akenerji
Elektrik Üretim A.Ş.

PI System O&M Management Tool in Power Generation Industry

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Scope of Presentation

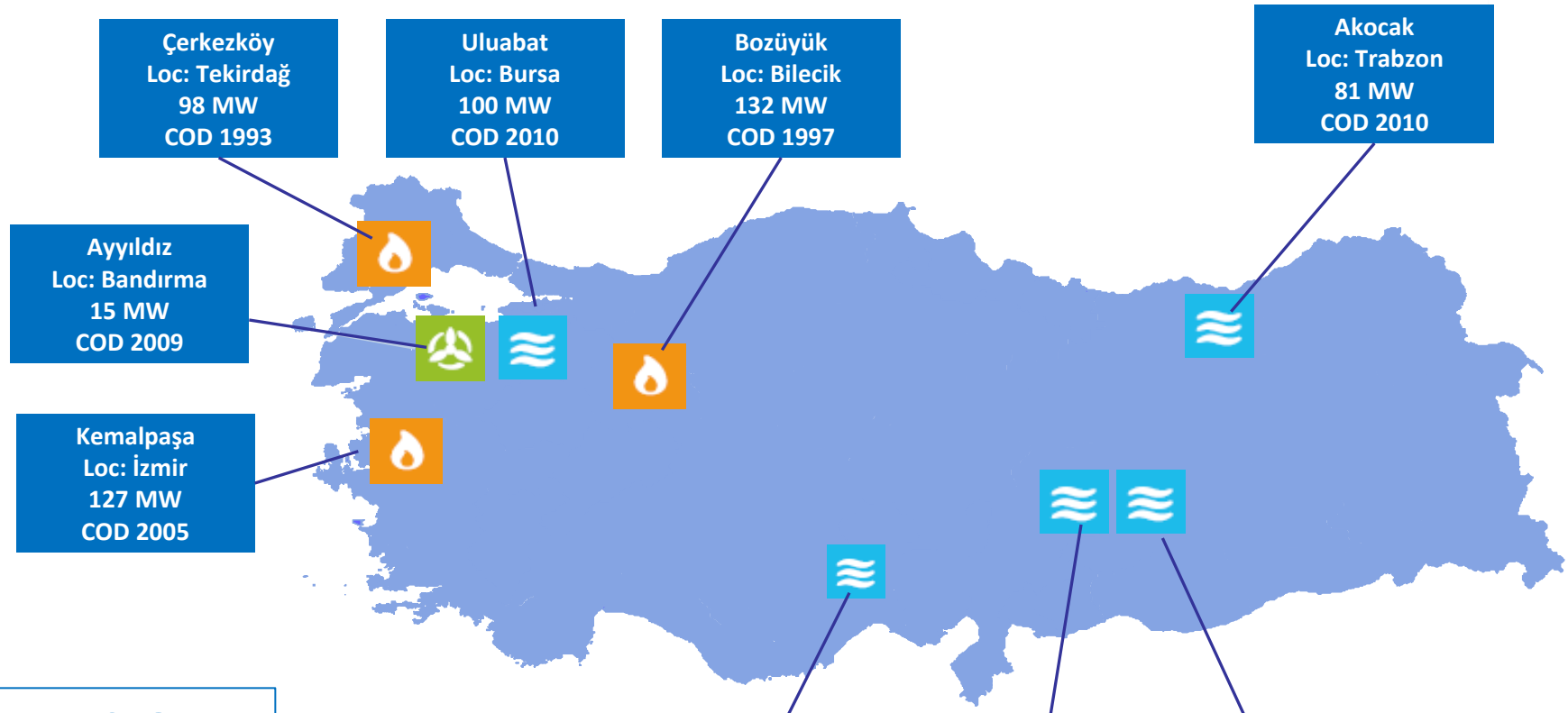
- AK Enerji Generation Portfolio
- Changing Market Conditions, Impacts to CCGTs
- PI System setup in CCGTs
- PI System and cycling operation recommendations

Vertically integrated utility

Electricity Market Value Chain and Integrated Structure of Sale Assets

- Natural gas wholesale business creating synergy when gas take-or-pay contracts are considered.
- Well diversified generation assets, capable of meeting various different profiles of demand.
- With renewable and natural gas plants Akenerji enjoys low CO2 emission electricity generation, hence advantageous in expected emission trading scheme. All of Akenerji's renewable projects are eligible for carbon certification process and trading.
- Wholesale business backed by generation assets, further providing risk management options.
- Large consumption of SEDAS, ready to be backed by large generation volume.

Operational Portfolio



658 MW in operation

Natural Gas Hydro Wind

Projects Under construction and Pipeline

UNDER CONSTRUCTION AND PIPELINE

Inst. Capacity
285 MW

Feke I (30 MW in Adana)
- EIA approval in October 2007
- Project under construction
- Expected commissioning in Q2 2012
- 115 GWh gen/yr

Yamanlı III (57 MW in Adana)
- EIA approval in August 2009
- Project under construction
- Expected commissioning in Q3 2012
- 225 GWh gen/yr

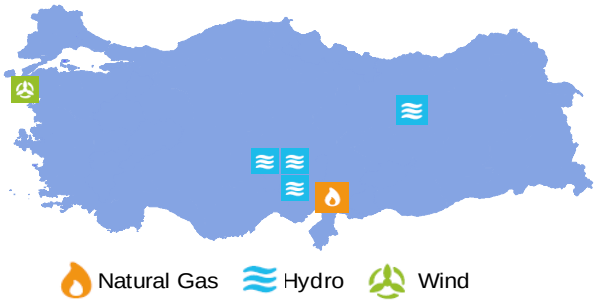
Kemah (198 MW in Erzincan)
- EIA approval in May 2009
- Project on development phase
- Expected commissioning in 2015
- 562 GWh gen/yr

Inst. Capacity
900 MW

Egemer (900 MW in Hatay)
- EIA approval in May 2010
- Expected commissioning in 2014
- Over 7,000 GWh gen/yr
- EPC contract with GE & GAMA consortium in December 2010

Inst. Capacity
600- 900 MW

Lignite/Coal Project
- Devolepment phase



2,085 MW in pipeline

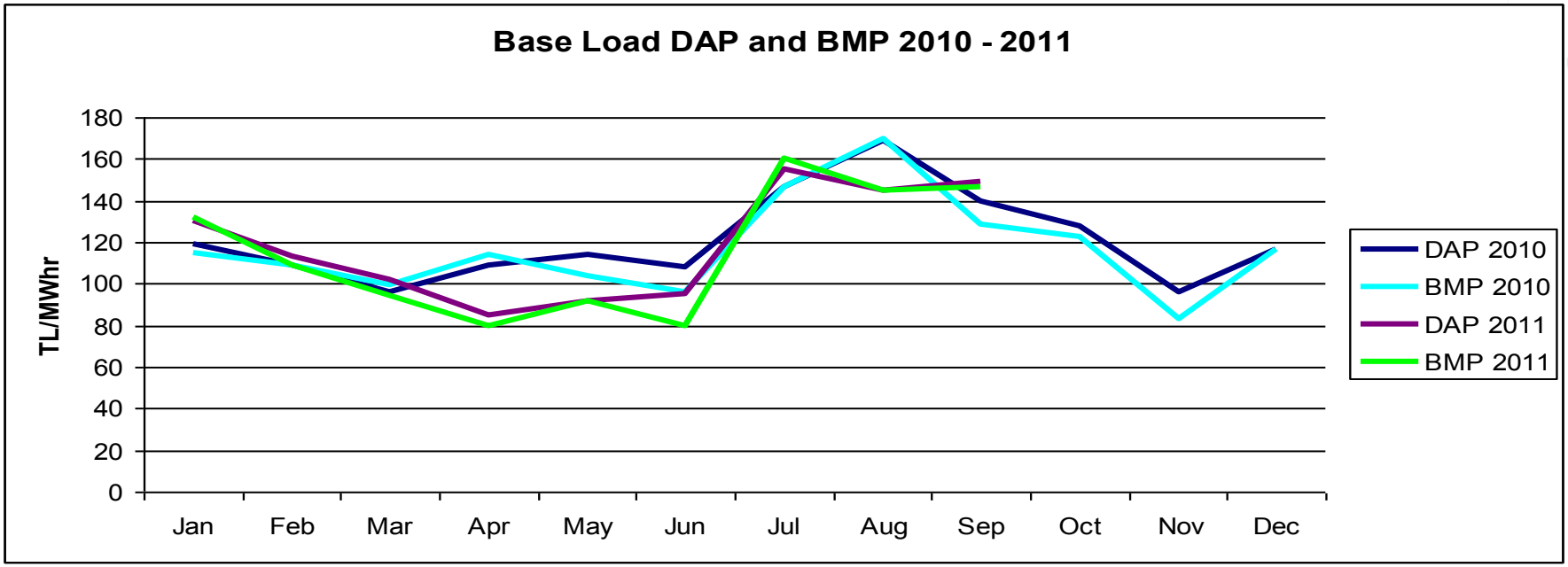
Changing market dynamics require new strategies

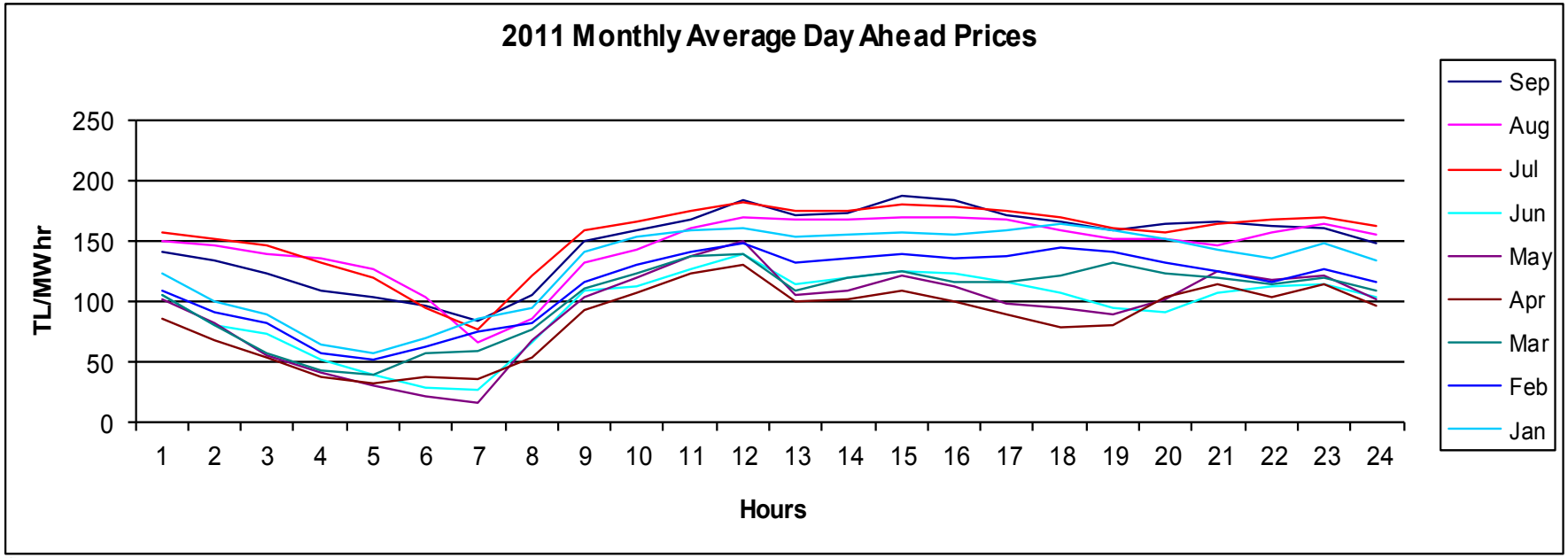
Markets are:

- Rapidly changing,
- In the process of being liberalized and privatized,
- Interconnected,
- More complex and riskier,

Energy Companies need to:

- Understand the Market and its Dynamics,
- Foresee where its heading to,
- Optimize and Structure Portfolio,
- Reach Targets within set Risk Policies,


Base Load DAP and BMP 2010 - 2011
TL/MWhr
180
160
140
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
DAP 2010
BMP 2010
DAP 2011
BMP 2011


2011 Monthly Average Day Ahead Prices
TL/MWhr
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Hours
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
Jan

Current Market Conditions & Impacts for CCGTs

- CCGT Spark spreads for year 2011 low due to relatively high gas prices and;
  - Growth of renewable energy capacity on the market.
  - Higher efficiency of new plants.
- The market is quite volatile and its very to difficult to predict the future.
- Load factors for all plants are lower than forecast.
- Income revenue streams depressed.

Current Market Conditions & Impacts for CCGTs

- Viability of CCGT plant in the market is currently marginal.
    - Operating costs under intense investigation.
    - Difficult to justify improvement Capex of existing plants
    - As a lower carbon source of generation, situation should improve.
    - The plant will survives will be efficient and flexible in operation.
- Less efficient CCGTs were mostly operated at base load during their first life time period. Since year 2010 they are forced to operate in cycling mode without taking appropriate measures.
- Typical running hours are between 5000-6000 hrs/year with 150 starts/year.
- Least efficient plants are being laid up.

Effects of Cycling Operation to CCGTs

- Cycling does have a negative impact on availability. Commercial cost became higher due to lower EAF.
- Penalties caused by failure to deliver power or non availability.
- Higher start costs (gas, auxiliary power, demin water).
- Successful cycling operation is possible with relatively lower maintenance costs and with high availability figures.
- Impact of cycling on power plant equipment can be influenced by taking appropriate measures.
- Higher costs due to cycling can be determined compared to costs related to base load.

Effects of Cycling Operation to CCGTs

They are designed for base load, without corrective measures;

- Plant forced outage rate will be 2.5 times worse
- Start up reliability will reduce 40 %
- Maintenance cost will increase
- OAR insurance premiums will increase 20%
- Be prepared for major forced outages and replacement of main equipment.
- Boilers in cycling operation failed 2 x as much compared to base load operation
- Steam turbines in cycling operation failed 1.4 x as much compared to base load operation
- Availability impact on Generators minimal
- Boilers failures often occurred after a standstill
- Boiler evaporators failed 2.4 x, superheaters 5 x and bypass valves 6 x in cycling operation compared to base load operation.

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PI System Objectives in Power Generation Industry

- Commercial data collection from;
    - Fuel meters
    - Electricity Revenue meters
    - Auxiliary consumption meters
    - Actual electricity market price
    - Customer consumption meters (Electricity and steam)
- Process data collection from main equipment for ;
    - Early identification of changes in equipment physical, thermal, operational, and environmental performance.
    - Mitigate degrading equipment condition and unit performance.
    - Maximize unit value, considering current market opportunities.

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PI System Set-up in Power Generation Industry

- Put PI System to your new build EPC specs to have initial data for your plant.
- Define all critical process variables and metering data
- Define data collection frequency for each PV to avoid aliasing errors
- Implement key performance indicators
- Prepare special purpose workbook and trend displays for
    - Operators
    - Operation and maintenance engineers
    - Plant Management
    - Fleet O&M management
    - Remote diagnostic center
    - Sales and Trading departments
    - Environmental compliance departments

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PI System Set-up in Power Generation Industry

- Additional to main equipment use data from BOP systems such as;
    - Fuel supply system
    - HV/MV/LV electrical system
    - Raw and demin water system
    - Fire detection and fighting systems
    - Condense system
- Implement trainings for each user group
- Develop SOP for system recovery and periodical backup
- Implement your own algorithms for diagnostic purposes
- Make sure that state of art diagnostic device outputs are tagged
- Use PI System to keep update your CBM system
- Use PI System for outage scope preparation and maintenance performance measurement

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PI System & Plant Performance

- Calculate real time
    - Plant heat rate, using gas flow, power and fuel CV
    - Fuel cost, using HR and fuel price
    - Spark spreads, using fuel cost and market electricity price
    - Make sure these data is available for sales & trading departments
- Monitor and evaluate plant HR for various ambient conditions and load levels
    - Find root-causes of the excess degradation
    - Plan and implement remedy works according to findings

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PI System & Plant Performance

- Calculate plant performance predictions using performance curves;
    - Power–ambient temperature, pressure and humidity
    - Heat Rate –ambient temperature, pressure and humidity
    - Part load – Heat rate curves for different ambient conditions
- Continuously compare deviation between actual and the predicted performance for total plant and for the following equipment;
    - Gas Turbine
    - Heat Recovery Steam Generator
    - Steam turbine
    - Condenser

PI System & Plant Availability

- Calculate plant and following equipment Equivalent Availability Factor (EAF) and Equivalent Forced Outage Rate (EFOR);
    - Gas Turbines
    - Steam Turbine
    - HRSGs
- Record following data for main equipment;
    - Running hours
    - Equivalent operating hours
    - Start and trip numbers
    - Failed start up numbers
    - Special operating condition hours; alternative fuel, off design operation etc…

PI System & Gas Turbine Data

- Important Process Variables and calculations for gas turbines
    - Vibrations; seismic, displacement
    - Exhaust temperature spreads and spread charts
    - Bearing metal temperatures
    - Combustion dynamic measurements-Wobbe Index
    - Emissions
    - Wheel Space temperature
    - Cycle and efficiency
    - Compressor efficiency
    - Coast down timer
    - Firing temperature calculations
- Implement rate of change limits additional to constant thresholds for early warning

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PI System & Steam Turbine Data

- Important Process Variables and calculations for steam turbines
    - Bore and surface stress calculations
    - Differential expansion, axial displacement
    - Vibrations; seismic, displacement
    - Bearing metal temperatures
    - Cycle efficiency
    - VWO operation-Bowl pressure vs. inlet pressure
    - Coast down timer
    - Off frequency operation timer
    - HP/IP/LP steam superheat temperatures
    - Steam seal consumption
    - Water ingress detection
- Implement rate of change limits additional to constant thresholds for early warning

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PI System & HRSG Data

- Important Process Variables and calculations for HRSGs
  - Cycle efficiency
  - HRSG pinch and approach points
  - Desuperheater water and valve leakage
  - Dearator pegging steam
  - HRSG pressure decay
  - Fatigue life consumption monitoring for thick HRSG components
  - Chemical control for Steam and water
  - Start up curves
  - Eco steaming during startup
  - Superheater flooding during startup
  - Steam-water leakage detection for each pressure level
  - Heat load of HRSG sections; economizer, evaporator, Superheater etc…

PI System & Condenser Data

- Important Process Variables and calculations for condensers and cooling towers
    - Heat loads of condenser and cooling tower
    - Wet-bulb temperature
    - CT Approach temperature
    - Cycle efficiencies
    - Condenser pinch temperature
    - Sub cooling
    - Condenser vacuum decay
    - Blow down and evaporation water losses
    - Back pressure
    - Bypass valve leakage

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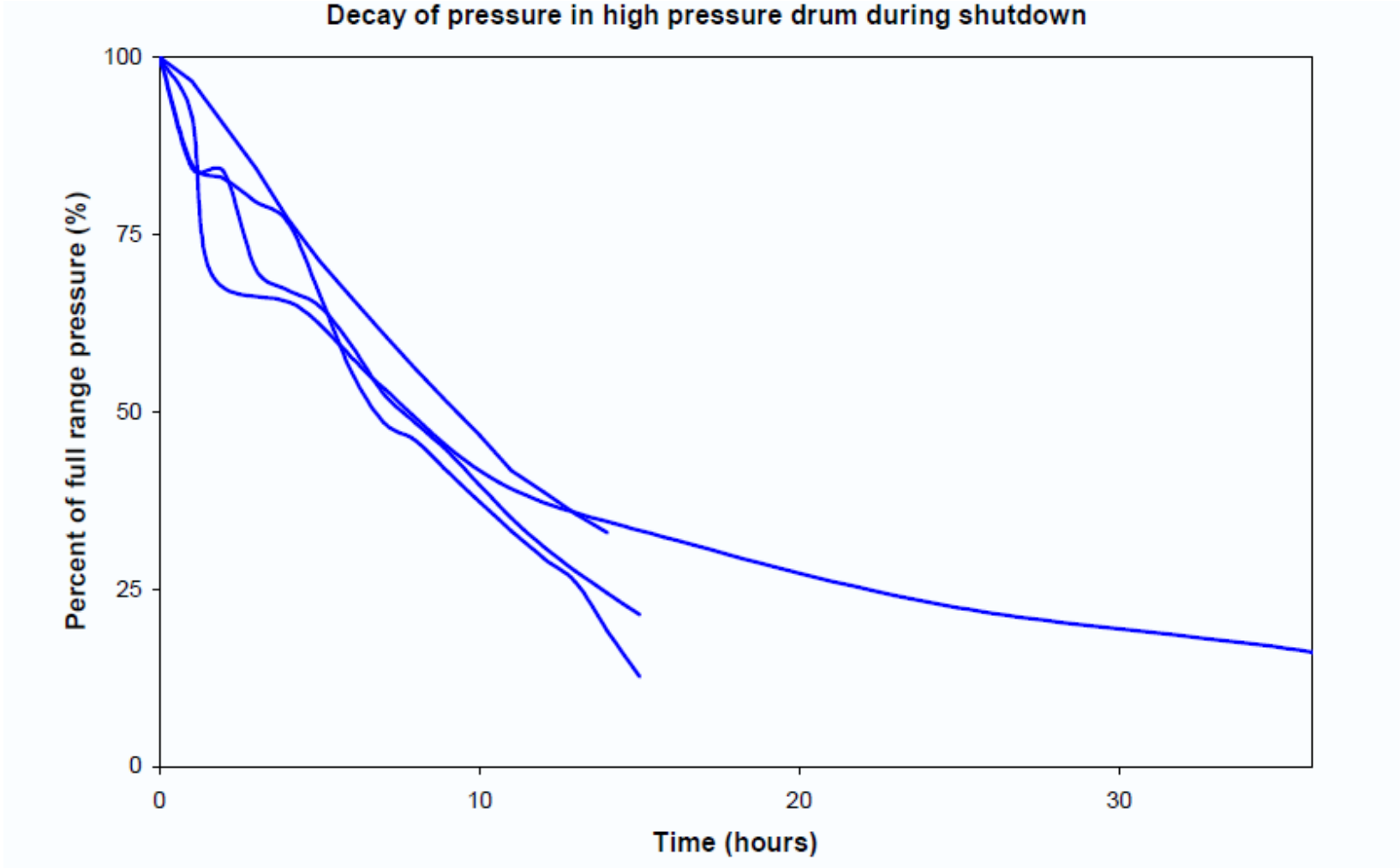
Cycling Operation

- Cold starts generally use most of the fatigue life.
  - Most severe temperature ramps.
  - Largest pressure range.
- Hot starts with GT purge can be extremely damaging if you don’t prevent condensate flooding.
- Take proper actions during shutdown to maintain heat and pressure in the HRSG to minimize the severity of the subsequent startup:
  - Avoid GT spin cools and purges,
  - Close stack damper,
  - Close vents, drains, blowdown, etc.
- Monitor rate of decay of pressure in high pressure drum.
  - Seek improvements to minimize warm and cold starts.
- Warm and hot starts can be faster due to smaller overall temperature change

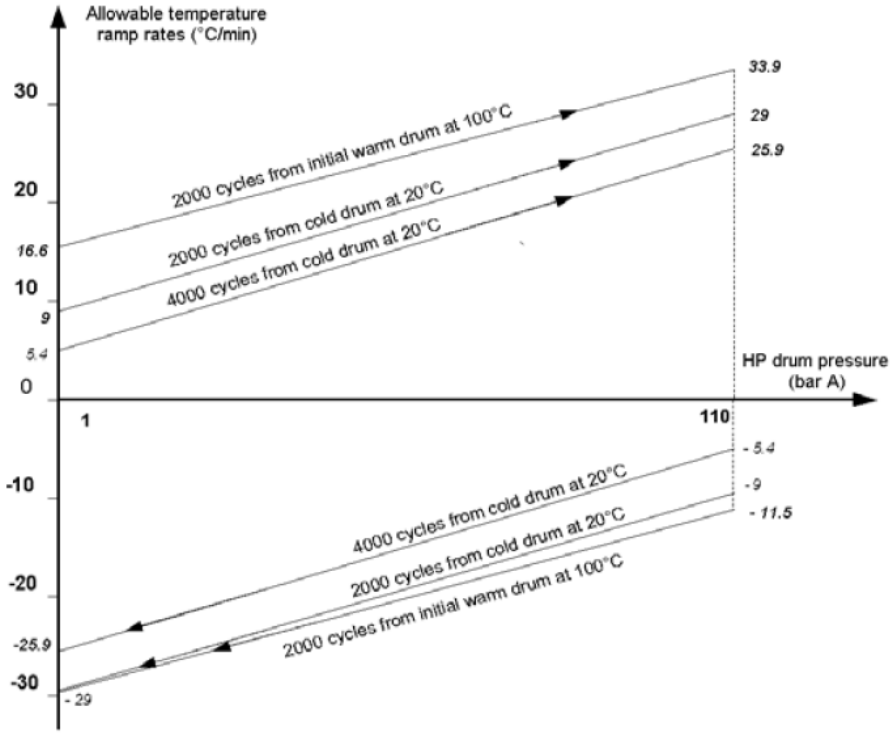
HRSG Pressure Decay

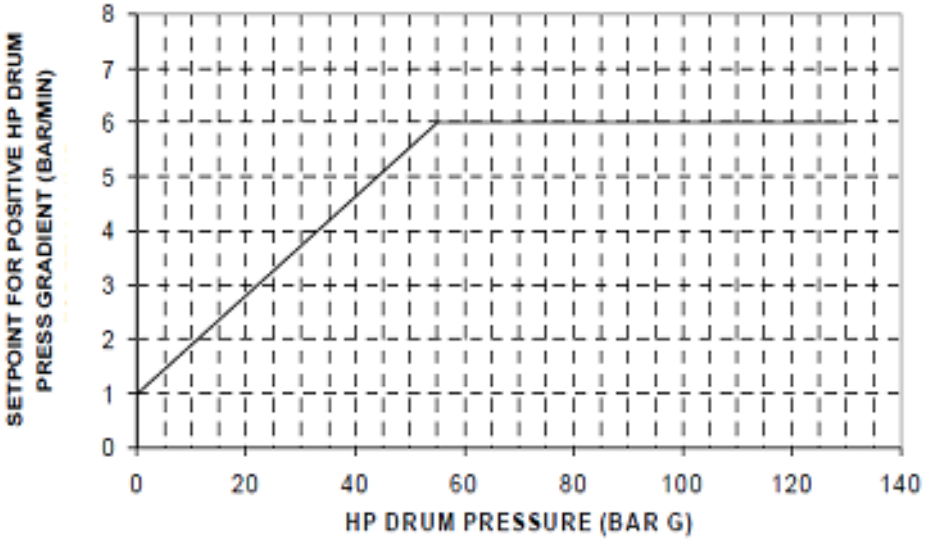


Cycling Operation

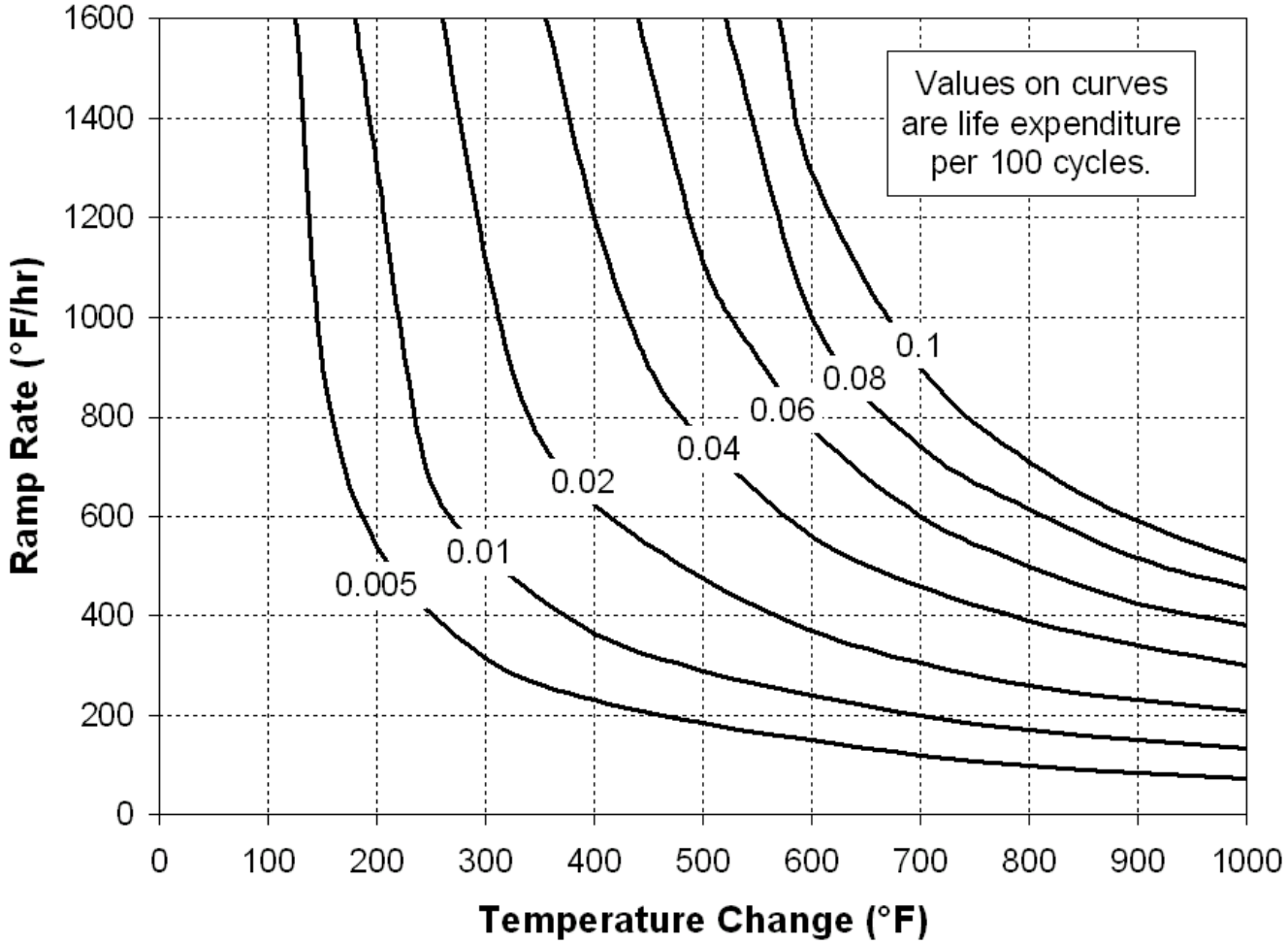
- Fatigue damage from rapid ramping
  - HP Steam Drum is the most vulnerable part of the plant
  - Less of a concern for steam systems <1500 psig (103 barg)
  - High heat transfer rates occur on the inside surface of the drum during startup causing significant through-wall temperature gradient.
  - Monitor rate of pressure rise in high pressure drum.
  - Use bypass to control rate of pressure rise, and hence through-wall temperature in HP drum.
  - Give enough time for soaking (thermal equilibrium through the wall)
  - Ramp downs cause more damage to drum than ramp ups

Ramp rates according TRD 301applied for a HP drum



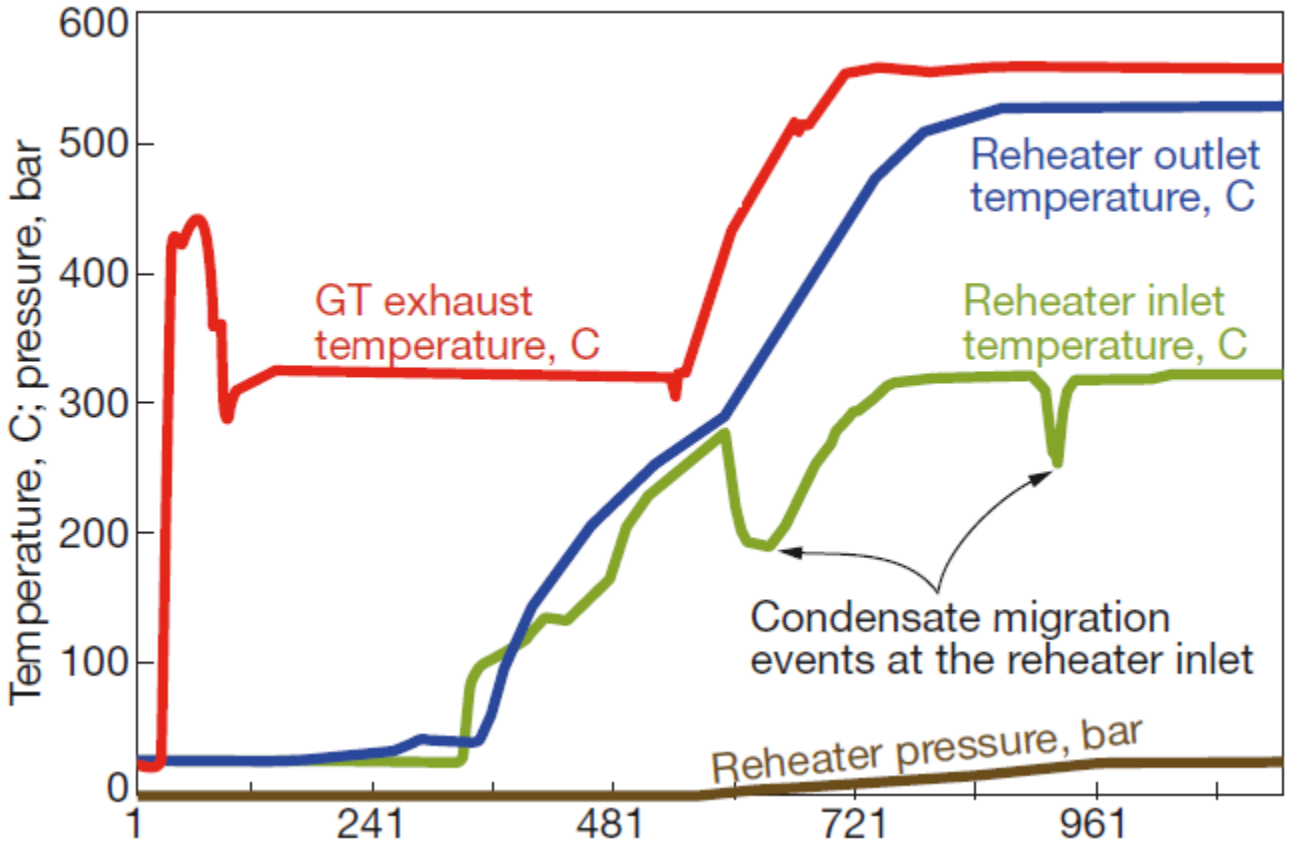


Fatigue-Driven Life Expenditure



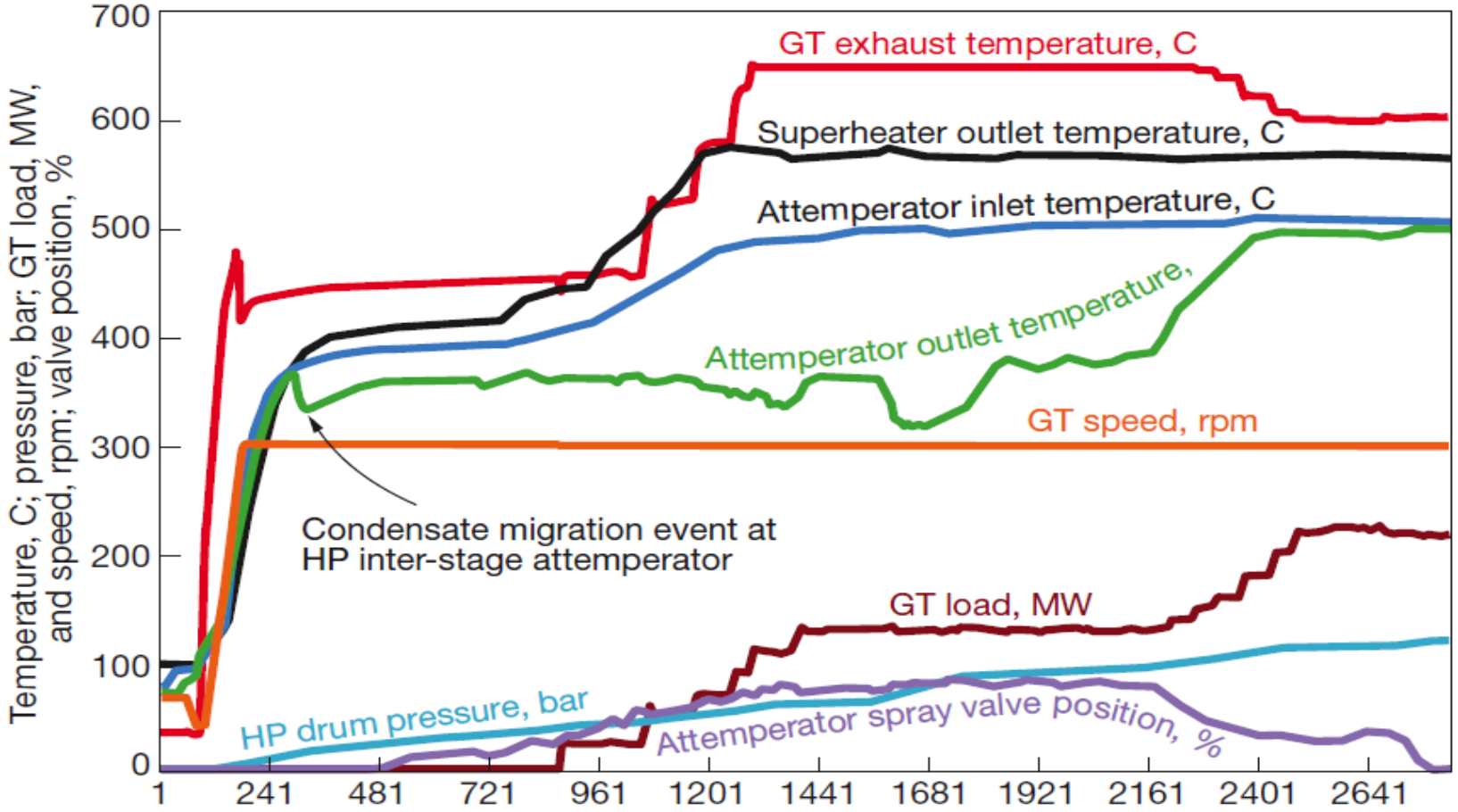
Template Startup curves

Condensate formed in pipe during warming is swept into the reheater inlet, as indicated by the large drops in reheater inlet temperature

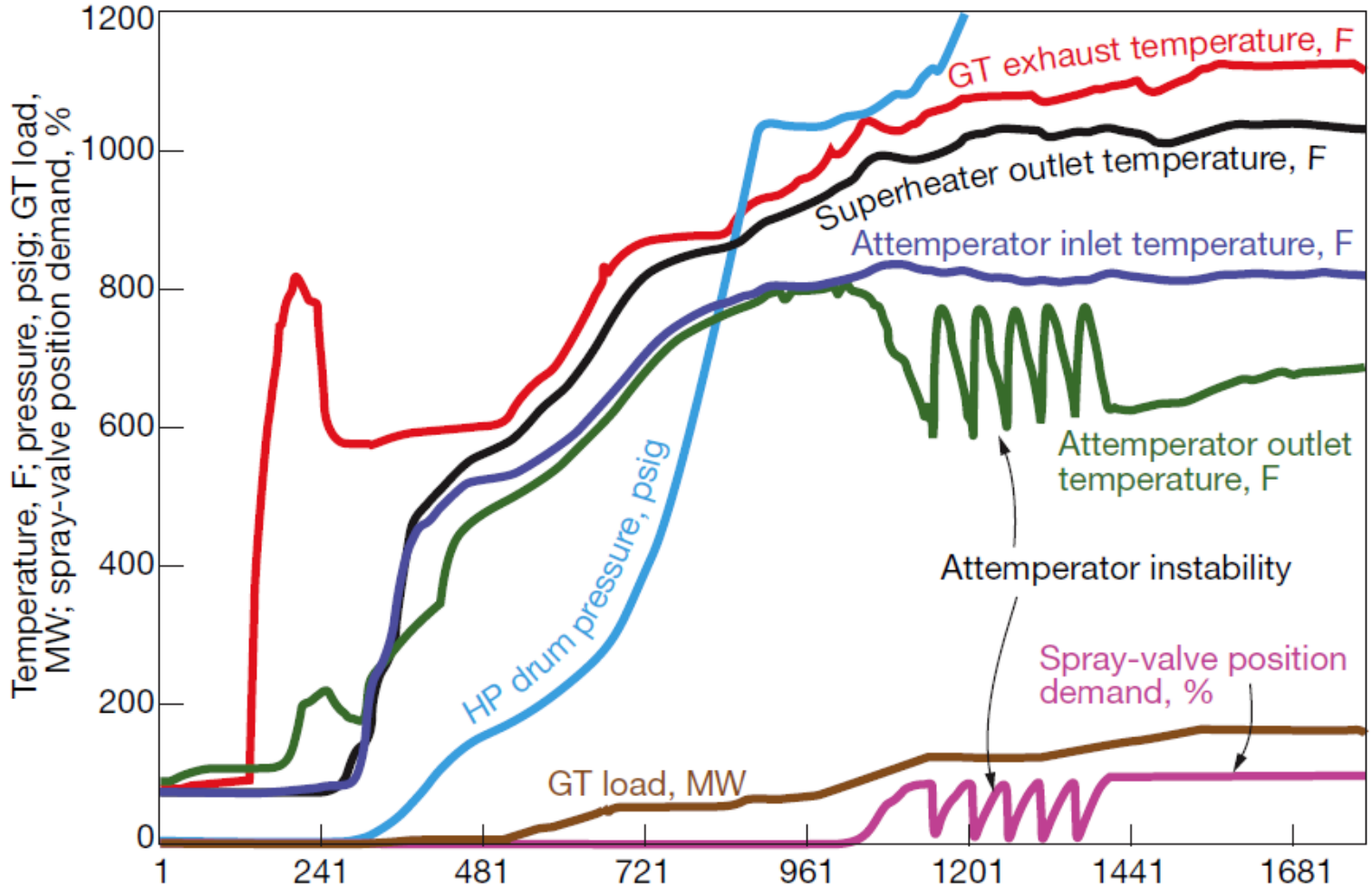


Template Startup curves

Large dip in attemperator outlet temperature indicates that un-drained condensate was carried by steam flow from the primary to the secondary superheater



Template Startup curves



Failure Mechanisms & Locations

Damage Mechanism	Low Cycle Fatigue	Creep	Thermal Shock	Differential Expansion	Corrosion Fatigue	Oxidation / Exfoliation	Chemical Corrosion	Flow Acc. Corrosion	Corr. Product Migration	Depositions	Erosion Inside Tubes	Erosion Outside	Corrosion outside tubes	Non Pressure part	Erosion of Non Pressure	Expansion - Non Press.	Others
HRSG Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Superheaters	√	√	√	√		√	√				√						
Attemperators	√	√	√	√			√	√	√		√						
Reheaters	√		√	√	√	√	√		√		√						
Evaporators	√			√	√	√		√	√	√							
Economizers	√			√	√	√		√	√	√	√						
Drums	√	√			√	√			√	√							
Piping	√	√	√	√	√	√			√	√	√						
Valves		√	√		√	√			√	√							
Fins & Tubes	√	√	√	√	√	√	√				√	√	√	√	√	√	
Liners, Casing etc.	√	√	√	√		√								√	√	√	
Ducts	√	√		√		√								√	√	√	
Dampers	√	√		√		√								√	√	√	
Structurals						√								√	√	√	
Stacks					√	√								√	√	√	

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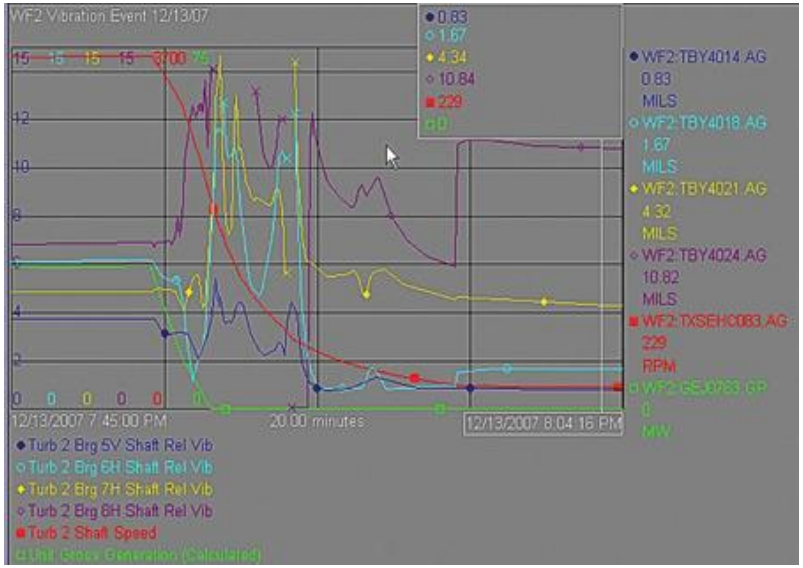
Rate of Change limits; early fault detection

- 180-degree, 1.5-inch-deep crack in Entergy's Waterford 2 generator shaft.
- Performance Monitoring and Diagnostic Center first identified an early vibration transient.
- That discovery allowed the unit to be safely shut down before a catastrophic failure occurred.
- Repairs were later estimated at approximately $5 million. Costs for picking up the pieces and putting out lube oil and hydrogen fires—which would have resulted if the shaft actually had failed—were estimated at between $20 and $40 million, not including personnel injuries.



Conclusion

- It is very difficult to predict the future of the electricity market in the long term - take this into account when devising O&M strategies.
- Use your PI System pro-actively to survive in challenging market conditions.
- Optimize generation on plant and fleet bas with using PI System.
- Prevent forced outages and consequential commercial penalties with early detection of abnormalities.
- Use PI System for life extension and CBM update opportunities.

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Thank you for time.