Exelon Generation®

FAMOS Enhanced Fleet-Wide Monitoring

January 2020 Curtiss Wright Plant Symposium

FAMOS

Monitoring and Diagnostics (M&D) Center
Performance Monitoring

Exelon.

Exelon Fleet Background

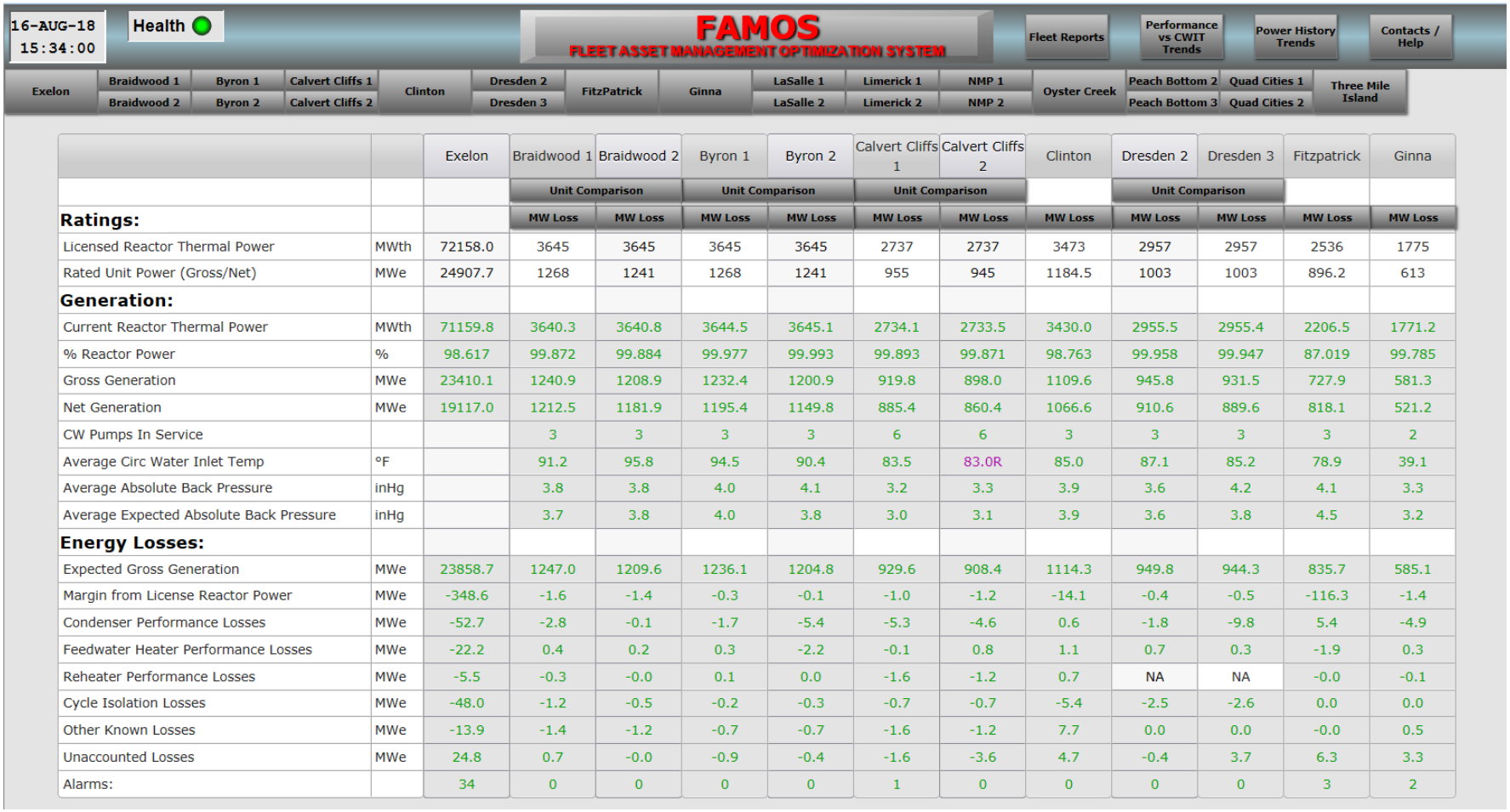
- Exelon operates 21 Units across 12 Sites in the Mid Atlantic, Northeast, and Midwest Regions
  - In the Mid Atlantic and Northeast Regions:
    - Nine Mile Point Units 1 & 2 (2x BWR)
    - Peach Bottom Units 1 & 2 (2x BWR)
    - James A. Fitzpatrick Nuclear Power Plant (1 x PWR)
    - Limerick Units 1 & 2 (2x BWR)
    - R.E Ginna (1 x PWR)
    - Calvert Cliffs Units 1 & 2 (2x PWR)
  - In the Midwest Region:
    - Quad Cities Units 1 & 2 (2x BWR)
    - Clinton Power Station (1x BWR)
    - LaSalle Units 1 & 2 (2x BWR)
    - Dresden Units 2 & 3 (2x BWR)
    - Braidwood Units 1 & 2 (2x PWR)
    - Byron Units 1 & 2 (2x PWR)

13 BWR Units

8 PWR Units

FAMOS Fleet Level Display

- The default homepage serves as the center for each Site's trends and reports while providing a fleet overview



		Exelon	Braidwood 1	Braidwood 2	Byron 1	Byron 2	Calvert Cliffs 1	Calvert Cliffs 2	Clinton	Dresden 2	Dresden 3	Fitzpatrick	Ginna
			Unit Comparison		Unit Comparison		Unit Comparison			Unit Comparison			
Ratings:			MW Loss	MW Loss	MW Loss	MW Loss	MW Loss	MW Loss	MW Loss	MW Loss	MW Loss	MW Loss	MW Loss
Licensed Reactor Thermal Power	MWth	72158.0	3645	3645	3645	3645	2737	2737	3473	2957	2957	2536	1775
Rated Unit Power (Gross/Net)	MWe	24907.7	1268	1241	1268	1241	955	945	1184.5	1003	1003	896.2	613
Generation:													
Current Reactor Thermal Power	MWth	71159.8	3640.3	3640.8	3644.5	3645.1	2734.1	2733.5	3430.0	2955.5	2955.4	2206.5	1771.2
% Reactor Power	%	98.617	99.872	99.884	99.977	99.993	99.893	99.871	98.763	99.958	99.947	87.019	99.785
Gross Generation	MWe	23410.1	1240.9	1208.9	1232.4	1200.9	919.8	898.0	1109.6	945.8	931.5	727.9	581.3
Net Generation	MWe	19117.0	1212.5	1181.9	1195.4	1149.8	885.4	860.4	1066.6	910.6	889.6	818.1	521.2
CW Pumps In Service			3	3	3	3	6	6	3	3	3	3	2
Average Circ Water Inlet Temp	°F		91.2	95.8	94.5	90.4	83.5	83.0R	85.0	87.1	85.2	78.9	39.1
Average Absolute Back Pressure	inHg		3.8	3.8	4.0	4.1	3.2	3.3	3.9	3.6	4.2	4.1	3.3
Average Expected Absolute Back Pressure	inHg		3.7	3.8	4.0	3.8	3.0	3.1	3.9	3.6	3.8	4.5	3.2
Energy Losses:													
Expected Gross Generation	MWe	23858.7	1247.0	1209.6	1236.1	1204.8	929.6	908.4	1114.3	949.8	944.3	835.7	585.1
Margin from License Reactor Power	MWe	-348.6	-1.6	-1.4	-0.3	-0.1	-1.0	-1.2	-14.1	-0.4	-0.5	-116.3	-1.4
Condenser Performance Losses	MWe	-52.7	-2.8	-0.1	-1.7	-5.4	-5.3	-4.6	0.6	-1.8	-9.8	5.4	-4.9
Feedwater Heater Performance Losses	MWe	-22.2	0.4	0.2	0.3	-2.2	-0.1	0.8	1.1	0.7	0.3	-1.9	0.3
Reheater Performance Losses	MWe	-5.5	-0.3	-0.0	0.1	0.0	-1.6	-1.2	0.7	NA	NA	-0.0	-0.1
Cycle Isolation Losses	MWe	-48.0	-1.2	-0.5	-0.2	-0.3	-0.7	-0.7	-5.4	-2.5	-2.6	0.0	0.0
Other Known Losses	MWe	-13.9	-1.4	-1.2	-0.7	-0.7	-1.6	-1.2	7.7	0.0	0.0	-0.0	0.5
Unaccounted Losses	MWe	24.8	0.7	-0.0	-0.9	-0.4	-1.6	-3.6	4.7	-0.4	3.7	6.3	3.3
Alarms:		34	0	0	0	0	1	0	0	0	0	3	2

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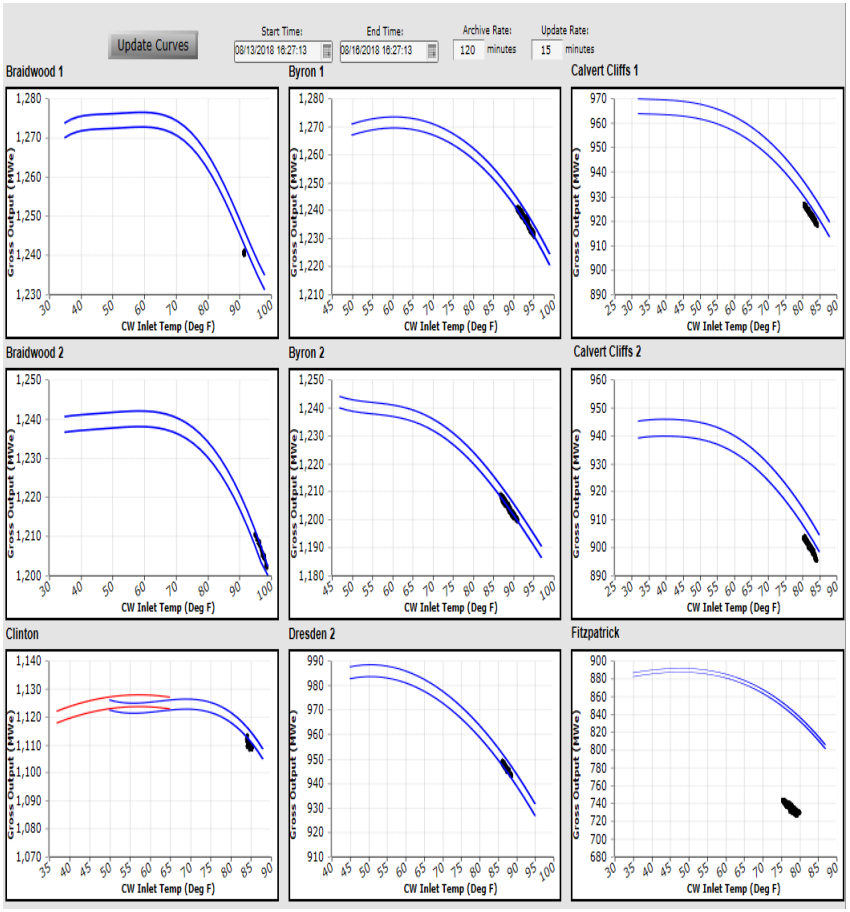
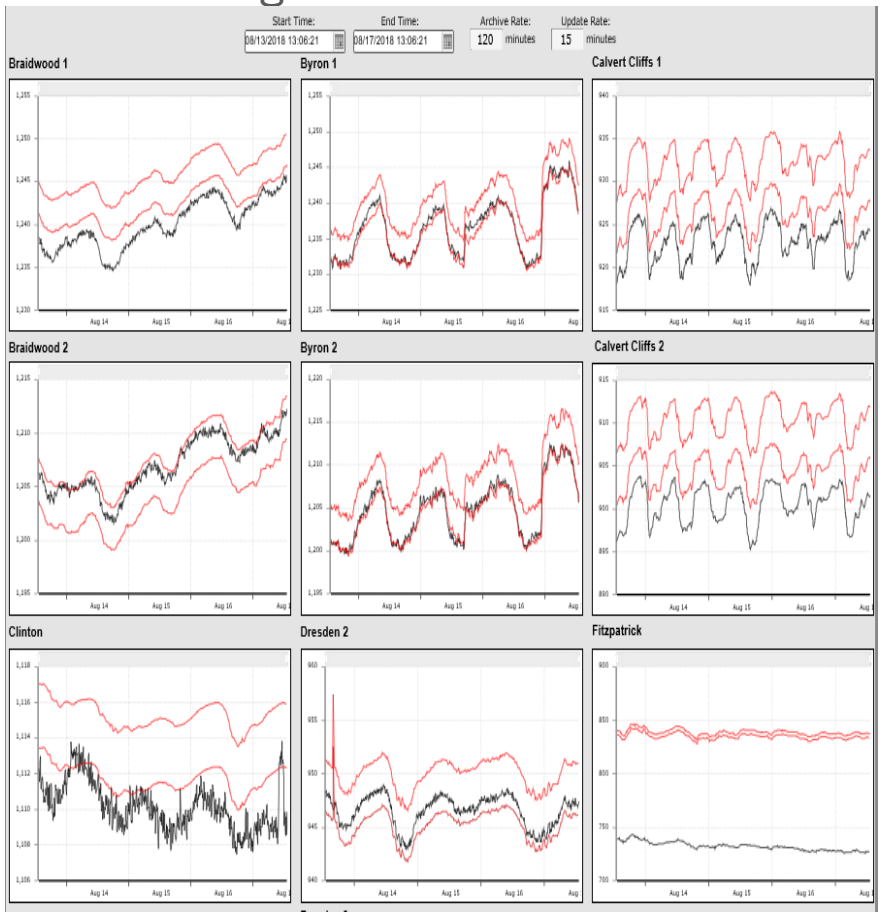
Continuous Monitoring of Power/Performance

- Fleet overview of plant performance vs expectations based on Circ Water Inlet Temperature



- Fleet overview of power history vs. expectations
- Adjustable graphs enable close monitoring



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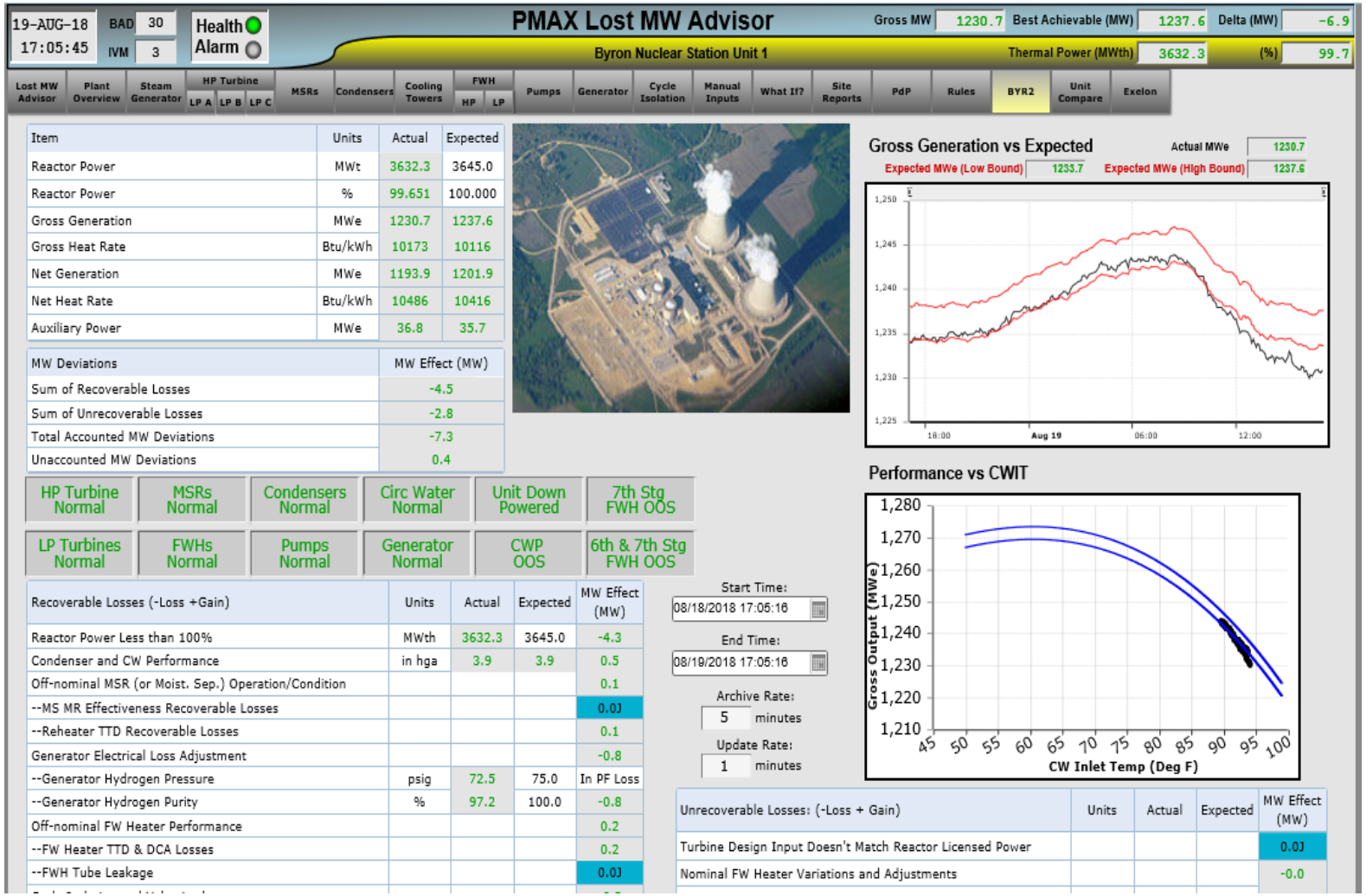
Unit Specific MWe Advisor

- Summary of Unit Specific MWe Accounting / Balance Sheet



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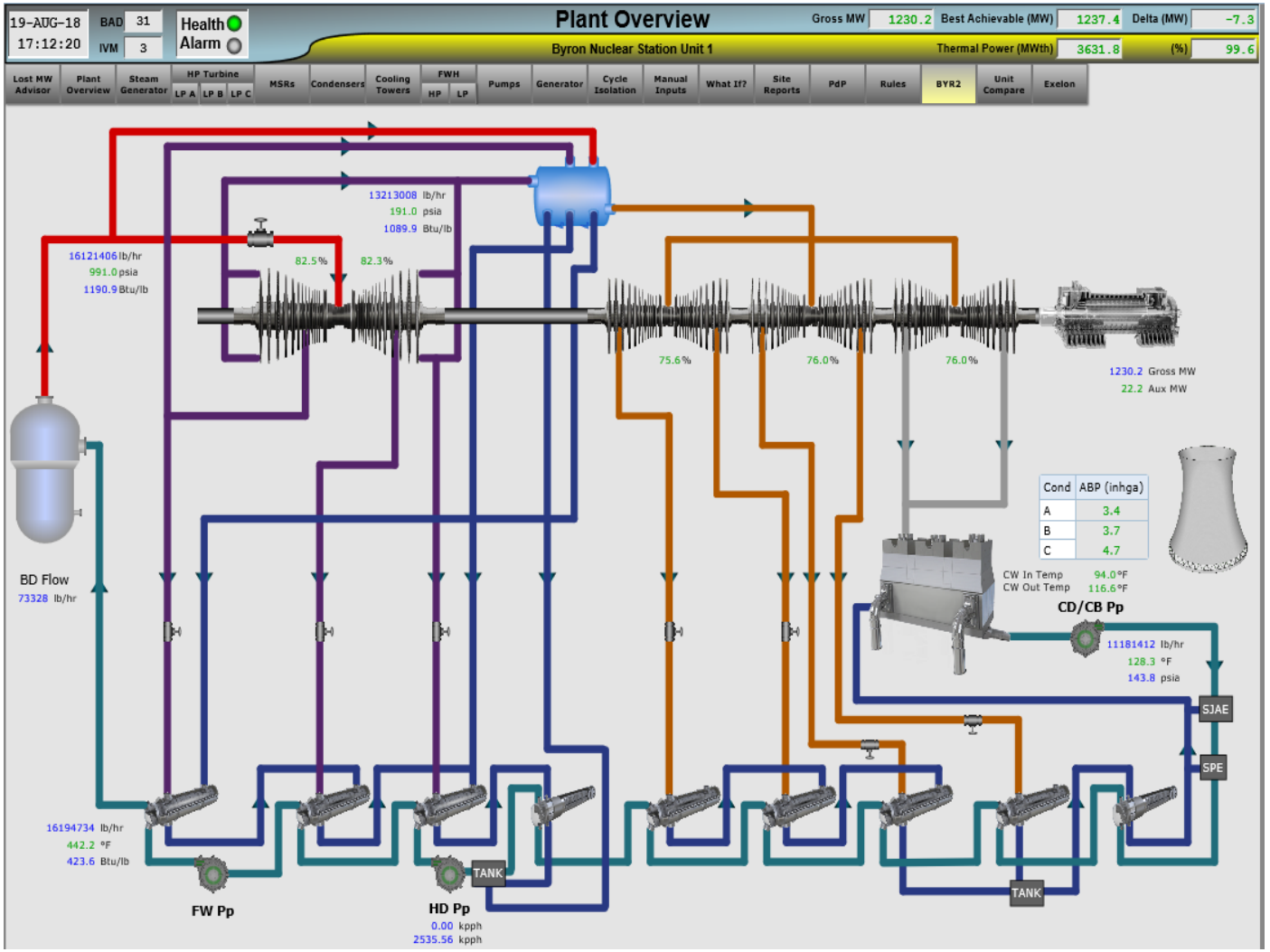
Unit Specific Plant Overview

- Simplified Diagram of Plant



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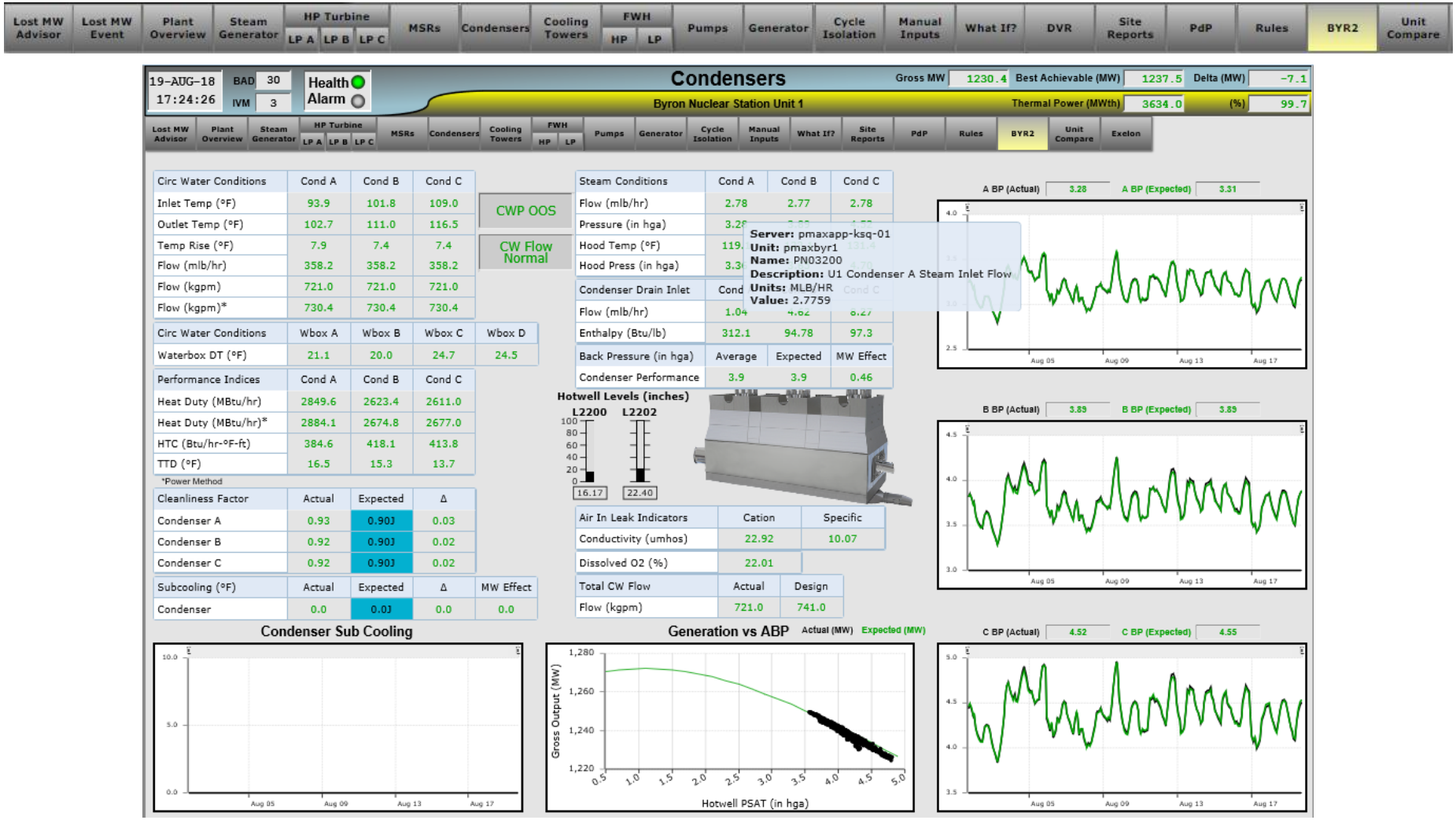
System Specific Performance Monitoring

- Multiple Systems available to review in detail for each Unit



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Dual-Unit Site Performance Comparison

- Shows performance of each unit at dual-unit sites side by side

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Unit Comparison — Byron Nuclear Station Unit 2

Gross MW 1232.7 | Best Achievable (MW) 1235.9 | Delta (MW) -3.3 | Thermal Power (MWth) 3641.5 | (%) 99.9

Lost MW Advisor | Lost MW Events | Plant Overview | Steam Generator | HP Turbine (LP A, LP B, LP C) | MSRs | Condensers | Cooling Towers | FWH (HP, LP) | Pumps | Generator | Cycle Isolation | Manual Inputs | What If? | DVR | Site Reports | PdP | Rules | BYR1 | Unit Compare | Exelon

Parameter	Units	BYR-1	BYR-2
Licensed Reactor Power	MWt	3645.0	3645.0
Reactor Power	MWt	3642.1	3641.5
Reactor Power	%	99.921	99.908
Circulating Water Inlet Temperature	°F	31.4	35.3
Gross Generation	MWe	1266.0	1232.7
Gross Heat Rate	Btu/kWh	9891	10196
Net Generation	MWe	1234.5	1197.3
Net Heat Rate	Btu/kWh	10143	10496
Auxiliary Power	MWe	31.4	35.3

MW Deviations	BYR-1	BYR-2
Sum of Recoverable Losses	-1.2	-5.5
Sum of Unrecoverable Losses	1.7	5.4
Total Accounted MW Deviations	0.5	-0.1
Unaccounted MW Deviations	-3.3	-3.2

Recoverable Losses (-Loss +Gain)	BYR-1	BYR-2
Reactor Power Less than 100%	-1.0	-1.1
Condenser and CW Performance	1.0	-1.2
Off-nominal MSR (or Moist. Sep.) Operation/Condition	0.2	0.0
Generator Electrical Loss Adjustment	-0.8	-0.9
Off-nominal FW Heater Performance	-0.5	-2.4
Cycle Isolation and Valve Leakage	-0.1	-0.0
Feedwater Errors (including Venturi Fouling & LEFM errors)	0.0	0.0
Other Abnormal Operation or Line-up	0.0	0.0
Total Recoverable Losses	-1.2	-5.5

Recoverable Losses: Plant Performance vs As-Installed PEPSE Heat Balance

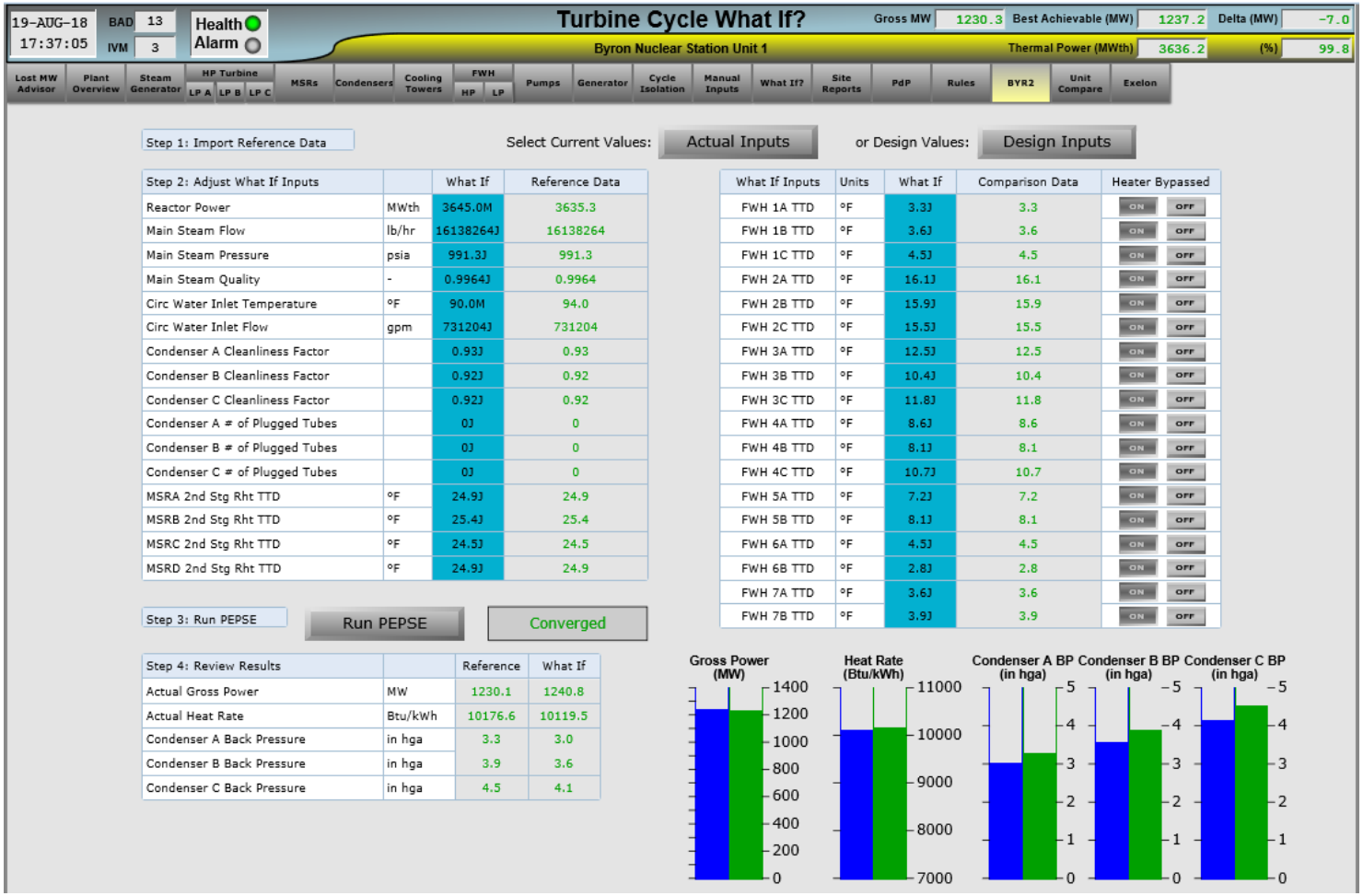
External Losses (-Loss +Gain)	BYR-1	BYR-2
Cooling Tower Performance Loss Effect	-2.8	-0.1
External Issues Affecting Generation	0.0J	0.0J

Unrecoverable Losses: (-Loss + Gain)	BYR-1	BYR-2
Turbine Design Input Doesn't Match Reactor Licensed Power	0.0J	0.0J
Nominal FW Heater Variations and Adjustments	-0.0	-0.0
Nominal MSR (or Moist. Sep.) Variations and Adjustments	0.0	0.0
Nominal RWCU and CRD Flow Variations and Adjustments (BWRs)	NA	NA
HP & LP Turbine Shortfall from Design	0.0J	0.0J
Operating Condition Variations (pressure, quality, throttling)	-0.0	4.8
Nominal Reactor Recirc. Pump Power Variations (BWRs)	NA	NA
Nominal Reactor/Steam-Generator Feed Pump Variations	0.0	0.0
Nominal Steam Generator Blowdown (PWRs)	-1.3	-2.2
Generator Electrical Loss Adjustment	3.0	2.9
Other Unrecoverable Effects	0.0	-0.1
Total Unrecoverable Losses	1.7	5.4

Unrecoverable Losses: Plant Performance vs 100% Power Thermal Kit

“What If” Analysis

- Run PEPSE Analyses from PMAX Web to assess “what-if” scenarios that simulate plant changes



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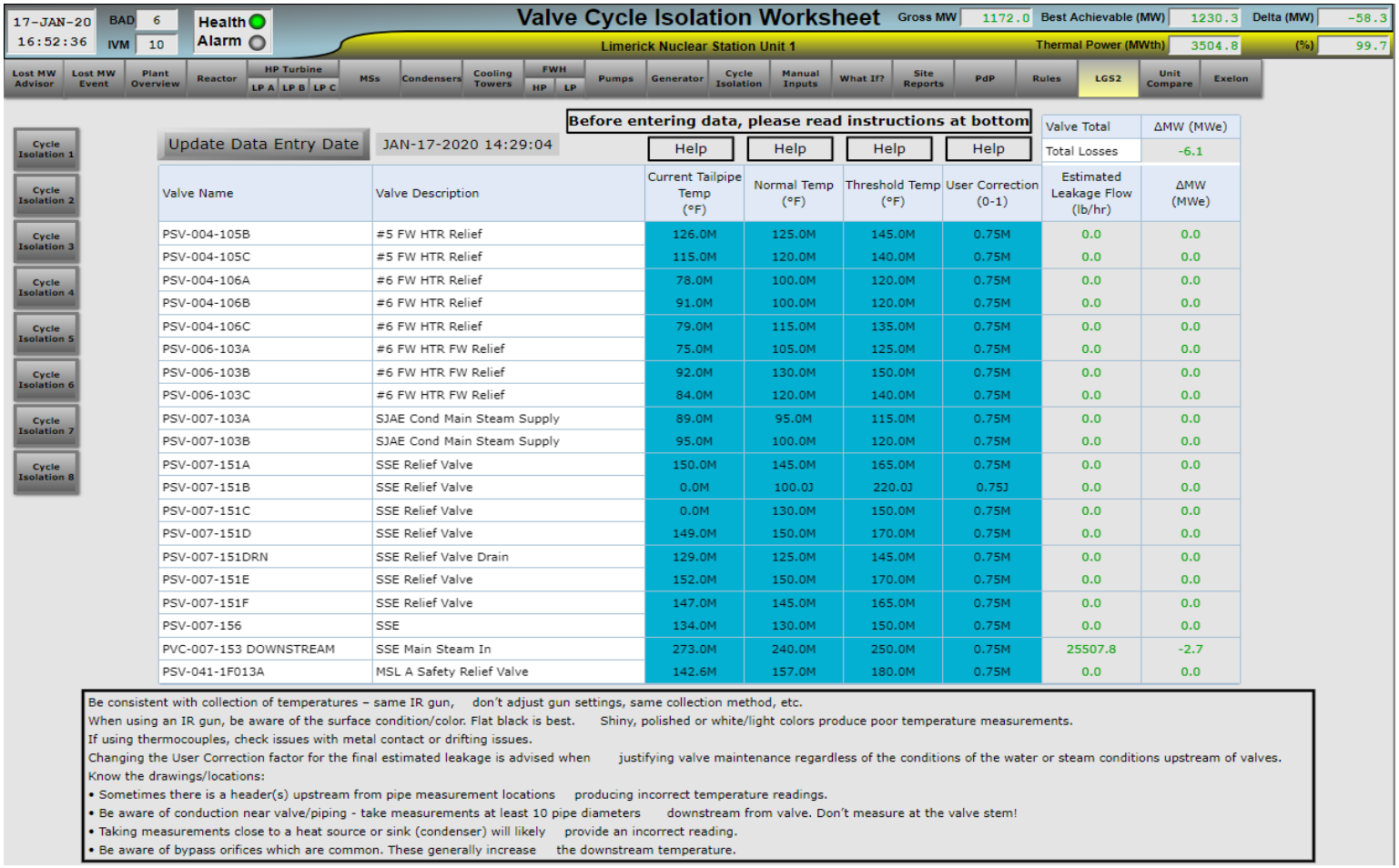
Cycle Isolation Valve Leakage

- Ability to monitor 2,400 cycle isolation valves modeled in PMAX with calculations included in MWe Accounting



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Valve Cycle Isolation Worksheet

Limerick Nuclear Station Unit 1

Gross MW 1172.0 | Best Achievable (MW) 1230.3 | Delta (MW) -58.3 | Thermal Power (MWth) 3504.8 | (%) 99.7

Lost MW Advisor | Lost MW Event | Plant Overview | Reactor | HP Turbine (LP A, LP B, LP C) | MSs | Condensers | Cooling Towers | FWH (HP, LP) | Pumps | Generator | Cycle Isolation | Manual Inputs | What If? | Site Reports | PdP | Rules | LGS2 | Unit Compare | Exelon

Cycle Isolation 1 | Cycle Isolation 2 | Cycle Isolation 3 | Cycle Isolation 4 | Cycle Isolation 5 | Cycle Isolation 6 | Cycle Isolation 7 | Cycle Isolation 8

Update Data Entry Date: JAN-17-2020 14:29:04

Before entering data, please read instructions at bottom

Help | Help | Help | Help

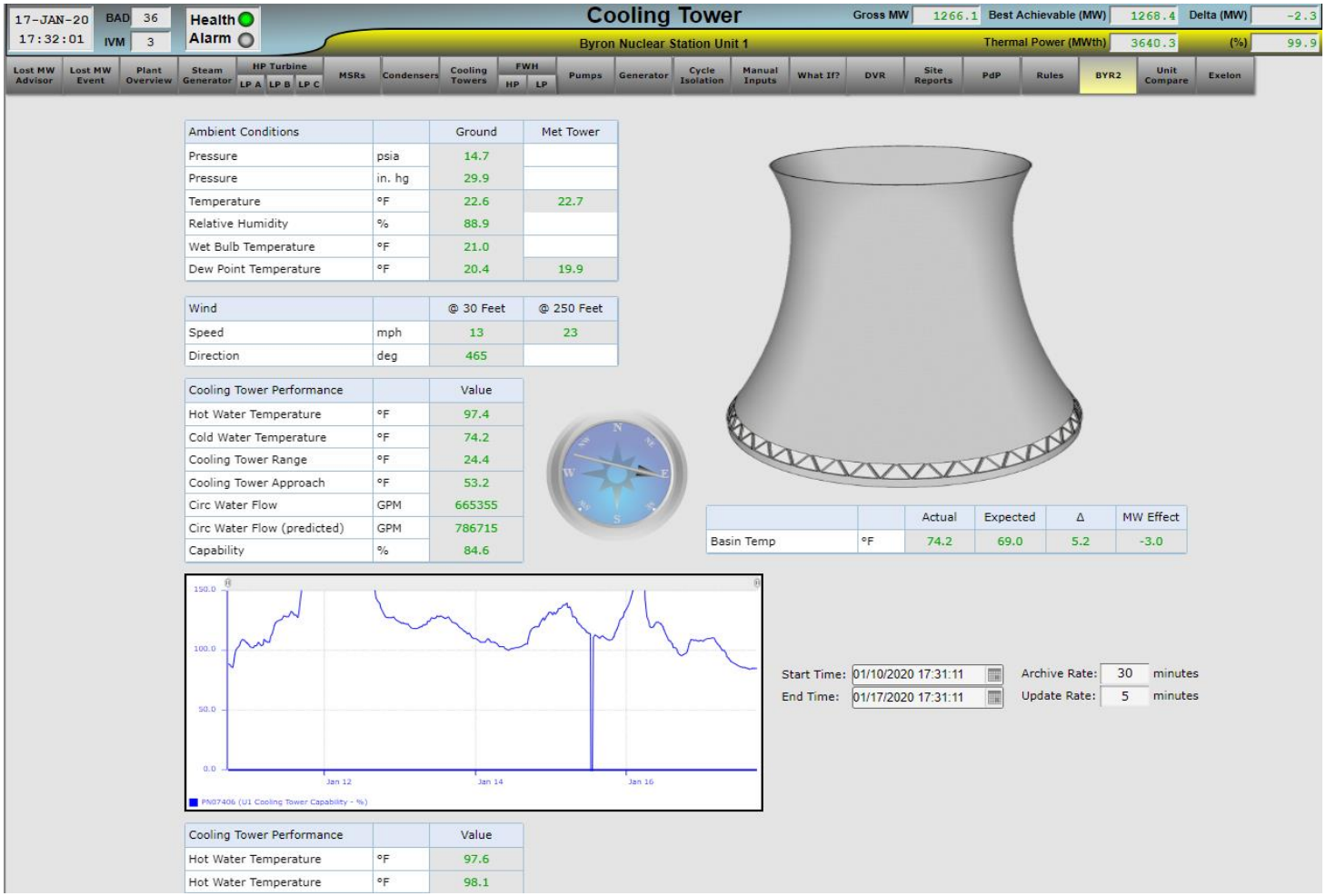
Valve Total	ΔMW (MWe)
Total Losses	-6.1

Valve Name	Valve Description	Current Tailpipe Temp (°F)	Normal Temp (°F)	Threshold Temp (°F)	User Correction (0-1)	Estimated Leakage Flow (lb/hr)	ΔMW (MWe)
PSV-004-105B	#5 FW HTR Relief	126.0M	125.0M	145.0M	0.75M	0.0	0.0
PSV-004-105C	#5 FW HTR Relief	115.0M	120.0M	140.0M	0.75M	0.0	0.0
PSV-004-106A	#6 FW HTR Relief	78.0M	100.0M	120.0M	0.75M	0.0	0.0
PSV-004-106B	#6 FW HTR Relief	91.0M	100.0M	120.0M	0.75M	0.0	0.0
PSV-004-106C	#6 FW HTR Relief	79.0M	115.0M	135.0M	0.75M	0.0	0.0
PSV-006-103A	#6 FW HTR FW Relief	75.0M	105.0M	125.0M	0.75M	0.0	0.0
PSV-006-103B	#6 FW HTR FW Relief	92.0M	130.0M	150.0M	0.75M	0.0	0.0
PSV-006-103C	#6 FW HTR FW Relief	84.0M	120.0M	140.0M	0.75M	0.0	0.0
PSV-007-103A	SJAE Cond Main Steam Supply	89.0M	95.0M	115.0M	0.75M	0.0	0.0
PSV-007-103B	SJAE Cond Main Steam Supply	95.0M	100.0M	120.0M	0.75M	0.0	0.0
PSV-007-151A	SSE Relief Valve	150.0M	145.0M	165.0M	0.75M	0.0	0.0
PSV-007-151B	SSE Relief Valve	0.0M	100.0J	220.0J	0.75J	0.0	0.0
PSV-007-151C	SSE Relief Valve	0.0M	130.0M	150.0M	0.75M	0.0	0.0
PSV-007-151D	SSE Relief Valve	149.0M	150.0M	170.0M	0.75M	0.0	0.0
PSV-007-151DRN	SSE Relief Valve Drain	129.0M	125.0M	145.0M	0.75M	0.0	0.0
PSV-007-151E	SSE Relief Valve	152.0M	150.0M	170.0M	0.75M	0.0	0.0
PSV-007-151F	SSE Relief Valve	147.0M	145.0M	165.0M	0.75M	0.0	0.0
PSV-007-156	SSE	134.0M	130.0M	150.0M	0.75M	0.0	0.0
PVC-007-153 DOWNSTREAM	SSE Main Steam In	273.0M	240.0M	250.0M	0.75M	25507.8	-2.7
PSV-041-1F013A	MSL A Safety Relief Valve	142.6M	157.0M	180.0M	0.75M	0.0	0.0

Be consistent with collection of temperatures – same IR gun, don't adjust gun settings, same collection method, etc.
When using an IR gun, be aware of the surface condition/color. Flat black is best. Shiny, polished or white/light colors produce poor temperature measurements.
If using thermocouples, check issues with metal contact or drifting issues.
Changing the User Correction factor for the final estimated leakage is advised when justifying valve maintenance regardless of the conditions of the water or steam conditions upstream of valves.
Know the drawings/locations:
- Sometimes there is a header(s) upstream from pipe measurement locations producing incorrect temperature readings.
- Be aware of conduction near valve/piping - take measurements at least 10 pipe diameters downstream from valve. Don't measure at the valve stem!
- Taking measurements close to a heat source or sink (condenser) will likely provide an incorrect reading.
- Be aware of bypass orifices which are common. These generally increase the downstream temperature.

Cooling Towers

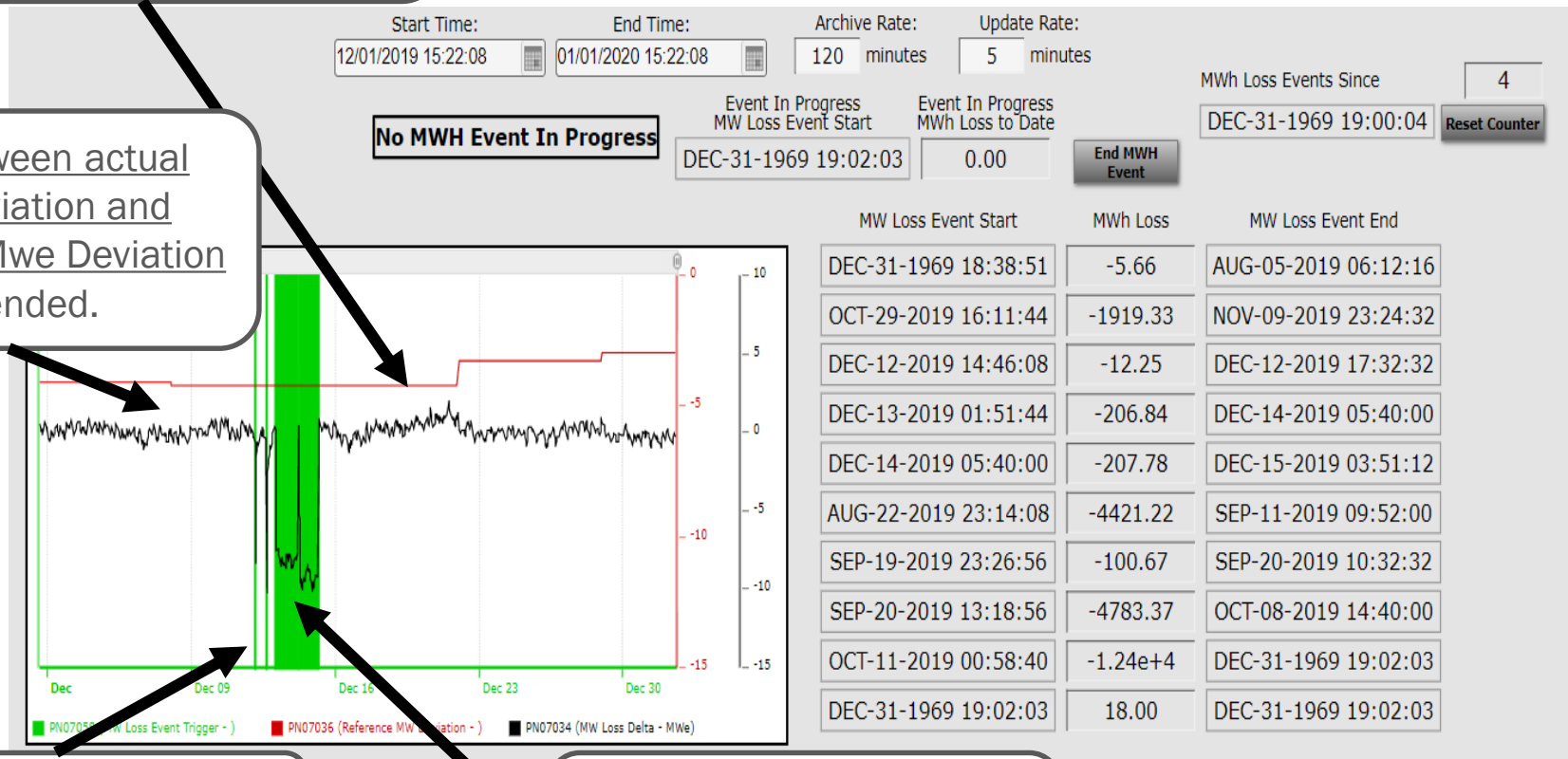
- Ability to monitor parameters related to cooling tower performance



FAMOS Lost MW Events Tracker

Reference Mwe Deviation from expected. Updated weekly to prevent flagging slow declines as “events”.

Delta between actual Mwe Deviation and Reference Mwe Deviation is trended.



Small events are not saved or reported

Events tracked and loss integrated when MW loss exceeds threshold

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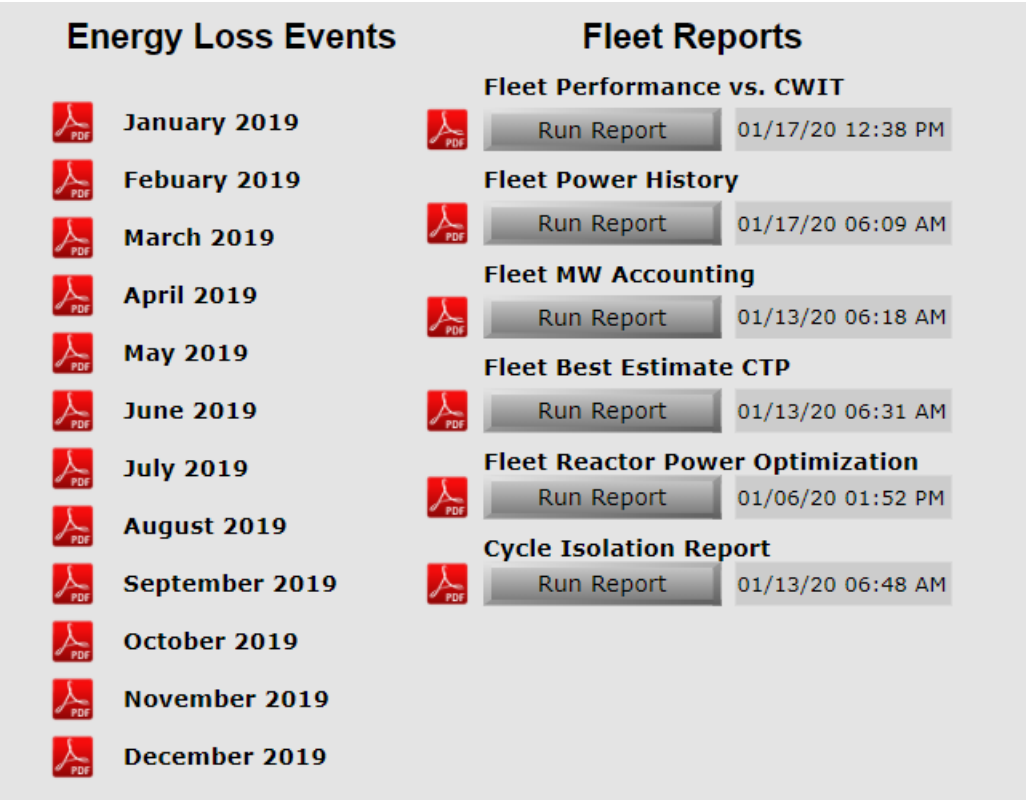
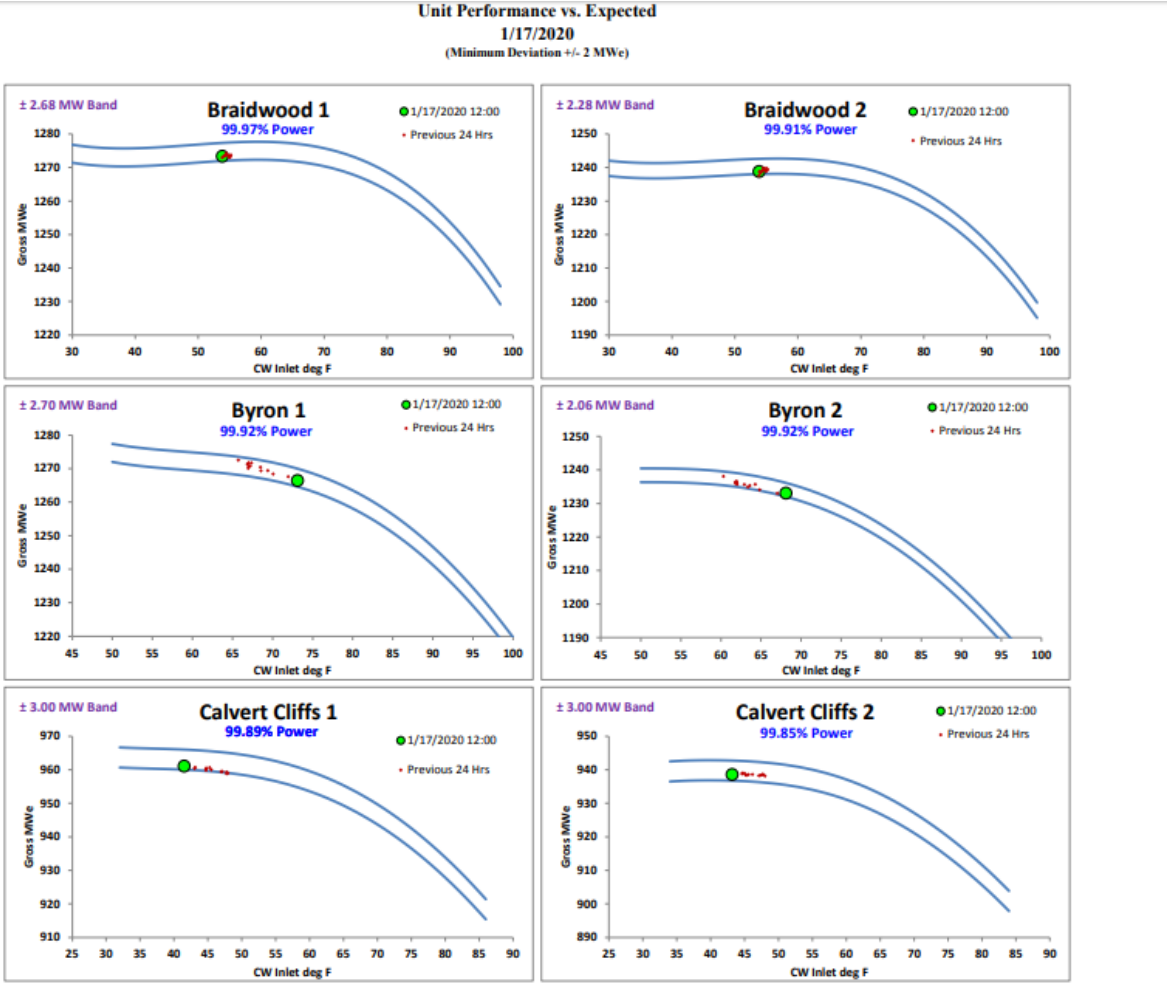
Fleet Reports

- Reports are designed to provide fleet overview information on-demand.
- These reports are made accessible to anyone who can access the FAMOS Web Viewer.



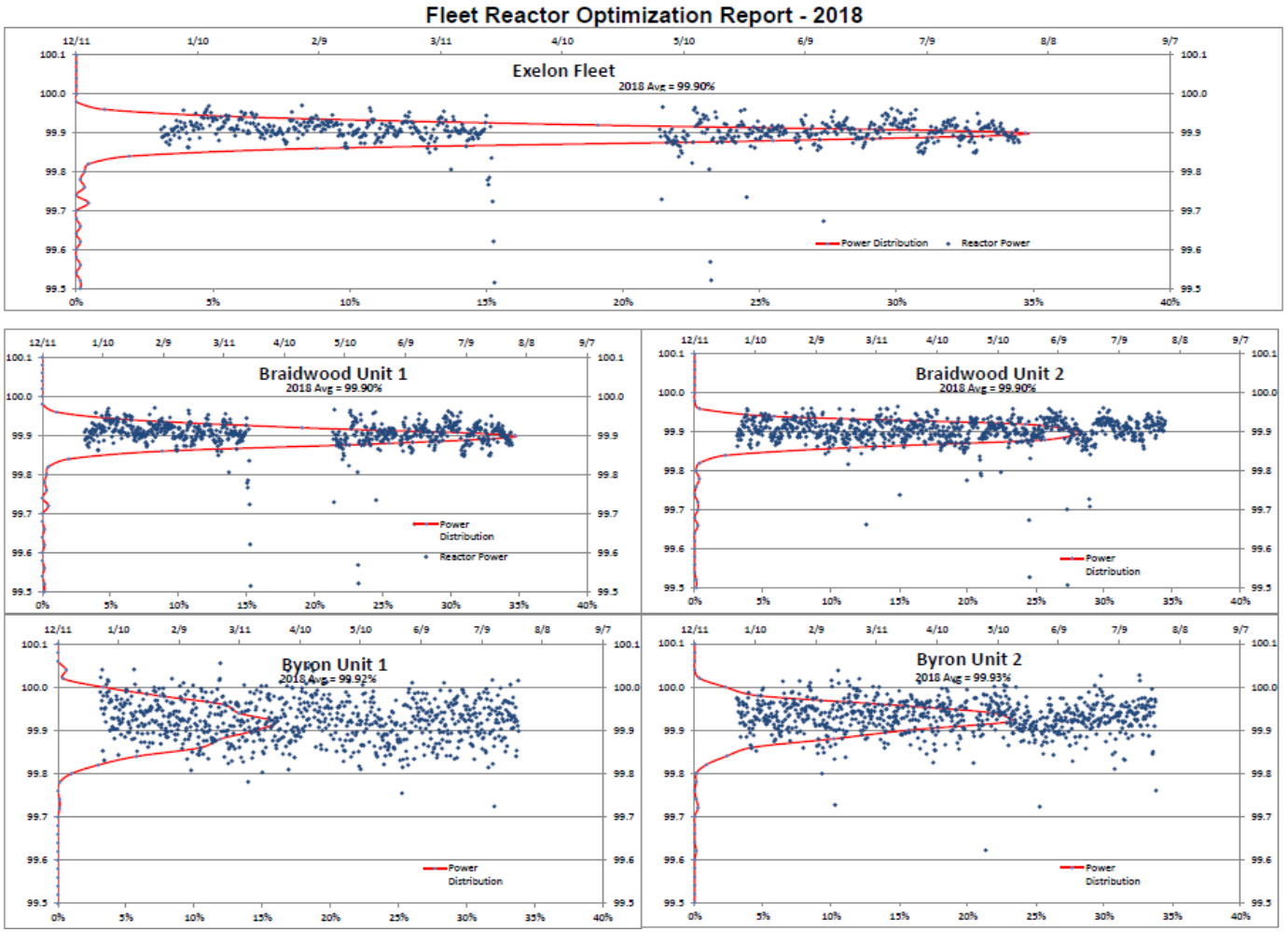
Fleet Performance vs. CWIT

- Summary graphs for fleet-wide monitoring of Plant Performance vs. CWIT automatically generated



Fleet Reactor Power Optimization

- Summary of Plant and Fleet Operation approaching 100% CTP



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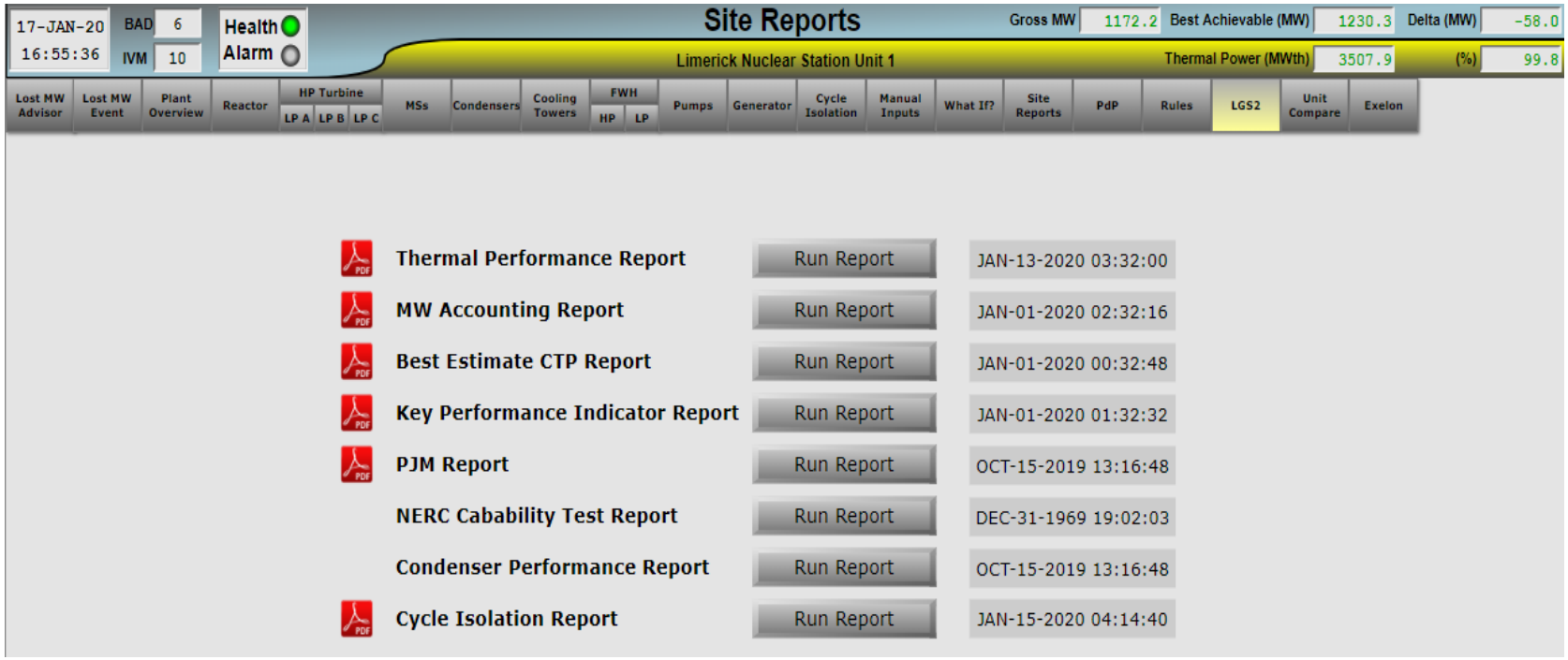
Site Reports

- Reports are designed to provide site specific information on-demand. Additional reports including cooling towers and energy loss events are currently in development



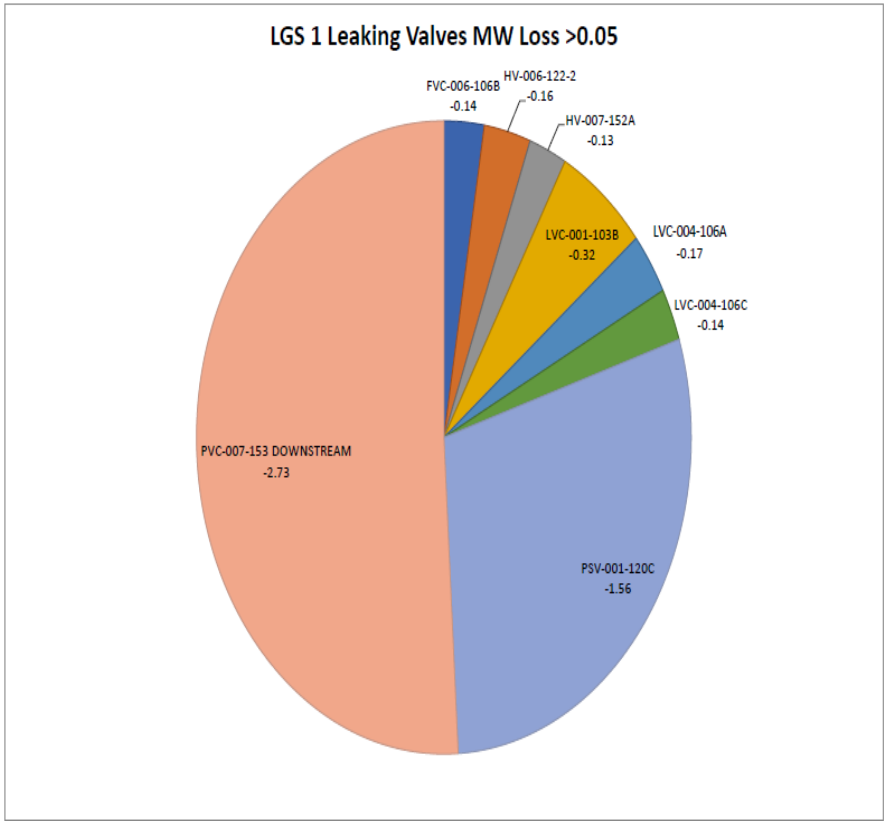
Cycle Isolation Losses Accounting

- For each site cycle isolation loss reports are automatically generated and made accessible as PDF's

LGS 1 Cycle Isolation and Work Management by Valve

1/17/2020

Valve	Valve Name	AR / WO #	Temp	Leakage	MW Loss
FVC-006-106B	RFP Min Flow Recirc	(blank)	167	13146	-0.14
HV-001-104-2	MSL Start-up Drn	WO 4820503	140	0	0.00
HV-006-112C-1	RFPT HP Stop VLV B Seat Drr	AR 4160823	226	83	-0.01
HV-006-122-2	Crossaround Header Drn	AR 4161480	273	2418	-0.16
HV-007-152A	Aux Steam to Air Ejector	AR 4256835	211	1239	-0.13
HVC-002-115	HP Turbine Cond Water Drn	WO 4813346	0	0	0.00
HVC-004-114A-1	#4 FW HTR Start-up Vent	WO 4813346	0	0	0.00
LVC-001-103B	Moist Sep Dump	(blank)	268	24510	-0.32
LVC-004-103C	#3 FW HTR Dump	WO 4821160	0	0	0.00
LVC-004-105A	#5 FW HTR Dump	WO 4821159	0	0	0.00
LVC-004-106A	#6 FW HTR Dump	(blank)	196	12980	-0.17
LVC-004-106B	#6 FW HTR Dump	WO 04813346	38	0	0.00
LVC-004-106C	#6 FW HTR Dump	(blank)	196	11043	-0.14
PSV-001-120C	Crossaround Relief	WO 4813346	150	23028	-1.56
PSV-007-151C	SSE Relief Valve	AR 4161478	0	0	0.00
PVC-007-153 DOWN	SSE Main Steam In	AR 4211505	273	25508	-2.73
Grand Total				113955	-5.37



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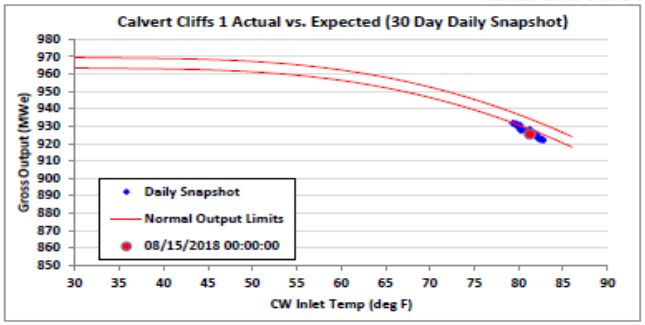
Site Thermal Performance Reports (POD)

- Site Thermal Performance Reports (POD) standardized and auto-generated

Calvert Cliffs Power Station Thermal Performance Report

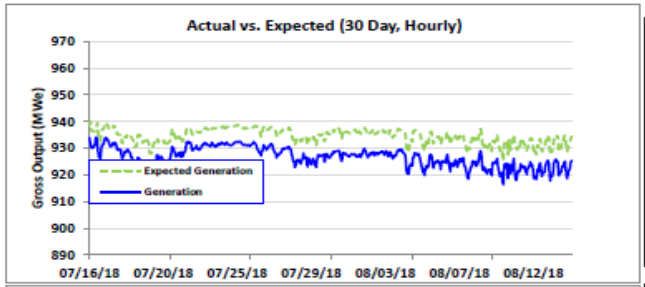
30 Days Ending August 15, 2018

Calvert Cliffs Unit 1 Thermal Performance Report

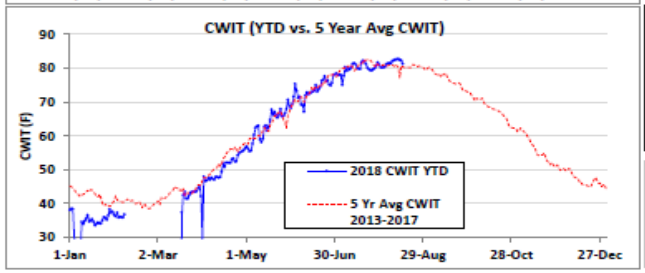


Calvert Cliffs Unit 1 Thermal Performance for 8/15/2018					
Reactor Thermal Power	(MWth)	Measured	2,735.9	% Pwr	99.9
Gross Generation	(MWe)	Expected	934.2	Actual	925.3
CW Inlet Temperature	(deg F)	5 Year Avg.	46.1	Actual	81.3
Absolute Back Pressure	(inHg)	Expected	2.83	Actual	3.08
Reactor Thermal Power	(MWth)	Licensed	2,737	CWP in Serv	6

Calvert Cliffs Unit 1 Energy Losses for 8/15/2018		
Margin from License Reactor Power	-0.6	MWe
Condenser Performance	-6.9	MWe
Feedwater Heater Performance	-0.1	MWe
Cycle Isolation Losses	-0.7	MWe
Other Recoverable Losses	-1.6	MWe
Non-Recoverable Losses	0.4	MWe
Unidentified Losses /Gains	0.7	MWe
TOTAL Energy Losses	-8.7	MWe



Date	Energy Loss Events During Past 30 Days		
18-Jul	13 Condensate Pump Oil Pump Failure	74.0	MWh
	TOTAL Energy Losses Past 30 Days	74.0	MWh



Thermal Performance Related Action Items				
IR or W/O	Component	Description	MW Loss	Due Date
C93673577	1PT4039	First Stage Pressure Indicating Incorrectly	0.0	TBD
			0.0	MWe

Comments:

Site MWe Accounting Sheet

- Site's MWe Accounting Reports are standardized and automatically generated through FAMOS

MW Accounting Balance Sheet
Calvert Cliffs Nuclear Station

Report from 7/9/2018 For 4 hours	Unit 1		Unit 2	
Item	Actual	Expected	Actual	Expected
Reactor Power (MWth)	2733.5	2737.0	2734.1	2737.0
Reactor Power (%)	99.9	100.0	99.9	100.0
Gross Generation (MWe)	932.4	934.9	911.0	916.7
Gross Heat Rate (Btu/kwh)	10064.0	10037.0	10302.2	10238.3
Net Generation (MWe)	896.6	897.9	874.0	880.7
Net Heat Rate (Btu/kwh)	10466.5	10450.5	10737.9	10656.8
Auxilairy Power (Mwe)	36.5	37.0	37.0	36.0

MW Deviations	Unit 1	Unit 2
Recoverable Losses	-1.7	-1.5
Unrecoverable Losses	0.8	-0.1
Total Accounted MW Deviations	-0.9	-1.7
Unaccounted MW Deviations	-1.6	-4.0

Recoverable Losses	Unit 1	Unit 2
Reactor Power Less than 100%	-1.2	-0.9
Condenser and CW Performance	1.6	0.4
Off-nominal MSR Operation/Condition	-1.3	-0.9
Generator Electrical Loss Adjustment	0.0	0.0
Off-nominal FW Heater Performance	-0.1	0.6
Cycle Isolation and Valve Leakage	-0.7	-0.7
Feedwater Errors	0.0	0.0
Other Abnormal Operation or Line-up	0.0	0.0

Unrecoverable Losses	Unit 1	Unit 2
Turb. Des. Doesn't Match Rx Licensed Pwr	0.0	0.0
FW Heater Variations and Adjustments	0.0	0.0
MSR Variationss and Adjustments	0.8	0.0
RWCU & CRD Flow Var./Adjust. (BWRs)	NA	NA
HP & LP Turbine Shortfall from Design	0.0	NA
Operation Condition Variations	-0.1	0.1
Reactor Recirc. Pump Power Var. (BWRs)	NA	NA
Steam Generation Blowdown (PWRs)	0.1	NA
Generation Electrical Losss Adjustment	0.0	0.0
Other Unrecoverable Effects	0.0	0.0

External Losses	Unit 1	Unit 2
Cooling Tower Performance Loss Effect	NA	NA
External Issues Affecting Generation	0.0	0.0

Next Steps

- Performing independent assessment of FAMOS/PMAX Tool to verify accuracy and capability
- Continue Webinar training and provide additional mentoring and training for Corporate Thermal Performance Engineers
- Continue refinement of PMAX and PEPSE Models
- Additional points to be added to models for enhanced monitoring
- Site and Fleet reports are to be enhanced and updated and additional reports are to be created.
- Several new displays to be added and existing displays enhancements.
- Add DVR (data validation & reconciliation) points to R*Time and PMAX display.
- Provide additional “What-If” capabilities.

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Questions?

FAMOS Enhanced Fleet-Wide Monitoring