



Optimization and Integration of 'Black-box' Models in Power Plant Flowsheets

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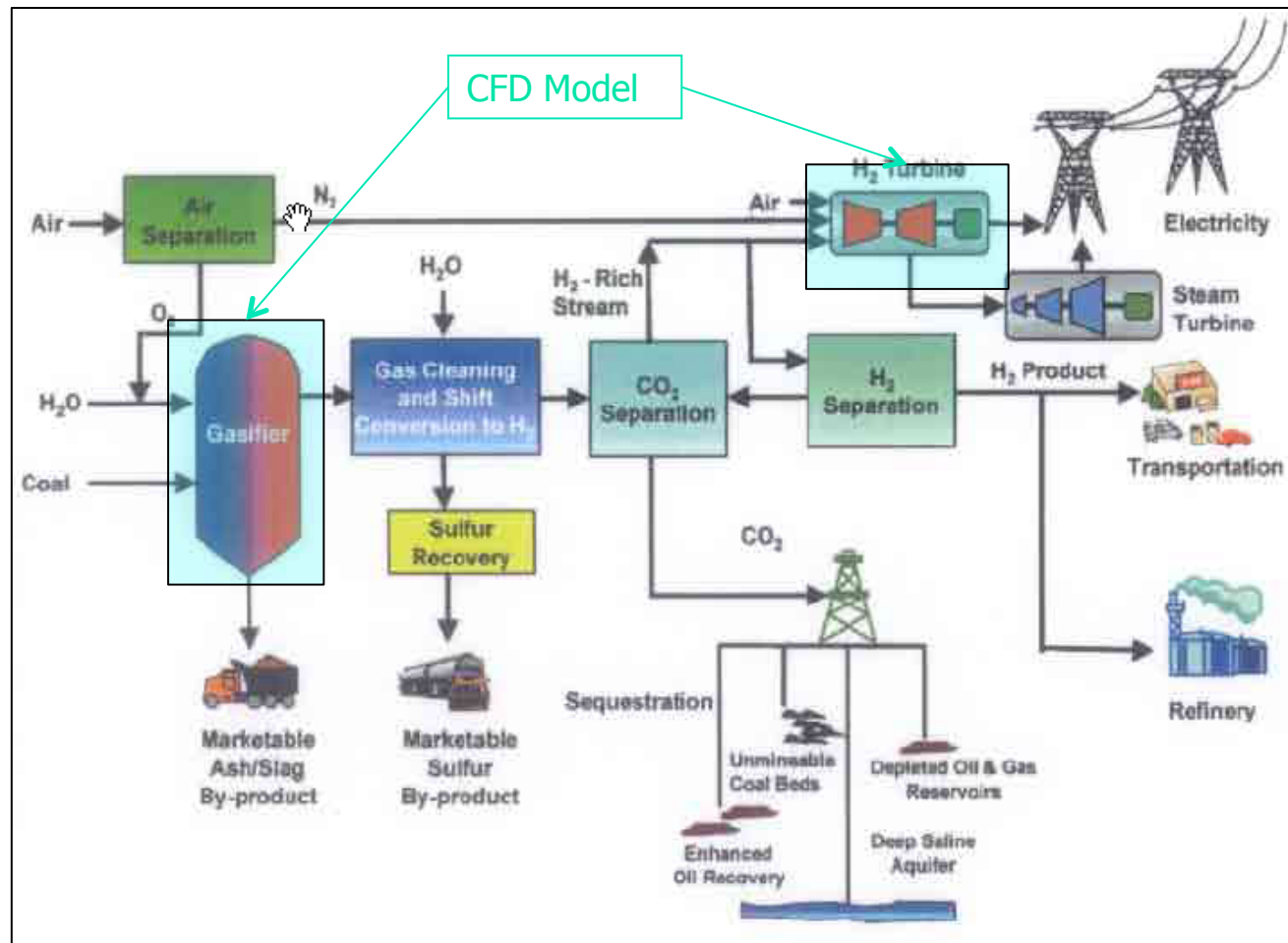
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Outline

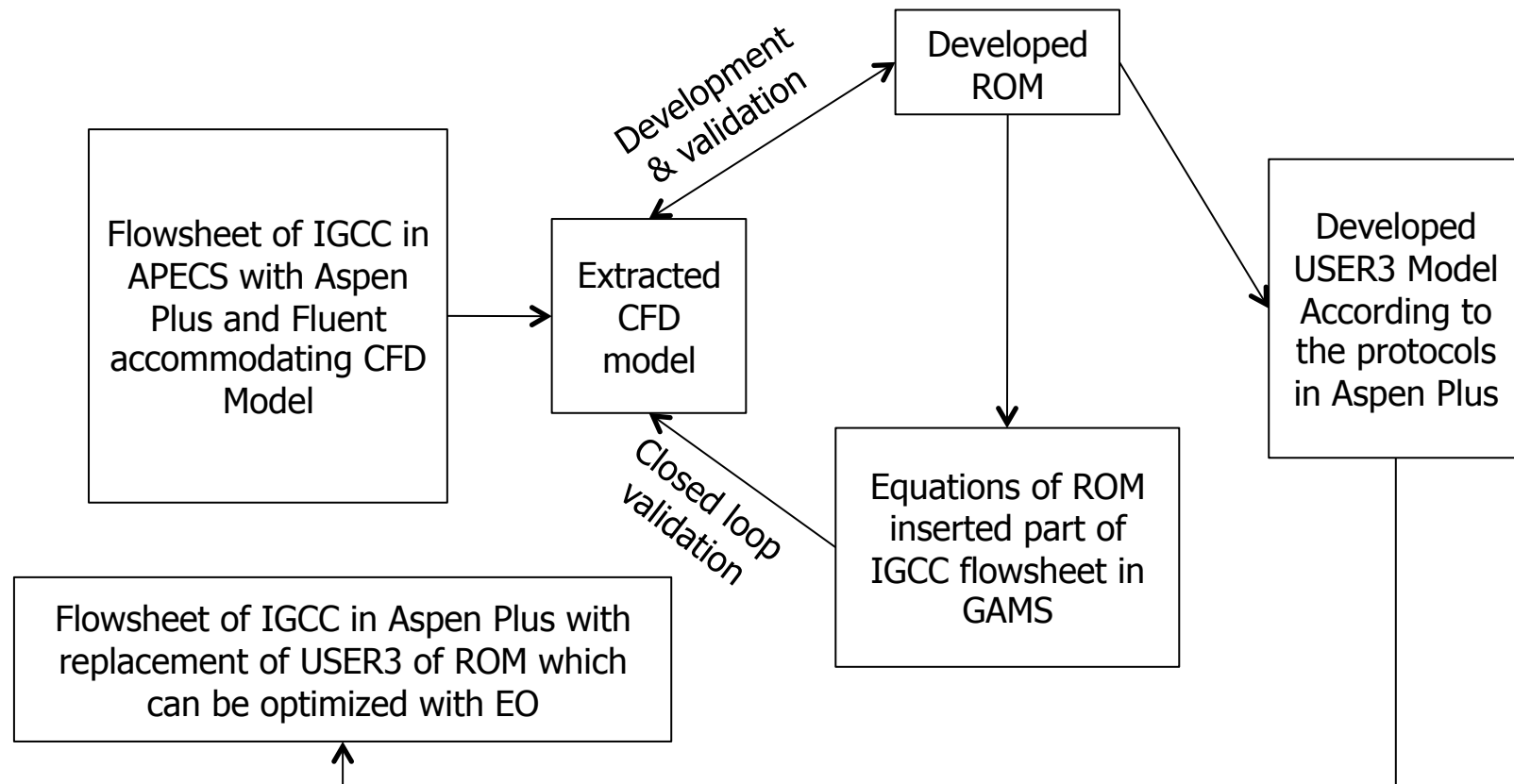
- Motivation
- Development of ROM
- Wrapped yROM for flowsheet
- Integration of ROM into Flowsheet in GAMS
- Optimization and Closed loop evaluation
- Converting yROM into USER3 model
- Integrating the USER3 with IGCC in AspenPlus for further Optimization with EO mode

Concepts of APECS: Co-Simulation with Aspen Plus and Fluent



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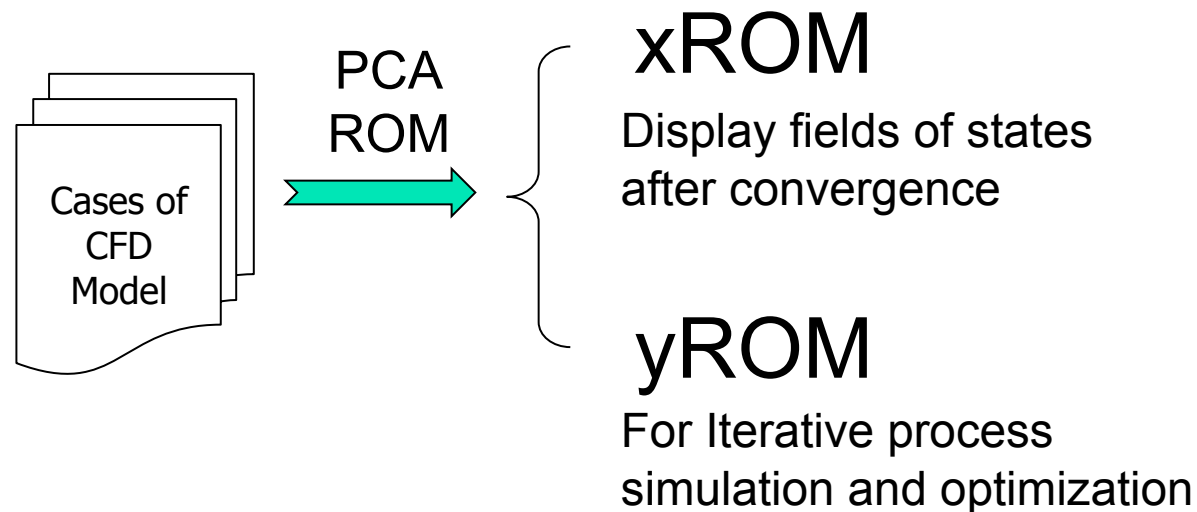
Road map from CFD model to "Black box" model



ROM Development for CFD Model

ROM is a remedy to overcome CPU time prohibited of CFD model in iterative computing of co-simulated flowsheet simulation and optimization

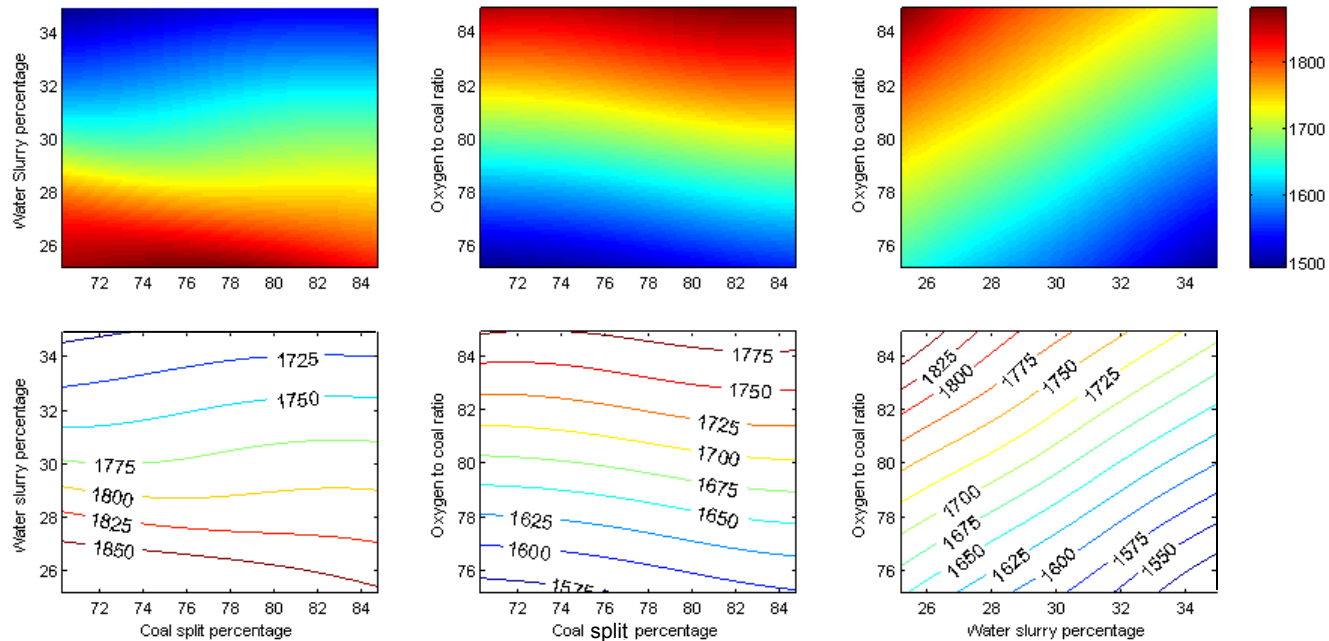
1. Determine operation domain, Experimental design (LHS)
2. Run Fluent cases according to the results of Experimental design



Ref: Lang et al., Reduced Order Model Based on Principal Component Analysis for Process Simulation and Optimization†, *Energy & Fuels* **2009**, 23, 1695–1706

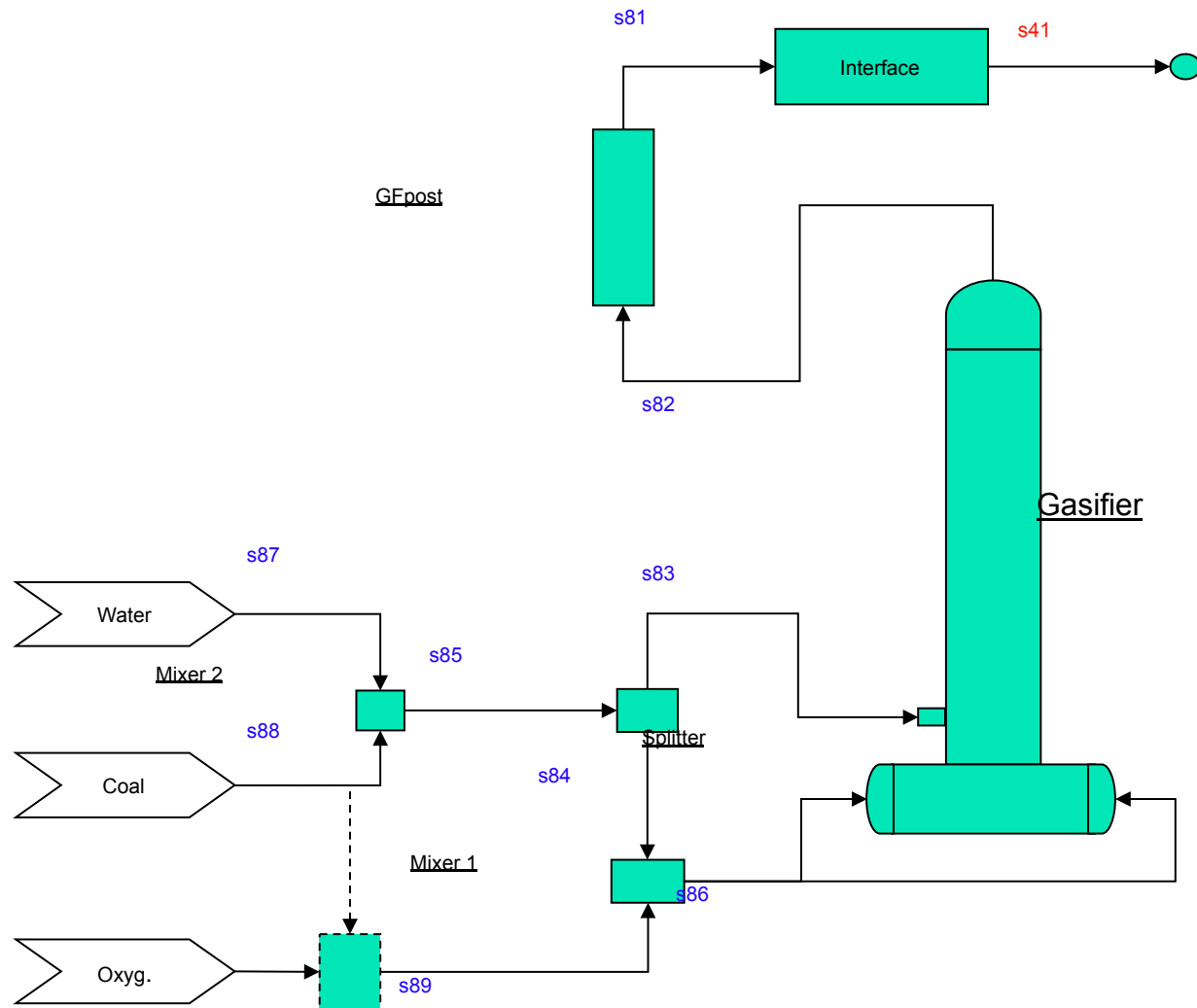
Development and Validation of ROM for Gasifier

The predicted effect of inputs on outlet temperature given by yROM shows reasonable reliability



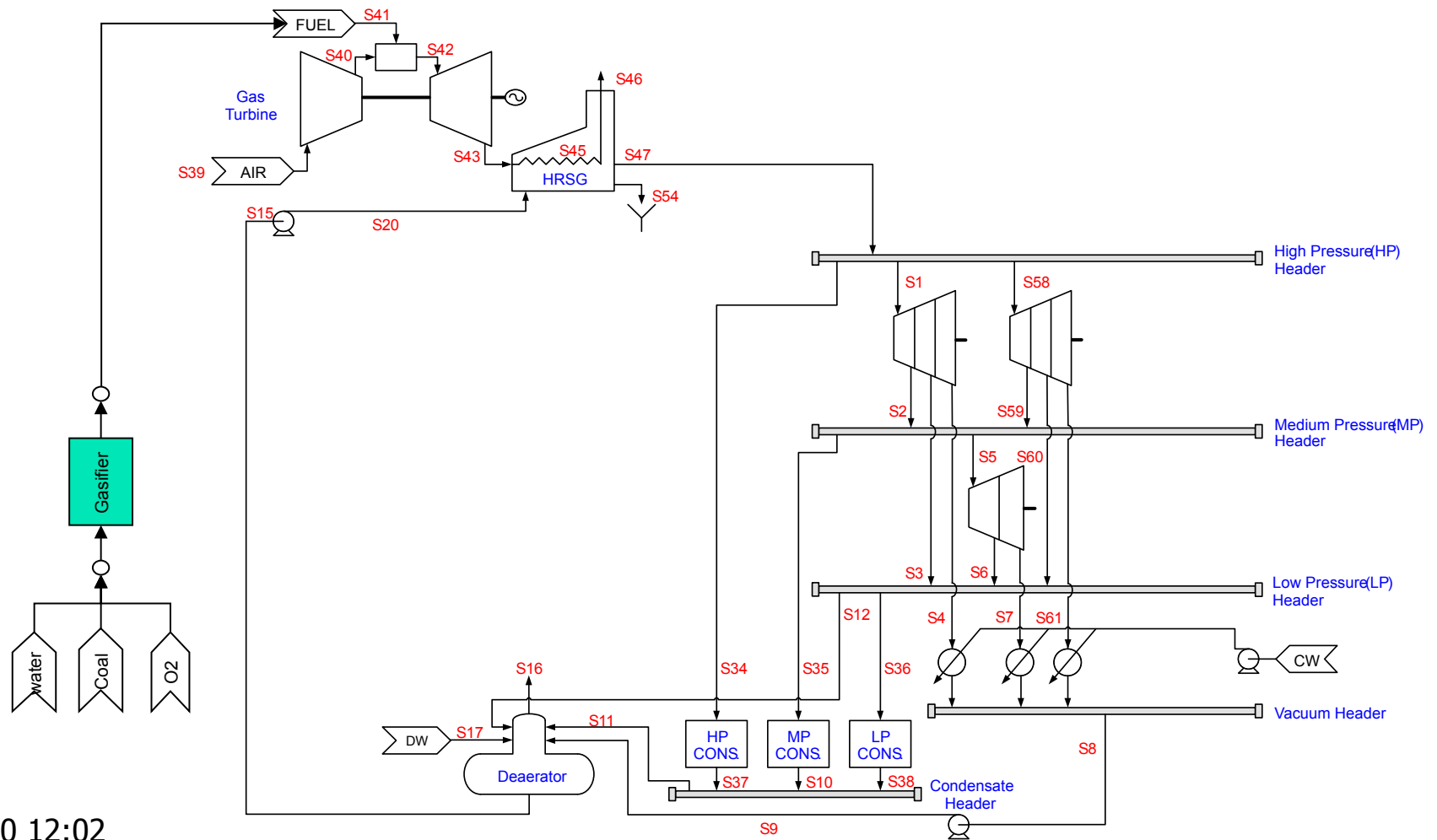
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Wrapping yROM of Gasifier as a section of flowsheet



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Integration yROM of Gasifier and Steam Cycle



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Optimal Solution

Minimizing Objective Function Subject to

Power Demand (Net Electricity): **500 MW**

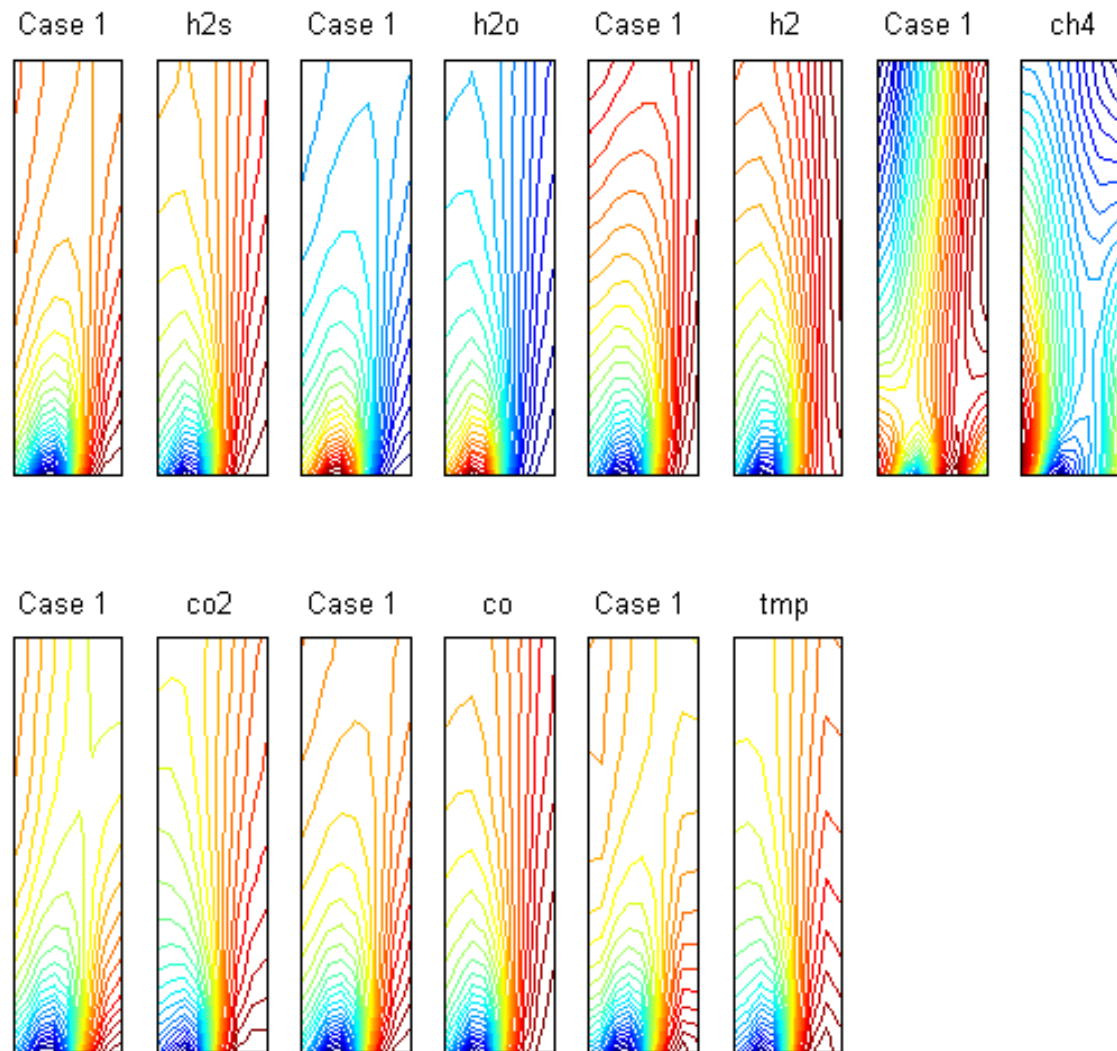
	Objective Function	Add. Constr	Optimal solutions		
			u1	u2	u3
1	Heating Value of Syngas	No	84.6928	34.9266	84.8813
2	Coal Feed flowrate	No	70.3411	25.2085	75.2154
3	Heating Value of Syngas	Tout > 1660 Tout < 1670	84.6928	34.9266	82.716198
4	Coal Feed flowrate	Tout > 1660 Tout < 1670	70.3411	25.2085	75.912813

Results of closed loop test for yROM

		H2S	H2O	H2	CH4	CO2	CO	Temp(K)
Loop test (1)	ROM	0.013172	0.305403	0.011566	0.025022	0.067842	0.552102	1709.19
	Fluent	0.013149	0.305228	0.011611	0.024865	0.069569	0.550176	1712.65
	Error(%)	0.17	0.06	0.38	0.63	2.48	0.35	0.20
Loop test (2)	ROM	0.015087	0.207855	0.017510	0.031057	0.065993	0.635727	1644.08
	Fluent	0.015114	0.206340	0.017904	0.030502	0.065742	0.638125	1627.54
	Error(%)	0.18	0.73	2.20	1.82	0.38	0.38	1.02
Loop test (3)	ROM	0.013277	0.304384	0.011538	0.027482	0.061432	0.557007	1670.00
	Fluent	0.013280	0.302956	0.011573	0.028183	0.065889	0.552833	1667.49
	Error(%)	0.02	0.47	0.30	2.49	6.76	0.76	0.15
Loop test (4)	ROM	0.015042	0.206258	0.017836	0.029846	0.073121	0.631096	1660.00
	Fluent	0.015602	0.211528	0.016875	0.031671	0.063249	0.635083	1657.04
	Error(%)	0.13	2.49	5.69	5.76	15.61	0.63	0.18

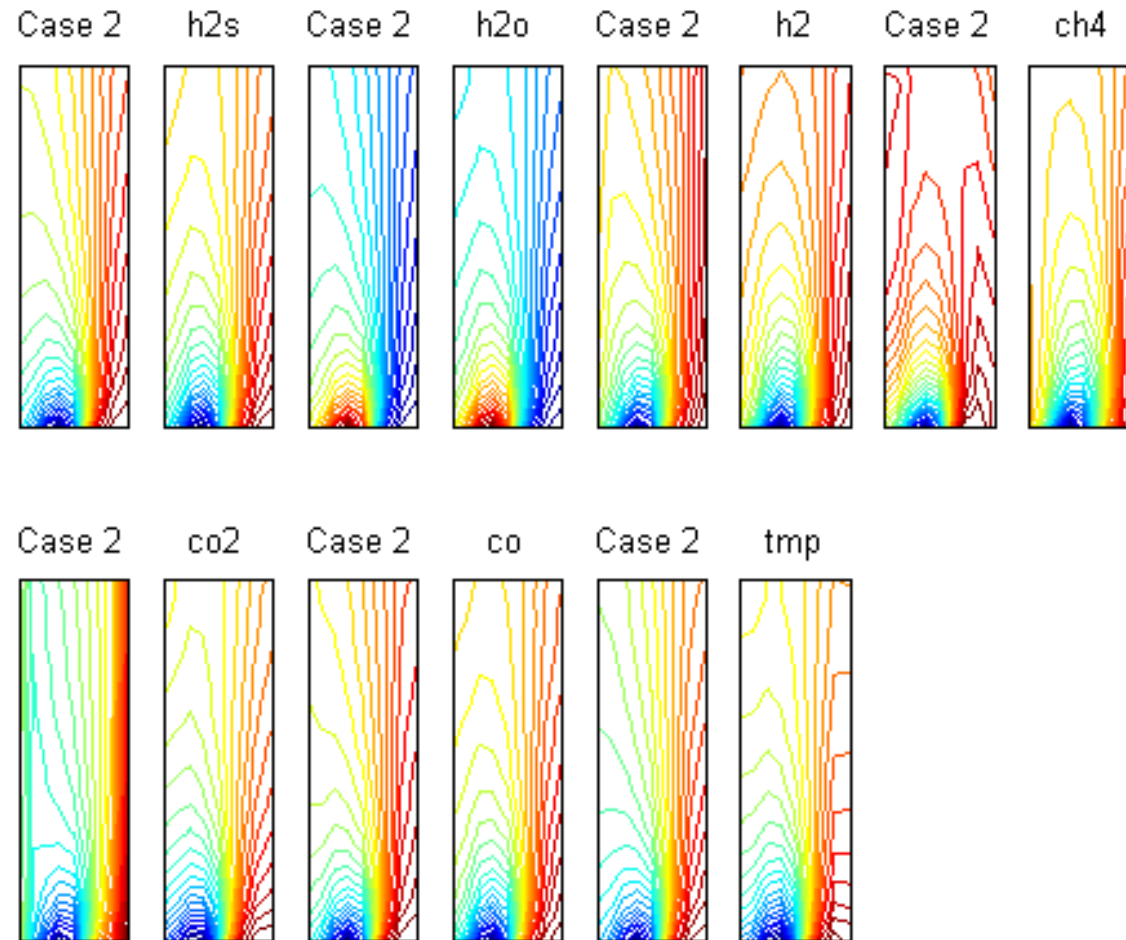
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Closed Loop (1) for xROM

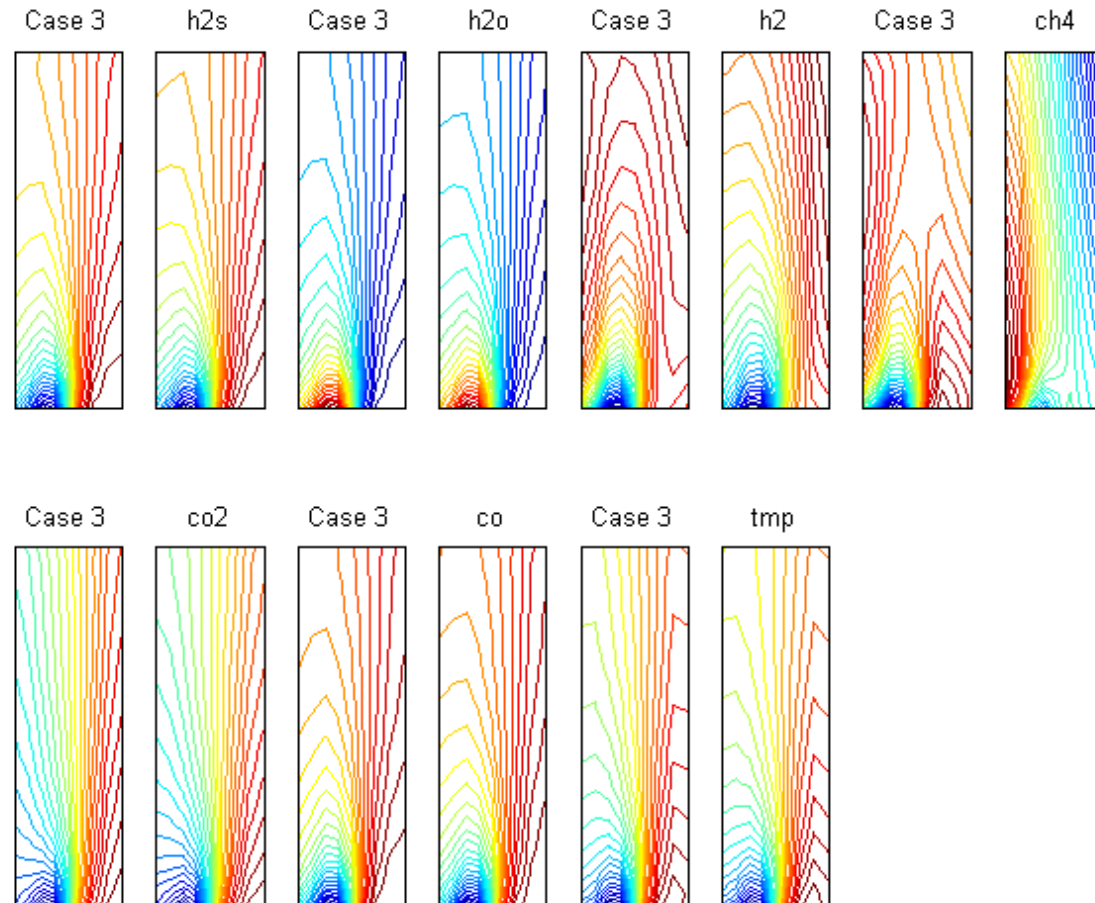


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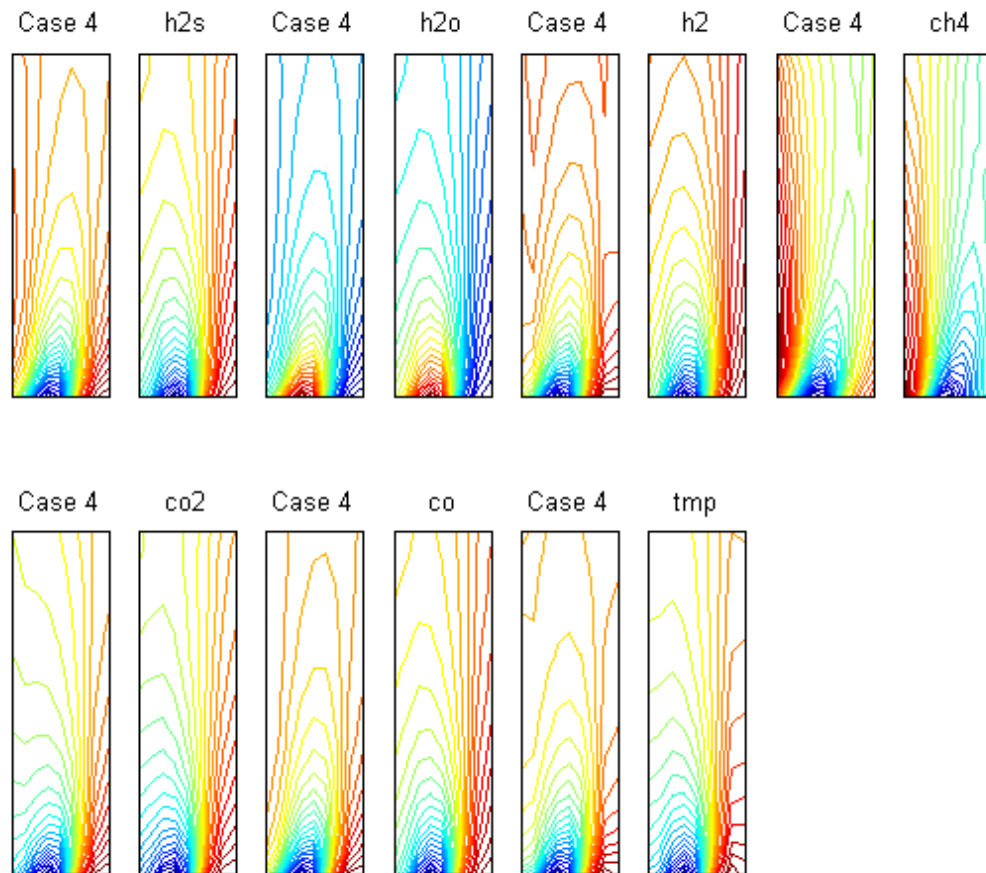
Closed Loop (2) for xROM



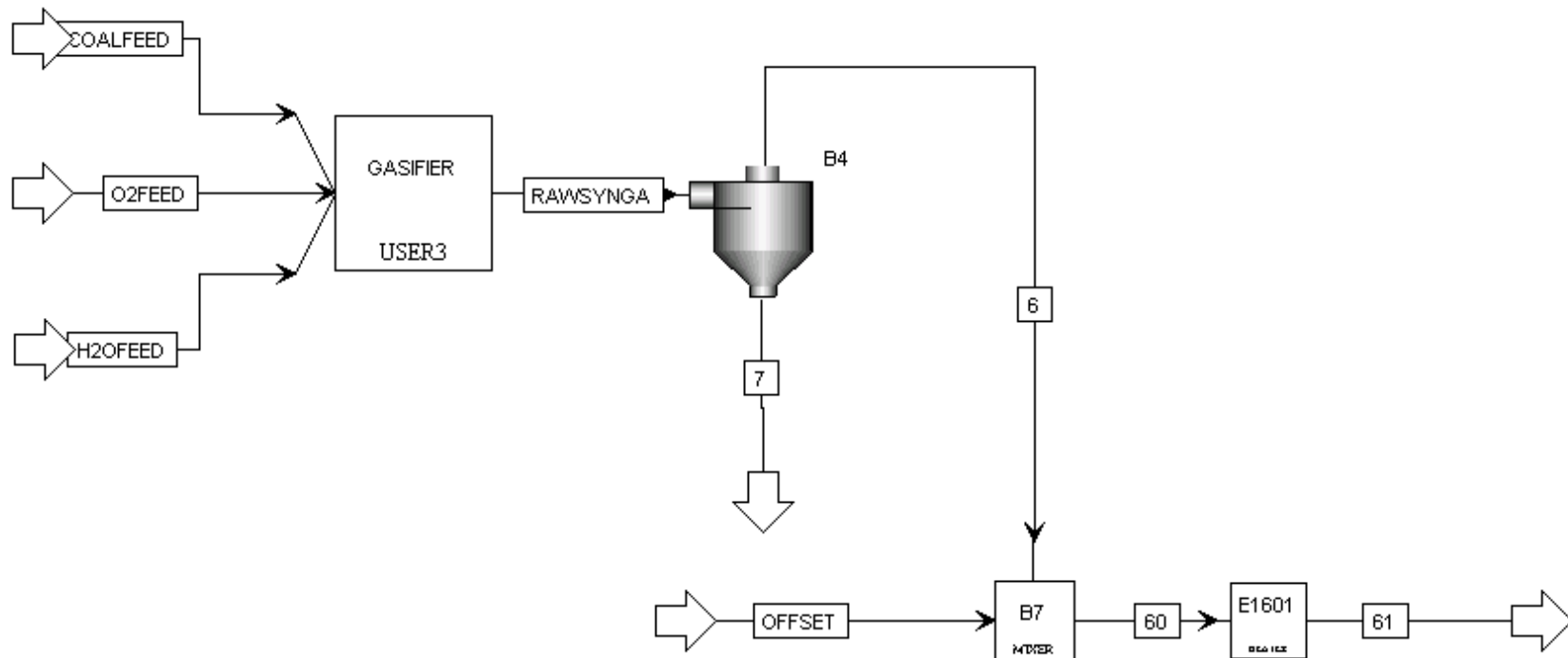
Closed Loop (3) for xROM



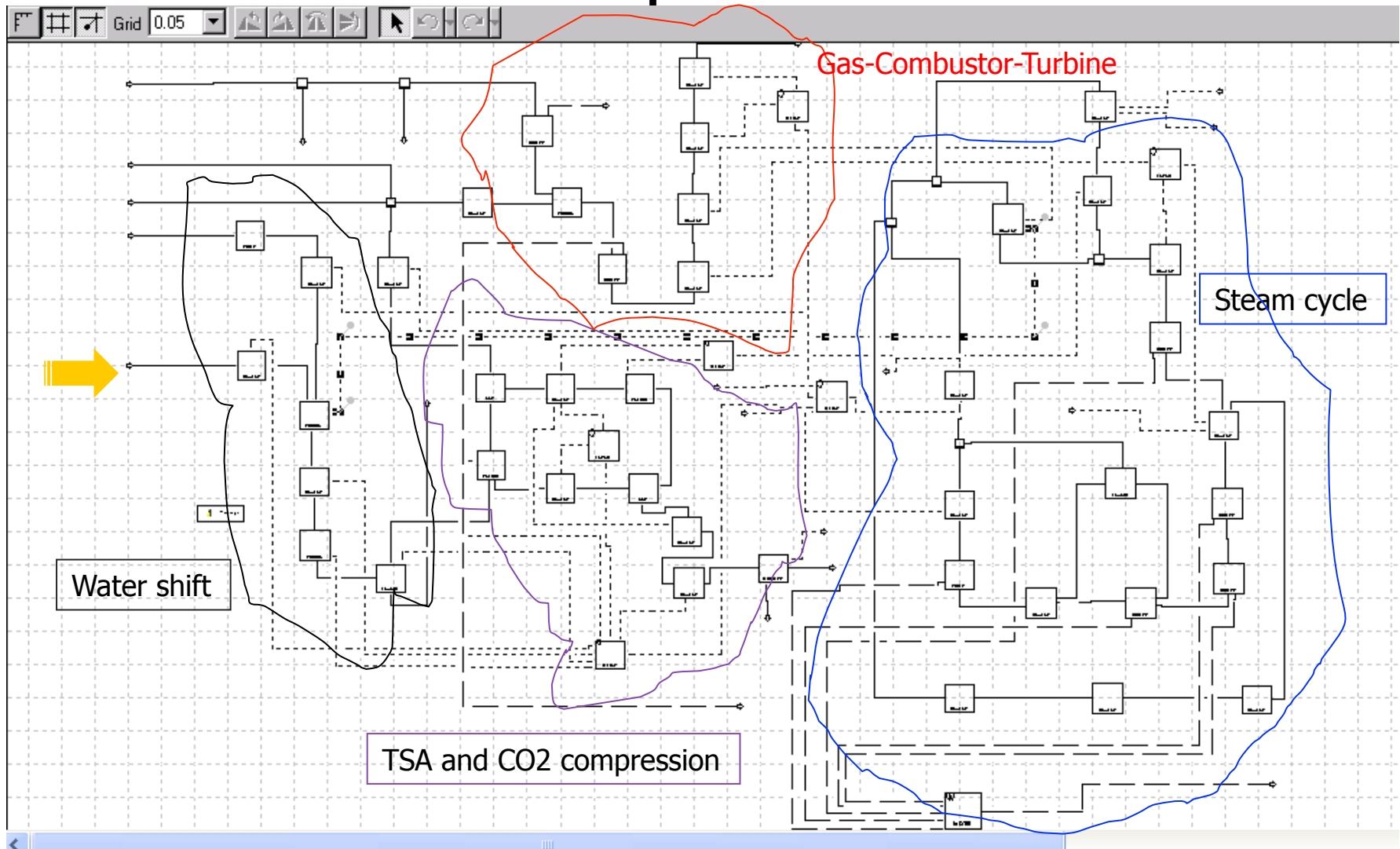
Closed Loop (4) for xROM



Converting yROM into USER3 model in Aspen Plus



IGCC flowsheet and integration of replaced CFD model



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Conclusions

- The concept of APECS is extended to process optimization by replacing CFD model with its PCA ROM in IGCC flowsheet
- ROM for gasifier is developed and validated
- 'Closed loop' tests in GAMS show that validation from converged Fluent case is encouraging.
- Conversion from yROM into USER3 model is successfully implemented and can be integrated with an existing IGCC flowsheet
- We are now aiming at EO mode of the simulator, it is potentially possible to use novel NLP solver like Ipopt in process optimization for IGCC

Future Work

- ROM of Gas turbine combustor will be developed following the procedures of PCA ROM
- Convert its yROM into USER3 in Aspen Plus and integrate with IGCC
- Implement optimization with integrated two 'Black-box'es using EO and open solver in Aspen Plus