Development of 1.5MW High Efficiency Gas Engine and Container Type Generation Set

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Recently, Mitsubishi Heavy Industries, Ltd. (MHI) has delivered two container-configured generator sets that incorporate a 1.5MW output high-efficiency gas engine, newly developed based on the design concept of "quick mobility, quick installation and quick commissioning," to a customer in Dongguan, Guangdong Province, China.

MHI's lean-burn gas engines (GSA and GSR series) were released to market in 1993 and have achieved both the world's highest generation efficiency and lowest emissions covering up to 1MW output cogeneration system application. In addition to the growing need for gas engines caused by soaring crude oil prices and sinking natural gas prices owing to the implementation of shale gas extraction technologies and the need for global warming mitigation and energy-saving measures, demand for cogeneration systems that can supply electricity and effectively utilize thermal and steam energy has rapidly increased. An introduction of MHI's 1.5MW output high-efficiency Miller cycle gas engine and container-configured generator set, both of which were newly developed to meet the aforementioned needs, is provided below.

1. 1.5MW High-efficiency Gas Engine

MHI's GSR gas engine series runs at medium to high speed and utilizes a Miller cycle system to achieve high thermal efficiency. The lineup of Miller cycle system gas engines and their main specifications are shown in **Table 1**. Previously, the maximum output of our products was 1MW, however higher output and higher efficiency 1.5MW engines were newly developed in order to meet the expected domestic and global growing demand toward engines with 1.5MW output.

MHI General Machinery & Special Vehicles has recently installed six packaged generator sets with the 1.5MW engine on the premises of Sagamihara Machinery Works. This was implemented as a part of a Business Continuity Plan (BCP) to ensure necessary electricity for factory operation at the time of grid power outage and also to conduct various demonstrative operations of the power generation sets. Demonstrative operations were performed to study the impact of continuous engine operation of thousands of hours, engine durability against DSS (Daily Start and Stop), the feasibility of longer engine maintenance intervals and reliability improvement possibilities. Operations started in March 2012.

Table 1 Lineup of GSR Miller cycle gas engine series

Engine model name			GS6R	GS6R2	GS12R	GS16R	GS16R2	GS16R2
Number of cylinders			6	6	12	16	16	16
	Bore/Stroke	mm	170/180	170/220	170/180	170/180	170/220	170/220
60Hz	Speed	min^{-1}	1200	1200	1200	1200	1200	-
	Generation output	kW	305	380	610	815	1000	-
50Hz	Speed	min^{-1}	1500	1000	1500	1500	-	1500
	Generation output	kW	320	315	700	930	-	1500

2. Main Features of 1.5MW High-efficiency Gas Engine

The following technologies are incorporated in the newly developed 1.5MW gas engine:

(1) Combustion technology that brings about high thermal efficiency
- For better thermal efficiency, a Miller cycle system that enables a larger compression ratio was employed
- Using CFD (computational fluid dynamics), a combustion strategy that can achieve both low NOx and high combustion efficiency is applied, and a generation efficiency of 42.1%, which is the world's top level for 1.5MW output engines, was achieved (Methane number 80, including +5% margin)

(2) High-efficiency and high compression ratio turbocharger technology
- To meet the required high Miller cycle level, a proprietary high-efficiency and high compression ratio turbocharger was used.

(3) Control technologies
- MHI's own combustion control technology, which results in a minimum knock margin to improve thermal efficiency, was employed
- Optimized air-fuel ratio control technology that enables an initial load acceptance of 30%, which is the world's highest level for lean-burn engines, was applied
- Engine control technology that enables a 100% load acceptance within two minutes after Blackout Start was used

(4) Combustion technology for engine cooling by Radiator
- In addition to a conventional cooling tower, combustion technology that also works with a remote radiator was employed to ensure operation even during water outages, as a part of BCP

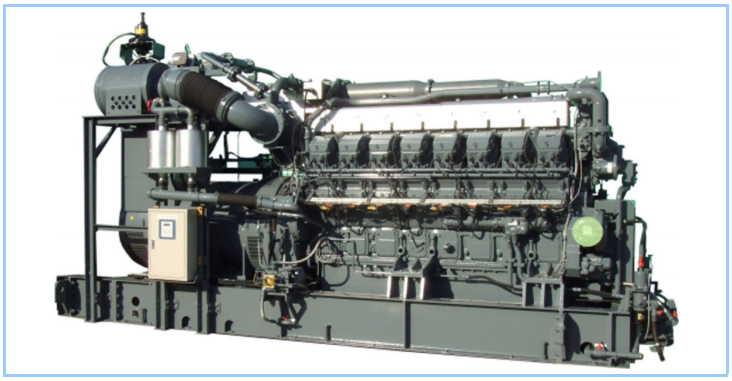

Figure 1 1.5MW/1500min^{-1} Miller cycle gas engine gen-set

3. "MEGANINJA" Container-Configured Generator Set

Conventional generator sets require at least one month from installation to start of power generation, as the generator set and auxiliary equipment including piping and wiring were individually installed. Around the world, there are still many regions where power transmission networks have yet to be established, and there are pressing needs to meet the demand for electricity as quickly as possible. To respond to these needs, MHI developed "MEGANINJA" (patent pending), a portable container-configured generator set with the product concept of "quick mobility, quick installation and quick commissioning."

(MEGANINJA: Mitsubishi Energy Gas Package NINJA Series)

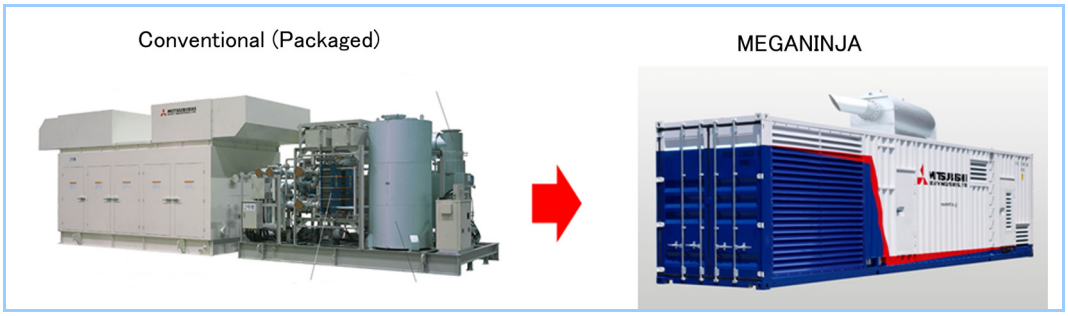

Figure 2 Conventional packaged gen-set and newly-developed MEGANINJA

4. Features of Container-Configured Generator Set

The newly developed container-configured power generation set features:

(1) Quick mobility

- For a mono-generation system, all that is required for power generation is an ISO 40-foot container loaded with a complete set of power generation systems
- For a cogeneration system, the 40-foot container for power generation can be used in combination with a 20-foor container loaded with a heat supply unit and related equipment
- The unit can also accommodate cogeneration through the simultaneous use of a 20-foot container for waste heat recovery incorporating a hot-water heat exchanger, exhaust gas steam boiler, etc., for cogeneration

(2) Quick installation

- Uses connector units for wiring and fuel piping connections, which enables significant simplification of the work that must be performed at the installation site

(3) Quick commissioning

- Needs only to be brought to the installation site, where it can be fully operational within 24 hours (typically it required approximately one month to carry out necessary procedures)

Conventionally, major maintenance for a generator set required 1-2 weeks. With the MEGANINJA, on the other hand, you simply replace the entire container and can immediately start generating power. This provides users with a great advantage – minimization of downtime.

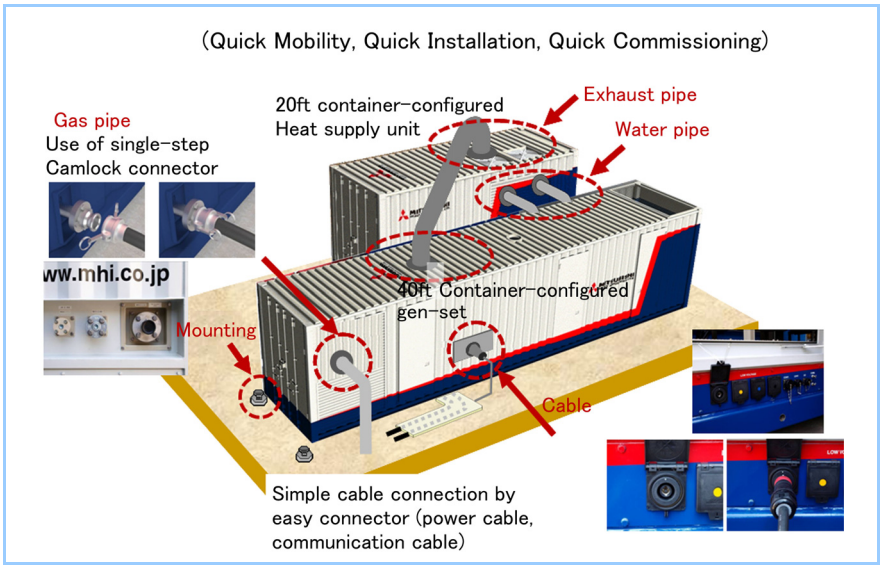

Figure 3 Outline of quick installation

5. Conclusion

The newly developed power generation set, created by mounting a high-efficiency gas engine in a container, is being improved every day for better generation efficiencies (power generation efficiency, overall efficiency), lower emissions and higher reliability, which we believe will ultimately help resolve global environmental issues and energy problems.