J920 FleXtra gas engine combines CHP and flexibility

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Kurzfassung

J920 FleXtra Gasmotor kombiniert KWK und Flexibilität

Die Vorteile von Jenbacher J920 FleXtra Groß-Gasmotoren von GE in Kombination mit Kraft-Wärme-Kopplung werden beschrieben, da durch die wachsende Installation von erneuerbaren Energien Betriebsflexibilität immer mehr an Bedeutung gewinnt. Die Kombination von KWK mit hohem Gesamtwirkungsgrad und Betriebsflexibilität lässt sich mit Gasmotoren in Kombination mit Wärmespeicherung sehr gut realisieren. Solche flexiblen Kraftwerke können basierend auf dem 9,5 MW J920 FleXtra installiert als Mehrmotorenanlage 100 MW oder 200 MW groß sein.

Die Wirkungsgradverbesserungen der letzten Jahre an den großen Jenbacher Gasmotoren hatte zwei Schwerpunkte: Erstens den elektrischen Wirkungsgrad zu verbessern, und zweitens den Gesamtwirkungsgrad bei KWK Anwendung zu erhöhen. Ein guter elektrischer Wirkungsgrad ist wichtig für reine Stromerzeugung, nicht nur dann wenn der Gaspreis hoch ist, sondern auch um die CO_2-Emissionen zu reduzieren. Bei KWK-Projekten, in denen die Abwärme vom Motor für die Bereitung von Heißwasser verwendet wird, setzt sich der Gesamtwirkungsgrad aus dem elektrischen und thermischen Wirkungsgrad zusammen.

(Gesamtwirkungsgrad = Elektrischer Wirkungsgrad + Thermischer Wirkungsgrad $= \frac{P_{el}}{Q_{Br}} + \frac{Q_{th}}{Q_{Br}} = \eta_{Ges}$.

Der J920 FleXtra bei den Stadtwerken Rosenheim ist seit Beginn 2013 im kommerziellen Betrieb. Dabei handelt es sich ist um eine typische KWK-Anwendung für ein deutsches Stadtwerk, die Anlage kann aber auch für die reine Stromerzeugung betrieben werden. Die KWK-Anwendung wird hier bezüglich Betriebsszenarien mit und ohne Wärmespeicherung untersucht.

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Introduction

GE Power & Water's Gas Engine business is a manufacturer of gas-fueled engines, generator sets, CHP modules, and ORC systems. With a legacy of technological innovation, GE's gas engines are a recognized leader in the industry for a wide range of output and applications, flexible fuel capability, low emissions, and high efficiency. Engines can operate not only on natural gas, but on a broad range of alternative gases such as biogas, landfill gas, coal mine gas, flare gas, and sewage gas to provide diverse power output, ranging from 0.2 to 9.5 MW (Figure 1).

GE Gas Engine business recently expanded its Jenbacher gas engine portfolio by adding a larger gas engine with 9.5 MW – the J920 FleXtra, Figure 2 – with an advanced electrical efficiency of 48.7 % and extra flexibility (FleXtra). The new advanced 2-stage turbocharging technology helps to achieve the high electrical efficiency of 48.7 % and to achieve a total efficiency (electrical and thermal) of 90 % and above for CHP applications. That is more than 1.5 % improved electrical efficiency and about 3 % higher total efficiency than gas engines with standard single stage turbocharging (Table 1).

GE's gas engines can also meet stringent emission standards. This makes gas engines a comparable cleaner technology for supplying electricity and heat around the globe as part of a distributed structure. Distributed power generation plays an important role in providing reliable and long-term power solutions in developed regions as well as in remote areas. In developed regions, there is a growing need for distributed power to participate in grid stabilisation and providing flexible power as renewable installations are continuously growing.

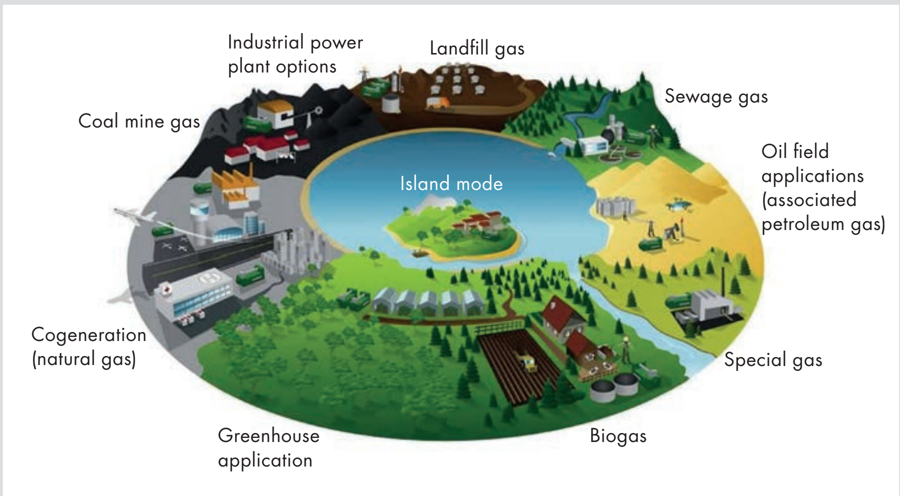

Fig. 1. GE gas engines fuel landscape.

Tab. 1. J920 FleXtra performance data.

	Units	J920 FleXtra (50 Hz/1,000 rpm)	J920 FleXtra (60 Hz/900 rpm)
Electrical output	kW_{el}	9,500	8,550
Electrical efficiency	%	48.7	48.7
Heat rate	kJ/kWh BTU/kWh	7,392 7,006	7,392 7,006
Thermal output	kW_{th}	8,100	7,300
Total efficiency	%	90	90

Output and efficiency at generator terminals, ISO 3046, Nat. Gas MN >80, Power Factor 1.0, 500 mg/Nm^3 (@ 5 % O_2) NO_x, Efficiency at LHV

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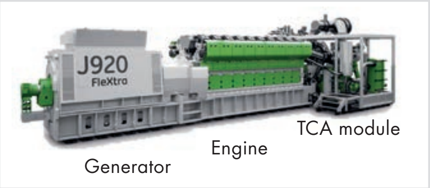

Fig. 2. J920 FleXtra with three module concept.

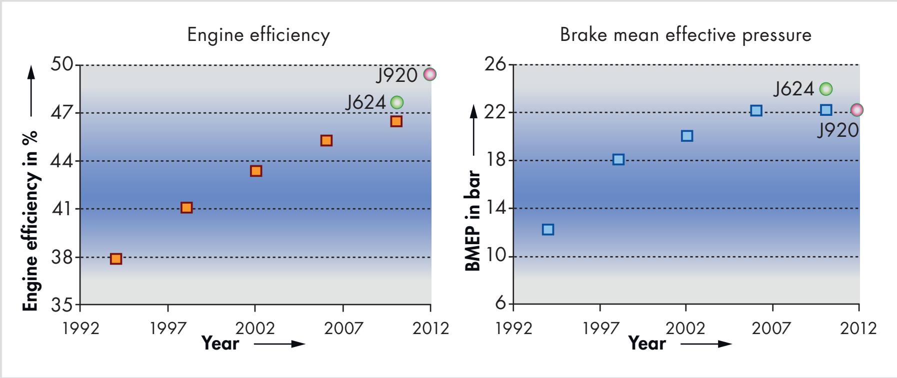

Fig. 3. Performance development history.

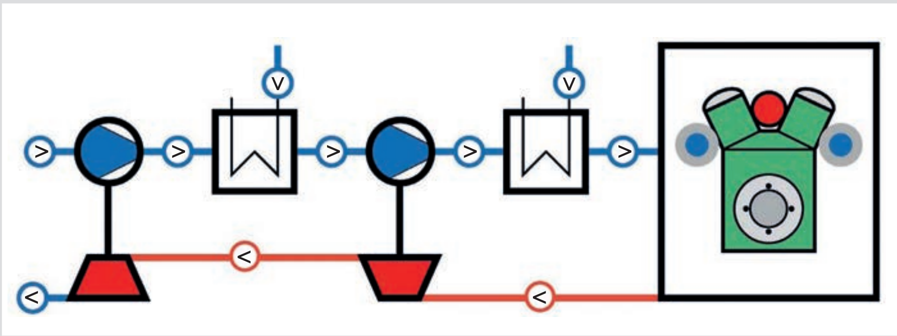

Fig. 4. The J920 FleXtra 2-stage turbocharging principle.

J920 FleXtra features and design

The J920 FleXtra gas engine's medium-speed design is based on GE's long experience with high-speed gas engines that have high power density. The J920 FleXtra is designed with the same 2-stage turbocharging system as the J624.

GE's Jenbacher type 6 gas engine with an output range between 2 and 4.4 MW provides a good example of the trend in the development of high-efficiency gas engines. By increasing the brake mean effective pressure (BMEP) in combination with a continuous improvement of combustion and optimisation of the charging as well as the charge exchange process, the electrical efficiency of the generator set could be increased from 38 % in 1994 (at 12 bar BMEP) to 45.6 % in 2009 (at 22 bar BMEP) while always meeting TA Luft. The first 2-stage turbocharging engine, the new J624, has an electrical efficiency of 46.5 % and an output of 4.4 MW (at 24 bar BMEP). The type 6 development is shown in Figure 3 with an engine efficiency of about 1 % point higher than the electrical efficiency.

While the J624 provides high specific output (24 bar BMEP), the J920 FleXtra was designed to achieve a high electrical efficiency level by taking advantage of the size of the engine. The J920 FleXtra provides very high efficiency and comes close to 50 %, while running at 22 bar BMEP.

The road to advanced *Miller* valve control timing and the optimised lean-burn combustion process, enabling high efficiency levels and low NO_x emissions, was paved by 2-stage turbocharging technology. Combined with the optimised MORIS high energy ignition system along with refined control strategies and algorithms, these technology blocks facilitate a sufficiently wide operating band between the knock and misfire limits. In particular they make operation possible at high altitudes and under tropical conditions without compromising efficiency. The turbocharger system on the engine consists of 4 turbochargers, one 2-stage turbocharging system for each bank. The principle of the 2-stage turbocharging system can be seen in Figure 4.

While advanced *Miller* valve timing reduces the knock tendency, it also increases the required charging pressure. To meet the required charging pressure, a required pressure ratio >6 together with high charging efficiency can be achieved only by using 2-stage turbocharging technology. It offers a charging efficiency of more than 75 % and consists of a low-pressure compressor, intercooler, a high-pressure compressor, and aftercooler (blue line in Figure 4), with the corresponding high- and low-pressure turbocharger turbines on the exhaust side (red line in Figure 4).

Applications

Gas engines offer high simple cycle electrical efficiency, and due to this high simple cycle efficiency most of the installations are in simple cycle. Therefore, investment costs are reasonable, which makes projects attractive. Also many gas engine units are installed for CHP applications. Because low grade heat is available from gas engines exhaust and auxiliary systems, gas engines are an ideal solution to providing hot water for district heating systems. Operating flexibility is another advantage of gas engines provided by multiple unit installations.

Fig. 5. J920 FleXtra multiple gas engines plant.

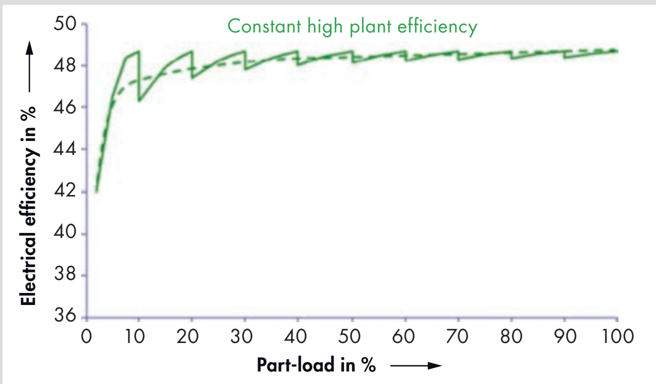

Fig. 6. Plant efficiency.

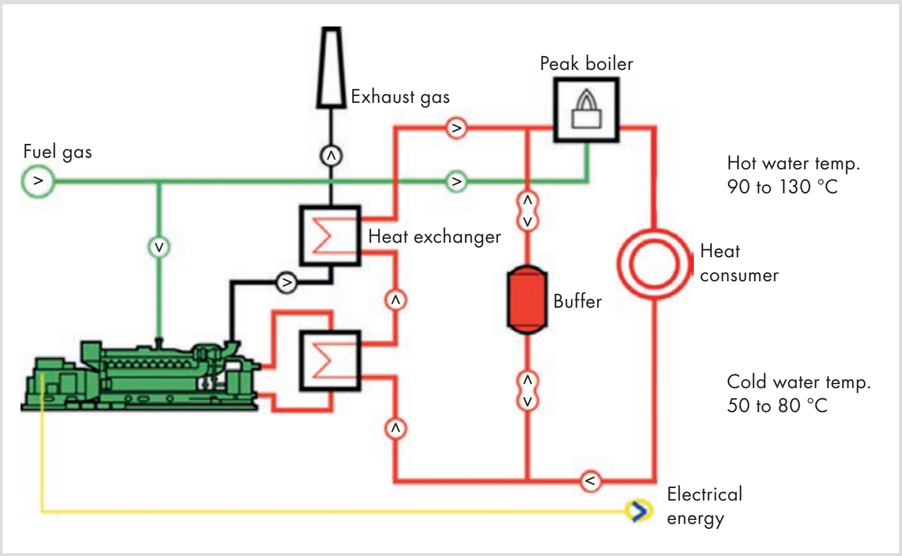

Fig. 7. J920 FleXtra CHP concept.

The advantages of high electrical efficiency, fit for CHP applications and multiple unit installations can be combined for many different project requirements.

Multiple gas engine power plant:

Either for power generation only (IPP projects) or combined heat and power, multiple gas engines offer several customer advantages. Due to multiple installed generating units, higher plant availability is achieved and plant output is reduced only by the incremental output depending on the number of engines installed – in case one engine is down for maintenance. Starting from a pre-heated engine, the J920 FleXtra can offer a 5-minute start-up time from initial start to full load, and multiple engines can be started in parallel. The short start-up time makes gas engine power plants an attractive solution for frequent start-stop operation and offers excellent load following capability. Figure 5 shows a J920 FleXtra multiple gas engine power plant from inside.

One other big advantage of a multiple gas engine power plant is the high plant part load efficiency. Starting with the high simple cycle gas engine efficiency, the efficiency stays high in part load operation due to the ability to start and stop incremental engines as needed by demand. Only the number of engines are online and running that are required to meet the target plant output and those engines are running near full load, hence at maximum efficiency (Figure 6).

Combined heat and power:

As already mentioned above, 2-stage turbocharging allows achieving 90 % total efficiency – about 3 to 4 % higher than a gas engine with single-stage turbocharging. Figure 7 shows how all the heat from the engine auxiliary cooling and engine exhaust can be used in a combined heat and power plant. A district heating water return temperature of up to 70 or 80 °C is acceptable for cooling the engines auxiliaries and a hot water temperature of up to 130 °C can be provided.

Gas engine power plants for CHP run with constant high electrical efficiency, whether or not heat is provided. Because there is no steam cycle applied, no steam extraction is done and hence no power and efficiency loss. For the CHP application the installation requires only one additional gas/water heat exchanger (exhaust gas heat exchanger) beyond the GenSet, because all other heat exchangers (mixture HX, oil HX and JW HX) are part of the auxiliary cooling system belonging to the GenSet. That makes the gas engine CHP installation simple, compact and easy to operate.

Renewable energy resources such as wind and solar have a low environmental impact but are not always available. With the accelerating growth of renewable installations, a higher demand for flexible power generation is required in general. Operating flexibility can be provided by multiple gas engine power plants and the fast start-up time, and that flexible power can be activated during periods of low feed-in from renewable sources or during tariff spikes and, conversely, can be quickly reduced during spells of high feed-in of renewable energy or low energy prices.

That is exactly what is offered by a CHP plant combined with heat storage (Figure 8). Up to a certain point, heat storage makes it possible to decouple a continuously required heat supply from power production, thus making more flexible use of the combined heat and power plant. In periods when the power supply can be met easily from renewable energy or during periods with low power prices, the CHP plant simply reduces load while the demand for heat is met from heat storage. The opposite occurs during periods of low heat demand and higher power tariffs, when GE's gas engines generate power while storing heat for periods of higher demand.

The Stadtwerke Rosenheim plant

Figure 9 shows the J920 field installation at the Stadtwerke Rosenheim in Germany – a typical CHP installation for a German city. Stadtwerke Rosenheim supplies water,

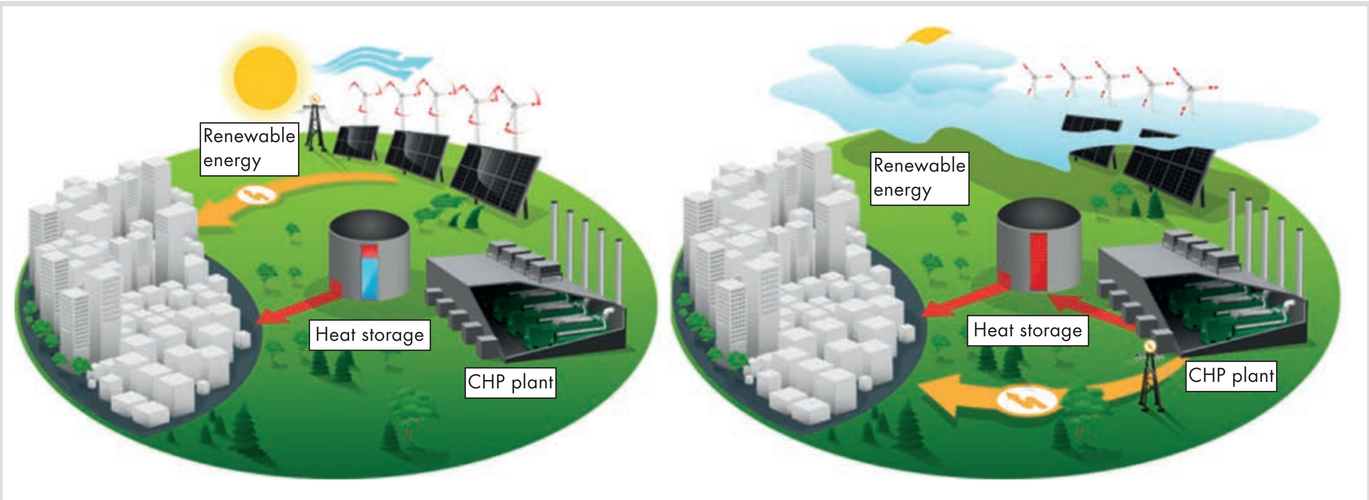

Fig. 8. CHP combined with heat storage.

Fig. 9. J920 FleXtra Rosenheim installation.

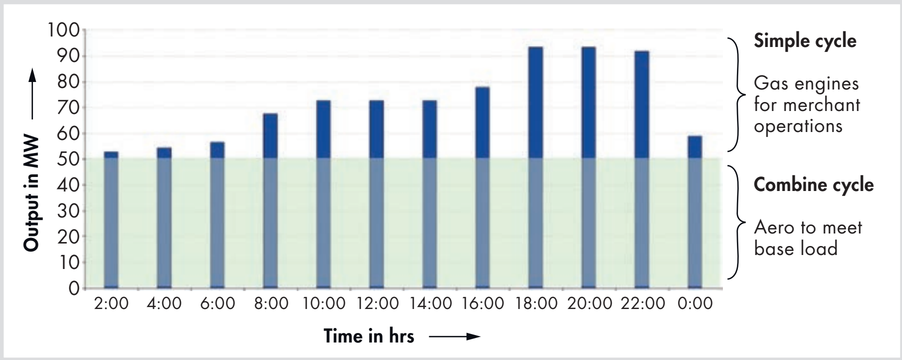

Fig. 10. GE's hybrid solution.

electricity, gas, process steam ,and district heating for residential and local industrial customers. With the J920 FleXtra addition the CHP plant now generates about 40 % of the electricity and provides about 20 % of the heating requirements of Rosenheim.

Using combined heat and power with gas engines technology is a critical piece of the municipality's energy concept. Given the fast growing presence of renewable energy sources such as wind and solar power, it is essential to create a more flexible energy supply infrastructure such as the gas engine based distributed CHP plants. The J920 FleXtra gas engine was installed at the Stadtwerke Rosenheim, where it joined four smaller Jenbacher gas engines installed in the previous years.

Since the Rosenheim CHP plant stores heat, it allows a daily optimisation of the gas engines operating hours and makes them an ideal complement to intermittently available wind and solar energy supplies. Although the J920 FleXtra is a CHP installation, it has all the necessary auxiliary cooling system installed and it bypasses the exhaust heat exchanger system to allow power-only operation in the summer time.

Combining efficiency and flexibility

The bigger GE portfolio for decentralised power solutions consists of gas engines from about 0.2 MW to 100 MW gas turbines. The smaller output range is traditionally covered by gas engines, while the larger output range above 10 MW is covered by aeroderivative gas turbines. Those gas turbines are derivatives from aircraft engines and are typically designed as dual shaft engines. The high speed shaft is running at about 10,000 rpm, while the outer shaft runs at 3,000/3,600 rpm. Especially the high speed of the inner shaft makes these turbines relatively small and allows for a very compact power generation package with high power density.

On the smaller side of the output range the portfolio consists of the type 3, type 4, and type 6 Jenbacher gas engines up to 4.4 MW output. The larger Jenbacher J920 FleXtra gas engine with 9.5 MW output bridges to the aeroderivative gas turbines starting with about 20 MW output. Gas engines have typically a 10 % higher electrical efficiency than turbines, but less energy in the exhaust gas because a significant portion of thermal heat goes to oil and jacket water coolers as well as to turbocharger intercoolers.

Gas turbines have a higher exhaust gas temperature than gas engines and provide almost all of the thermal heat in the exhaust gas. That makes gas turbines more favorable for combined cycles. The steam bottoming cycle of a gas turbine combined cycle provides about 50 % additional output and hence a significant increase in electrical efficiency. The power plant net electrical efficiency of such a gas turbine combined cycle is well above 50 %, typically in the range of 52 to 54 %.

Combining the efficiency advantages of a combined cycle and the higher simple cycle efficiency of gas engines in a hybrid concept provides a unique power plant concept with high efficiency and high flexibility in one (Figure 10).

Typically that kind of power plants will consist of a single or dual (2 on 1) gas turbine combined cycle and multiple gas engines. While the gas turbine combined cycle provides more continuous load between part load and full load, the gas engines provide peaking and mid merit power with daily starts and stops. Because of the multiple unit installations of gas engines, only those engines are started that are required at the current time and all advantages of a multiple gas engine power plant as explained in the section applications above are valid for a hybrid solution.

Summary

The J920 FleXtra gas engine with its 9.5 MW electrical output was designed to achieve a high electrical efficiency of 48.7 %, and 2-stage turbocharging is the enabling technology for higher electrical efficiency and allows achieving higher heat output to improve the total efficiency of gas engine CHP plants to 90 % and more.

The flexibility of the J920 FleXtra makes it an ideal solution for larger IPP projects and bigger CHP power plants of 50, 100 or 200 MW. The fast start/stop cycles allow good load following, especially with multiple engines installed in one power plant. Combining CHP projects with heat storages, makes power production independent from heat demand and allows CHP plants to benefit from the flexibility of the J920 FleXtra.

Combining the flexible J920 FleXtra with a highly efficient gas turbine combined cycle provides a unique concept with high efficiency and flexibility in one power plant solution, and that should fit well with thermal power plants as the renewable installations grow.

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