OTU-CFB boiler control design with the dynamic relative gain array and partial relative gain

SUPPORTING INFORMATION

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Table S1. Steady-state gain effects in the OTU-CFB, normalized with the input maxima.

	T.valve	**FW**	**Fuel**	**Prim air**	**Sec air**	**Tot DSH**	**DSH 1**	**DSH 2**	**DSH 3**	**RHvalve**	**Firing power**	**Boiler load**
Steam p	–1.0	0.04	0.2	–0.1	–0.1	0.04	0.04	0.03	0.03	0.1	0.2	0.2
Steam T	–0.2	–1.0	1.0	–0.4	–0.4	–1.0	–1.0	–1.0	–1.0	0.8	1.0	0.02
Evap. T	–0.4	–0.2	0.3	–0.2	–0.1	–0.1	–0.1	–0.1	–0.1	0.3	0.3	0.1
FG O_2	0.0	0.0	–0.0002	0.001	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FG T	–0.1	–0.3	0.6	–1.0	–1.0	–0.2	–0.2	–0.2	–0.2	0.1	0.4	0.1
SH2 T	–0.3	–0.8	0.8	–0.3	0.04	–0.5	–0.8	–0.4	–0.3	0.8	0.8	0.02
SH3 T	–0.2	–1.0	1.0	–0.6	–0.2	–0.8	–1.0	–1.0	–0.4	0.9	1.0	–0.02
RH T	–0.1	–0.7	0.8	0.002	–0.3	–0.7	–0.7	–0.7	–0.6	–1.0	0.8	0.1
Tot MW_e	0.01	0.1	1.0	–0.2	–0.4	0.1	0.1	0.1	0.1	–0.3	1.0	1.0

Table S2. The steady-state RGA matrix of the case 2 system, 5 input MVs and 5 output CVs.

RGA	**MV →**	**T.valve**	**DSH1**	**DSH2**	**DSH3**	**Boiler load**
CV ↓	INDEX	**1**	**2**	**3**	**4**	**5**
Steam p	**1**	0.989	0.025	–0.011	–0.002	–0.002
Steam T	**2**	0.0006	–0.661	0.008	1.651	0.001
SH2 T	**3**	0.005	1.797	–0.796	–0.007	0.0007
SH3 T	**4**	0.002	–0.153	1.800	–0.649	–0.0001
Tot MW_e	**5**	0.003	–0.008	–0.001	0.006	1.000

Table S3. The steady-state RGA matrix of the case 3 system, 6 input MVs and 6 output CVs.

RGA	**MV →**	**T.valve**	**FW**	**Fuel**	**Prim air**	**Sec air**	**Tot DSH**
CV ↓	INDEX	**1**	**2**	**3**	**4**	**5**	**6**
Steam p	**1**	0.983	0.127	–0.012	0.025	–0.014	–0.109
Steam T	**2**	0.008	–0.643	0.055	–0.210	0.119	1.671
Evap T	**3**	0.017	1.806	0.040	–0.186	0.078	–0.756
FG O_2	**4**	0.000	0.000	–0.058	–1.205	2.263	0.000
FG T	**5**	–0.012	–0.349	0.028	2.664	–1.507	0.176
Tot MW_e	**6**	0.003	0.059	0.947	–0.088	0.062	0.018

Table S4. The steady-state RGA matrix of the case 4 system, 8 input MVs and 8 output CVs.

RGA	**MV →**	**T.valve**	**FW**	**Sec air**	**DSH1**	**DSH2**	**DSH3**	**RHvalve**	**Firing**
CV ↓	INDEX	1	2	3	4	5	6	7	8
Steam p	1	1.049	0.122	0.000	–0.118	–0.018	0.005	–0.025	–0.015
Steam T	2	–0.014	–1.102	–0.0002	–0.065	0.175	1.629	0.270	0.108
Evap T	3	–0.050	1.764	0.0002	–0.832	–0.052	0.051	0.077	0.042
FG O_2	4	0.000	0.000	1.001	0.0002	–0.0001	0.000	0.000	–0.001
SH2 T	5	0.001	–0.212	0.000	1.934	–0.785	–0.01	0.043	0.028
SH3 T	6	0.0005	–0.147	–0.0001	–0.053	1.819	–0.651	0.026	0.006
RH T	7	0.01	0.490	0.0001	0.130	–0.136	–0.031	0.629	–0.091
Tot MW_e	8	0.004	0.086	–0.001	0.004	–0.002	0.006	–0.020	0.924

Table S5. Time domain behavior of the main MVs from the APROS dynamic model. Results are normalized for each CV with respect to the largest MV (smaller percentage, shorter time).

Normalized times	**Turbine valve**			**Firing power**			**Feedwater flow**		
% of max time	Rise time	Settling time	Time delay	Rise time	Settling time	Time delay	Rise time	Settling time	Time delay
Main steam p	5	26	0	100	100	67	0.4	89	100
Total MW_e	0.01	33	0	100	100	0	0.1	90	0
Main steam T	100	100	0	74	82	60	83	94	100
Evaporator T	17	60	0	100	100	100	96	95	50