Proceedings of the 3rd International Conference on Green Energy, Environment and Sustainable Development (GEESD2022), X. Zhang et al. (Eds.)

doi:10.3233/ATDE220398

Operation Strategy of Single Unit Tripping in Multi-Units IGCC Power Plant

Jianwei DU, Hui LI, Miaochen ZHANG and Hongtao LIU[1]
SEPCO Electric Power Construction Corporation, Jinan, Shandong, China

Abstract. Integrated Gasification Combined Cycle power generation technology is recognized as one of the important future development directions of clean power generation. Taking a large-scale IGCC power plant as the research object, the operating strategy of single unit tripping in multi-units was discussed in this paper. Gasification unit and air separation unit shall ramp down and balance with various gas demand in 1-2 minutes after one-unit trips. Duct burners of heat recovery steam generator can be used to produce more steam and increase steam turbines output subsequently. New stabilized power output can be reached within 20 minutes after the tripping.

Keywords. IGCC, combined cycle, trip, operation strategy

1. Introduction

Integrated Gasification Combined Cycle power generation technology has the advantages of high power generation efficiency, outstanding environmental protection characteristics, wide fuel adaptability, water saving and polygeneration [1, 2]. It has developed rapidly since 1990s [3], and it is recognized as one of the important development directions of clean power generation in the future [4-6]. Compared with conventional coal-fired power plants, IGCC power plants have characteristics of complex process systems, numerous equipment, and high integration [7, 8]. The operating state of the IGCC unit is affected by various factors, and it is often in a state that deviates from the design conditions [9].

In this paper, a large-scale IGCC power plant is taken as research object. Operation strategy when one 2×1 (two gas turbines on one steam turbine) generating set trips was discussed [10]. The overall process flow diagram of the studied IGCC power plant is shown in Figure 1. Vacuum residue or high sulphur fuel oil is gasified in gasification unit and translated to syngas. Clean syngas is then sent to gas turbine and combusted to generate power. In addition to power, the plant also undertakes the tasks of supplying steam, nitrogen, hydrogen, water, etc.

[1] Corresponding Author, Hongtao LIU, SEPCO Electric Power Construction Corporation, Jinan, Shandong, China; E-mail: lhtsepco@163.com.

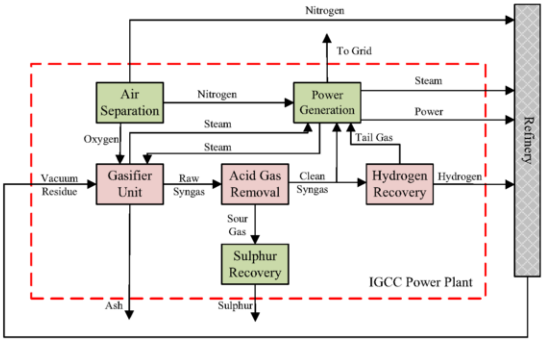

Figure 1. Overall process flow diagram of IGCC power plant.

2. Critical System Configuration

2.1. Gasification Unit (GFU)

- Fifteen sets gasifiers installed.
- Rated gasification capacity of 1000t/d per set.
- Max expected capacity of 107% of rated capacity.
- Min expected capacity of 60% of rated capacity.
- Normal and max ramp rate of 1%/min and 3%/min.

2.2. Power Generation Block (PGB)

- Five 2×1 (two gas turbines on one steam turbine) combined cycle blocks (CCBs), each block equipped with 2 gas turbines, 2 heat recovery steam generators and 1 steam turbine.
- Combustion gas turbine (CGT), max load of 242 MW when fueled with syngas.
- CGT max load change rate of 13.4 MW/min when fueled with syngas.
- CGT max load of 178 MW when fueled with diesel.
- CGT max load change rate of 13.0 MW/min when fueled with diesel.
- CGT fueled with diesel at start-up stage and low load stage. Fuel switching is allowed in the 50%-70% load range. Fuel switching time is within 10 minutes.
- Heat recovery steam generator (HRSG), type is double pressure, reheating, horizontal, natural circulation, with two-stage duct burner.
- Steam turbine generator (STG), type is reheating, three-cylinder, combined-cycle. Operation mode is sliding pressure operation. The rated steam pressure, temperature and load under TMCR condition is 10.68 MPa, 585°C, and 312 MW, respectively.

2.3. Air Separation Unit (ASU)

- Six air separation units installed.
- Rated air separation capacity of 3500 t/d per unit.

- All units normally in operation at equal capacities, i.e., 80%-85% normal load range.
- Min expected capacity of 75% of rated capacity.
- Liquid oxygen with 12 hours capacity installed, about 6000 tons.
- Liquid nitrogen with 10 hours capacity installed, about 4000 tons.

2.4. Other Process Units

The design capacity of other process units, such as acid gas removal unit, acid water stripping unit, desulfurization unit, etc., all matches capacity of GFU. The design capacity of all utility systems, such as water, compressed air, sewage treatment, etc., satisfies the operation requirements of various working conditions.

3. Initial Operating Configuration

Initial operating configuration of the IGCC power plant studied in this paper is assumed as below:

- Refinery in normal operation, i.e., -64,000 cubic meters of crude feed, ~13,000 cubic meters of vacuum residue production, zero asphalt production.
- 14 GFUs operating and 1 GFU on hot stand-by, product syngas is enough for the whole IGCC plant.
- 6 ASUs operating at 84% of rated capacity, i.e., daily output of oxygen and nitrogen is 17,700 tons and 56,000 tons, respectively.
- 5 CCBs operating, i.e., all CGTs at full load on syngas, no HRSG duct firing.

Based on above conditions, the total output of CGTs can be calculated as:

$$10 \times 242 \text{ MW} = 2420 \text{ MW}$$

The total output of STGs can be calculated as:

$$5 \times 256 \text{ MW} = 1280 \text{ MW}$$

In above formula, 256 MW is the full output of STG with no HRSG duct firing.

Hence, the total output of the IGCC power plant studied in this paper can be calculated as:

$$2420 \text{ MW} + 1280 \text{ MW} = 3700 \text{ MW}$$

4. Operation Strategy and Discussion

We assume electrical or instrument/control failure leading to the trip of one complete CCB, i.e., 2 sets of CGTs, HRSGs and 1 set of STG. This scenario results in a rapid reduction in export power due to the CCB trip. To partially mitigate this loss of power generation, the HRSG duct burners of the 4 existing CCBs remaining on-line can be used to produce more steam to generate increased power in the STGs. In the discussion below, all times/durations are referenced to the initial event at time=0.

This scenario of one complete CCB trip will result in problems as below:

- Due to 2 sets of CGTs trip, consumption of syngas will decrease. Accordingly, pressure of syngas main pipe will increase. Pipe pressure will exceed the limit value if no effective measures are implemented. The remaining 8 sets of CGTs will trip subsequently.
- In addition to the reduction of syngas consumption, the corresponding consumption of nitrogen used to be mixed with syngas will also reduce. Accordingly, pressure of nitrogen main pipe will increase. Pipe pressure will exceed the limit value if no effective measures are implemented. The remaining 8 sets of CGTs will trip subsequently.
- Very high pressure (VHP) steaming from the GFUs that should have been received by the tripping CCB needs to be processed. Otherwise, excessive steam will cause over-pressure of the steam pipe.
- Due to one CCB trips, output of steam and power will both reduce. Effective measures need to be implemented to guarantee generate steam and power as much as possible.

Table 1. Operation strategy in the scenario of one complete CCB trip.

Time (minutes)	**GFU**	**ASU**	**PGB**	
			CGTs and HRSGs	**STGs**
t=0			2 sets of CGTs trip	1 set of STG trips
	Syngas pressure begins to increase due to decreased demand	Nitrogen pressure begins to increase due to decreased demand	All remaining CGTs continue operation at 100% load without change	
	Gasifiers begin to ramp down	Oxygen pressure begins to increase due to decreased demand and ASUs begin to ramp down	VHP steam from GFU going to tripped HRSGs is diverted to remaining on-line HRSGs/STGs	Steam extractions from remaining STGs increase to compensate and maintain steam header pressures with support from steam letdown stations as required
t=3			T=-3mins, the HRSG HP duct burners in the units remaining on-line are ignited	VHP steam flows begin increasing to STGs
t=4	T=-4mins, gasifiers have ramped down to be in balance with demand			
t=5		T=-5mins, ASUs have ramped down to match GFU oxygen consumption		
t=10			T=10mins, HRSG HP & LP duct burners are fully ramped up	
t=20				T=-20mins, STGs reach the maximum output with duct fired steam generation

In order to deal with above problems, operation strategy in the scenario of one complete CCB trip is formulated. It shall be noted that technical characteristics of all critical equipment in IGCC power plant shall be fully considered. The specific operation strategy is shown in Table 1.

The direct consequence of one complete CCB trip is the reduction of power output. In order to alleviate this situation, the HRSG duct burners of the 4 existing CCBs remaining on-line need to execute the instruction of purge (about 3 minutes), ignite and ramp up (about 7 minutes). With the commissioning of HRSG duct burners, the steam production keeps increasing. Correspondingly, power output of STGs keep increasing. However, there will be some time lag (about 10 minutes). The max level of duct firing will be limited by one of the following parameters, i.e. fuel availability, burner capacity, max firing temperature, or max STG throttle pressure. It is expected that the duct firing will be limited by the max STG throttle pressure which will be reached an increase in output of -40 MW per STG.

According to above operation strategy, change of power output can be roughly inferred as Figure 2.

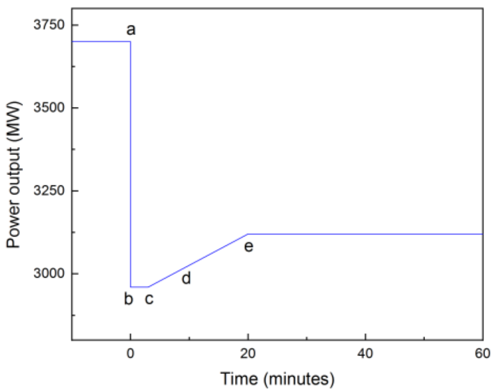

Figure 2. Power output change trend.

Notes: a: t=0-, all CCBs are in normal operation, the total power output is about 3700MW; b: t=0+, one complete CCB trip, the power output decreases rapidly, 3700MW-2×242MW-256MW=2960MW; c: t=3, the HRSG HP duct burners in the units remaining on-line are ignited; d: t=10, HRSG duct burners are fully ramped up, output of STGs increase gradually; e: t=20, STGs reach the maximum output, the power output is about, 2960MW+4×40MW=3120MW.

5. Conclusion

One complete CCB trip will result in consumption of syngas and nitrogen decrease. Load of GFUs and ASUs need to be adjusted within 1-2 minutes to maintain gas balance. The direct consequence of one complete CCB trip is the reduction of power output. To partially mitigate this loss of power generation, the HRSG duct burners of the 4 existing CCBs remaining on-line can be used to produce more steam to generate increased power in the STGs. The max level of duct firing will be limited by fuel availability, burner capacity, max firing temperature, and max STG throttle pressure. 20 minutes after the trip, power output of the IGCC power plant can be restored to -84% of the original.

References

[1] Ren YQ, Che DF, Xu SS, Li XY, Tao JY, Liu G. Study on typical domestic and foreign IGCC technology applications. Electric Power. 2019;52(2):7-13+184.

[2] Li XC, Sun YB. Comparison between IGCC power plant and gas turbine power plant. Clean Coal Technology. 2015;21(5):123-126.

[3] Bai ZL. Comparative study on typical IGCC power stations in China, USA and Japan. Sino-Global Energy. 2021;26(5):9-15.

[4] Chen F, Wang SY, Yu HC, Chen R, Yang YJ, Lu SJ. Technological innovation paths of coal industry for achieving carbon neutralization. Journal of China Coal Society. 2022;47(4):1452-1461.

[5] Sun XD, Zhang B, Peng SP. Development trend and strategic countermeasures of clean coal technology in China toward 2035. Strategic Study of CAE. 2020;22(3):132-140.

[6] Shi ZH, Ni SF. Accounting and case application of greenhouse gases from Integrated Gasification Combined Cycle (IGCC) multi supply power generation unit. Shanghai Energy Conservation. 2021;8;898-903.

[7] Han L, Deng GY, Li Z, Fan YC, Li WK. Status of large-scale coal gasification technologies in IGCC power plants. Energy construction. 2015;2(1);42-45+50.

[8] Liu K, Xu SS, Li GY, Ren YQ. Technological process and system analysis of pre-combustion CO_2 capture based on IGCC. Chemical Industry and Engineering Progress. 2018;37(12):4897-4907.

[9] Chen XL, Wu SH, Li ZZ, Pang KL, Wang Y, Chen L, He X, Wang J. Research on off-design characteristics of integrated gasification combined cycle system. Proceedings of the CSEE. 2009;29(14):6-11.

[10] Liu HT, Xu XH, Chi YW, Xue L, Xu DF, Ma HJ. Study on startup procedure and steam distribution philosophy in integrated gasification combined cycle power plant. Electric Power Technology and Environmental Protection. 2017;33(5):49-51.