Critical Gas-Fired Power Plants in Integrated Natural Gas and Electricity Systems - Complementary material

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Abstract

This document provides some details about the case study presented in the paper entitled "Critical Gas-Fired Power Plants in Integrated Natural Gas and Electricity Systems" and has been accepted to the *65th ESReDA Seminar from risk imagination to safety intervention – Managing risks with knowledge.*

1 Case study: RTS-GMLC system

We apply the proposed model of the conference paper entitled "Critical Gas-Fired Power Plants in Integrated Natural Gas and Electricity Systems" to the updated IEEE Three-Area RTS, which is hereinafter referred to as RTS-GMLC system [1, 2]. This document provides additional details about the electricity system. Some information is already contained in the paper but it is kept also in this document for the sake of completeness.

1.1 Electricity system

The electricity network for the RTS-GMLC system is made up of 73 buses and 121 branches in total, as represented in Fig. 1. The system consists of three regions: regions 1 and 2 comprise 24 buses and 38 transmission lines, whereas region 3 has 25 buses and 39 transmission lines. There are five AC cross-border interconnectors: the one connecting buses 107 and 203 has a capacity of 175 MW while the capacity of the remaining interconnectors is 500 MW. There is also one 100 MW DC link connecting the buses 113 and 316. Moreover, each region is divided into two zones (e.g. region 1 has zones 11 and 12 and region 2 has zones 21 and 22). The zones 11, 21, and 31 are predominantly consumption areas (lower voltage) whereas most of the production facilities are located in zones 12, 22, and 32 (higher voltage).

The generation fleet is made of units powered by a variety of fuels, such as nuclear, coal, gas, and oil. Also, solar, hydro and wind renewable generation are available at various locations in the RTS-GMLC system. Fig. 2 illustrates the installed capacity in each of the three regions. Region 1 includes nuclear power plants and the highest share of coal-fired generation. The installed capacity of region 2 is much lower than in regions 1 and 3, and it contains a high share of coal-fired generation and the highest share of hydro generation. Region 3 represents a more renewable-oriented electricity system in which renewable energy sources (RES) play an important role, nuclear power plants being phased out, and coal-fired units representing only 2% of the total installed capacity in that region. Moreover, the installed capacity of gas-fired generation is the highest among the three regions. We disregard the battery energy storage device and the concentrating solar power plant in this study.

There are 10 natural gas-fired combined cycle (CC) generators with an installed capacity of 355 MW each, and 27 natural gas-fired combustion turbines (CT) generators with an individual installed capacity of 55 MW. Hence, the total capacity amounts to 1095 MW, 1560 MW, 2380 MW, for regions 1, 2, and 3, respectively. Table 1 shows the locations, type, and number of gas-fired units, and the aggregated installed capacity per bus of the gas-fired generation fleet. The highest installed capacity can be found at bus 323 in region 3.

Conventional generators fuelled by gas, oil, coal, and nuclear, are also characterised by the following technical characteristics: heat rate curve, start and shutdown costs, minimum stable level, and minimum up and down times . Table 2 shows the fuel prices for coal, natural gas, nuclear, and oil, that come with the model.

Table 1: Nodal installed capacity for the gas-fired generation fleet for the RTS-GMLC system.

Region	Bus	GFPP type	Number	Capacity (MW)
Region 1	107	CC	1	355
	113	CT	4	220
	118	CC	1	355
	123	CT	3	165
Region 2	207	CT	2	110
	213	CC, CT	3	465
	215	CT	2	110
	218	CC	1	355
	221	CC	1	355
	223	CT	3	165
Region 3	301	CT	2	110
	302	CT	2	110
	307	CT	2	110
	313	CC	1	355
	315	CT	3	165
	318	CC	1	355
	321	CC	1	355
	322	CT	2	110
	323	CT	2	710

Table 2: Fuel prices for the RTS-GMLC case study.

Fuel	Price ($/MWh)
Coal	7.2
Natural gas	13.3
Nuclear	2.8
Oil	35.3

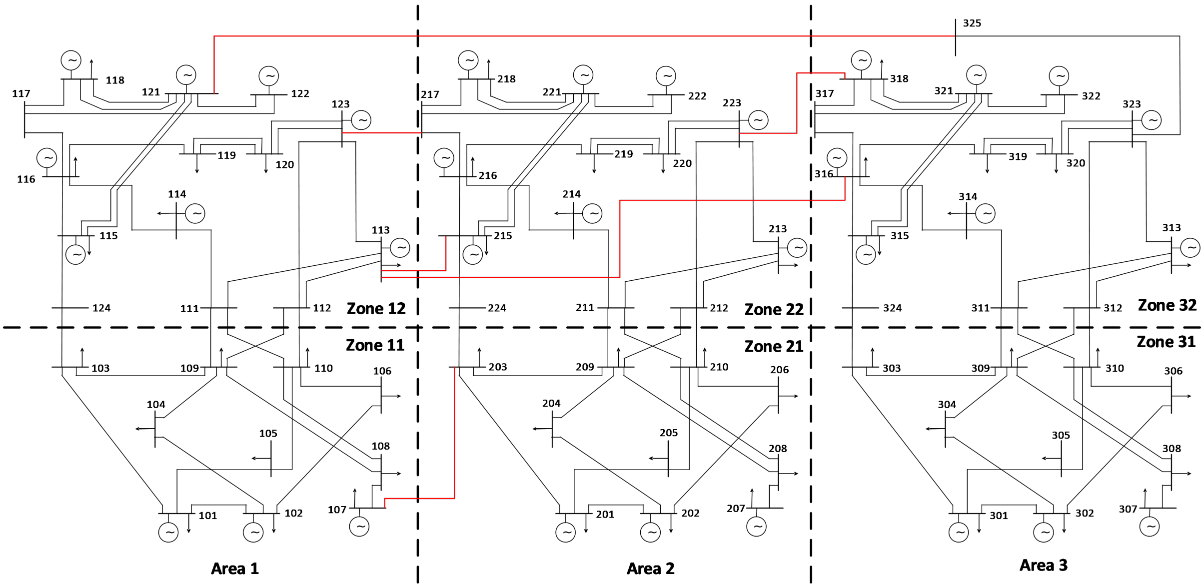

Figure 1: RTS-GMLC electricity network. The network is divided into three areas and each area into two zones.

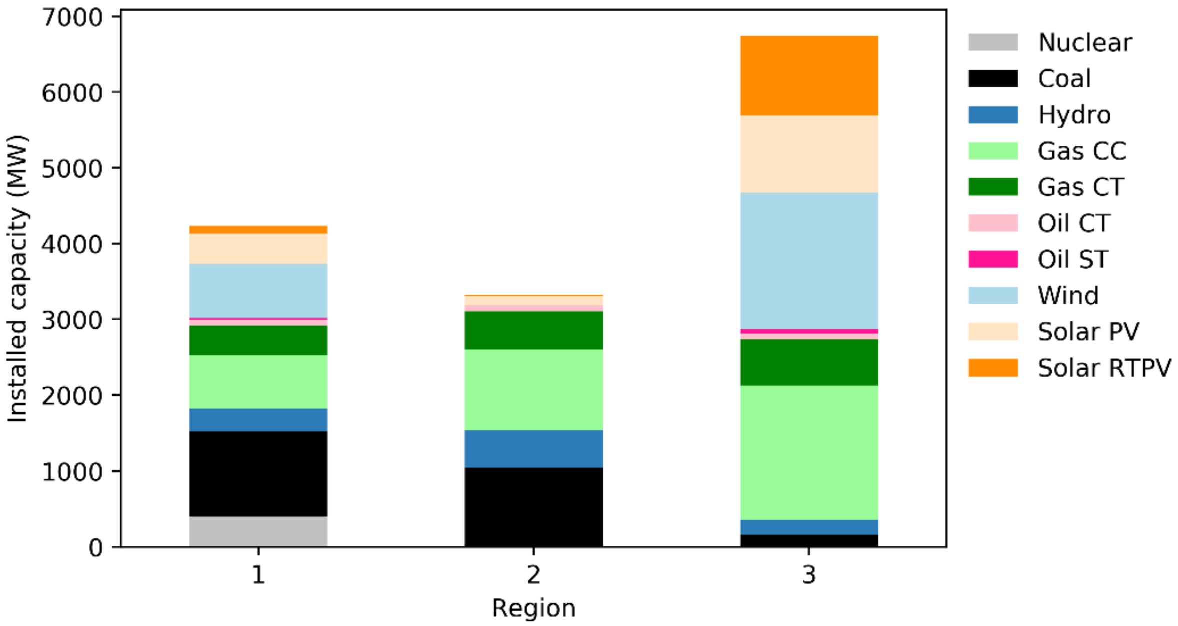

Figure 2: Regional installed capacity for the RTS-GMLC system.

Finally, Fig. 3.(a) provides the hourly system demand profile for the 5 days spanning from 26 August until 30 August of a representative year. We select this simulation period because the electricity peak demand hour occurs on 26 August at 3 pm. The total electricity demand for that week is 926.8 GWh: 308.8 GWh in region 1, 321.9 GWh in region 2, and 296.2 GWh in region 3. The available capacity for renewable generation including solar photovoltaics (PV), roof-top solar photovoltaics (RTPV), and wind, as well as the total hydropower generation, is shown in Fig. 3.(b). At the end of the period, the total wind power generation falls below 500 MW. It should be noted that, for this case study, the electricity peak demand occurs in summer when the gas peak demand is low (the gas peak demand usually takes place in winter). Therefore, the identification of the critical GFPP is not necessarily linked to the gas peak demand period because the GFPP could be critical for the electricity system when gas demand is not so high.

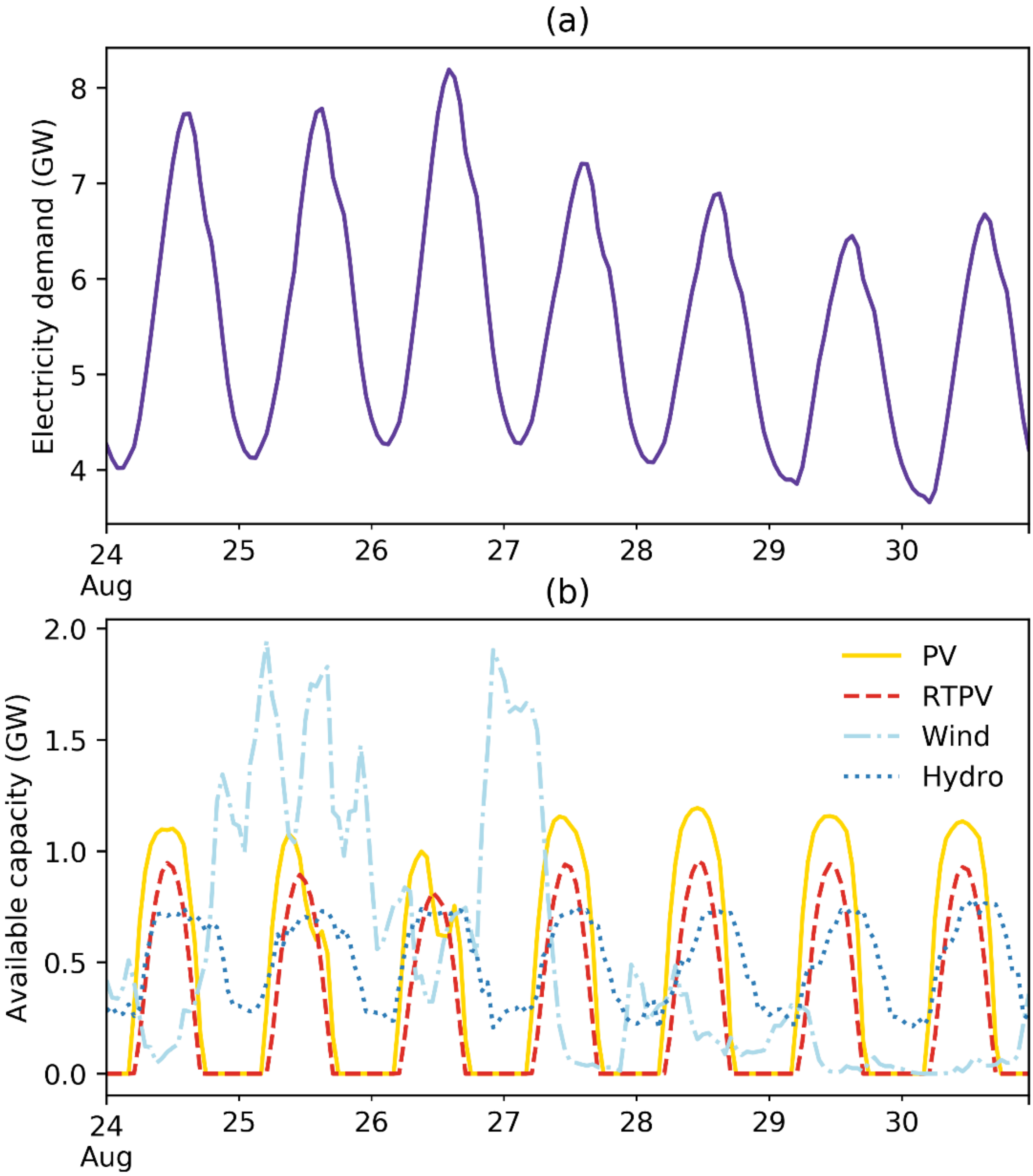

Figure 3: Hourly electricity system demand (a) and available capacity of solar PV, solar RTPV, wind, and hydropower (b) for the period 24-30 August of a representative year and the RTS-GMLC case study.

References

[1] C. Barrows, A. Bloom, A. Ehlen, J. Ikäheimo, J. Jorgenson, D. Krishnamurthy, J. Lau, B. McBennett, M. O'Connell, E. Preston *et al.*, "The ieee reliability test system: A proposed 2019 update," *IEEE Transactions on Power Systems*, vol. 35, no. 1, pp. 119–127, 2019.

[2] C. Grigg, P. Wong, P. Albrecht, R. Allan, M. Bhavaraju, R. Billinton, Q. Chen, C. Fong, S. Haddad, S. Kuruganty *et al.*, "The ieee reliability test system-1996. a report prepared by the reliability test system task force of the application of probability methods subcommittee," *IEEE Transactions on power systems*, vol. 14, no. 3, pp. 1010–1020, 1999.