Air-blown IGCC System -- World's First Successful Continuous Three-month Operation and Commercial Application Plans

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1. Introduction

Integrated gasification combined cycle (IGCC) power plants are designed to increase power generation efficiency by as much as 20% compared to conventional coal-fired systems by combining coal gasification with a gas turbine combined-cycle system.

Mitsubishi Heavy Industries (MHI) has been working with the national government, electric power companies, and the Central Research Institute of Electric Power Industry (CRIEPI) to develop more efficient and highly reliable air-blown IGCC technology. MHI constructed a Process Development Unit (PDU) with a 2 t/day coal processing capacity, followed by a 200 t/day pilot plant. MHI then built a 250-MW (1,700 t/day) IGCC demonstration plant as the final commercialization stage, and started a demonstration test there in September 2007.

The test progressed as planned, and the plant reached its rated load in March 2008. During June–September 2008, the plant achieved its scheduled target of more than 2,000 hours of continuous operation. Since a power generating plant operates throughout the year, it must be very reliable to allow it to generate power continuously, especially for the summer months when the demand for power is high. The target of 2,000 hours of continuous operation is thus very significant. No other IGCC plant in the world has achieved such a long period of continuous operation in such a short time after startup. This has demonstrated that commercialization of this type of plant is possible in terms of reliability as well as efficiency and environmental performance.

The air-blown IGCC system is capable of reducing CO_2 emissions by 20% compared with a conventional coal-fired power plant, and can be combined relatively easily with CO_2 recovery and sequestration equipment. For these reasons, it has attracted attention from around the world as an environmentally friendly power generation technology.

2. Air-blown IGCC demonstration system

2.1 Overview of the IGCC demonstration system

Figure 1 shows the block flow diagram of the air-blown IGCC system.

Europe and the United States have had the lead in IGCC demonstration projects, generally using oxygen-blown gasifiers developed for use in chemical plants. These gasifiers require substantial power to produce oxygen. They therefore result in low net power plant efficiency and lack the reliability required for power generation.

Working together with the electric power companies and CRIEPI, MHI has promoted the development and implementation of an IGCC design that includes a highly efficient and reliable air-blown gasifier suitable for power generation. Clean Coal Power R&D Co., Ltd., formed by the electric power companies in 2001, has been pushing to construct an IGCC demonstration plant. MHI received orders for all the equipment for this IGCC plant, including gasifiers, the desulfurization unit, gas turbines, steam turbines, exhaust heat recovery steam generators (HRSGs), and control units. The contract includes design, construction, and commissioning of the plant.

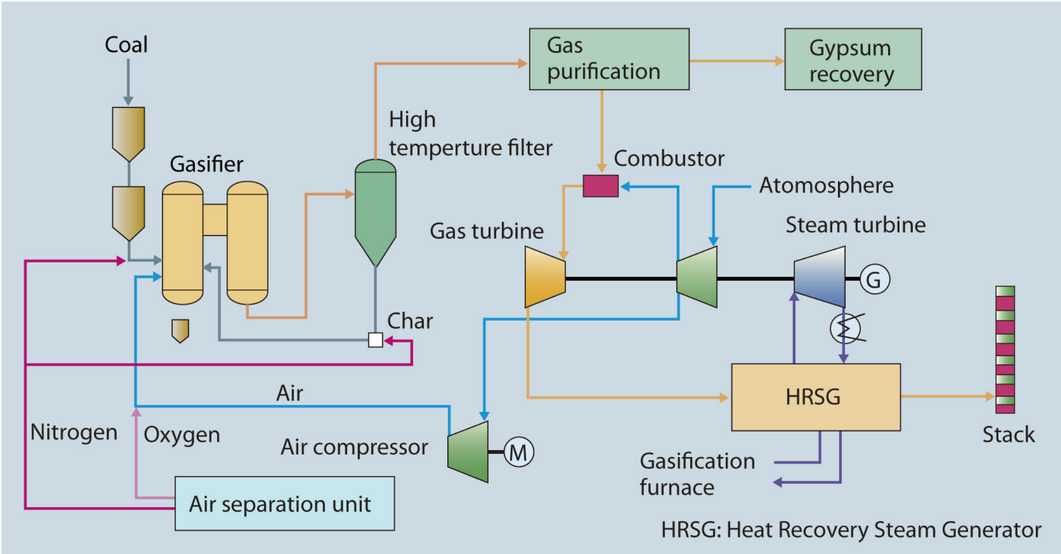

Figure 1 Air-blown IGCC system

2.2 IGCC verification testing results

Figure 2 shows the verification testing results. We lit the gasifier for the first time in September 2007 and started gasification operations with coal in October. MHI then started power generation with the gas turbines running on the coal gasification gas in December and reached the rated load of 250 MW in March 2008. Starting in June 2008, we successfully performed a scheduled three-month period of continuous operation, which was one target of verification testing.

Many of the previous IGCC plants in Europe and the United States have not achieved 2,000 hours of continuous operation even more than 10 years after startup[1]. Achieving continuous operation less than one year after startup demonstrates the high reliability of MHI's air-blown IGCC design.

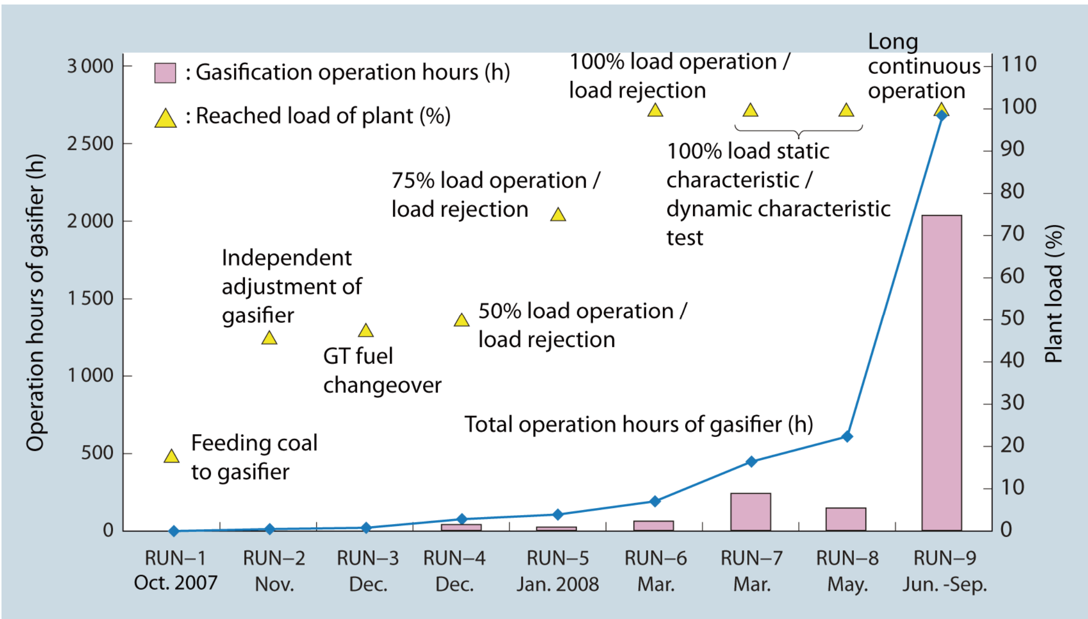

Figure 2 Verification testing results

Table 1 shows verification testing results. Both the power generation output and efficiency met the planned values. The carbon conversion was almost 100% and the slug contained almost no unburned carbon. All the environmental values were considerably better than the planned values, demonstrating the plant's high environmental performance.

These data were obtained prior to operation optimization, and the results are expected to improve with further adjustments. For verification testing, MHI plans to perform a coal-type change test, an operation optimization test, and a 5,000-hour endurance test before March 2010.

Table 1 IGCC verification testing results

Ambient temperature		13.1°C
Gross power output (generating end)		250 MW (Planned: 250 MW)
Gas turbine output		124 MW
Steam turbine output		126 MW
Net plant efficiency (performance measurement result prior to operation optimization)		42.4% (lower heating value) (Planned: 42% minimum)
Cold gas efficiency		75.3%
Carbon conversion efficiency		>99.9%
Produced gas HHV wet		5.4 MJ/m^{3}N (1290 kcal/m^{3}N) lower heating value 5.2 MJ/m^{3}N
Produced gas composition	CO	30.5%
	CO_2	2.8%
	H_2	10.5%
	CH_4	0.7%
	N_2 and others	55.5%
Environmental value	SOx	1.0 ppm (Planned: 8 ppm maximum)
(16% O_2 conversion)	NOx	3.4 ppm (Planned: 5 ppm maximum)
	Particulate matter	< 0.1mg/m^{3}N (Planned: 3.3 mg m^{3}N maximum)

3. Plan for a commercial plant

IGCC commercial plants are being planned in Europe and the United States. The United States in particular, is moving ahead with the construction of a 630-MW IGCC unit (Duke Energy Corporation) in Edwardsport, Indiana. The IGCC design is considered to be a clean coal technology in the United States because of its excellent environmental performance. The IGCC design has also recently attracted attention with regard to CO_2 recovery and sequestration to prevent global warming, as it permits a lower cost and higher efficiency than conventional coal-fired thermal power plants.

In Japan, MHI is planning a highly efficient IGCC commercial plant using the latest gas turbines with a 1,500°C combustion temperature to meet market needs for further enhancements in efficiency and improved environmental performance. **Table 2** shows a comparison of the main specifications for the IGCC demonstration plant and the follow-on commercial plant.

Table 2 Specifications of the IGCC demonstration plant and commercial plant

Parameter		Units	250-MW demonstration plant	Commercial plant (50/60 Hz)
Gross power output (generating end)		MW	250	600/500
Type of coal		—	Bituminous	Bituminous
Gasifier		—	Dry feed air-blown	Dry feed air-blown
Gas purification system		—	Wet desulfurization	Wet desulfurization
Gas turbine		—	M701DA	M701G/M501G
Net power plant efficiency		%, LHV	42	48
Environmental targets (16% O_2 basis)	SOx	ppm	8	8
	NOx	ppm	5	5
	Particulate matter	mg/m^{3}N	4	4
Start of operation		—	2007	2014 at earliest

The IGCC commercial plant gasifier will have twice the capacity of that used in the demonstration plant. Because the pressure vessel operates at even higher pressure to match that of the gas turbine and increase output capacity, the gasifier's pressure vessel is only about 20% larger in diameter and the advantage of scaling up to capacity is great. Technology verified during scaling up from the 200-t/day pilot plant to the 1,700-t/day demonstration plant is applied by a factor of nine to IGCC commercial plant gasifier design.

A dry coal-feeding system for the gasifier will be used, like that of the demonstration plant. The nitrogen use for coal transfer will be reduced in the commercial plant to reduce the power required for nitrogen production.

The dry coal feeding system can also be used with low-grade coal such as subbituminous coal with high moisture content. Plenty of low-grade coal is available, but it cannot be easily burned in a boiler because of its high moisture content and low ash melting point. Using it in this system will help reduce operational cost.

Wet desulfurization using methyldiethanolamine (MDEA) as the absorbing liquid for gas purification will be used in the same manner as in the demonstration plant. The use of MDEA requires less power and incurs less heat lost than other systems. The use of MDEA also results in excellent environmental performance.

The gas turbine will use a combustor for igniting the coal gasification gas. This is based on the latest highly efficient G-type gas turbine, which has proven itself in natural gas firing applications with low-calorie firing technologies such as for blast furnace gas. An integrated system with a high generating efficiency will be used to extract air for gasification from the gas turbine in the same manner used in the demonstration plant. The IGCC commercial plant combined with the latest gas turbine technology allows the CO_2 emission rate to be significantly reduced because of its improved net power plant efficiency compared to that of a conventional coal-fired plant.

4. Conclusion

The IGCC is expected to be introduced as a core technology for use in the next generation of coal-powered thermal power generating plants. Even so, it is a complex system containing many components including the HRSGs, the steam turbine, the gasifier, the desulfurization unit, and the gas turbine. Ensuring overall plant reliability requires an adequate overall system design as well as reliable individual components.

The successful long, continuous operation period of the IGCC demonstration plant has demonstrated its high reliability as an electric power facility as well as its efficiency and environmental performance. We believe that this is largely attributable to our unified and consistent design as well as to the construction and delivery of all the IGCC facilities by a single supplier. MHI will continue working to achieve even higher efficiency, reliability, and economy for the commercial plant based on our success with the demonstration plant.

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