GTX100 – a new high-performance gas turbine

ABB developed the GTX100 gas turbine to meet growing market demand for power generation equipment that combines high reliability, low emissions and high efficiency. Rated at 43 MW, the advanced, dual fuel unit closes a gap in ABB's extensive gas turbine power range. NO_x and CO emissions with natural gas are below 15 ppm (15 % O_2) and with liquid fuel below 25 ppm (15 % O_2) over a 50–100 % load range.

The ability to produce power and heat efficiently is of growing importance to a power generation industry faced with deregulation, privatization and fast-changing customer requirements. Utilities, industries and independent power producers (IPPs) are all searching for technologies that will give them high levels of performance without compromising reliability or safety. To meet this need and to close a gap in its extensive gas turbine power range of 1.5 to 265 MW, ABB has developed the GTX100 1. At 43 MW ISO output, the new unit lies between the 25-MW GT10 and the 53-MW GT8C 2.

A growing industrial market

The worldwide market for gas turbines in the 30–50 MW power range has grown in recent years to more than 100 units per annum. A truly global market, it is made up increasingly of industrial and independent power producers whose primary concern is to generate electrical energy efficiently and dependably, often in combination with process heat. In an environment of growing uncertainty, these customers demand compact plants offering high reliability and availability, low life-cycle costs and short delivery times. The GTX100 meets the needs of this market.

Designed for robust simplicity

Reliability is a key customer requirement in this market segment. IPPs and process industries are highly dependent on a smooth and uninterrupted supply of power and heat. To ensure the reliability of the GTX100, its design has been based upon simplicity, robustness and the use of proven technology.

The GTX100 features a simple shaft arrangement 1. The compressor rotor and the three-stage bolted turbine module form a single shaft which rests on two standard hydrodynamic bearings of the tilting pad type. This is the configuration normally used for ABB's larger gas turbines [1]. The generator is driven from the cold end of the gas turbine, thereby allowing a simple and efficient exhaust arrangement. Modularity, few parts, long component life and easy inspection ensure long intervals between overhauls as well as low maintenance costs.

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Design

Compressor section

The compressor is a scaled-down version of the LP compressor used in ABB's large GT24/26 gas turbines [2]. It has 15 stages and uses controlled diffusion airfoils for maximum efficiency. The first three stages feature variable geometry. To minimize leakage over the blade tips, abradable liners are applied to stages 4–15. The vane carrier of the high-pressure section, stages 11 to 15, where the blades are shortest, is made from IN 909, a low-expansion material that helps keep clearances to a minimum.

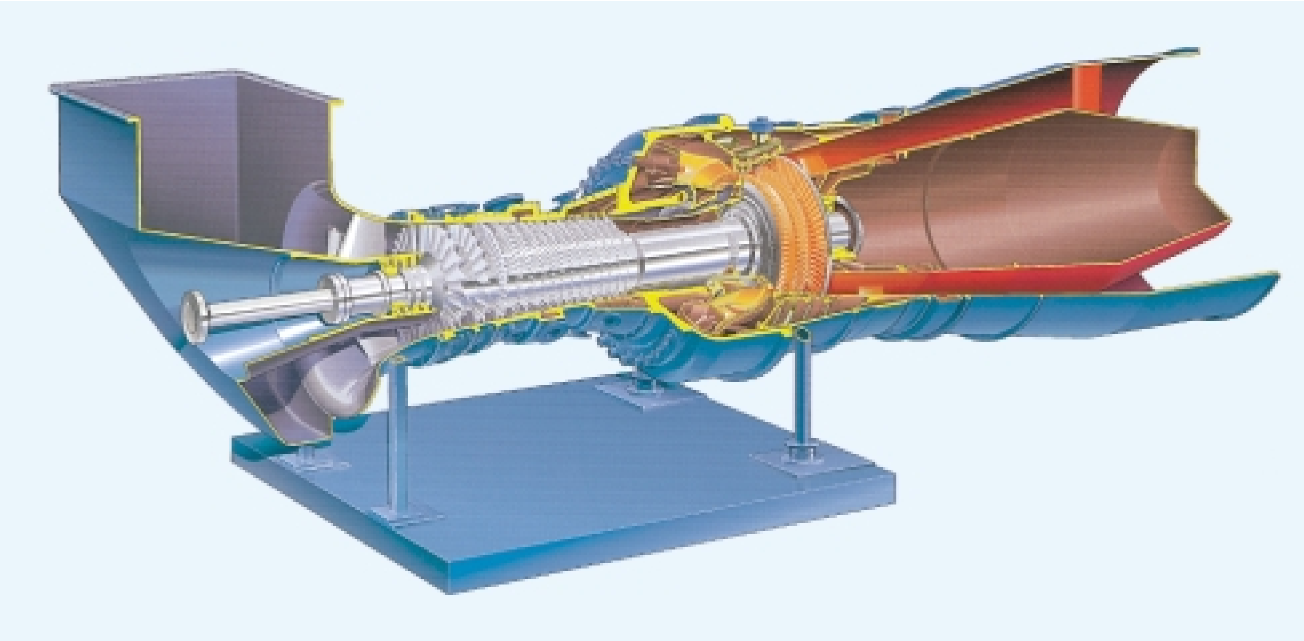
The compressor rotor is built up from discs which are welded together into a robust unit using electronic beam welding. The technology has been used for many years in the GT10, and compressor rotors constructed in this way have proved to be very reliable in operation.

Cooling air for the hot sections of the turbine is extracted from the compressor at stages 3, 5, 8, 10 and 15.

Combustor section

The annular combustor is a welded sheet metal construction. Its inner surface has a thermal barrier coating which reduces the level of heat transfer and extends the life of the combustor. This design concept has been used for many years in the GT10.

Compliance with strict environmental regulations is already required in many markets and ecological awareness is spreading to new regions. ABB recognized the strategic importance of environmental issues at an early stage



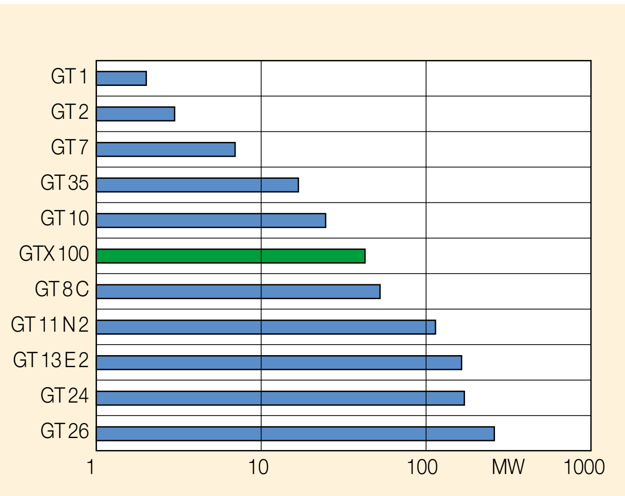
The GTX100 industrial gas turbine **1**

and has taken a lead in gas turbine emissions control. In 1988 it introduced the first so-called EV burner to the market. To date, the total accumulated experience with this dry, low-emission (DLE) technology amounts to more than 1.6 million operating hours, including numerous GT10 installations [3].

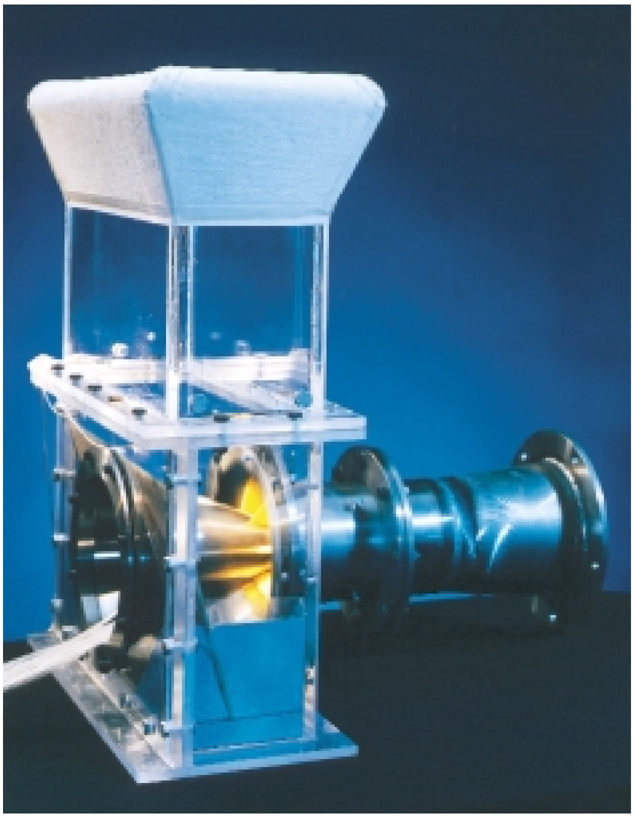
With the GTX100, ABB has taken another step towards lower emissions. The combustor has 30 burners of the new Advanced EV (AEV) design **3**. AEV burner technology was developed at the ABB Corporate Research Center in Dättwil, Switzerland, and, as applied in the GTX100, will offer NO_x and CO emissions below 15 ppm (15 % O_2) on natural gas and below 25 ppm (15 % O_2) on liquid fuel over a 50–100 % load range without the need for water or steam injection. Dual-fuel DLE capability is a built-in feature.

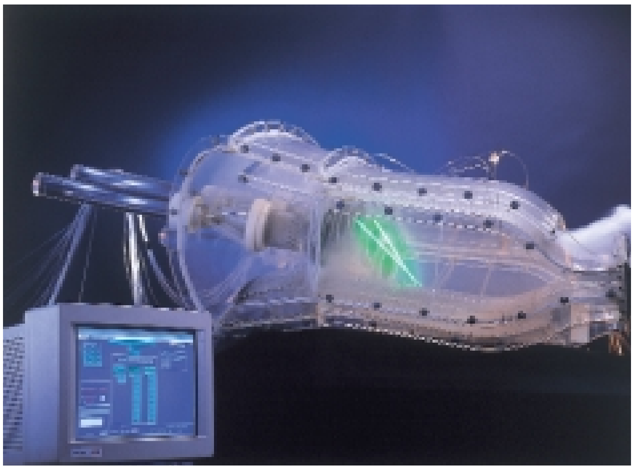
Extensive tests have been conducted to verify the lower emission levels over the full load range of the machine, using liquid as well as gaseous fuels.

At 43 MW, the GTX100 closes a gap in the ABB gas turbine program. **2**



AEV dry, low-emission burner used in the GTX100 **3**





Validation test being carried out on a full-scale model of the combustor section **5**

Testing a model of the inlet section to validate its design **4**

Turbine section

The three-stage turbine has been designed as a single module for ease of maintenance and is bolted to the stub shaft of the compressor. Its advanced aerodynamic design features a fully 3D-analyzed flow path with cylindrical sections over the first and second-stage blades. The first and second-stage vanes and blades are cooled using the same technology as that used in the GT24/26. The first blade is made of single-crystal material to ensure durability and long life. The turbine stator flanges are cooled by compressor air to reduce clearances and improve efficiency.

The cold-end drive arrangement allows an optimized axial exhaust diffuser section to be fitted, resulting in better performance. Special attention given to the design of the connection between the diffuser and the heat recovery steam generator (HRSG) minimizes losses in combined cycle and cogeneration applications.

Main gearbox

The gas turbine is connected to the generator via a gearbox of the double helical parallel type, which reduces the 6,600 rev/min of the turbine shaft to a generator speed of 1,500/1,800 rev/min. The electric starter motor is connected to the main gearbox via a self synchronizing and switching clutch and a separate starting gear.

Design validation

A comprehensive test program has been conducted to validate the design of the critical components of the GTX100.

A scale model of the entire compressor has been built and thoroughly rig-tested at MTU in Germany. Tests in models of the compressor inlet and plenum chamber have verified the flow characteristics and the pressure drop **4**. Model tests have also been carried out on the diffuser section behind the compressor to validate the design and the pressure gain in the upper and lower channels.

The combustor and the burners have been tested extensively at the ABB works in Finspong, Sweden, at ABB in Switzerland, and at the CIAM test center in Moscow. Two combustor cylinders have been built for design validation under hot conditions, at atmospheric as well as at full pressure.

A full-scale model section of the combustor has been built to verify design details such as surface design, pressure drop and vortex breakdown. Special model tests have been conducted to verify the proper cooling at the combustor outlet and the first vane **5**.

The turbine cooling technology has been verified in tests conducted at a newly-built hot test rig in Finspong, where cooling flows and heat transfer coefficients can be measured **6**. Tests have also been carried out to validate the mechanical integrity of the first vane and blade film cooling designs.

Auxiliary systems

Lubrication

Since the two shaft bearings of tilting pad design are lubricated with mineral oil, a common lube oil system can be used for the gas turbine, gearbox and generator. In a combined cycle plant, the lube oil system would be extended to also include the steam turbine and its reduction gear.

Oil pressure is supplied by three 50 % AC-driven pumps controlled by static frequency converters.

Fuel systems

The GTX100 runs on a range of gaseous and liquid fuels, including natural gas, LPG, naphtha and diesel oil. Two fuel systems, for gaseous and liquid fuels, are available; in dual-fuel operation, automatic switch-over between the fuels is possible at full and part load.

Hot test rig used to verify the advanced turbine cooling technology **6**

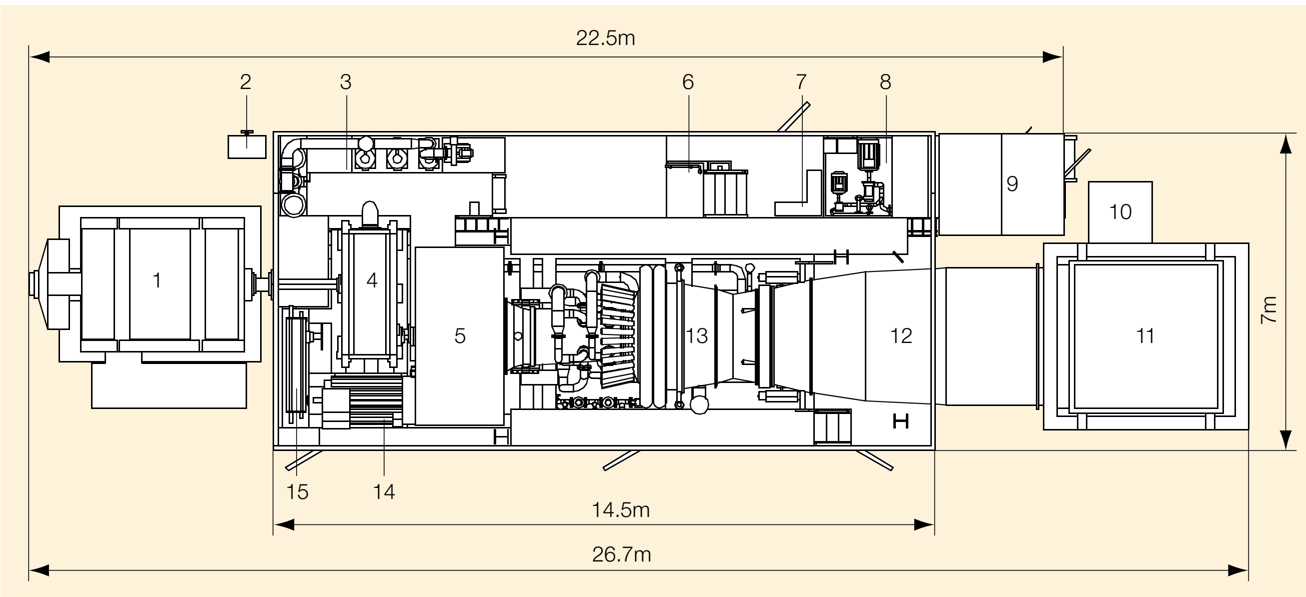
Control system

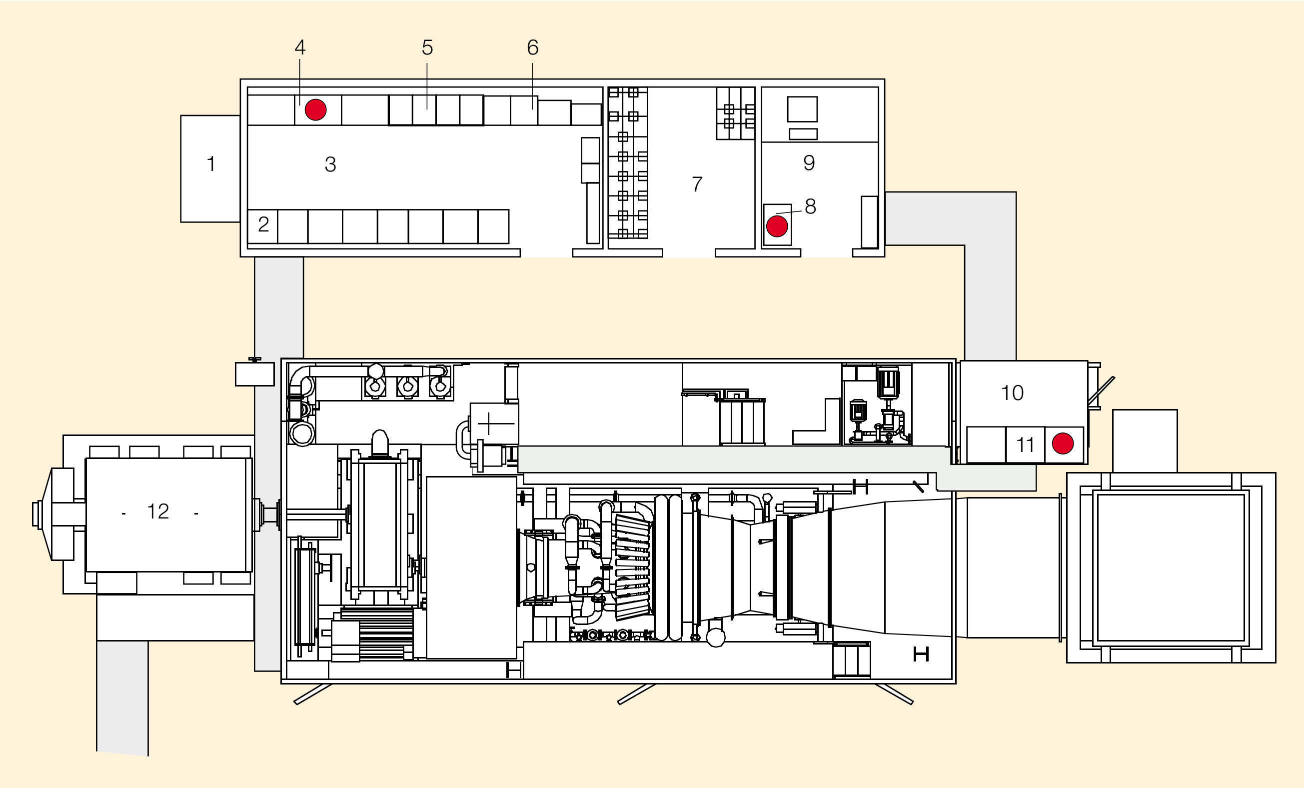
The GTX100 control system is based on ABB Advant and has four controllers operating in four nodes:

- The first node uses an Advant AC160 for closed-loop control of alarms and shutdowns, starting, synchronizing, load and fuel-valve positioning.

General layout of the GTX100 **7**

1 *AC generator*
2 *Ignition gas*
3 *Lube oil*
4 *Gearbox*
5 *Inlet*
6 *Cleaning system*
7 *Fuel gas*
8 *Liquid fuel*
9 *Signal treatment room*
10 *Firefighting system*
11 *Exhaust*
12 *Exhaust diffuser*
13 *Gas turbine*
14 *Starting motor*
15 *Starting gearbox and clutch*





GTX100 layout with outdoor electrical and control enclosure **8**

1 *Starting transformer*
2 *SFC starter panels*
3 *Auxiliary room*
4 *Motor control center*
5 *Lube oil panels*
6 *Chargers and inverter*
7 *Battery room*
8 *Generator panel*
9 *Control room*
10 *Signal treatment room*
11 *Process control equipment*
12 *Generator*

- The second node is an open loop for controlling sequencing and protection, and is also based on the AC160. It takes care of the event handling, sequencing and interlocks, and produces trend curves.
- The third node, a closed loop for control of the generator, is based on the Advant AC110 and also handles the voltage and generator protection.
- A fourth node, also in the generator control panel, is responsible for synchronizing, motor controls and open-loop control of the lube oil. It is based on another AC160.

Man-machine communication takes place via an Advant 160 operator station, which is a standard PC using Windows technology. The Advant controllers can also communicate with external systems via standard buses.

Installation

The GTX100 installation meets today's market requirements by offering compactness, short erection and commissioning times, and ease of maintenance. The gas turbine is skid-mounted, with the auxiliaries grouped in a self-contained module placed to one side of the main skid. The footprint is only 27 × 7 m.

The layout is basically the same for all applications, whether simple or combined cycle and whether indoors or outdoors.

The gas turbine skid is made of steel beams and carries the gas turbine, reduction gear and starter motor. It rests on a concrete foundation and may be fitted with spring mounts if required. The main and auxiliary skids are covered by a weather-proof enclosure extending from the gearbox to the gas turbine exhaust.

The air intake and exhaust stack are supported by separate external beam structures. A two-stage disposable air filter is supplied as standard, but other options are also available. The standard exhaust stack is 15 m in height; however, it can be built to other site requirements as an option **7**.

Electrical and control equipment may either be installed in the customer's control room or in a separate enclosure with auxiliary power room, battery room and control room **8**.

Generator

The standard model is a 4-pole generator of type GBA 1250AL, driven from the cold end of the gas turbine via the parallel reduction gear. It is of simple and rugged design and has a salient pole rotor with solid pole plates and a rotating brushless exciter. The GBA design is well proven, having been used in numerous GT10 installations.

The generator is installed outside of the main enclosure and is protected from the weather by a roof. As an option, it may be fully enclosed.

Combined cycle

In combined cycle applications the GTX100 can be arranged in a single-string configuration with the steam turbine driving a common generator. A dual-pressure HRSG feeds an ABB single-cylinder impulse steam turbine with an axial exhaust to the condenser. This well-proven configuration has been used in many GT10 combined cycle plants and offers a compact solution with a footprint of only 60 × 20 m for the entire 62-MW power plant, including the boiler and all auxiliaries **9**.

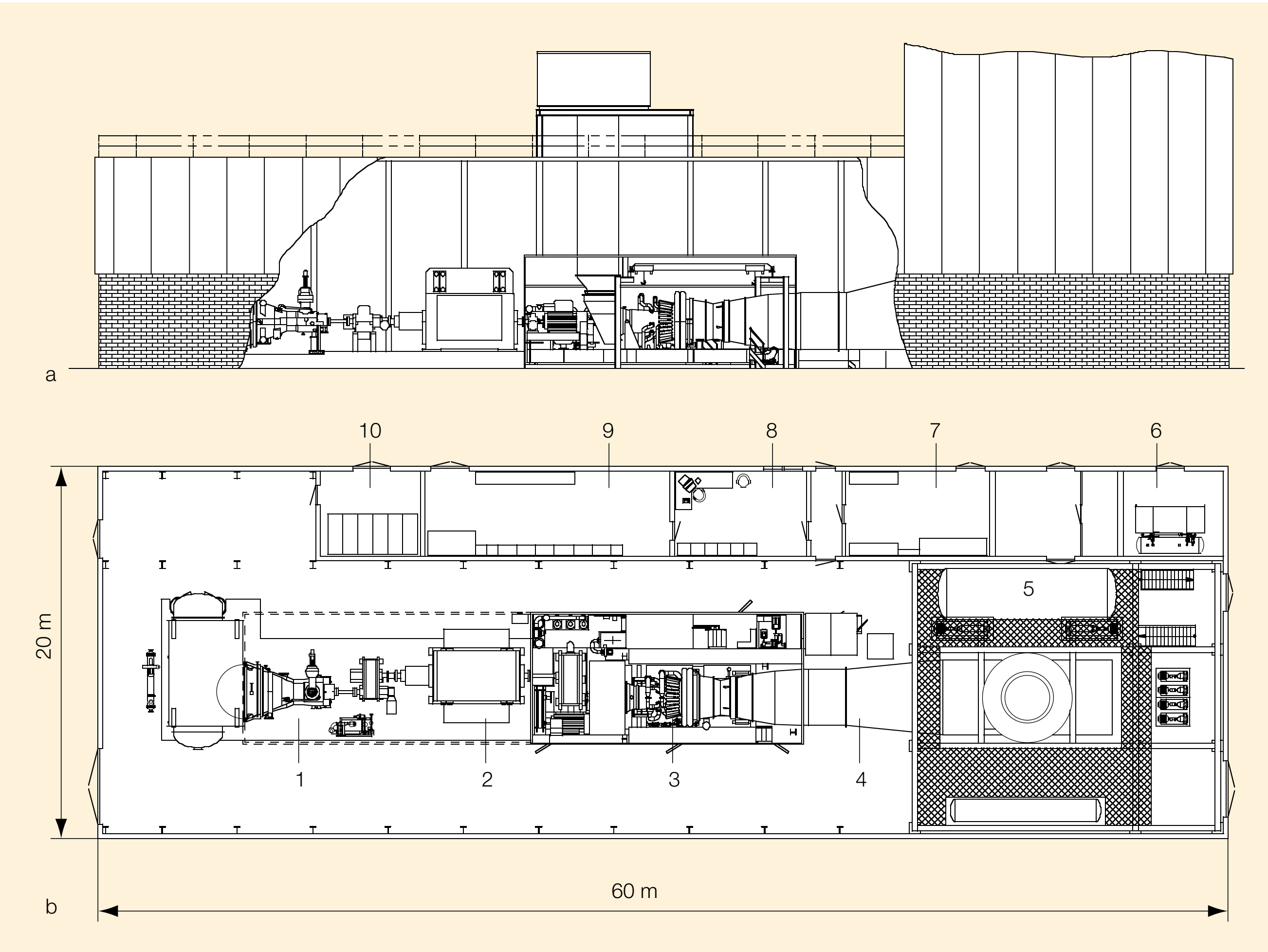
For higher power levels, two GTX100 units, each with its own HRSG, may be arranged such that they feed a common steam turbine. One gas turbine would then operate separately, while the other would operate in a single-string arrangement with the steam turbine. The total output would be 124.5 MW.

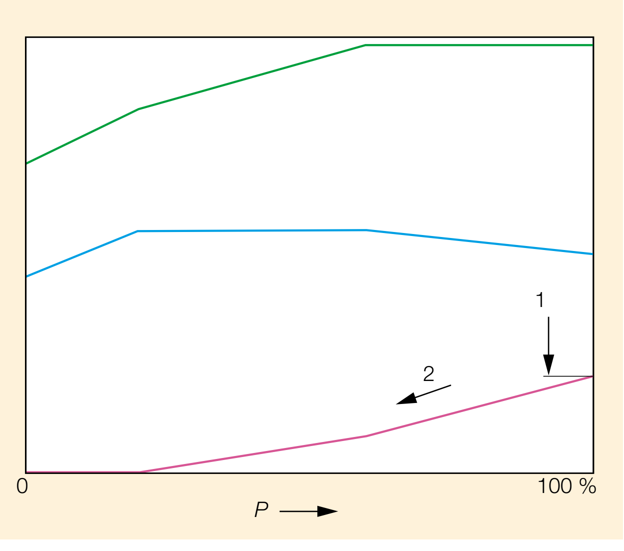
Erection and commissioning

In order to shorten the on-site erection time, the GTX100 comes in modules which are assembled and tested in the workshop prior to shipment. Most of the

Side view (a) and layout (b) of the KAX100-1 combined cycle power plant **9**

1 *Steam turbine*
2 *Generator*
3 *Gas turbine*
4 *HRSG*
5 *Feedwater tank*
6 *Air compressor*
7 *Battery room*
8 *Control room*
9 *LV switchgear*
10 *MV switchgear*

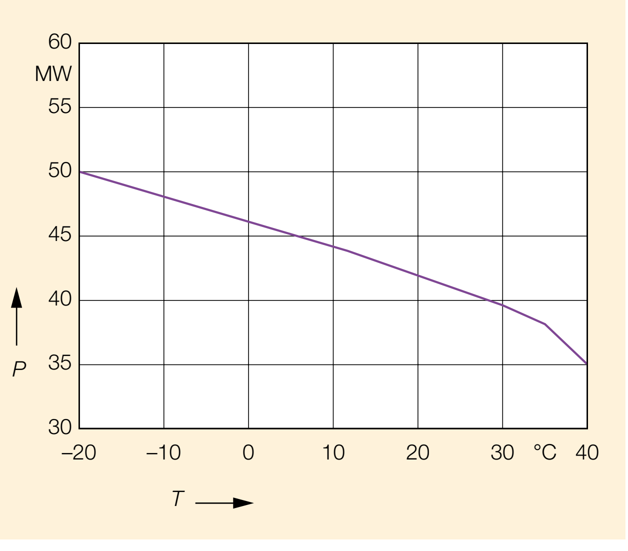




Operation concept for part-load operation **10**

Blue *Exhaust temperature*
Green *Turbine inlet temperature*
Pink *VGV position*

1 *0° angle*
2 *Closing*
P *Load*



GTX100 performance versus ambient temperature **11**

P *Nominal generator output*
T *Compressor inlet-air temperature*

piping and cabling work is also carried out on the shop floor to minimize the time needed for this on site.

The biggest shipping module, weighing a total of 76 tons, is made up of the gas turbine, gearboxes and starter motor, mounted on the main base frame.

Starting and operation

The GTX100 is started by means of an electric starter motor connected to the gearbox. The compressor has two bleed valves at stages 5 and 10, which are open at the beginning of the starting procedure and close during the start-up sequence. The starting sequence takes approximately 13 minutes, plus time for the ventilation, which varies from installation to installation. During operation, the load is controlled by manipulating the variable guide vanes (VGV) and the firing temperature. Initially, the load is reduced by closing the VGVs until the exhaust temperature reaches 600 °C. Further load reduction is achieved by reducing the firing temperature and closing the VGVs while maintaining the exhaust temperature at 600 °C. When the VGVs are set to their minimum positions, the load can be reduced further by lowering the firing temperature **10**.

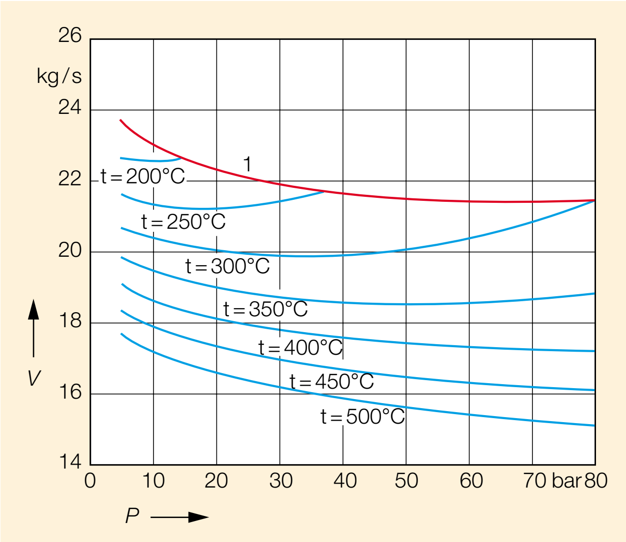
The firing temperature and VGVs are also used to control load at high ambient temperatures. For ambient temperatures above 35 °C the VGVs are closed while the temperature rises and the firing temperature is adjusted to keep the exhaust temperature below 600 °C.

Table 1:
GTX100 nominal performance under ISO conditions, with open cycle

Nominal performance, ISO conditions	Natural gas	Diesel oil no. 2
Power	43,000 kW	41,400 kW
Specific heat cons.	9,720 kJ/kWh	9,920 kJ/kWh
Thermal efficiency	37 %	36.3 %
Exhaust mass flow	122 kg/s	123 kg/s
Exhaust temperature	546 °C	548 °C

Performance

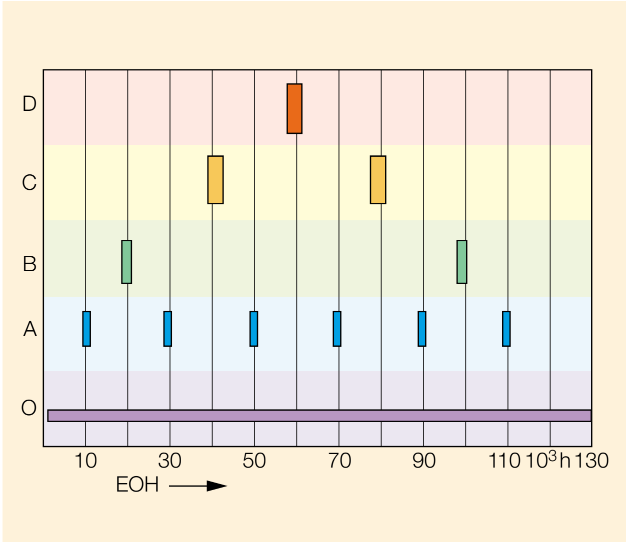
If a gas turbine is to achieve high-level performance, due attention has to be given to its intended operating cycle. In the case of the GTX100, market studies had revealed that combined and cogeneration cycles would become dominant in the 30–50 MW market segment, an assumption that has been borne out by recent developments. Hence, the machine has been optimized for such cycles, with



GTX100 steam performance capability for an ambient temperature of 15 °C and pressure of 1.013 bar, with natural gas as fuel (LHV = 48,815 kJ/kg) 12

P *Steam pressure*
V *Steam production rate*

1 *Saturated steam*



Inspection and maintenance intervals for the GTX100 13

A–D *Maintenance program levels*
EOH *Equivalent operating hours*
O *Operation maintenance*

the pressure ratio set at 20 : 1. *Table 1* shows nominal performance figures for the GTX100.

The care taken in designing the GTX100 has contributed to its high level of performance. In particular, the advanced aerodynamic design, the use of abradable liners and low-expansion materials in the compressor section, as well as features such as turbine stator clearance control and the axial diffuser, contribute to the high level of efficiency.

In combined cycle operation based on a dual-pressure, non-reheat steam cycle, the net output of the machine is 62 MW at 54 % efficiency 11. Excellent part-load performance is also achieved with 54 % efficiency maintained down to 70 % load under ISO conditions.

Cogeneration applications benefit from the high exhaust temperature, which allows a high level of steam production, thereby meeting the demand requirements of a wide range of process industries and other consumers of heat, such as district-heating networks 12.

Low life-cycle costs

Two key elements of the life-cycle costs are the cost of fuel and maintenance. Due consideration was given to these already at the design stage of the GTX100, and as a result operators are assured of low costs without any reduction in the machine's basic reliability and availability.

The excellent performance figures in key applications keep fuel costs under control, an important requirement where fuel is purchased at world market prices. A high level of efficiency is particularly critical when fuel is expensive, making combined cycle/cogeneration the preferred solutions. A drop in efficiency of two percentage points will typically lead to an increase in life-cycle cost of almost USD 5 million over a 15-year period.

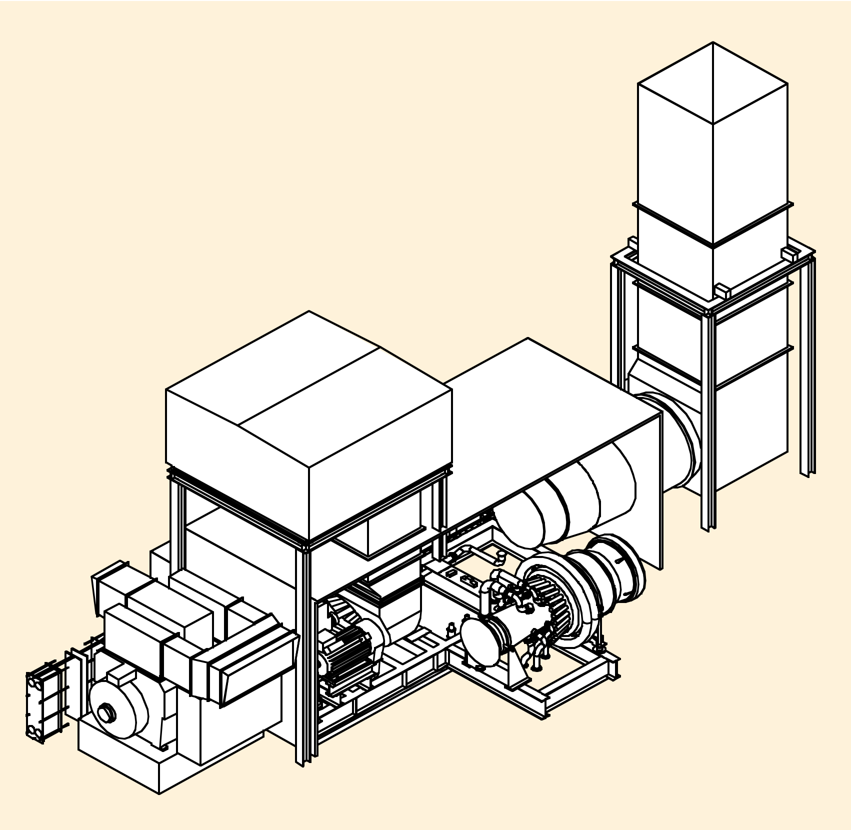
The basic robust simplicity of the GTX100 and an optimized maintenance schedule translate into very competitive maintenance costs. This is of significance, since a variation in maintenance cost of 1 USD/MWh in this size range is typically worth USD 4 million over 15 years.

Ease of maintenance

The GTX100 has a number of features that simplify maintenance and inspection. One side of the gas turbine has been kept 'clean', avoiding unnecessary piping, cabling and connections, to allow for easy inspection. Borescope ports are provided on the clean side for inspection of each compressor stage. A manhole with plexiglas window at the front of the inlet chamber allows easy inspection of the compressor inlet bellmouth.

The compressor casing is split vertically in the longitudinal direction, which allows half of it to be removed for easy access to the rotor and stator parts. The rotor center line is 1.6 m above the floor, making inspections very convenient.

The burner section has been designed so that each of the 30 AEV burners can



Removing the gas turbine from the installation **14**

be removed individually without having to dismantle the machine. Easy inspection of the combustion chamber is also ensured.

An overhead crane is installed inside the gas turbine enclosure to facilitate maintenance, and enough space is available to allow operating personnel to walk around the machine. The gas turbine can be removed from either side of the installation. If required, the walls of the enclosure can also be removed.

Maintenance program

A well-established maintenance program is available for ABB's industrial gas turbines of types GT35 and GT10, and the same principles apply to the GTX100. Inspections and maintenance are carried out at intervals of 10,000 equivalent operating hours and come in four levels, a philosophy which has ensured high reliability for the gas turbine types concerned **13**. The time between major overhauls is 40,000 equivalent hours.

If required, the complete gas turbine can be replaced in 24 hours after it has cooled down to the necessary temperature. This involves disconnecting it from the air intake and diffuser and then removing it sideways on a rail assembly **14**.

A comprehensive service portfolio is offered by ABB that meets the individual requirements of GTX100 customers. It ranges from a simple support agreement to full responsibility for preventive as well as corrective maintenance.

ABB will also store emergency spares and a spare gas turbine for emergency back-up as part of its service agreements.

Outlook

The market for efficient and clean power generation based on gas turbines in the 30–50 MW range continues to grow at the same time that customers are demanding equipment that can deliver high-level performance without sacrificing reliability. The GTX100 gas turbine from ABB has been developed to meet this demand. It is designed to ensure very low life-cycle costs and to be used for a wide range of applications. These and other features of the GTX100 are in line with current as well as future customer requirements.

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