



Technical University
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TEST CASE

Unit Commitment with Frequency Constraints and HVDC Emergency Power Control

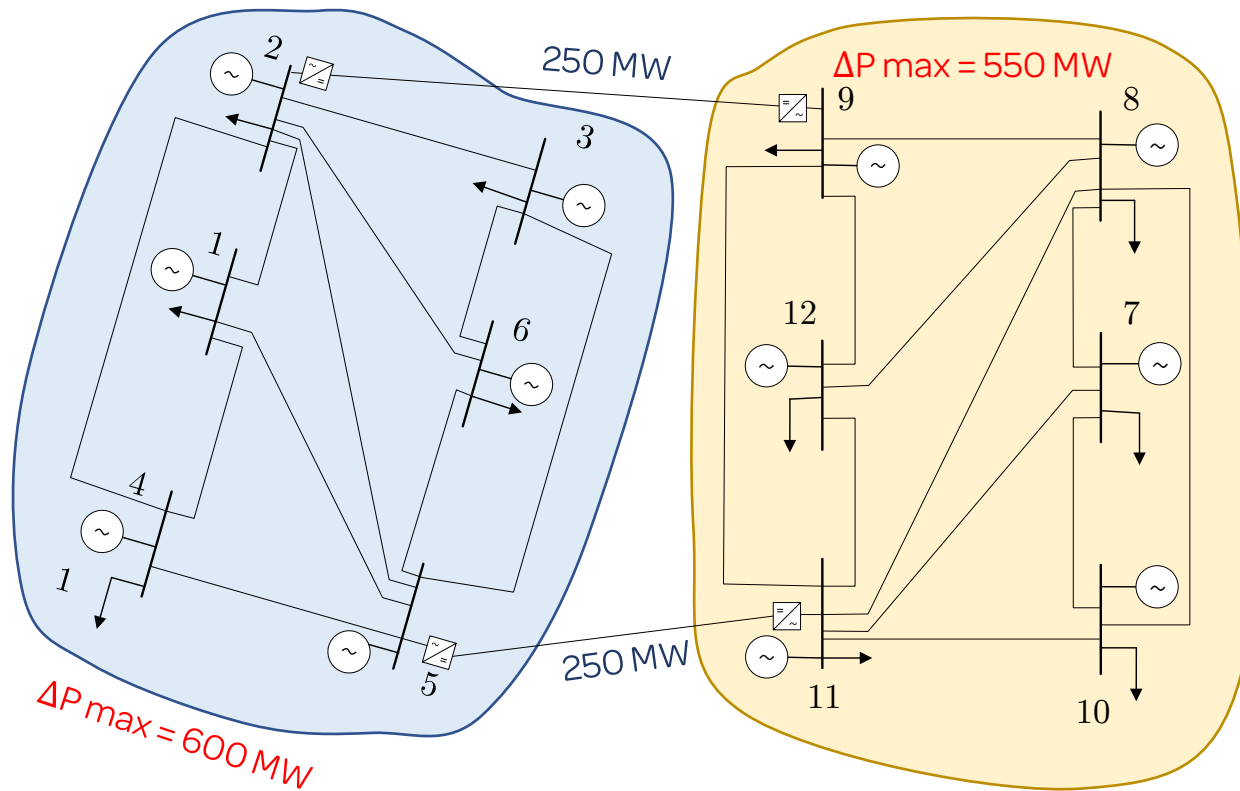
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November 24, 2020

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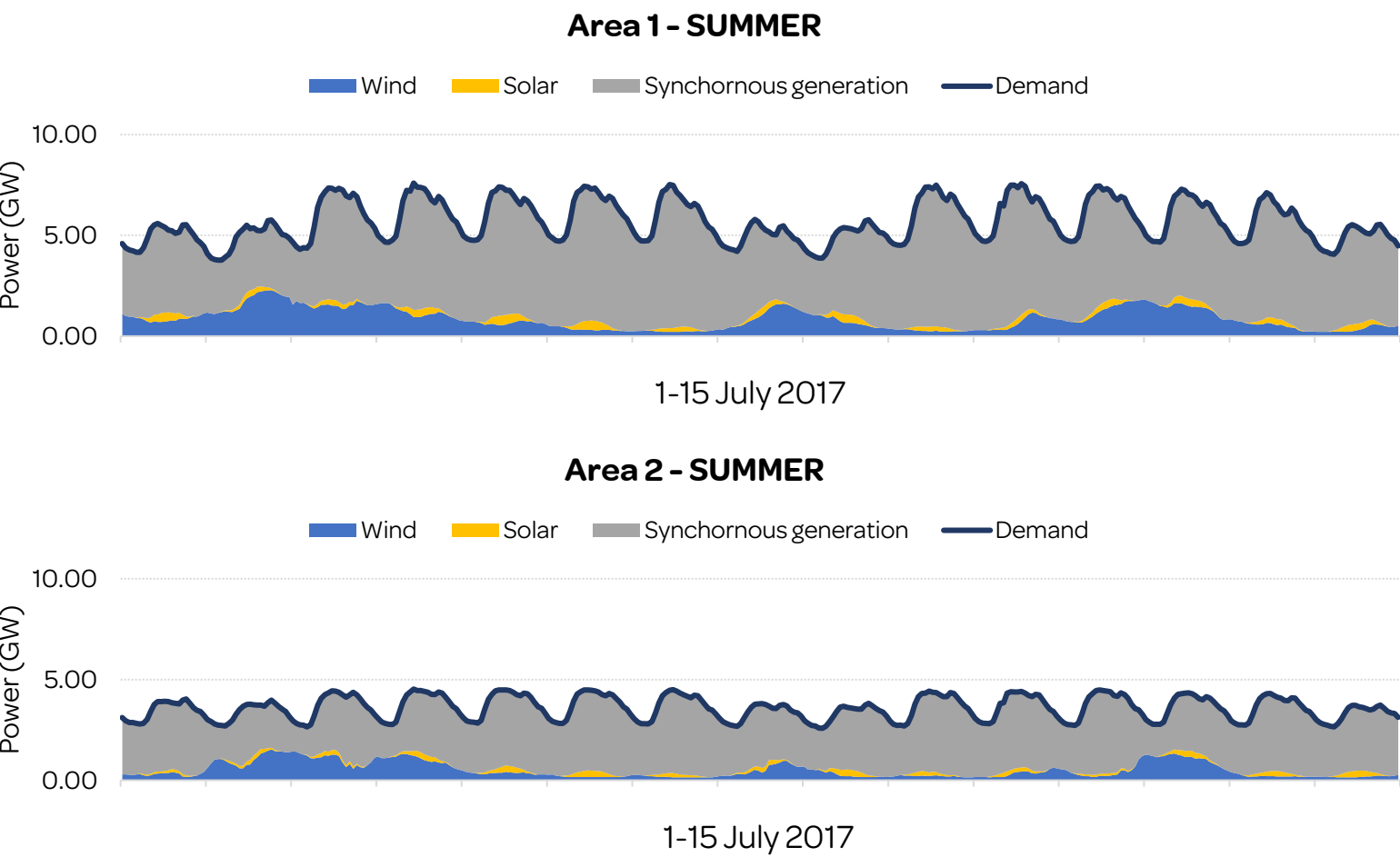
- Two 6-bus systems connected by **2 HVDC links** (500 MW in total)
- The **biggest units** in both areas are nuclear power plants (600MW area 1, 550MW area 2)
- **Peak load** is 9 and 6 GW respectively, valley load is
- The maximum penetration of **RES** is respectively 47% and 55%.

System parameters

Base power 1000 MVA		Area1	Area2
Value of Lost Load	$VoLL$	2000 €/MWh	2000 €/MWh
Value of RES curtailment	$VoRC$	1600 €/MWh	1600 €/MWh
Time constant	T	9 s	9 s
Damping	\hat{D}	2	2
Maximum IFD	Δf^{max}	0.7 Hz	0.7 Hz
Maximum RoCoF	\dot{f}^{max}	0.625 Hz/s	0.625 Hz/s
Maximum SSFD	Δf_{SS}^{max}	0.4 Hz	0.4 Hz
Base frequency	f^b	50 Hz	50 Hz

ID_GEN	BUS_#	TYPE	PMAX	PMIN	O&M COST	SU COST	SD COST	RAMP (MW)	ON TIME (h)	OFF TIME (h)	RESERVE	Ri (k€)	Fi	Ki	H (M/2)	T
1_1	1	fossil hard coal	434	130	34.82	8,800	2,200	120	17	17	1	0.03	0.35	0.95	5.00	9.00
1_2	1	fossil gas	423	127	56.04	5,600	1,400	149	2	4	1	0.01	0.15	0.95	6.00	9.00
1_3	1	fossil hard coal	399	120	47.67	5,600	1,400	98	5	5	0	0.03	0.35	1.10	5.00	9.00
1_4	1	lignite	280	84	25.89	13,600	3,400	221	7	7	1	0.03	0.35	1.10	5.50	9.00
1_5	1	fossil gas	231	69	47.32	15,200	3,800	231	2	4	1	0.01	0.15	1.10	6.00	9.00
1_6	2	nuclear	600	300	11.26	280,000	70,000	350	24	24	0	0.04	0.25	0.98	4.65	9.00
1_7	2	fossil gas	412	124	63.88	6,400	1,600	183	2	4	1	0.01	0.15	1.10	6.00	9.00
1_8	2	fossil gas	276	83	64.44	9,600	2,400	130	2	4	1	0.01	0.15	1.10	6.00	9.00
1_9	3	nuclear	550	275	13.74	228,000	57,000	234	24	24	1	0.04	0.25	0.98	4.60	9.00
1_10	3	fossil oil	428	128	139.67	800	200	5	4	4	0	0.01	0.15	0.95	5.50	9.00
1_11	3	biomass	314	94	50.13	1,600	400	17	4	4	0	0.01	0.00	0.00	5.50	9.00
1_12	3	lignite	291	87	29.89	9,600	2,400	132	7	7	0	0.03	0.35	1.10	5.00	9.00
1_13	3	fossil hard coal	201	60	45.28	11,200	2,800	177	22	22	1	0.03	0.35	0.95	5.00	9.00
1_14	4	nuclear	590	295	14.24	254,000	64,000	268	24	24	1	0.04	0.25	0.98	4.60	9.00
1_15	4	fossil oil	391	117	136.74	5,600	1,400	92	9	9	1	0.01	0.15	1.10	5.50	9.00
1_16	4	biomass	389	117	37.41	19,200	4,800	370	8	8	0	0.01	0.00	0.00	6.00	9.00
1_17	4	fossil gas	322	97	42.98	1,600	400	26	2	4	1	0.01	0.15	0.95	7.00	9.00
1_18	4	fossil hard coal	241	72	32.23	10,400	2,600	157	20	20	0	0.03	0.35	0.95	7.00	9.00
1_19	5	nuclear	485	243	11.00	125,000	31,000	121	24	24	0	0.04	0.25	0.98	4.60	9.00
1_20	5	lignite	408	122	25.94	4,000	1,000	87	6	6	1	0.03	0.35	0.95	5.00	9.00
1_21	5	biomass	397	119	40.01	1,600	400	20	4	4	0	0.01	0.00	0.00	5.00	9.00
1_22	5	fossil gas	342	103	44.31	4,800	1,200	150	2	4	0	0.01	0.15	0.95	7.00	9.00
1_23	5	lignite	341	102	25.73	8,800	2,200	143	6	6	1	0.03	0.35	0.95	7.00	9.00
1_24	5	fossil hard coal	331	99	35.51	9,600	2,400	95	11	11	1	0.03	0.35	1.10	5.00	9.00
1_25	6	fossil gas	435	130	68.55	4,000	1,000	87	2	4	1	0.01	0.15	0.95	7.00	9.00
1_26	6	lignite	391	196	27.51	20,800	5,200	215	8	8	0	0.03	0.35	1.10	7.00	9.00
1_27	6	fossil oil	380	114	116.33	4,800	1,200	76	6	6	1	0.01	0.15	0.95	5.00	9.00
1_28	6	fossil hard coal	351	105	41.50	9,600	2,400	161	19	19	0	0.03	0.35	0.95	5.00	9.00
1_29	6	fossil gas	345	104	68.11	12,000	3,000	184	2	4	1	0.01	0.15	1.10	7.00	9.00
1_30	6	fossil oil	256	77	104.24	1,600	400	40	4	4	1	0.01	0.15	1.10	5.00	9.00
2_1	1	lignite	426	128	26.64	10,000	2,000	132	7	7	0	0.03	0.35	1.10	5.00	9.00
2_2	1	fossil hard coal	420	126	33.08	5,000	1,000	98	11	11	1	0.03	0.35	1.10	5.00	9.00
2_3	1	lignite	399	120	28.48	10,000	3,000	109	7	7	1	0.03	0.35	0.95	5.00	9.00
2_4	1	fossil gas	339	102	45.37	12,300	2,900	359	2	4	1	0.01	0.15	0.95	6.00	9.00
2_5	1	fossil hard coal	268	81	42.81	5,000	1,000	81	19	19	1	0.03	0.35	1.10	5.00	9.00
2_6	2	nuclear	550	275	11.00	247,000	62,000	250	24	24	0	0.04	0.25	0.98	4.60	9.00
2_7	2	fossil hard coal	417	125	49.37	19,000	5,000	211	20	20	1	0.03	0.35	0.95	5.00	9.00
2_8	2	fossil gas	331	99	39.98	4,000	1,000	72	2	4	1	0.01	0.15	0.95	6.00	9.00
2_9	3	biomass	485	146	42.41	24,000	6,000	422	4	4	0	0.01	0.00	0.00	6.00	9.00
2_10	3	fossil gas	340	102	62.22	6,000	1,000	220	2	4	0	0.01	0.15	0.95	5.50	9.00
2_11	3	fossil gas	293	88	71.22	8,000	2,000	150	2	4	1	0.01	0.15	1.10	5.50	9.00
2_12	3	fossil gas	240	72	60.86	10,700	2,900	248	2	4	0	0.01	0.15	1.10	6.00	9.00
2_13	4	fossil gas	445	134	51.99	9,000	2,000	131	2	4	0	0.01	0.15	1.10	6.00	9.00
2_14	4	lignite	431	129	26.14	11,000	3,000	136	8	8	1	0.03	0.35	0.95	5.00	9.00
2_15	4	fossil hard coal	416	125	34.28	10,000	2,000	127	22	22	1	0.03	0.35	0.95	5.00	9.00
2_16	4	fossil gas	330	99	72.30	8,200	2,100	150	2	4	1	0.01	0.15	1.10	5.50	9.00
2_17	4	fossil oil	311	93	104.24	13,000	3,000	171	9	9	1	0.01	0.15	1.10	5.00	9.00
2_18	4	lignite	259	78	26.91	8,000	2,000	116	6	6	0	0.03	0.35	1.10	5.00	9.00
2_19	5	nuclear	540	270	12.34	191,000	48,000	200	24	24	1	0.04	0.25	0.98	4.65	9.00
2_20	5	fossil gas	359	108	48.04	13,000	3,000	359	2	4	1	0.01	0.15	0.95	6.00	9.00
2_21	6	biomass	480	240	39.28	52,000	13,000	495	8	8	0	0.01	0.00	0.00	5.00	9.00
2_22	6	fossil gas	430	129	62.99	11,000	3,000	248	2	4	0	0.01	0.15	1.10	6.00	9.00
2_23	6	fossil oil	372	112	139.67	4,000	1,000	62	4	4	0	0.01	0.15	0.95	5.00	9.00
2_24	6	lignite	212	64	24.04	10,200	2,800	136	8	8	1	0.03	0.35	0.95	5.00	9.00

Demand and RES profiles



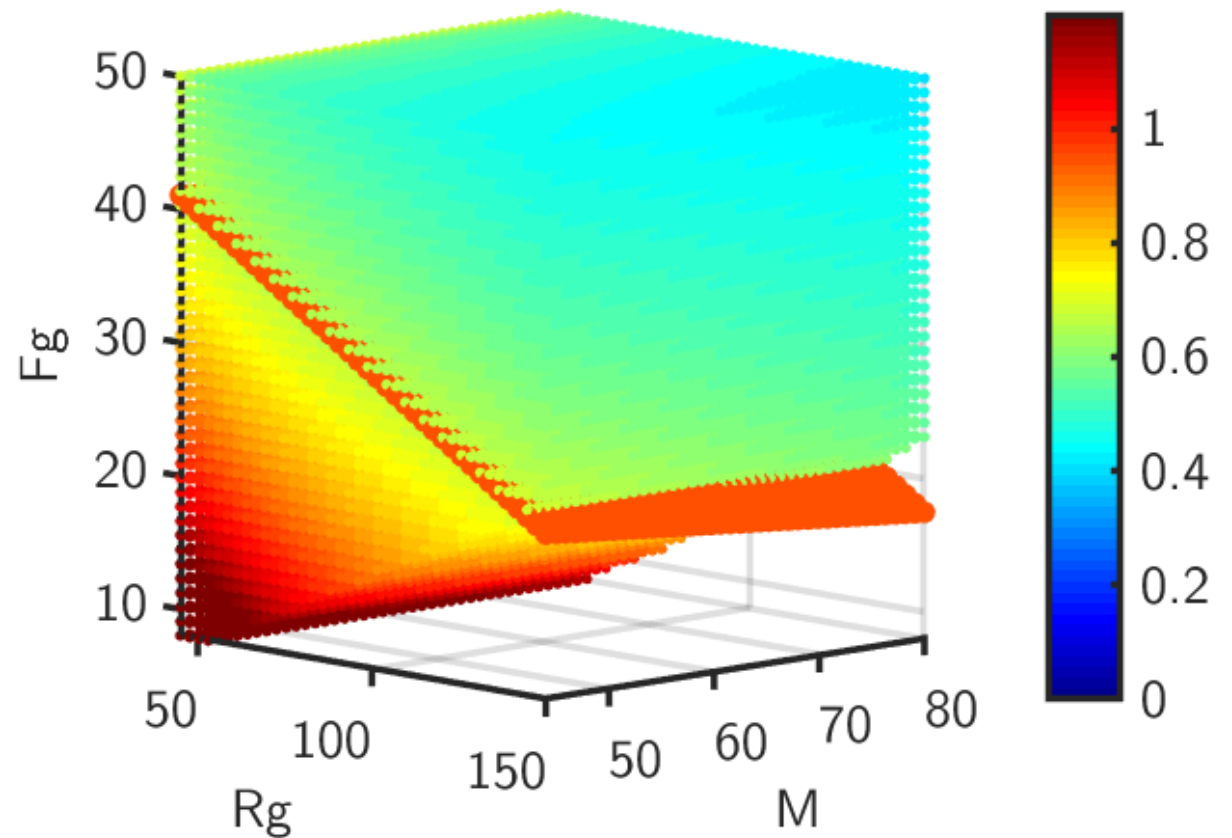
Load	[p.u.]	Area1	Area 2
	Bus 1	1.68	1.14
	Bus 2	1.30	0.88
	Bus 3	3.17	2.15
	Bus 4	0.61	0.41
	Bus 5	2.10	1.42
	Bus 6	0.47	0.32

Wind	[p.u.]	Area1	Area 2
	Bus 1	0.79	0.57
	Bus 2	0.15	0.11
	Bus 3	0.52	0.38
	Bus 4	0.12	0.08
	Bus 5	0.42	0.30
	Bus 6	0.32	0.23

Solar	[p.u.]	Area1	Area 2
	Bus 1	0.17	0.11
	Bus 2	0.03	0.02
	Bus 3	0.11	0.07
	Bus 4	0.02	0.02
	Bus 5	0.09	0.06
	Bus 6	0.07	0.05

Hyperplane – Unilateral scheme

	Area1	Area 2
A_a^R	-0.19	-0.17
A_a^M	-0.20	-0.16
A_a^0	56.22	47.86



Hyperplane – Bilateral scheme

	Area1	Area2
A_a^R	-0.18	-0.13
A_a^M	-0.28	-0.20
A_a^0	67.21	48.39
$A_{a,b}^{R_g}$	-0.03	-0.02
$A_{a,b}^F$	0	0
$A_{a,b}^M$	-0.03	0
$A_{a,b}^{R_c}$	-0.65	-0.54

