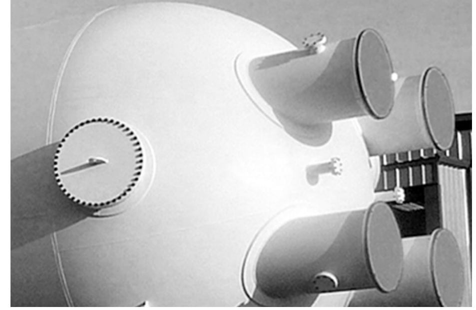
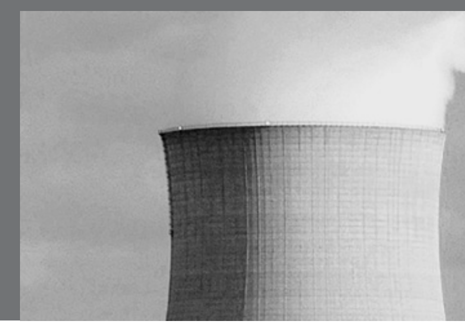


Throttle Valve Considerations

Greg Alder, Scientech

Brian Davenport, Exelon



Background

- Understanding a plant’s turbine control valve behavior is important to a thermal performance program
- Plant equipment modifications, power uprates, and equipment degradation impact throttle valve behavior and plant performance
- Exelon’s Peach Bottom generating plant teamed with Scientech to produce a study using the PEPSE thermal performance software to review the impact of turbine control valve changes resulting from an EPU (extended power uprate) power ascension
- This presentation discusses the study performed at Peach Bottom and considers turbine control valve position impacts on thermal performance that pertain to all nuclear power plants

Turbine Control Valve Pressure

- Depending on the turbine manufacturer, the pressure at the exit of the valves is not measured
- It is often challenging to estimate the exiting steam pressure to calculate throttling losses
- Turbine vendors usually provide thermal kits in conjunction with major modifications
  - Sometimes turbine control valve characteristic curves are included in thermal kits or provided in PTC 6 turbine warranty test procedures

Turbine Control Valve Position Impacts

- Turbine control valve position can change for a variety of reasons
  - Pressure control – plant type (BWR/PWR), full or partial arc
  - Extended Power Uprate (EPU)
  - Measurement Uncertainty Recapture (MUR)
  - Downpowers
    - Derates (pumps OOS, thermal limits, dispatch, etc.)
    - Waterbox cleaning
  - Equipment Degradation
    - MSRs
    - Feedwater Heaters
    - Steam generators/reactors

How Can We Estimate Impact of TCV Position Changes?

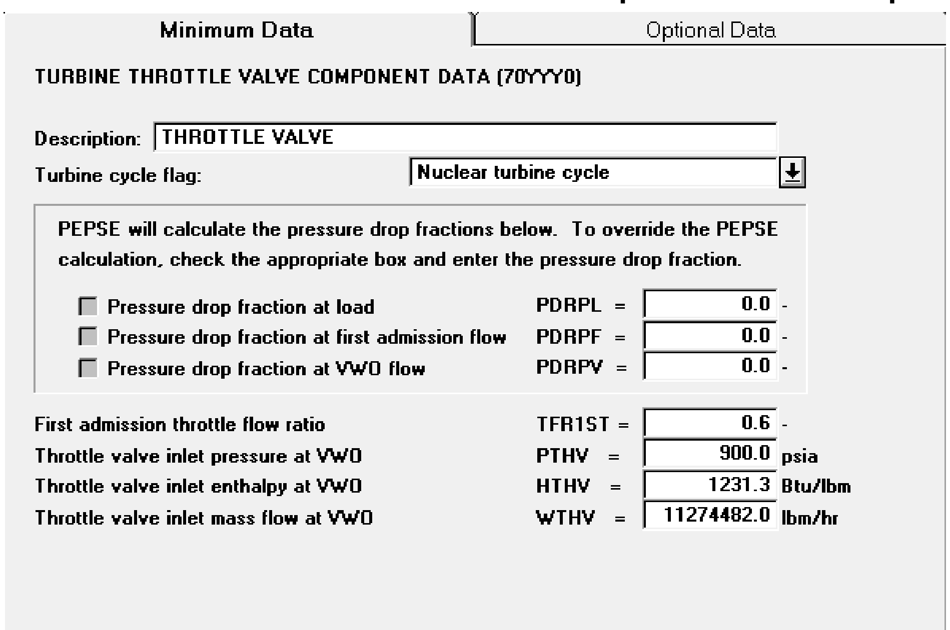
- Plant Empirical Data
  - Corrected generation – requires correction curves or equations
- Thermal Performance Software (PEPSE)

PEPSE Modeling Considerations

- Feedwater Heaters/Reheaters
  - Design Mode vs Performance Mode
- Constant Pressure Drops in Piping (PEPSE Streams)
  - Use Type 7 vs Type 2 streams between steam generator/reactor outlet and TCV inlet
    - Type 2 = constant fractional pressure drop at all loads
    - Type 7 = pressure drop is function of volumetric flow (density)
- Other Items
  - Main steam pressure change with thermal power (PWR)
  - Correct thermal power calculation in PEPSE
  - Tuned to representative data
    - Recent MCO (BWR), feedwater heater/reheater, other boundary data, etc.

Modeling Turbine Control Valves

- PEPSE Turbine Control Valve Component
  - Constant pressure drop at all loads above 1st Admission Throttle Flow Ratio (TFR1ST) = 4%
  - Internally calculated pressure drop below TFR1ST
    - Theoretical and not plant specific
  - Overwrite internal pressure drop calculation using PDRPL – <u>need a curve</u>!



Minimum Data | Optional Data

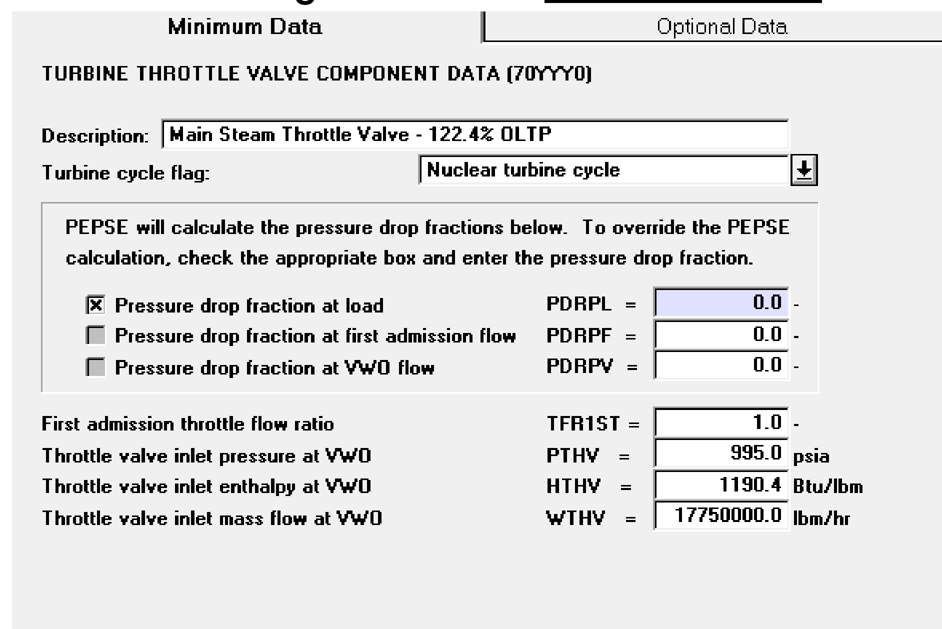
TURBINE THROTTLE VALVE COMPONENT DATA (70YYY0)

Description: THROTTLE VALVE

Turbine cycle flag: Nuclear turbine cycle

PEPSE will calculate the pressure drop fractions below. To override the PEPSE calculation, check the appropriate box and enter the pressure drop fraction.

☐ Pressure drop fraction at load	PDRPL =	0.0	-
☐ Pressure drop fraction at first admission flow	PDRPF =	0.0	-
☐ Pressure drop fraction at VWO flow	PDRPV =	0.0	-
First admission throttle flow ratio	TFR1ST =	0.6	-
Throttle valve inlet pressure at VWO	PTHV =	900.0	psia
Throttle valve inlet enthalpy at VWO	HTHV =	1231.3	Btu/lbm
Throttle valve inlet mass flow at VWO	WTHV =	11274482.0	lbm/hr



Minimum Data | Optional Data

TURBINE THROTTLE VALVE COMPONENT DATA (70YYY0)

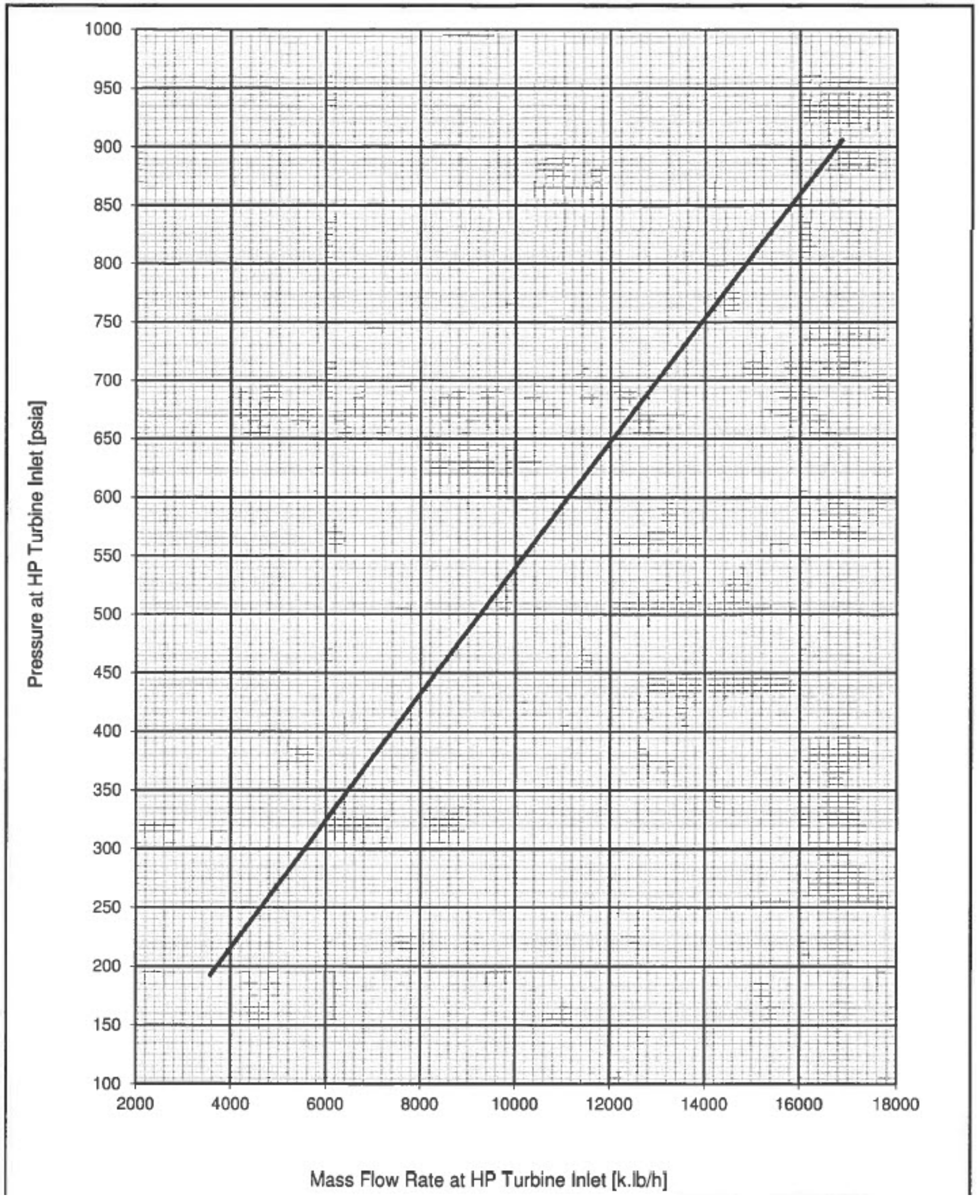
Description: Main Steam Throttle Valve - 122.4% OLTP

Turbine cycle flag: Nuclear turbine cycle

PEPSE will calculate the pressure drop fractions below. To override the PEPSE calculation, check the appropriate box and enter the pressure drop fraction.

☒ Pressure drop fraction at load	PDRPL =	0.0	-
☐ Pressure drop fraction at first admission flow	PDRPF =	0.0	-
☐ Pressure drop fraction at VWO flow	PDRPV =	0.0	-
First admission throttle flow ratio	TFR1ST =	1.0	-
Throttle valve inlet pressure at VWO	PTHV =	995.0	psia
Throttle valve inlet enthalpy at VWO	HTHV =	1190.4	Btu/lbm
Throttle valve inlet mass flow at VWO	WTHV =	17750000.0	lbm/hr

Turbine Control Valve Characteristic Curve



What If You Don't Have a Vendor Curve?

- Take the vendor golfing
- Find a curve from a similar plant
- Estimate a curve

Making a Curve

Throttle Valve Characteristic Curve - PWR

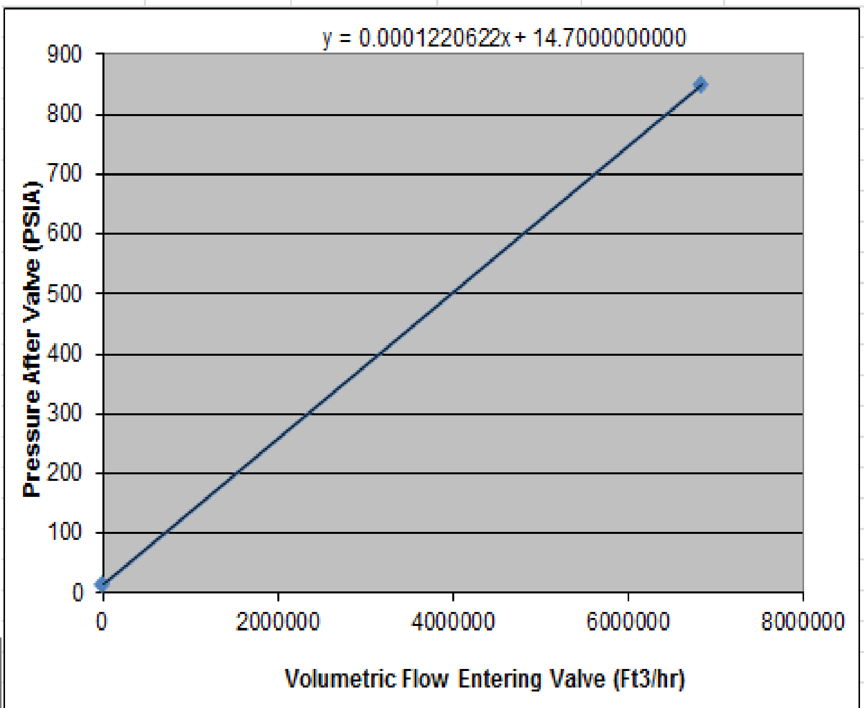
Flow into TV	Volumetric Flow Into TV	Specific Volume Into TV	MS Pressure	Throttle Pressure	Pressure After Valve (Curve 1)	Pressure After Valve (Curve 2)	TV DP/P (Curve 1)	TV DP/P (Curve 2)	Source	Comments
3290147	1933820	0.5878	888.5	884.5	250.7	247.3	0.7165	0.7204	HBD 35%	
4964140	2930997	0.5904	893.5	884.7	372.5	367.2	0.5790	0.5850	HBD 50%	
7985833	4741041	0.5937	905.3	883.7	593.4	584.9	0.3285	0.3381	HBD 75%	
11343070	6705051	0.5911	925.5	884.0	833.1	821.1	0.0576	0.0712	HBD 100%	
11608310	6845618	0.5897	927.3	885.7	850.3	838.0	0.0400	0.0539	HBD VWO	
	6767268			885.0	840.7	828.6	0.0500	0.0638	Similar Plant	
11456198	6818379	0.5952	897.7	877.0	847.0	834.7	0.0342	0.0482	Measured Data	

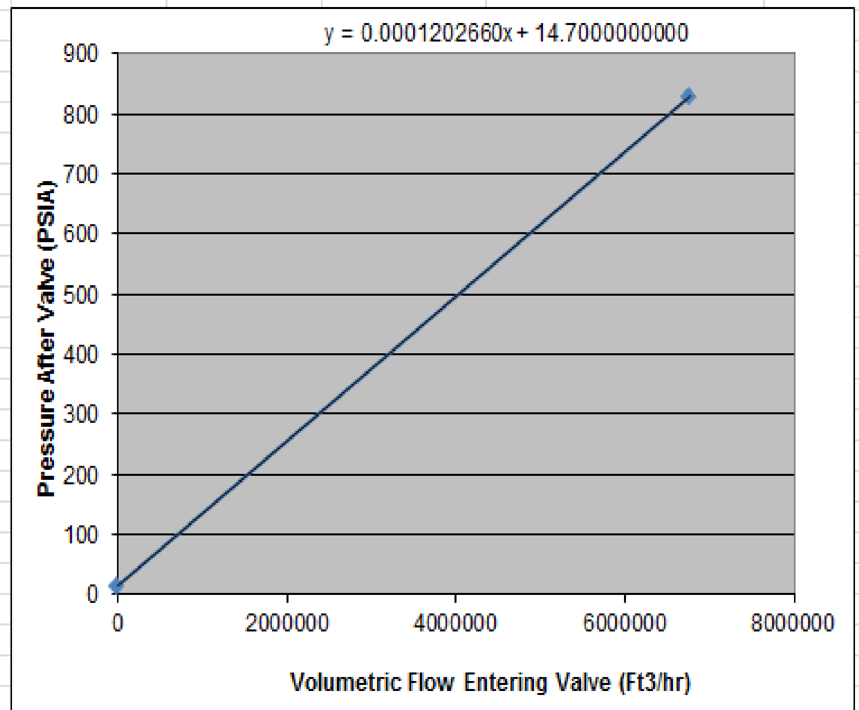
Curve 1
Current Plant

Vol Flow	P After Valve		DP/P
0	14.7		
6845618	850.3		0.04

Curve 2
Similar Plant

Vol Flow	P After Valve	DP/P
0	14.7	
6767268	828.6	0.0638





Exelon Peach Bottom Unit 2 & 3

- Located 50 mi. southeast of Harrisburg, Pennsylvania
- Type – BWR/4
- MWt - 3951
- MWe – 1320
- Turbine – Alstom
- Reactor – GE
- Commercial Op – 1974

Peach Bottom Power Up Rate Summary

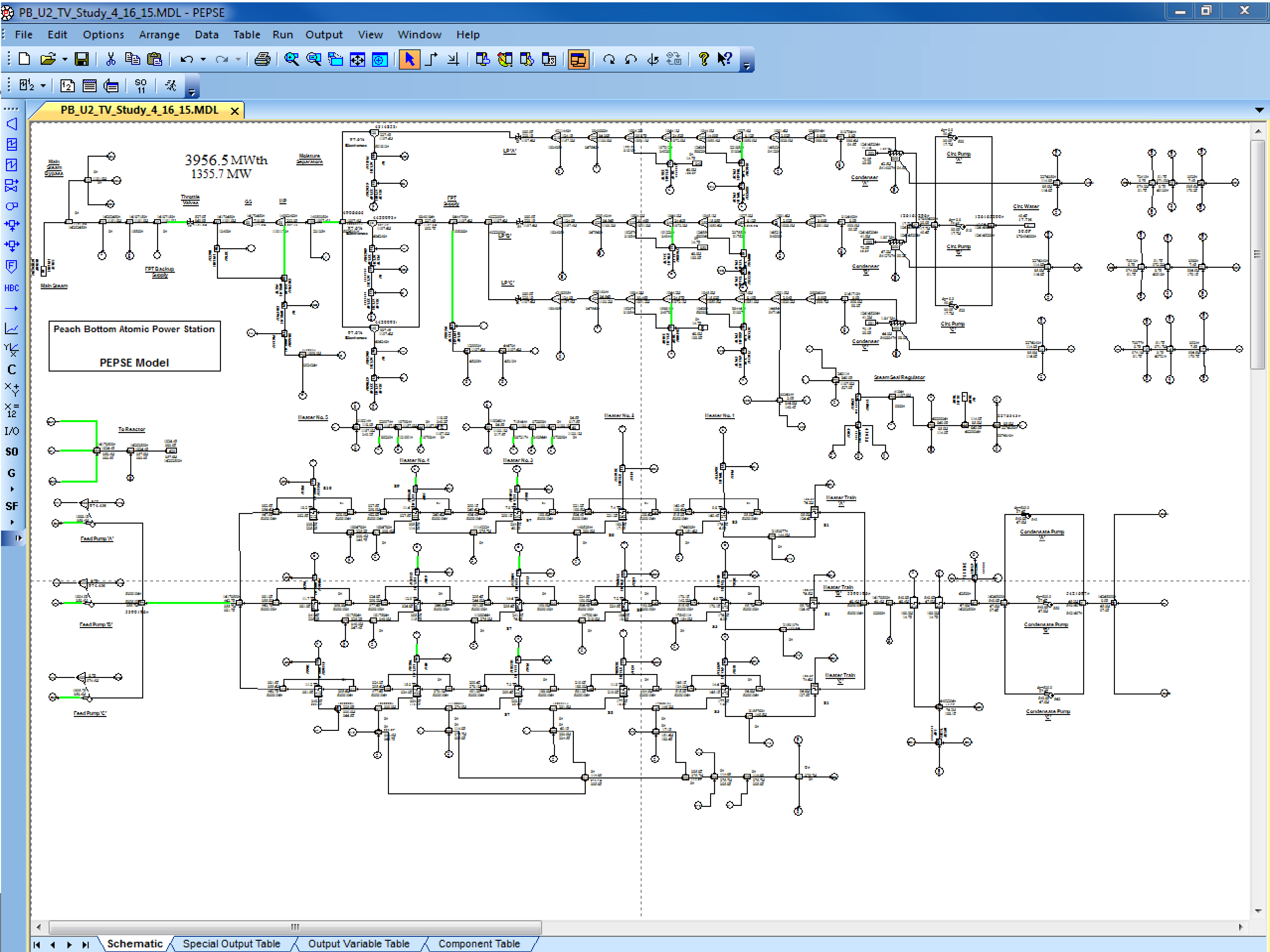
- Peach Bottom Units 2 & 3 undergoing EPU:
  - Unit 2 achieved full EPU power at end of May 2015
  - EPU Thermal Power -- 3951 MWth (~ 12% increase)
  - Constant Reactor Pressure Uprate; i.e. increased feedwater and main steam flows
    - Significant Plant Changes affecting Thermal Performance:
    - HP Turbine Retrofit
    - RFPT Replacements (replace degraded casings)
    - 2 L.P. Feedwater Heater Replacements/4th Stage heater tube sleeving
    - Rewind Generator
    - New Current Transformers (CT) - Unit 2 only
- Extensive use of PEPSE to model cycle changes, e.g. increased flow, pressure and efficiency of the new equipment, used to lessor extent for condenser performance

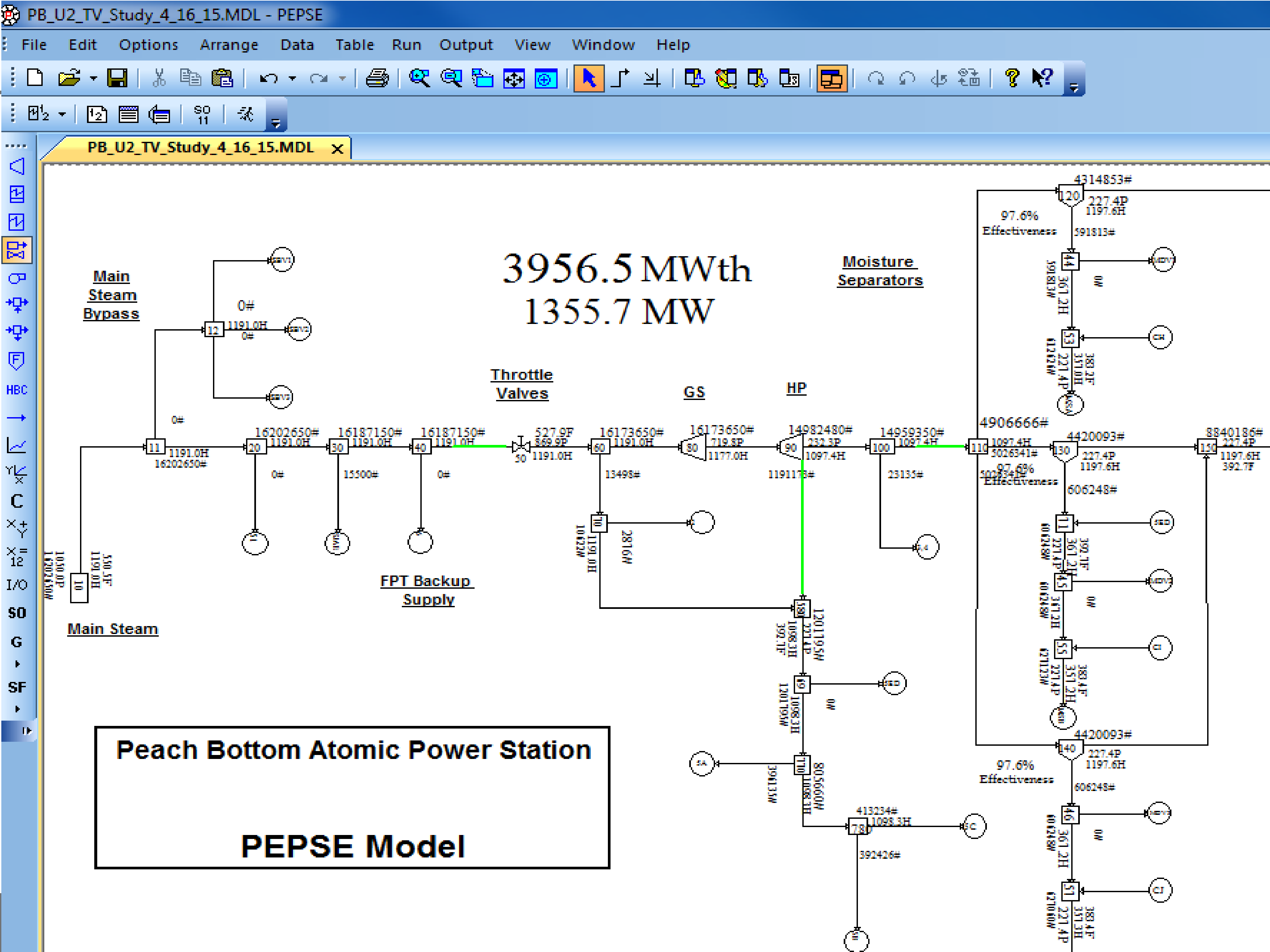
EPU Turbine Control Valve Position Considerations

- During the power ascension leading up to EPU there was an increase in Turbine Control Valve (TCV) throttling due to the increased flow capacity of the HP Turbine
- Exelon was concerned where the TCV's position would end up at full power
- Also there was interest in whether it made sense to change reactor pressure and thus allow the valves to open more and how much impact that would have on plant thermal performance
- A limited set of plant data for the HP Turbine inlet pressure was obtained using temporary instruments on one plant unit
- Third party studies performed before EPU to assist in TCV behavior predictions
  - Losses
  - Valve margin

Peach Bottom PEPSE Model

- PEPSE model updated to reflect new steam turbine replacement
  - Based largely on turbine vendor thermal kit
  - Multiple thermal power levels modeled
- Model tuned to available plant data
- Model features
  - Simplified design mode feedwater heaters
  - HEI mode condensers
  - Thermal Power calculation
  - Type 7 Stream (Reactor to TCV inlet)


PB_U2_TV_Study_4_16_15.MDL - PEPSE
File
Edit
Options
Arrange
Data
Table
Run
Output
View
Window
Help
PB_U2_TV_Study_4_16_15.MDL
3956.5 MWth
1355.7 MW
Peach Bottom Atomic Power Station
PEPSE Model
Schematic
Special Output Table
Output Variable Table
Component Table


PB_U2_TV_Study_4_16_15.MDL - PEPSE
File Edit Options Arrange Data Table Run Output View Window Help
PB_U2_TV_Study_4_16_15.MDL
3956.5 MWth
1355.7 MW
Main Steam Bypass
Moisture Separators
Throttle Valves
GS
HP
FPT Backup Supply
Main Steam
97.6% Effectiveness
Peach Bottom Atomic Power Station
PEPSE Model

PEPSE - Methodology

- Good Representation of Thermal Power Calculation
- Reactor or Steam Generator Outlet to Throttle Valve Inlet
  - Type 7 Stream
- Throttle Valve Characteristic Curve
  - Enter as a Schedule or Operation
- Simplified Design Mode Feedwater Heaters
  - Especially top feedwater heaters
    - Tune to recent plant data
    - Simplified design mode feedwater heaters

PEPSE – Boundary Conditions

- Thermal Power
- Steam Quality – recent MCO test
- Reactor Outlet Conditions
- Reheater Outlet Conditions
- Final Feedwater Temperature
- Condenser Pressures

Preliminary PEPSE Results

Without TCV Curve, Default TCV DP/P, Type 2 Stream, Performance Mode FWHs

MWth	Plant	PEPSE	Delta	Delta	Plant	PEPSE		
%	MW	MW	MW	%	FW Temp	FW Temp	Delta	Delta %
88.9	1193.3	1220.8	-27.5	-2.30%	372.9	374.2	-1.3	-0.35%
96.0	1294.1	1313.9	-19.8	-1.53%	379.5	380	-0.5	-0.13%

With TCV Curve, Type 2 Stream, Performance Mode FWHs

MWth	Plant	PEPSE	Delta	Delta	Plant	PEPSE		
%	MW	MW	MW	%	FW Temp	FW Temp	Delta	Delta %
88.9	1193.3	1195.6	-2.3	-0.19%	374.1	374.2	-0.1	-0.03%
96.0	1294.1	1296.1	-2	-0.15%	379.5	380.8	-1.3	-0.34%

With TCV Curve, Type 7 Stream, Design Mode FWHs

MWth	Plant	PEPSE	Delta	Delta	Plant	PEPSE		
%	MW	MW	MW	%	FW Temp	FW Temp	Delta	Delta %
88.9	1193.3	1194.9	-1.6	-0.13%	374.1	374.1	0	0.00%
96.0	1294.1	1294.2	-0.1	-0.01%	379.5	379.2	0.3	0.08%

Summary

- Many PEPSE models are not adequately configured to account for power changes or plant degradation studies
  - PEPSE Stream Type 7 vs Type 2 for SG or Reactor Outlet to TCV inlet
  - Turbine Control Valve characteristic curve
  - Simplified design model feedwater heaters
  - Tune model to representative plant data; boundary data
  - Thermal Power calculation configured correctly
  - Design mode reheaters
  - Other parameters specific to the plant that may change with thermal power

Questions?