

Evaluating Generation Considering All Plant Losses and Efficiencies

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Plant Issue

- Browns Ferry Unit 1 restarted in June 2007
- Steam path was optimized for 20% EPU
- Licensing approval of EPU has been delayed
- Unit currently operates at 105% OLTP
- Unit generating 14 MWe less than expected
- Need to make a full accounting of the difference













Background Info

- •U1 started commercial operation in 1973
- Unit is an 1800-RPM tandem-compound design
- Double-flow HP section w/ six (6) stages
- Six-flow LP section w/ eight (8) stages (43" LSB)
- Five (5) stages of Feedwater Heating
- Cycle is non-reheat (moisture separators only)





Background Info









Background Info

- Steam supplied by Boiling Water Reactor (BWR)
- Operates with four (four control valves (full arc)
- No precision testing performed following Restart
- No vendor balances at current 105% OLTP
- •U1 generating 38 MWe less than U2 & U3
- EPU delays TVA exploring recovery options



Theories

- Feedwater flowrate reading higher than reality
- HP turbine was less efficient than thermal kit data
- Excessive control valve throttling as a result of:
 Significant flow margin at this power level

and/or

- Physical configuration (poor manufacturing)
- Other possible plant losses (e.g., cycle isolation)



Evaluation

- PMAX was used to gather plant and calculated data from its own historian
- PEPSE was used to validate the generation based on this data.



Evaluation - PMAX





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Evaluation - PMAX

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ke "		ACTUAL (OUTPUT OUTPUT	(MWe) 1 CORRECTED FOR I	102.0 Know MW EFFECTS (M	n MW Meter IWe)	Dev	0.0Ј	1102.0 Co 1114.7	rrected MW Met	ter Output
		BASELIN	E FOR TH	IERM PERFORMAN	ICE MODEL (MW	/e)			1117.0 3	Circ Pumps i	n Service
💼		DESIGN (OUTPUT "	TAKING MW EFFEC	TS INTO ACCOU	NT (MWe)			1105.3		
		OUTPUT	ratio: A	CTUAL OUTPUT \ E	ESIGN OUTPUT	(%)			98.75		
i i i i i i i i i i i i i i i i i i i	ACCOUNTED MW DEVIATIONS (-LOSS +GAIN			S +GAINS)	ACTUAL		DESIGN	MW EFFE (MWe)	MW EFFECTS ESTIMATED (MWe) VALUE (\$/HR)		
	т	RENDS		Control Rod Drive	Flow	35482	LB/HR	50000	0.2	27.	0
				LP Turbine Relief	Valve Flow	0	LB/HR	0	0.0) 0.	0
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	-	_		FWH Off-Design					-2.0	-64.	4
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MAN	Hee	oominio		Generator Power	Factor	0.997	FRAC	1.0	0.1	2.	6
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<i></i>				Power Level 1	00.10 %	3461.0	MWTH	3458	-1.1	L -35.	1
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				Reactor Water Cle	an Up Loss	-4.4	MWTH	-4.4	0.0	0.	5
				other Reactor Los	5	-1.10J	MWTH	-1.1	0.0	0.	0
			TOTAL A	CCOUNTED MW DE	VIATIONS				-11.7	-375.	6
		UNACCOUNTED MW DEVIATIONS						-2.3	-72.	4	
		AUXILIARY LOAD (MW) 26.0 BEST ACHIEV					ACHIEVA	BLE HEAT	RATE (BTU/KWH	l) 10570.	9J
		DESIGN	GROSS H	EAT RATE (BTU/KV	VH) 10694	. 8 ACT. 4	DJ. GRO	SS HEAT R	ATE (BTU/KWH)	10741.	2
		NET CYC	LE HEAT	RATE (BTU/KWH)	10948	. 4 THERI	MAL PER	FORMANC	E INDICATOR	0.984	1
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Evaluation - Data

- An hour of data was collected on 3/24/2010 from 15:00:00 to 16:00:00
- An average of this data was then used in the predictive heat balance software.



Evaluation - PEPSE





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Results – Case Studies

CASE	DESCRIPTION	GENERATION
		(MW)
1	BASE MODEL	1130.935
2	3/24/2010 ACTUAL PLANT DATA BOUNDARY CONDITIONS	1130.786
3	ALL ACTUAL CONDITIONS W/O TURBINE EFFICIENCIES	1133.428
4	LP TURBINE EFFICIENCIES INCLUDED	1120.019
5	ACTUAL THROTTLE VALVE OUTLET PRESSURE INCLUDED	1111.576
6	HP TURBINE EFFICIENCIES INCLUDED	1107.888
7	HP TURBINE DEGRADED TO MATCH GENERATION	1103.024
8	NEW HP TURBINE & THROTTLING CONDITIONS INCLUDED	1157.679
9	NEW HP TURBINE WITH 4.15% THROTTLED PRESS DIFF	1150.361



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Results - MW Losses

- With the plant data from 3/24/2010 without turbine efficiencies, the generation should be 2.642 MWe higher than design conditions
- With LP Efficiencies 13.409 MWe drop
- With throttle valve pressure reduced to 704.5 from 738.9 psia (4.15% drop) 8.443 MWe drop
- With HP Efficiencies based on design expansion line and actual plant pressures – 3.688 MWe





Results – MW Losses

- About 5 MWe short of actual measured output
 - Instrument Error (HP exhaust 11 psia low; worth 3 MWe)
 - Other cycle losses (valve leaks, feed flow error, etc.)
 - HP turbine not expanding on design expansion line
- New HP efficiencies if the 5 MWe due to HP turbine

Governing85.10%84.41%0.69%1st Stage82.20%80.30%1.90%	HP Stage	Case 6	Case 7	Delta
1 st Stage 82.20% 80.30% 1.90%	Governing	85.10%	84.41%	0.69%
	1 st Stage	82.20%	80.30%	1.90%

Results – New HP Turbine

- New HP turbine and throttling conditions 1157.679 MWe 54.655 MWe gain
- If 5 MWe of unaccounted is not HP turbine related 49.791 MWe
- If the throttle valve outlet pressure is 4.15% less as it is currently, the gain is only 42.473 MWe
- The vendor suggests that the gain will be at least 27.5 MWe





- Throttling loss is a large contributor to underproduction
- Turbine efficiency contributes a large portion of loss as well
- The HP turbine modifications have the ability to supply the vendor suggested 27.5 MWe to as much as 50 MWe.



Future Plans

- Continue to operate at 105% OLTP
- Replace first 4 stages of HP Turbine (Fall 2010)
- •1st Stage P Tap being reinstalled (Fall 2010)
- Pre and Post Test Evaluation will be performed
- Recover Minimum 27.5 MWe (Vendor Predicted) up to Maximum 50 MWe (Based on Analysis)





Future Plans



Highlighted First 4 Stages Buckets/Diaphragms To Be Replaced













