Dynamic Simulation of a Conceptual 600MW Oxyfuel Combustion Power Plant

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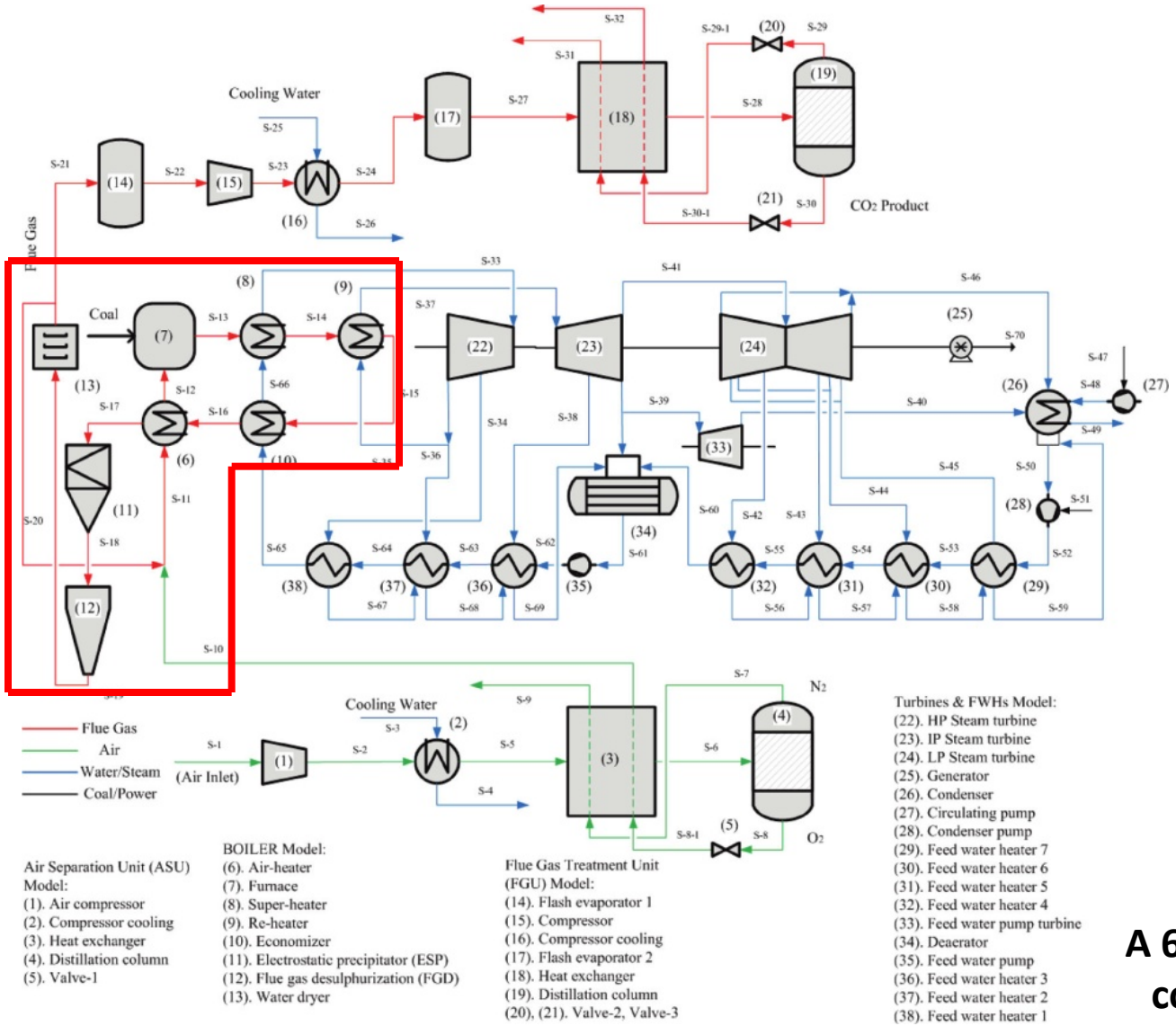
Process simulation

- **Steady-state simulation**
  - mass and energy balances
  - material and energy flows
  - exergy analysis, thermoeconomic evaluation,….
- **Dynamic simulation**
  - dynamic characteristics
  - system operation/design/optimization
  - control strategy
  - safety analysis
  - ……

Outline

- From steady-state simulation to dynamic simulation
- Dynamic analysis
- Conclusion

Steady state model



- Coal, an <u>unsupported</u> material in Aspen dynamics
- ✓ **Pseudo-coal (C_aH_b+S+N+O) to meet proximate and ultimate analysis**

A 600MWe conceptual oxy-combustion power plant

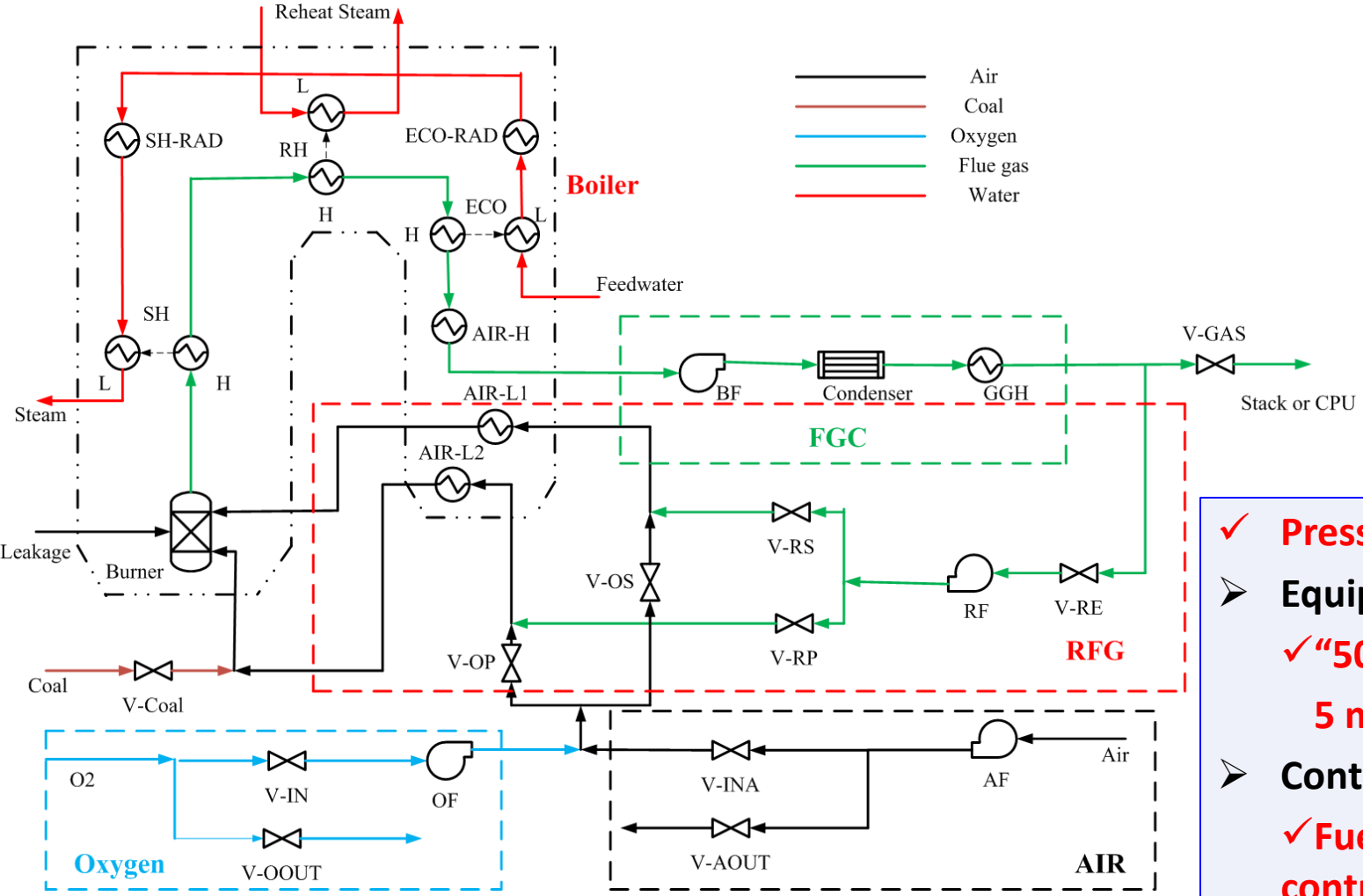
Xiong, J., H. Zhao*, C. Zheng, *Energy & Fuels* 25(5)(2011) 2405-2415.

Pseudo-coal validation

Composition	Air combustion		Oxyfuel combustion	
	Real coal	Pseudo coal	Real coal	Pseudo coal
O_2 (%)	3.14	3.15	3.35	3.13
N_2 (%)	73.30	74.24	7.42	6.26
Ar (%)	0.92	0.93	3.13	3.39
H_2O (%)	7.59	7.70	13.16	14.20
CO_2 (%)	14.99	13.92	72.73	72.82
NO (ppm)	252	254	83	74
NO_2 (ppm)	0.77	0.77	0.26	0.22
SO_2 (ppm)	395	377	1913	1970
SO_3 (ppm)	5.26	5.03	26.35	26.21
CO (ppm)	0.51	0.47	2.40	2.49

Relative error less than 8.3 %

Steady-state model converted into dynamic model



Dynamic model of a conceptual 600MWe Oxyfuel pulverized coal-fired boiler

- ✓ Pressure driven
- ➢ Equipment sizing
  - ✓ "50 percentages, 5 minutes" principle
- ➢ Control structure;
  - ✓ Fuel feed flow controller;
  - ✓ Pressure controller;
  - ✓ Tasks

Dynamic simulation validation

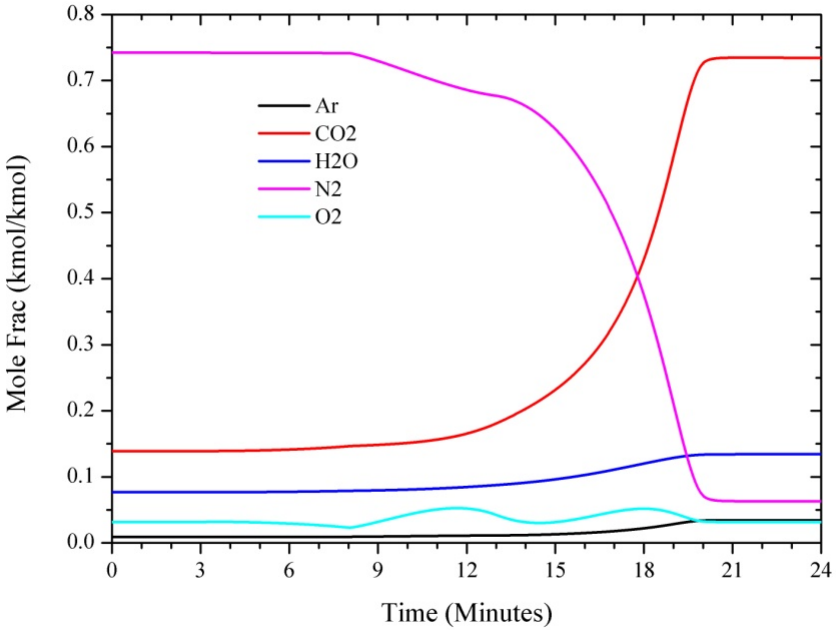
Items	Steady model	Dynamic model	Items	Steady model	Dynamic model	Items	Steady model	Dynamic model
Gas Composition			Flow rate (kmol/s)			Temperature (°C)		
O_2, %	3.13	3.16	Flue gas (w)	17.72	17.58	Burner	1100	1100
N_2, %	6.26	6.31	Fuel (Coal)	0.50	0.50	Superheater	1023	1023
Ar, %	3.39	3.42	Oxygen	5.15	5.15	Reheater	891	889
H_2O, %	14.20	13.46	Air-Inleak.	0.31	0.31	Economizer	792	790
CO_2, %	72.82	73.44	Recy. flue gas	10.90	10.75	Air prehe.	174	177
NO, ppm	73.50	74.26	Flue gas (d)	15.68	15.47	Cooler	30	24
NO_2,ppm	0.22	0.23				Stack	172	181
SO_2,ppm	1970	1983				Primary air	110	115
SO_3,ppm	26.21	26.54				Second. air	330	339
CO, ppm	2.49	2.49				Oxygen	30	35

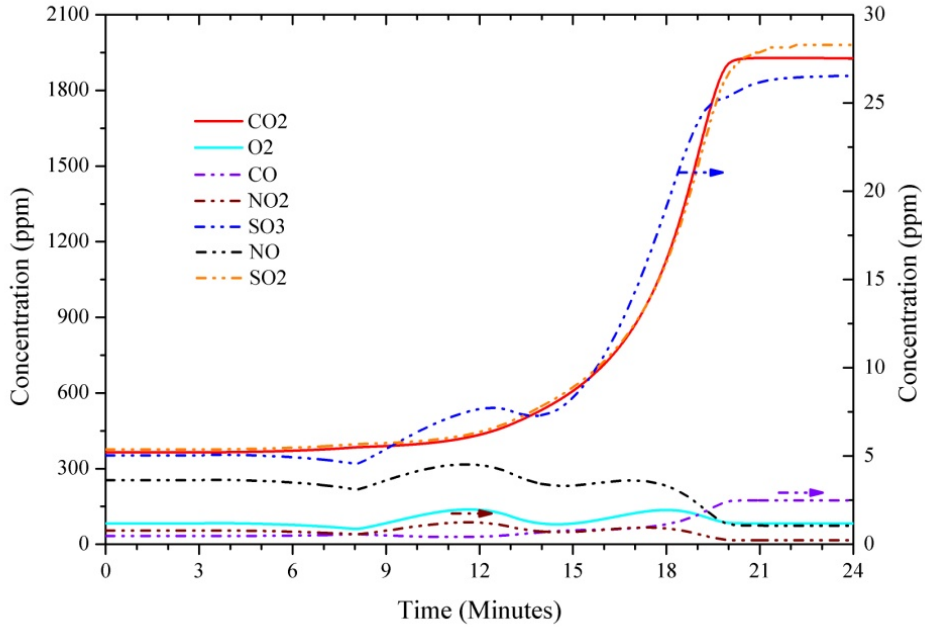
Relative error less than 5.2%

Outline

- From steady-state simulation to dynamic simulation
- Dynamic analysis (mode switching)
- Conclusion

Switching from air-combustion to oxy-combustion (17 min)

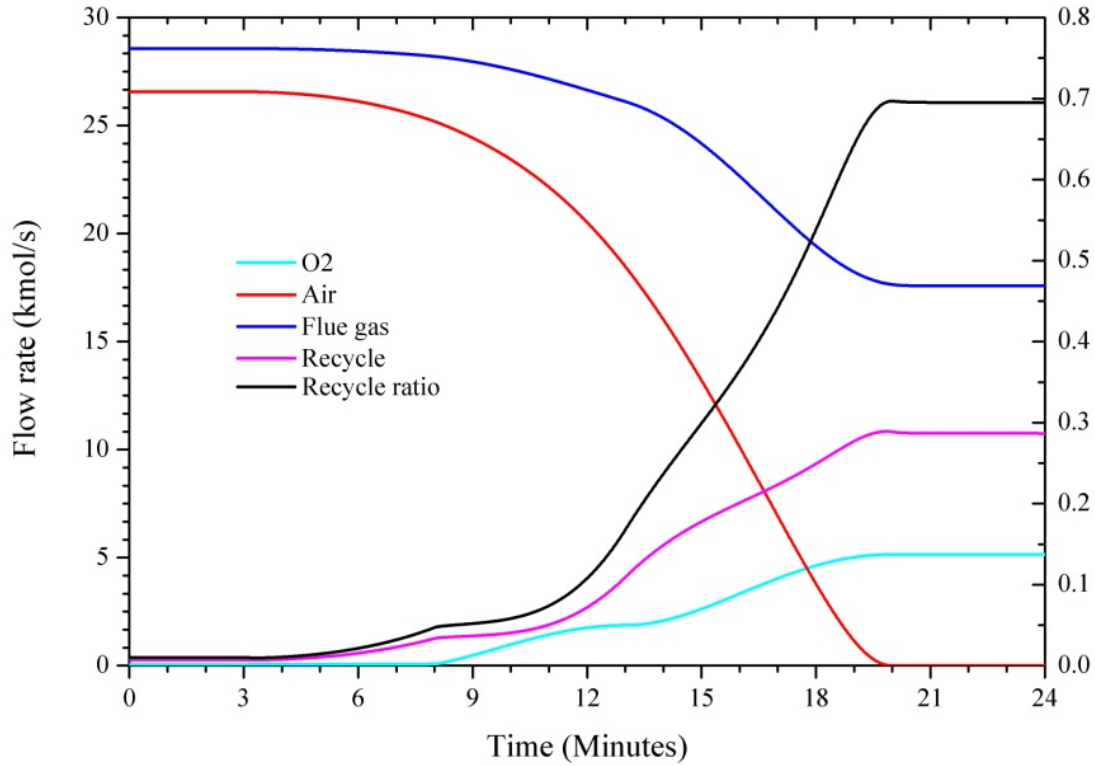




- ✓ CO_2 : 13.92% to 73.44% ; H_2O: 7.68% to 13.46%; CO concentration increases slightly.
- ✓ NO_x concentration decreases slightly, and **follows with the oxygen concentration evolution**.
- ✓ SO_x concentration increases to **5.3** times of that of air combustion, and **follows with the CO_2 concentration evolution**.

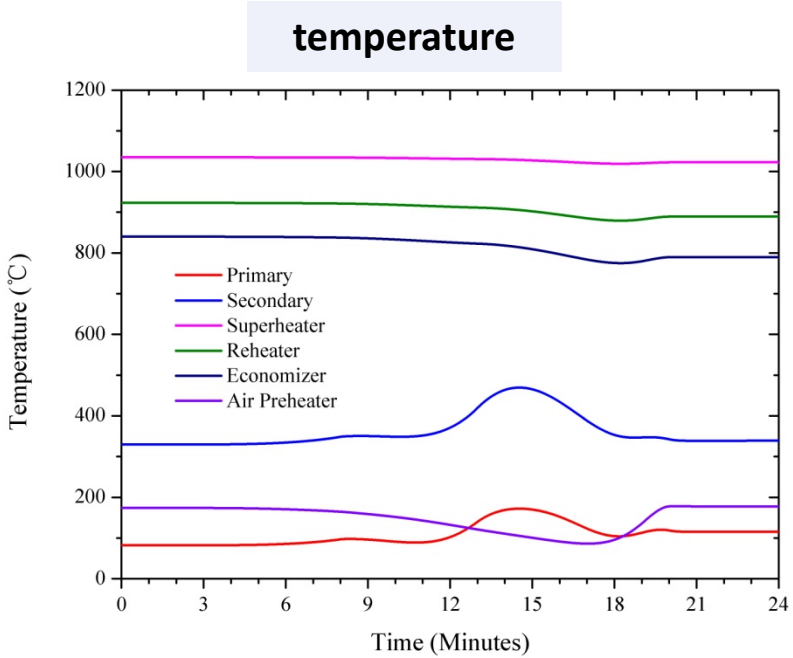
Switching from air-combustion to oxy-combustion

- **Operating air, recycled flue gas (RFG) and oxygen with individual flow rates**
  - ✓ **Cutting off air: 1.56kmol/min;**
  - ✓ **Oxygen injection: 0.39kmol/min (8-13min) and 0.72kmol/min(13-20min);**
  - ✓ **Recycled flue gas by the pressure PID controller.**



- **Recycle ratio Increases to 69.5% and changes in three stages.**
  - ✓ **From 3 to 8 min, it increases gradually, while it changes flatly from 8 to 13min. At last, it increases in another rate from 13 to 20 min.**

Switching from air-combustion to oxy-combustion

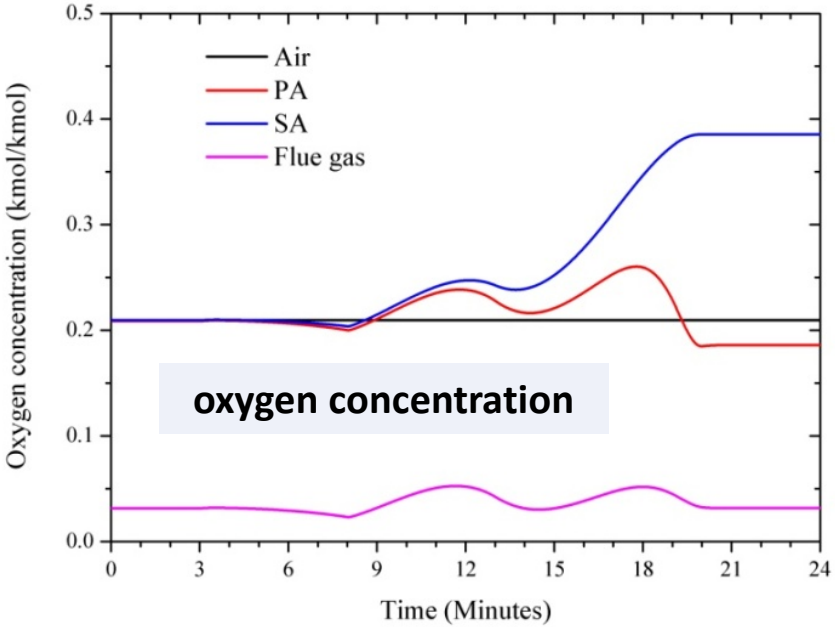


➢ Flue Gas Temperature

- ✓Superheater, reheater, economizer: decrease slightly;
- ✓Primary and secondary airs, air heater flue gas : change drastically.
- ✓Reducing the heat transfer area in the air preheater to regulate the PA and SA temperature

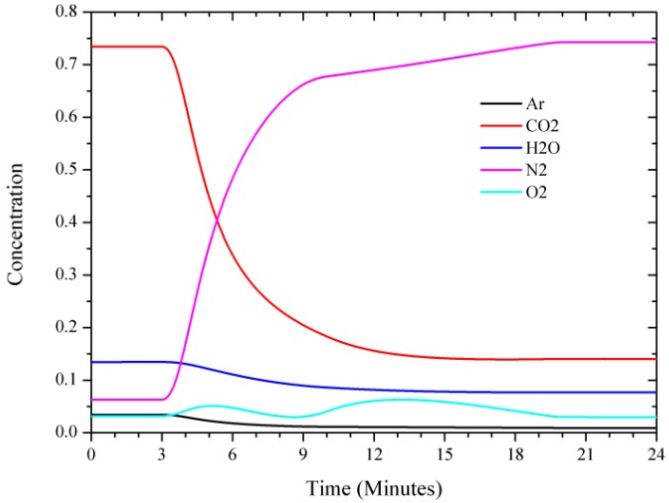
➢ Oxygen concentration

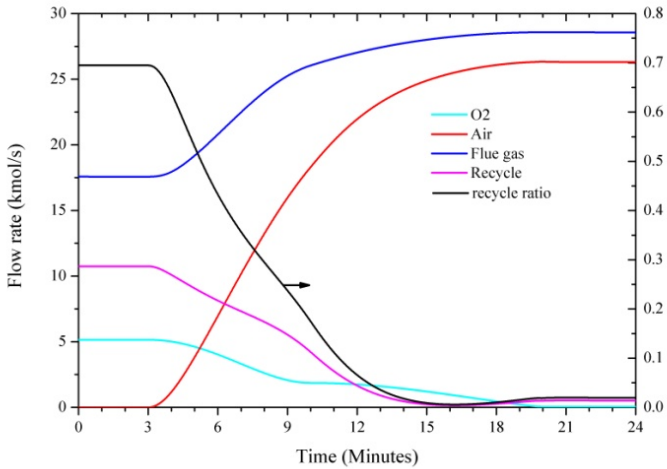
- ✓ Oxygen concentration in flue gas at the exit of furnace is maintained at 2 to 7 % to make similar heat transfer profile wit that of air-combustion.
- ✓ The oxygen concentration decreases to 18.61% in primary gas and increases to 38.55% in secondary gas.



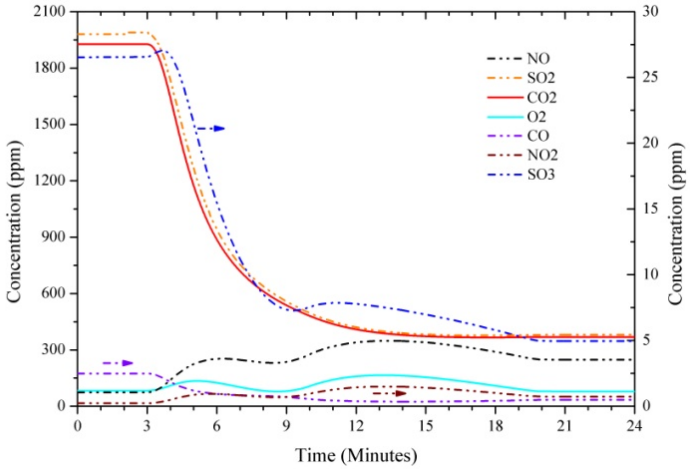
Switching from oxy-combustion to air-combustion

- The dynamic processes evolve **in an opposite way**.
- Difference rates to Cut off the oxygen, Supply the air and Recycle flue gas





flow and recycle ratio



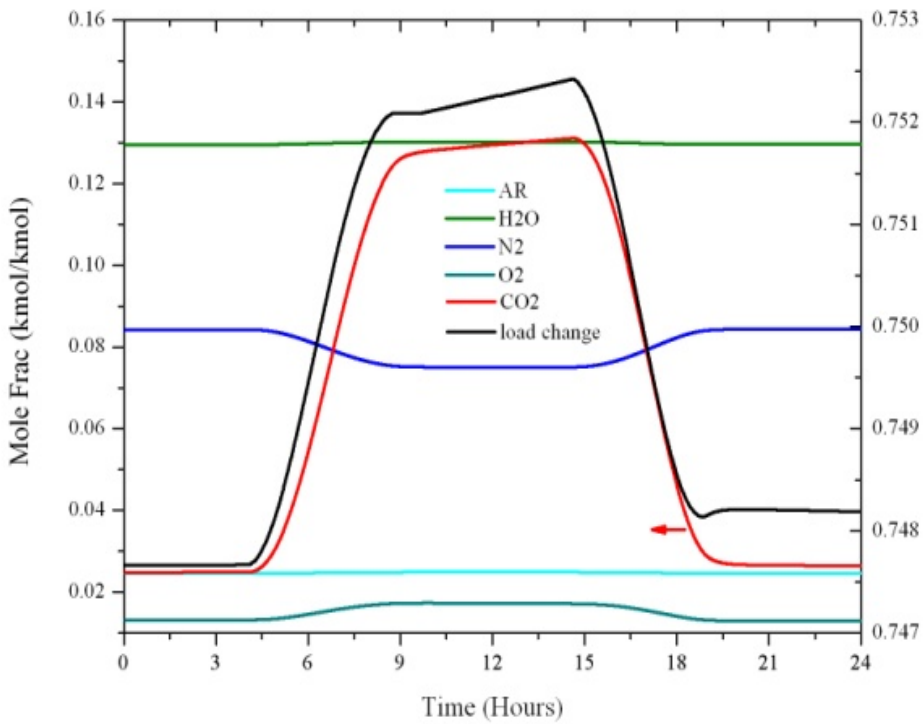
Gas composition

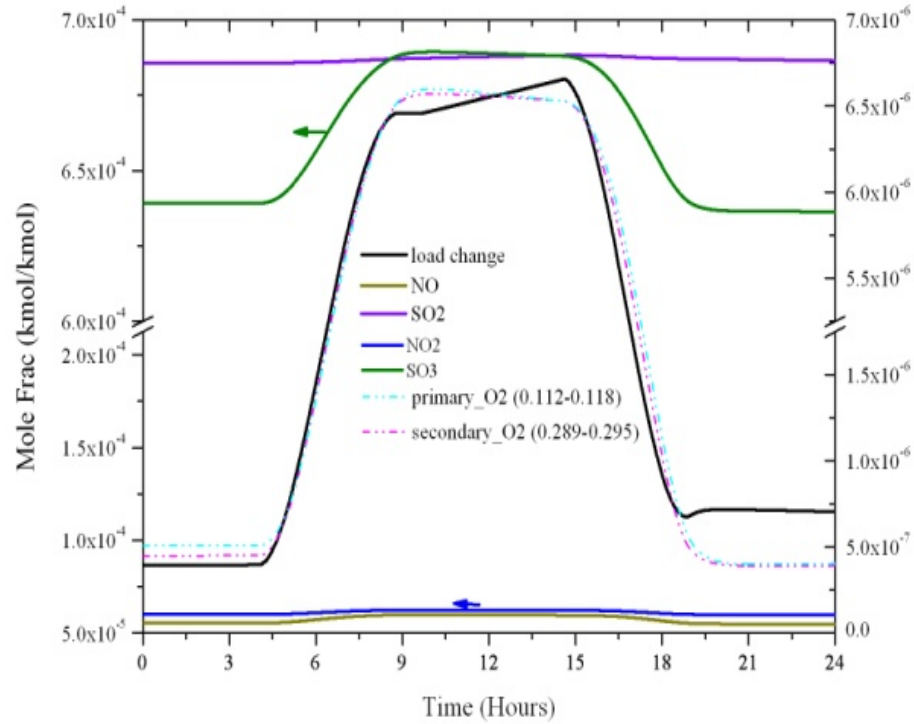
Outline

- From steady-state simulation to dynamic simulation
- Dynamic analysis (disturbances)
- Conclusion

Load Change

- the load increases 6% with 5 hours, then stabilizes within 9 hours, and finally drops 5% within 5 hours
- the concentrations of CO_2, SO_3 in final flue gas and O_2 in primary and secondary airs respond the load change very fast





Outline

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Conclusion

- **Dynamic model of a 600MWe Oxyfuel pulverized coal-fired boiler in Aspen Dynamics was established and validated.**
- **Switching process from air-combustion to oxy-combustion and then back to air-combustion was realized.**
- **A switching strategy, which operates the oxygen, air and recycled flue gas simultaneously at individual rates, was developed.**
- **The effect of some planned disturbances on dynamic characteristics was investigated.**

THANK YOU FOR YOUR ATTENTION!