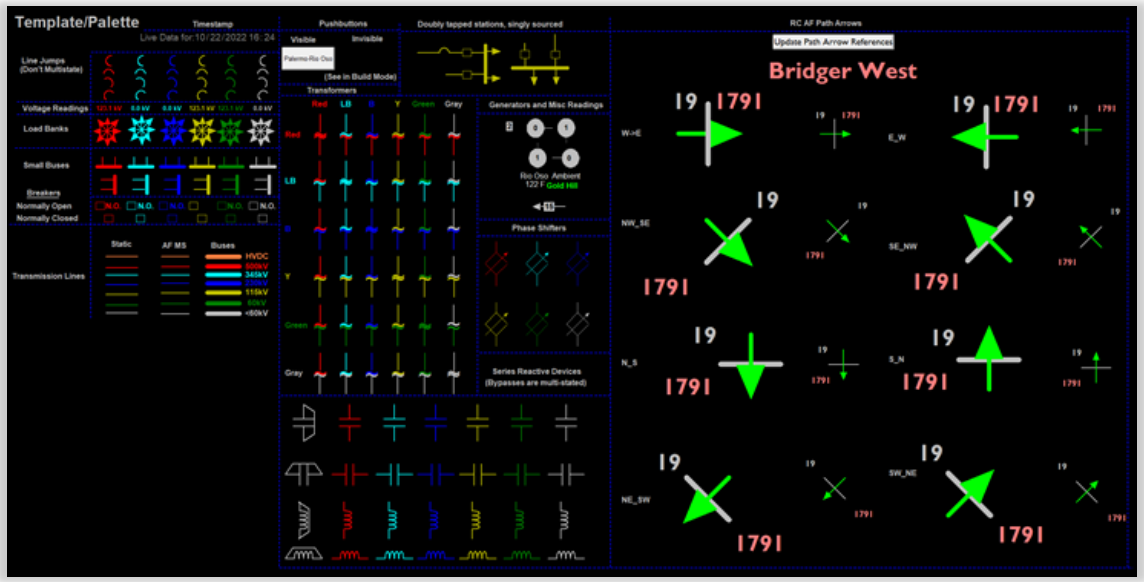
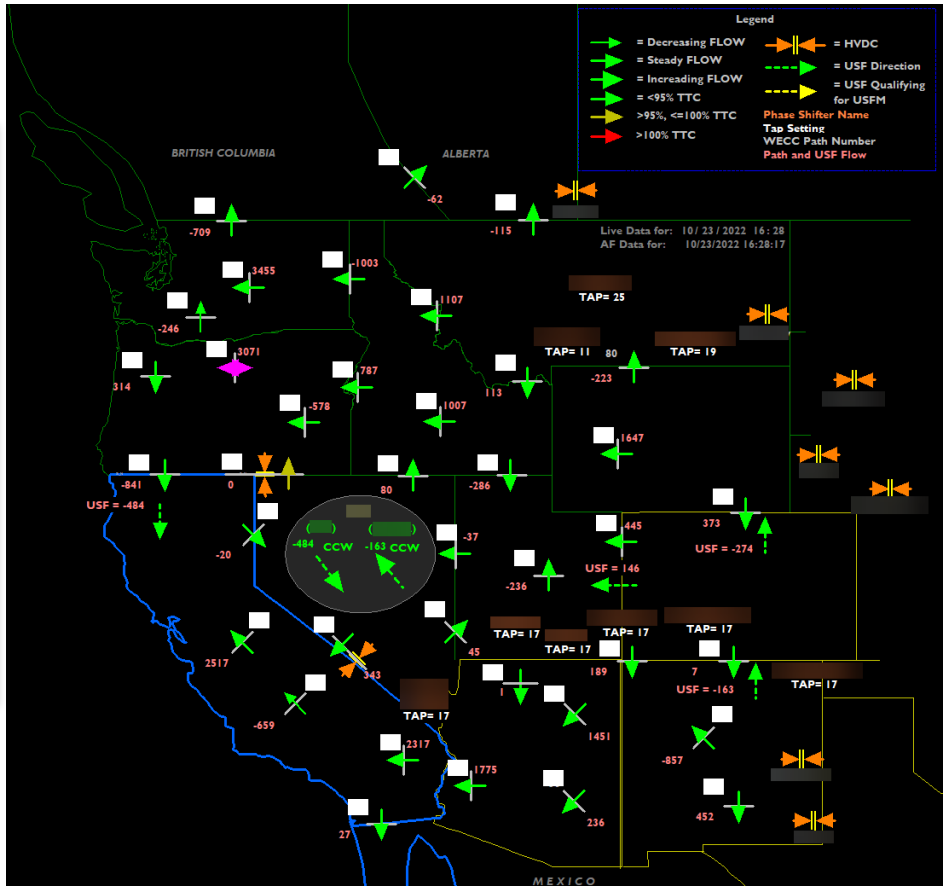
Solutions for Problem 1

(Needed to build a lot of displays with a standard format)

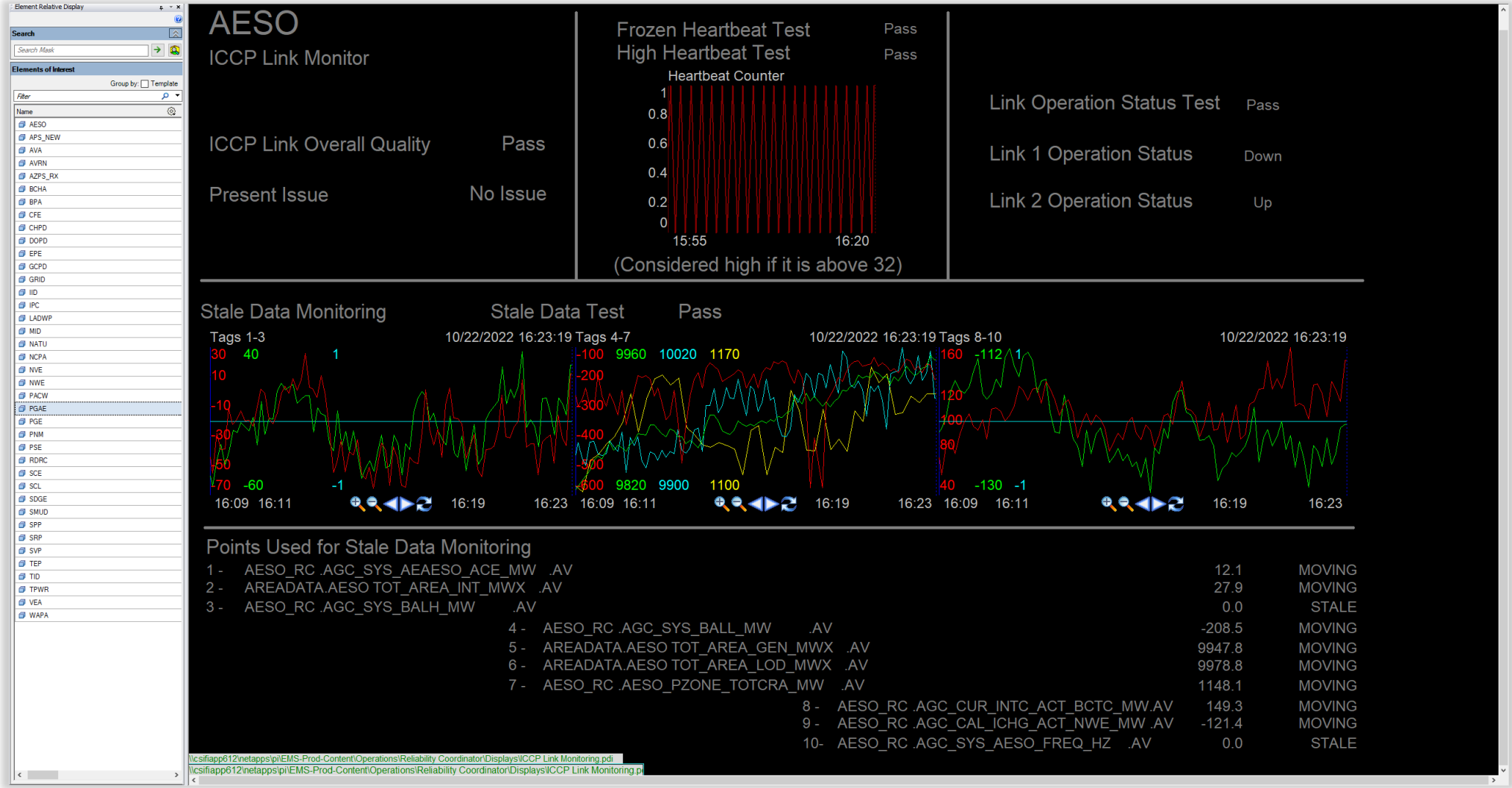
An Overview Drawing Palette to Bring Element-Relative Ease to Multi-Element Displays





Solutions for Problem 1

(Element-Relative Displays for Tabular Data)



Solutions for Problem 3
(Needed ability to see transmission statuses at a glance)

Wrote a three-tiered process to convert our Common Information Model (CIM) of the Western Interconnection into an Asset Framework Database (AF DB)

1. Determined which breakers and disconnects in the CIM were sent to PI
2. Process the topology of the CIM into PI calculations
   - Determined “In-Service”, “Out of Service”, “Bypassed”
3. Upload PI calculations into an AF DB
   - Roughly 17,000 assets created with calculations based upon 127,000 discrete state tags
   - Thank you for PI Builder

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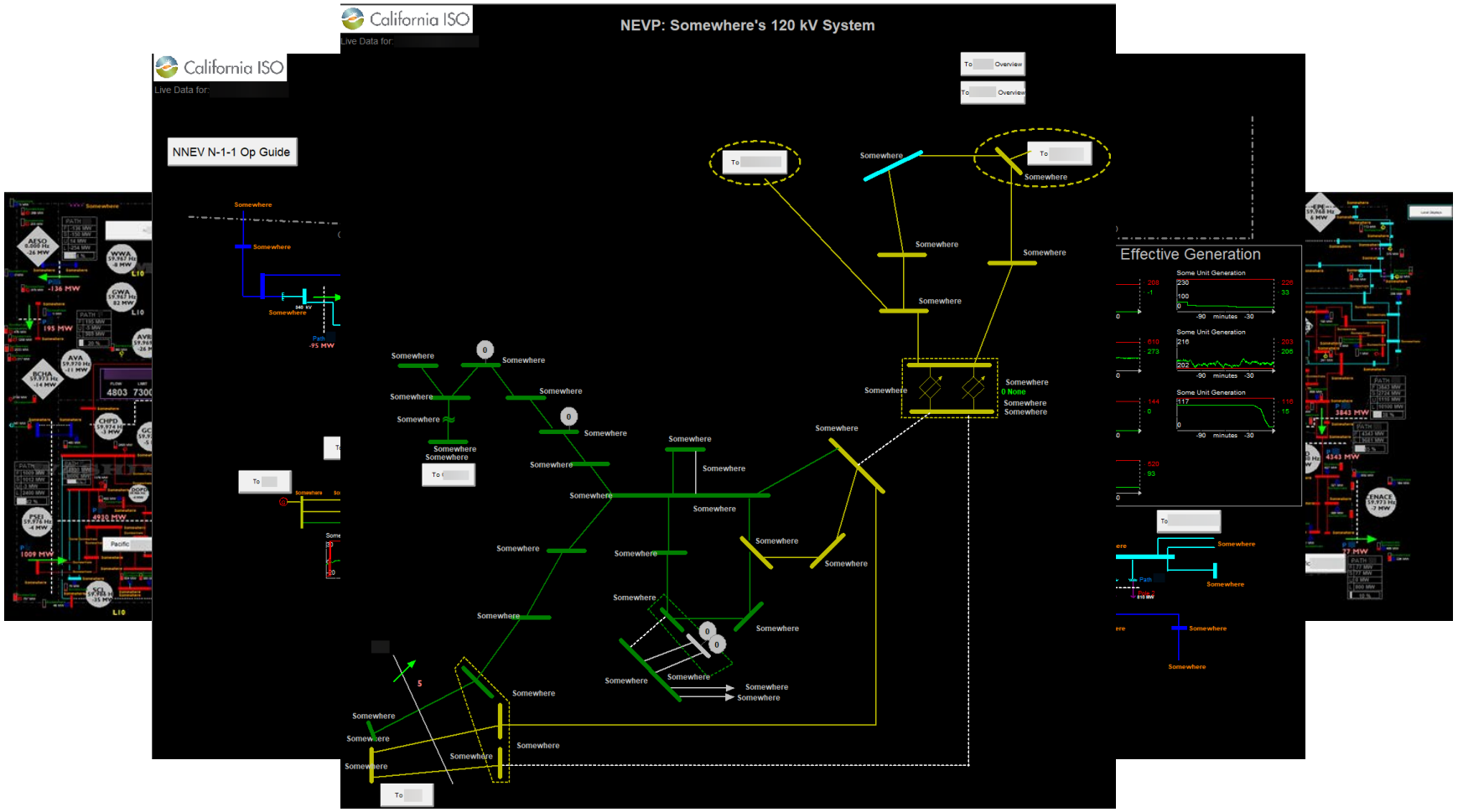
Transmission Overviews & Navigation

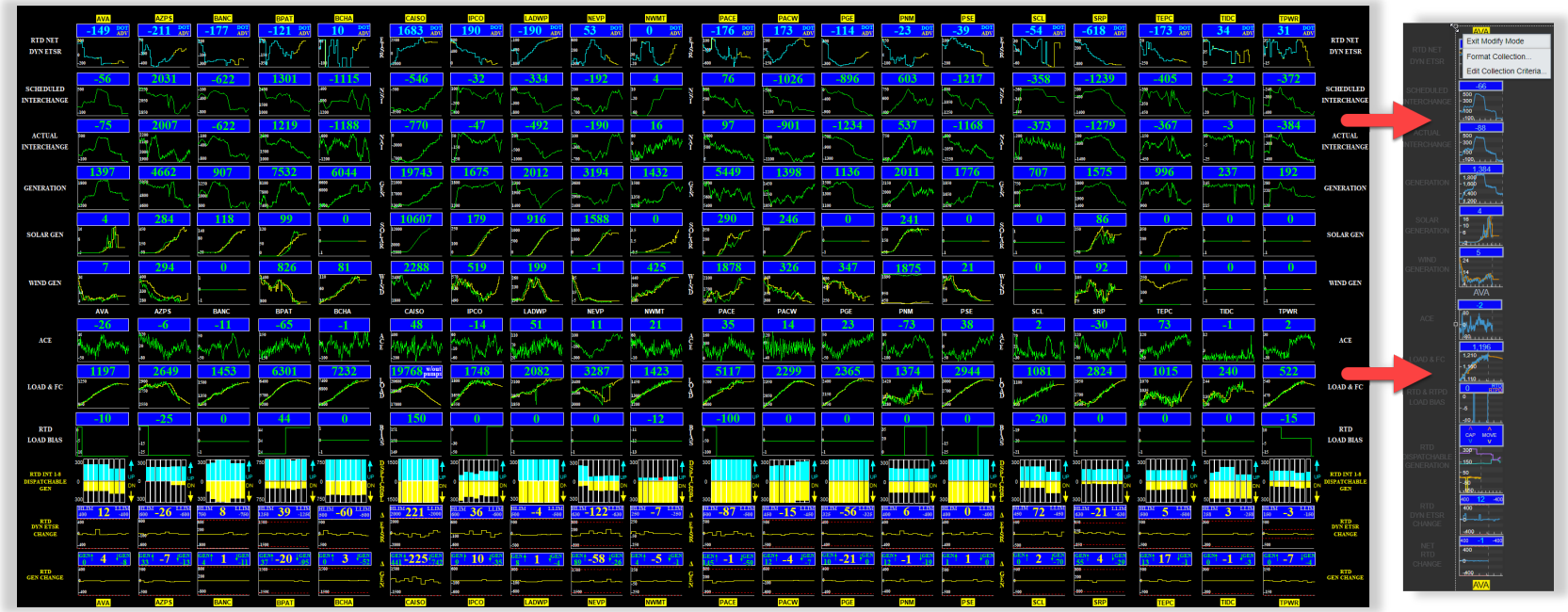


Solution for Problem 4
(Needed transmission status changes to be accentuated)

- This required a mix of Visual Basic and Multi-Stating
- Currently unused states were flagged to blink via VB code
- Elements found in blinking states started timers
- After 5 minutes, the blinking elements would toggle between solid and dashed lines and all the non-current states were set to blink.

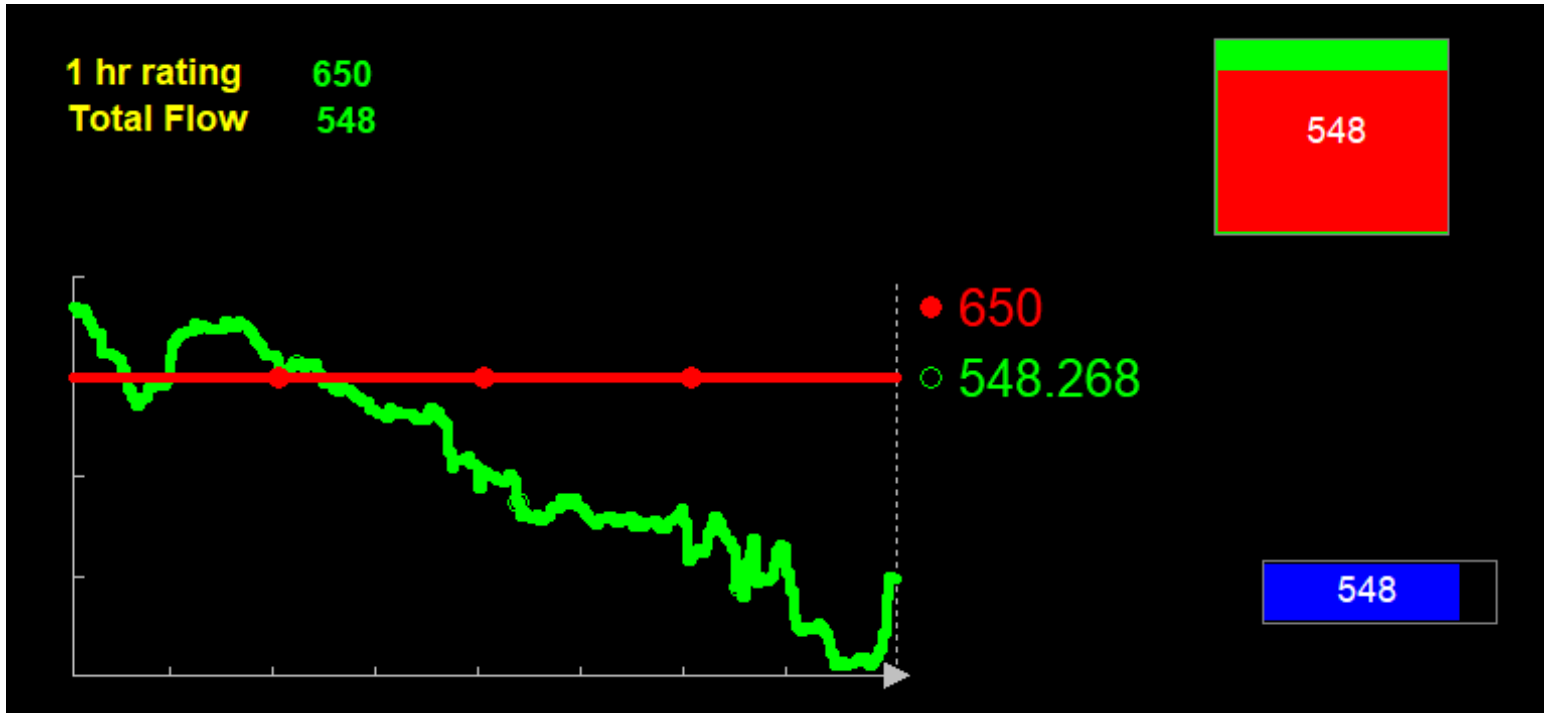
Scalability for WEIM

- We've redesigned our displays to be more scalable
- Using AF and Collections, it was faster to redesign the entire framework than to add the last three new entities
  - Collections work with our new security paradigm (more later)
  - Asset-relative Vision displays automatically pulled in new entities



Evolution of Focusing Attention

- In the beginning there was chaos
- Different display builders used bars, trends or only values
- Multi-stating was intermittently used
- Too much time was spent trying to interpret the displays



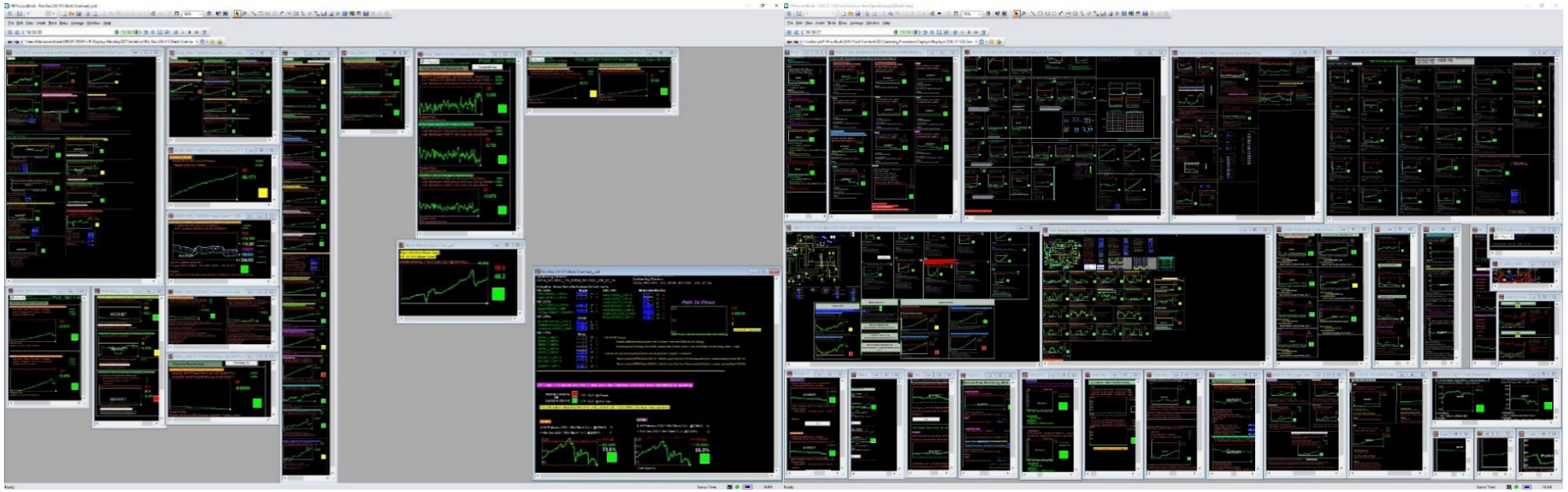
Creating a Standard (2010)

- A standard “Control Point” format was agreed upon by all

- Format
  - Description of issue
  - Trend
  - Multi-stated Box
    - Green, Yellow, Red
  - Mitigation actions

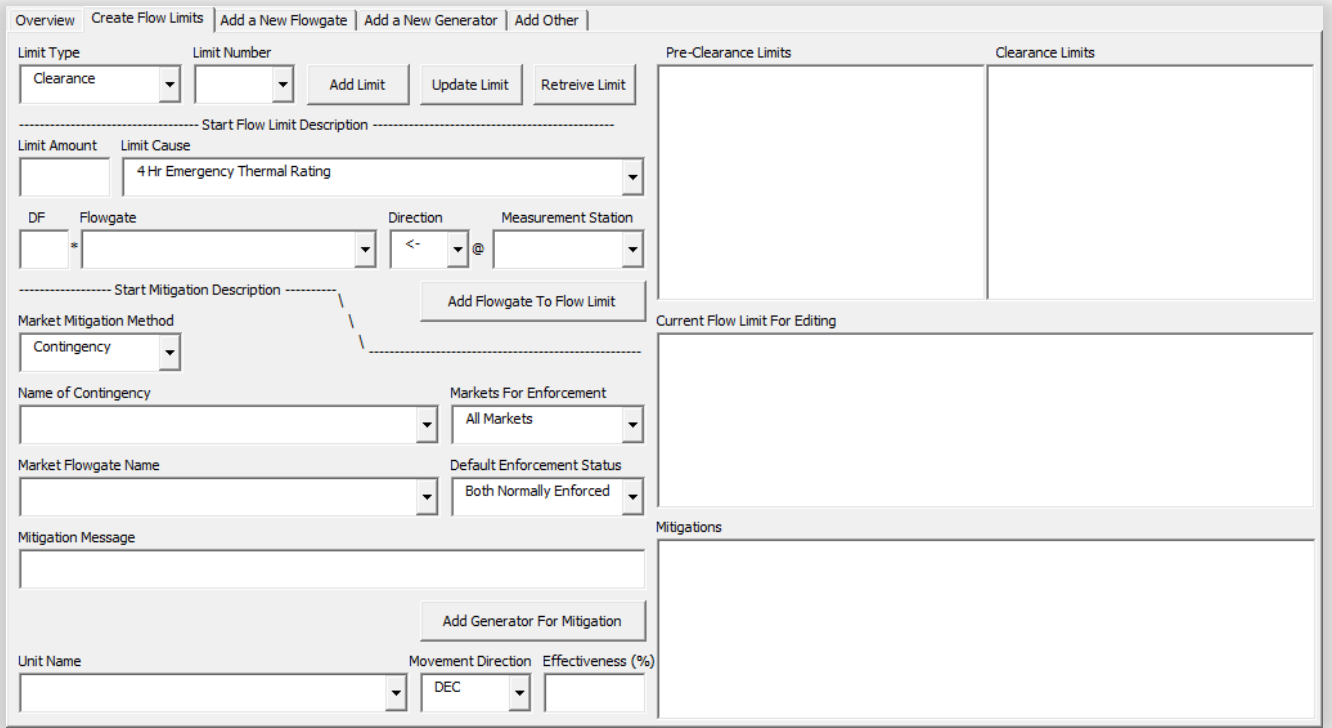
Improving the Implementation

- We had hundreds of active Control Points at all times
  - Too much monitor space being consumed
  - Hard to see issues, even with multi-stating
- During maintenance seasons, there could be 30 Control Points to draw, validate and organize for each day
  - A lot of tedious work



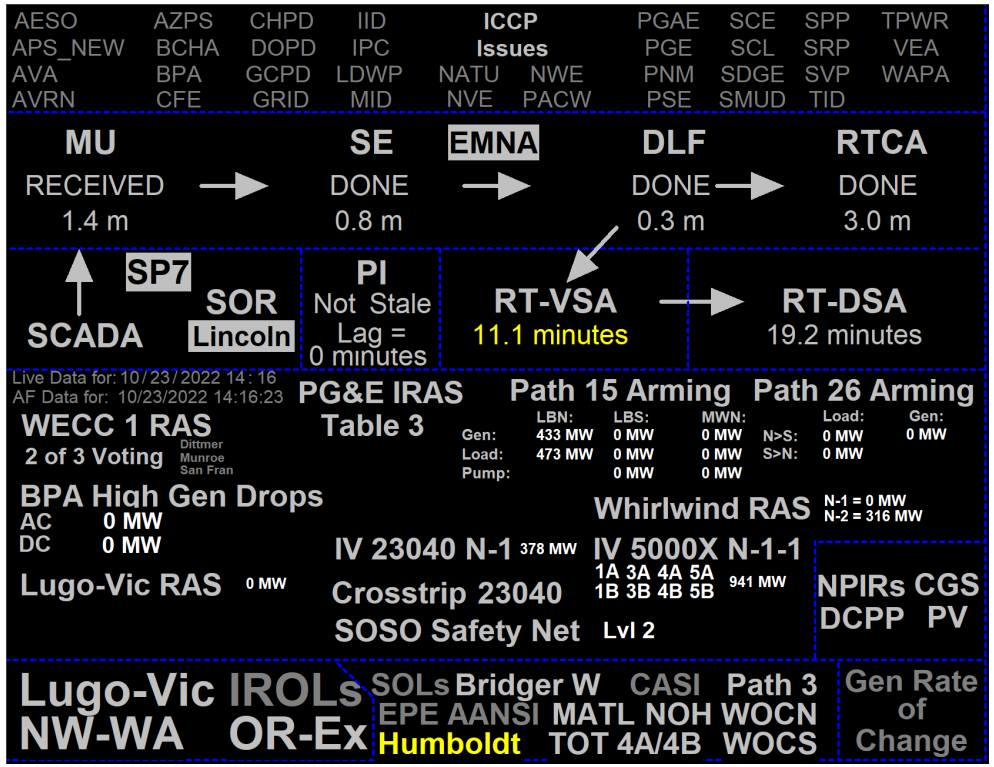
Lessening Design Repetition

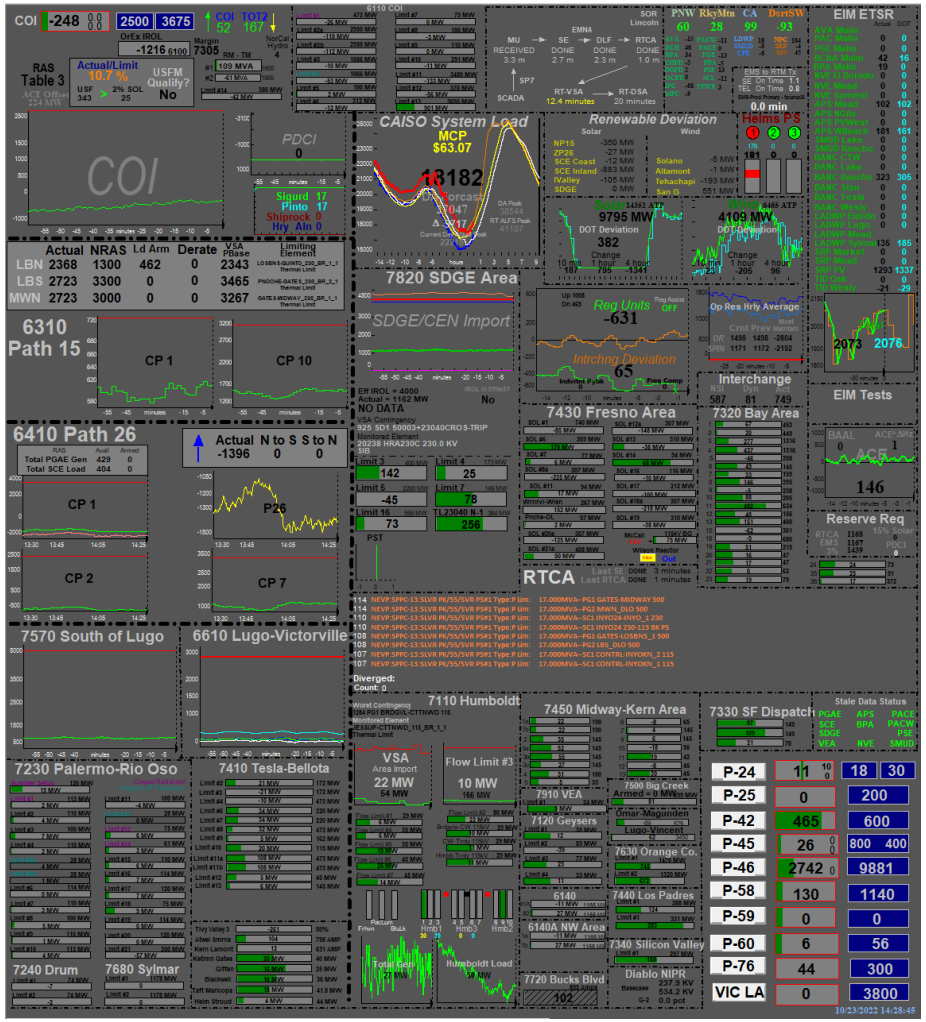
- We automated the creation of SVGs for Control Points
- We leveraged our Common Information Model, Master File (Generation Data) and Transmission Registry data to allow humans to use human-friendly names to create displays using tag names.
  - Saved an estimated ¾ of a FTE's time

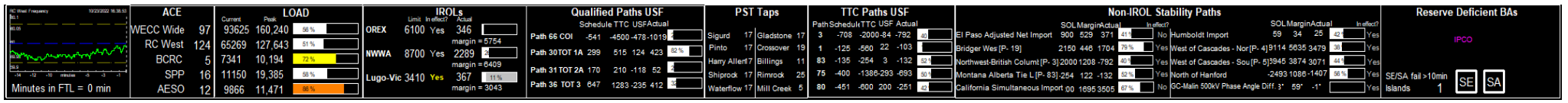


Using Comprehensive Displays

- We made a few dense displays
  - Not visually appealing
  - Extremely Useful







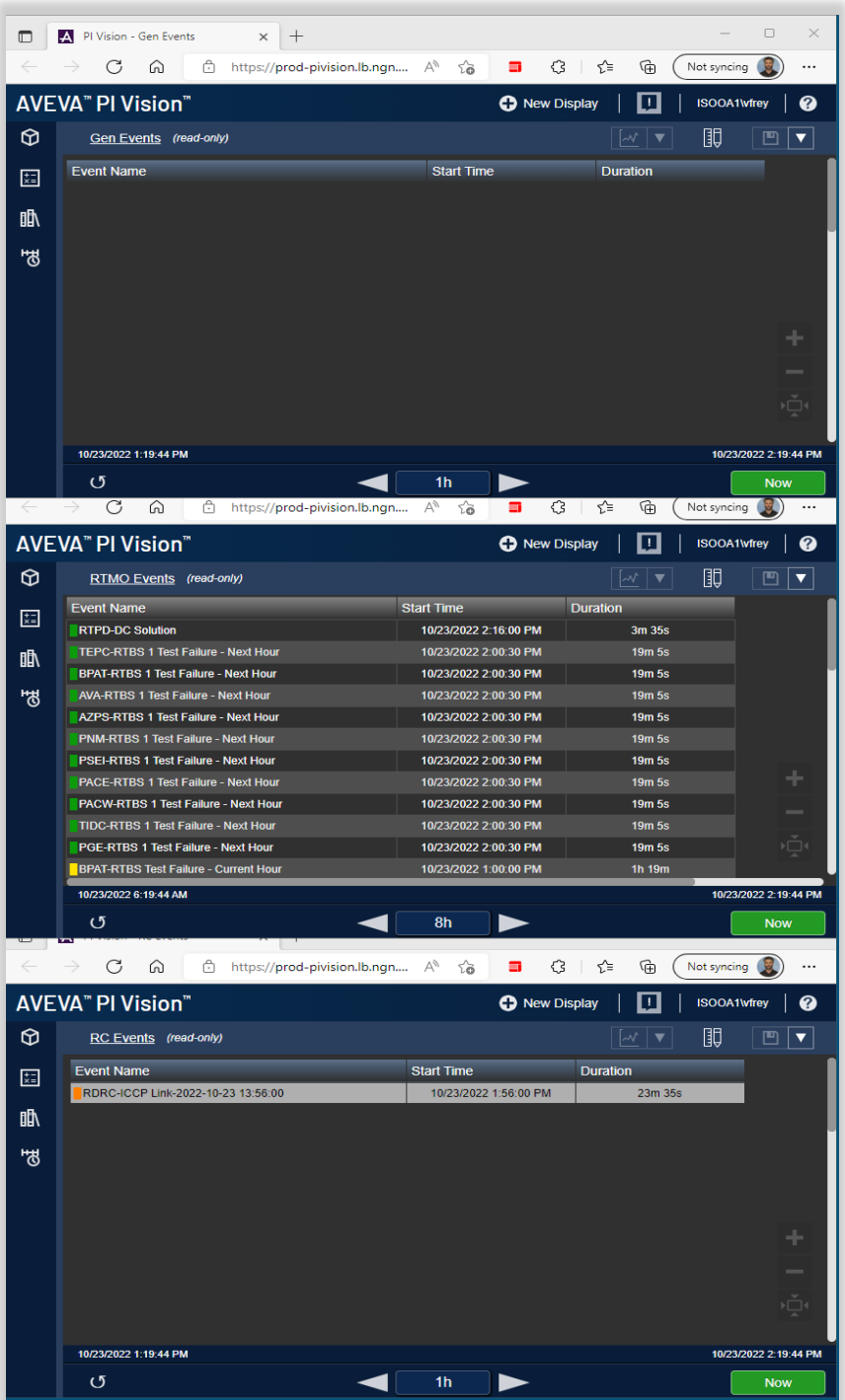
Reducing Eye Strain

- We made a “PI Alarms Alternative” spreadsheet using PI DataLink and Performance Equations
- It audibly alarmed when multi-stating would have changed in the previous paradigm
- It would filter to only show items near the limits
  - It also organized data needed when logging events
- It was only used for standard Control Points, not one-offs

Start		8/22/2020 20:27	☐ Hide Entries that are not CLOSE/OVER			
		Y or Yes to inhibit, N	☐ Hide Entries that are INHIBITED			
Constraint Name		or No to always sho	Flow Value	Limit Value	Statu	Close/Over?
High Frequency			60.06	60.068		CLOSE
NWPP Reserves Margin			7118	3044		NOT CLOSE
NWPP Alberta Zone Reserves Margin		y	2465	543		INHIBITED
Otay Mesa (CISO) 5 minute change			350	300		OVER

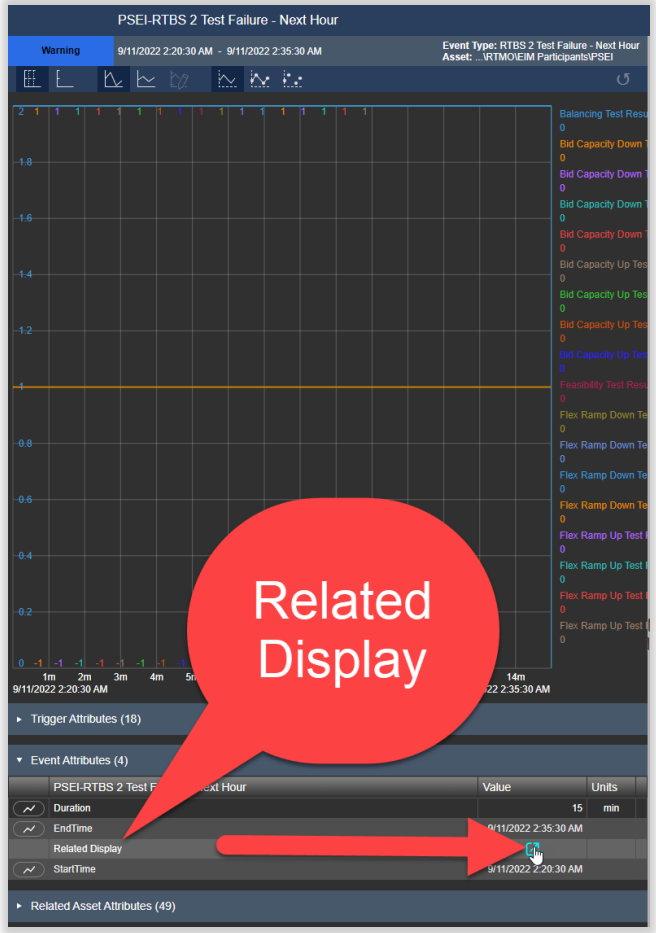
AVEVA Offered a Better Solution

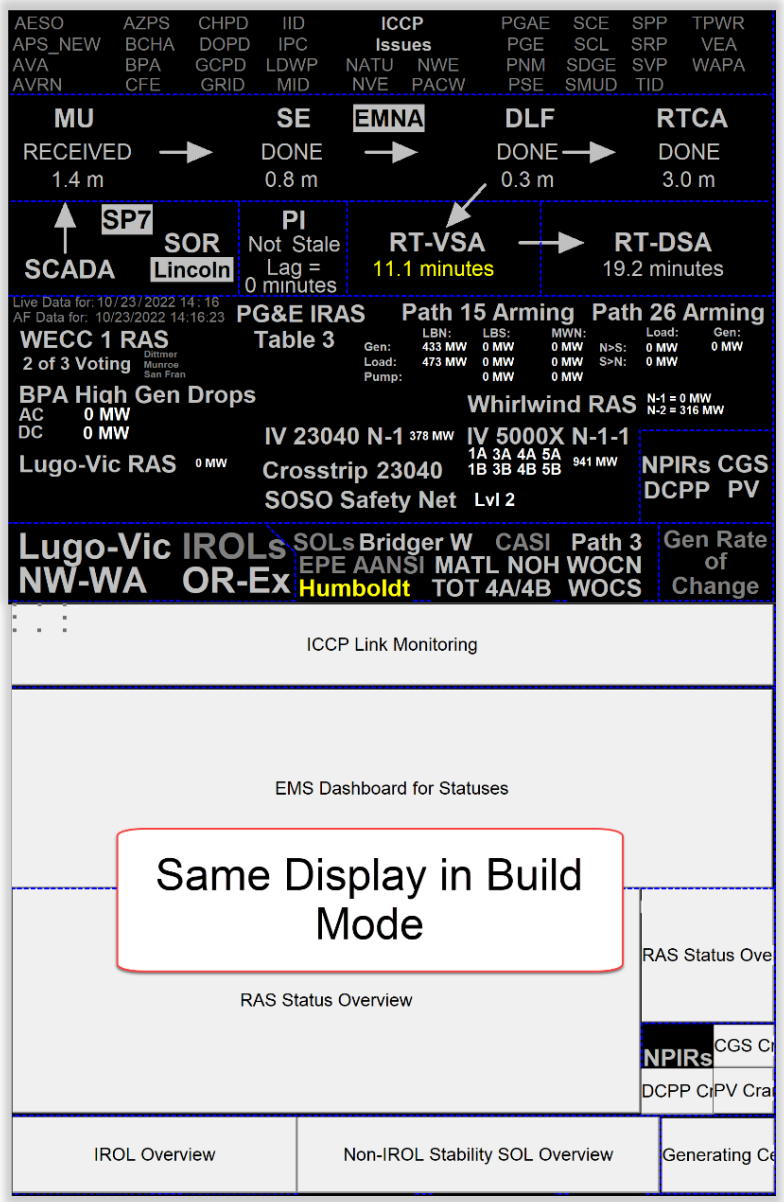
- Event Frames and Tables have provided a scalable, vendor-supported option
- Event Frames and PI Notifications are expected to lessen our Compliance burdens without additional overhead to Operations.



Connecting the Abbreviated with the Detailed

- PDIs linked via pushbuttons
- Event Frames use URLs





Evolution of Content Consolidation

Templates and Element-Relative Displays

- RC West defined a dozen base templates to create ~20,000 elements
- We were able to implement what were previously expected to be 140 displays into 3 element-relative displays
- Market Operations defined 5 templates
- We were able to reduce 28 displays into 4 while simplifying security and improving readability
- Expression and rollup analyses in templates improved onboarding processes by changing detailed, custom performance equations to hollow tag creations

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Content Organization Needed

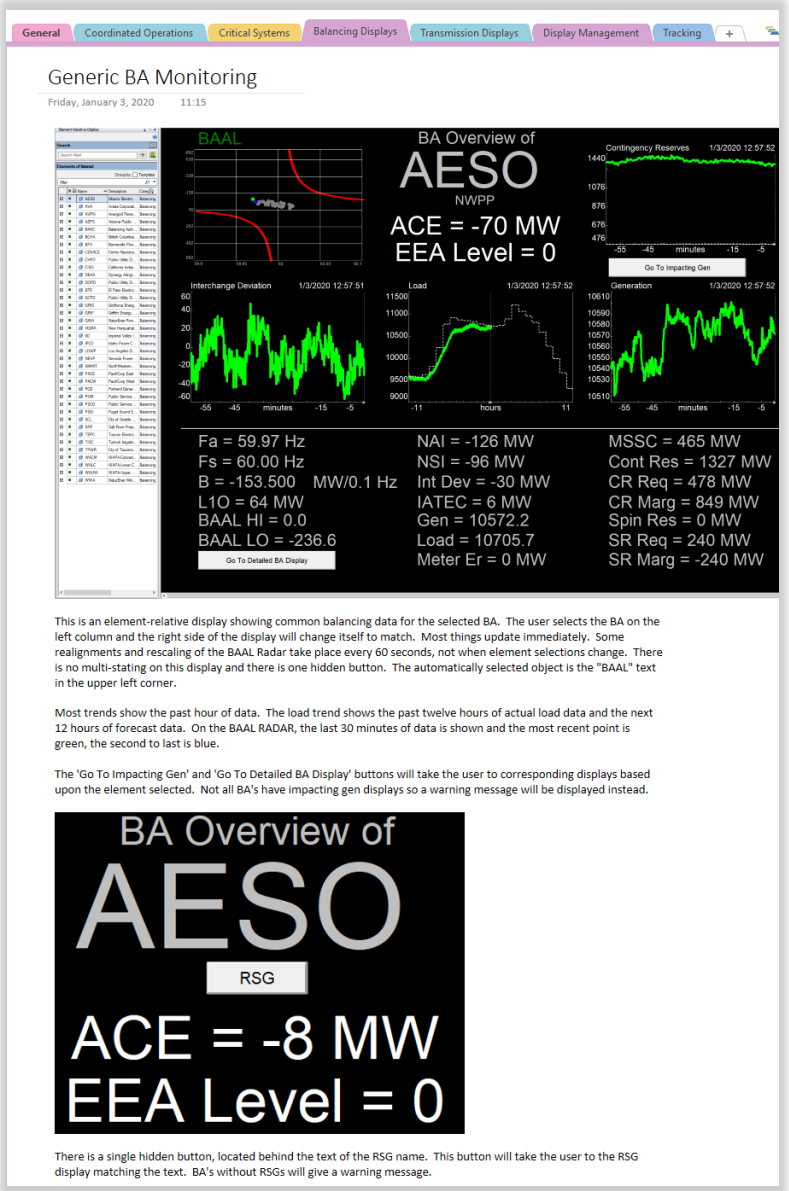
- We have dozens of systems historizing data to PI
  - Each has its own naming convention
  - Overlapping responsibilities lead to redundant tags, calculations and displays
- We have over 2 million tags (1.4 million are active)
  - Aspiring Power Users are intimidated when searching for the “best” or “right” tags
  - Expert Power Users either know the right tags, the best way to search or know the correct person to ask

Content Organization Improvements

- Our EMS team made descriptors associating PI tags to the related displays in our new EMS system
  - Covers roughly 1.4 million tags
- We created training for using PI's Search functionality in the context of our company's conventions
  - Expected to deliver early next year
- 3 roles have embraced Asset Framework
- 6 more want to start
- More are looking to synergize with the existing roles

Content Organization Improvements

- We have OneNotes describing our standard displays
- Organized by categories
- Describes
  - Purpose
  - Multi-stating
  - Hidden Buttons
  - VB Code



Evolution of PI Data Sharing with the “Community”

- 68 External Companies (…and counting)
- PI Vision Display Call-up is better than a Fax
- Must be Maintainable and Scalable
  - Hardware and software Load Balancers used
  - Automate as much as possible
  - Content Management (using off-the-shelf tools!)
- Must Adhere to Security Requirements
  - Certificate based, Firewalls, etc
  - Leverage both AF security and PI Vision security

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Asset Framework Offers Improvements

- Unparalleled Maintenance Capability
  - Fixing users' displays without them needing to re-open a display
  - A single repository means any sweeping changes can be accommodated succinctly

SUMMARY

Challenge

- Various complex data sources and systems
- Hundreds to thousands connecting entities
- Supporting large numbers of internal/external users
- Reliability for complex grid and management of dynamic market system

Solution

- Have been using PI System for 20+ years
- Continual innovative development and system improvement via PI tools
- Visualization and asset-based models for situational awareness

Benefits

- Improving visibility of the grid for both internal and external users
- Reduced maintenance – improving standards leads to fewer, more relevant and concise displays
- Thin client benefits - easier to build and share displays

“Efficient and secured community data sharing is key to managing a reliable grid and a fast-moving energy market.”

AVEVA

Vince Frey

ISO Lead Market Operator

- VFrey@caiso.com

Jim Hiebert

ISO EMS Power Technology Engineer Lead

- JHiebert@caiso.com

“EVERYTHING STARTS WITH DATA.”

Questions?

Please wait for the microphone.

State your name and company.

Please remember to…

Navigate to this session in the mobile app to complete the survey.

Thank you!