Green House Gas Emission Reduction and Extension of Facility Life of a Power Plant – Exemplified at a Brownfield Gas Turbine Installation

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Abstract

Constraints and regulations in terms of environmental aspects, like emissions, as well as fuel costs and the lack of flexibility can make the operation of older simple cycle gas turbine or co-generation plants less attractive. Also, the power demand may have changed considerably since the installation of the current core engine, making the plant over- or under-sized. The costs of the actual power generation equipment or the core engine represent only a fraction of the total costs of a power plant. Furthermore, if the core engine is a gas turbine, the auxiliary equipment, waste heat recovery unit etc. have a lifetime that exceeds that of the turbine by far. These factors can lead to a situation in which the operator would like to replace solely the gas turbine with as few modifications to the existing infrastructure as possible.

The path to a decision for such a refurbishment predominantly based on anticipated future challenges in power generation and the demand for enhanced fuel-flexibility, shall be exemplified based on a case study for a German local utility. Here, after a feasibility study, one aero-derivate gas turbine with an ISO power output of 25.5MW_{el} was replaced by a newer MGT8000 industrial gas turbine with an ISO power output of approx. 9MW_{el}. The new turbine is fitted into a brownfield site and existing peripheral equipment and ducting are utilized to the highest possible extent. The required modernisations and rework as well as the resulting challenges up to and including commissioning shall be discussed. First operating experiences shall be reported as well.

A brief outlook on possible (co-) firing of hydrogen or other gases and the necessary adaptations to the newly installed gas turbine for these fuels shall be provided.

Introduction

MAN Energy Solutions SE has a comprehensive and decades-long experience in the design and manufacturing, installation and servicing of gas turbines and gas turbine packages. Activities at the Oberhausen plant in Germany in this field started in 1988 with the THM-range of industrial gas turbines. These engines were continually improved in line with market requirements, increasing their efficiency as well as substantially reducing their emissions [1]. In 1990 a long-term cooperation with Pratt & Whitney was initiated. The two companies jointly offered aero-derivative versions of the JT8D jet engine, the FT8, for the European market, which were rated at 25.5MW_{el}. MAN took responsibility for the design and manufacturing of the freestanding power turbine as well as packaging.

In 2013 a new series of modern engines was introduced to the market by MAN, the MGT. During its development, it was taken into account that the technical requirements for power generation units were changing due to the ongoing worldwide trends in electrical power generation structures. The MGT power generation units fulfil increasingly stringent requirements with regard to availability and reliability [2] as well as dynamic behaviour in case of rapidly changing grid loads or grid failures [3]. An additional design parameter was the CHP capability, with state-of-the-art electrical efficiency and high thermal output.

In the early 70’s MAN developed a closed-loop helium turbine that was projected as part of a nuclear power plant. A demonstrator plant was built at the Oberhausen municipal utility company “Energieversorgung Oberhausen”, or *evo*, adjacent to the MAN works. For this application the required heat was provided by a boiler rather than a nuclear reactor. Furthermore, the turbine was scaled down from its intended application, so it provided only 50MW of power and 53MW of heat. The working fluid and the envisaged use in nuclear power plants necessitated a complicated and costly spherical design of the casing.

One FT8 was installed at the *evo* in December 1995 and used for co-generation as a brownfield application, replacing the helium turbine. Towards the end of its lifetime the FT8 was operated primarily during winter, accumulating approx. 3500 operating hours per year. After running for over 100,000 EOH the engine was decommissioned in 2019. After a business case study and a market survey *evo* decided to replace the old gas turbine with a new one from MAN's product portfolio based on the following criteria:

1. The strategy of the utility was to have a number of smaller decentralized plants; at another site gas engines were installed.
2. The costs of refurbishing the existing building and including as many of the existing components as possible, thus extending their life were only a fraction of developing a green field site. This also eliminated lengthy application procedures.
3. The new turbine had to fulfil current and projected future emission standards as well as the criteria that qualified the plant for German CHP subsidies, e.g. provision of a sufficient overall thermal efficiency.
4. MAN had proven its reliability as OEM, especially with regard to complex brownfield installations and could provide a robust and efficient gas turbine with low-emissions. Because this is not solely a commercial project, but also serves as the launch site for a new gas turbine (see below), the proximity of the MAN works to the installation site and the resulting availability of service personnel were important factors in the decision.
5. The capability to burn blends with 20 vol.-% hydrogen (and the commitment to extend the range to 100% hydrogen until 2030) made it a future-proof investment
6. In addition, the proven reliability of the MAN'S service was of the utmost importance.

Some other factors were not as important as in the past. The FT8, being an aero-derivative, could reach full-load within 310 seconds after a cold start. The newly installed turbine is of the industrial type and hence the cold start-up times are longer than those of the FT8. Flexibility is required due to the ever-increasing amount of renewable power in the grid, though. Because the MGT can provide a fairly constant heat output over a wide load range and the emphasis is on continuous CHP operation, the demands from the grid can be met both now and in the future.

The project was very attractive for MAN as well, as it enabled the operation of a new type of gas turbine, the MGT8000, in close proximity to the MAN-works with a trusted partner as launch customer.

In order to give a better overview over the plant pre- and post-refurbishment, the thermodynamic data and the emissions of both the FT8 and the MGT8000 are listed in Table 1. Note that the FT8, being an aero-derivative engine, has a higher simple-cycle efficiency but a lower CHP efficiency. The values indicated for the MGT8000 fulfil the requirements stipulated above. Because a dry low emission combustion system with dual fuel capability was not available at the time, the FT8 was installed with the standard combustion system. In order to achieve the required NO_x emissions of 50mg/Nm³, water injection into the combustion zone was required. At 88g of water for every 100g of fuel injected, this amount was non-negligible. This increased the power output relative to the ISO-rated nominal value (27.1 vs. 24.4 MW), but it also decreased the electrical efficiency from 38.1 to 36%, although the large generator at the site, which shall be discussed in further detail below, played its part in this lower efficiency as well.

Table 1: Thermodynamic and Emission Data for the FT8 and MGT8000 at site conditions

	FT8	MGT8000
Electrical Power [MW]	27.1	8.9
Electrical Efficiency [%]	36.0	34.1
Exhaust Flow [kg/s]	80	30.2
Exhaust Temperature [°C]	465	516
Hot Water Prod. @ 120°C [MWth]	35	14.2
Overall CHP Efficiency [%]	86	88.4
NO_x Emissions 50-100% load [mg/Nm³]	50[1]	30
CO Emissions < 60% load [mg/Nm³]	100	30

[1] Value with wet-low-NO_x technology

Because considerations regarding possible scenarios for a future European energy market and policy were at the heart of the decision-making process, the next section gives an overview over these aspects as well as some tentative implications for utilities. Then the actual brownfield installation shall be discussed followed by a brief outlook into the development of hydrogen combustion systems.

The Current Situation in the European Power Market

The attitude towards investments in power generation in Germany and indeed in most of continental Europe is characterized by reluctance caused by uncertainty regarding future technologies and regulations. The only thing that seems certain at the moment is the commitment of the European Commission to reduce greenhouse gas emissions (predominantly CO_2) by 2030 and eliminate them by 2050. Electricity generated by wind and photovoltaics is subsidized and gets preferential access to the grid. In this context it is important to note that the EU, for example via the European Investment Bank, supports the erection of CHP plants for power generation, heating and cooling, as long as they adhere to the Emissions Performance Standard of 250 gCO_2/kWh_e, even if fossil fuels are used [4]. This has led to some interest in innovative CHP plants that guarantee the highest possible efficiency for certain well-defined applications [5].

At the moment, hydrogen is considered by many the carbon-neutral fuel of the future in power engineering, as green hydrogen could be produced by renewables like solar and wind. Currently, though, there is neither supply of nor demand for hydrogen and most players are hesitant to invest in the technology. The utilization of the hydrogen in small-scale decentralized CHP applications might become attractive nonetheless because of the high energy conversion rates. For the utilities this implies they need to project plants that burn a blend of gases with up to 10-20$\%_{Vol}$ of hydrogen in the short-to-mid-term, but 100$\%_{Vol}$ of hydrogen in the long-term. At the same time, they cannot afford to neglect the efforts towards establishing ammonia as a fuel or the subsidies for burning biogas or waste gases from industrial processes.

Brownfield Applications – Planning & Commissioning

Brownfield installations can be very attractive from a financial point-of-view, yet some challenges need to be met when replacing equipment in such sites:

1. Original drawings and layouts of the plant are sometimes no longer available. The lack of data concerning the design of components can be even more severe.
2. The power and heat output requirements of the original and refurbished plant may differ, making components over- or under-sized.
3. Controls need to be updated and modified.
4. All construction work (removal of old equipment, erection & commissioning etc.) need to be done within the confines of an existing building. There are additional spatial restrictions posed by auxiliaries and, to some extent, piping and ducting that will not be removed.
5. The original layout is designed to match the connection points of the old equipment, and this seldom matches the requirements of the newly installed machinery.

These points shall be exemplified with the installation of a new gas turbine at the HKW II (German: Heizkraftwerk II or cogeneration plant II) of the municipal utility *evo* in Oberhausen.

Before going into the details, it should be mentioned that no Engineering, Procurement and Construction (EPC) company was involved in the project. The *evo* took responsibility for all plant-related issues including the connection points and MAN took responsibility for everything related to the gas turbine package, the waste heat recovery unit (WHRU) as well as all design and construction work related to the intake air and exhaust gas. Some of the calculation and design and the majority of the erection work was outsourced to sub-contractors by both companies. This arrangement was chosen because of the intimate knowledge of the site and equipment of both companies.

The first challenge was, in this case, not a problem, because most data was available from the archives of both *evo* and MAN. This is not always the case in other projects, where 3D laser scans of the interior of the plant and its piping and ducting may need to be made. One important component of which, more than 45 years after installation, no documentation existed anymore was the steel base frame of the equipment. In addition, since no calculations regarding the statics and vibratory analyses could be provided, it was decided to replace this in its entirety.

The second and third challenges can be important when significant auxiliaries of the old train need to be maintained, e.g., the lube oil system or the generator. In such a case, new controls need to be programmed for old components and their characteristics need to be adapted. In this case, a completely new package was installed together with the generator. Therefore, the overhaul of the controls was not a matter of concern. The gas turbine can be operated from the control compartment that is part of every package. The preferential solution is remote operation from a central control room located at the headquarters of the utility.

Regarding the fourth challenge mentioned above, it should be noted that not only part of the piping needed to remain in place, but also other machinery in the power plant, like a MAN steam turbine operated at the same site, was not shut down. Furthermore, the permissible noise level during the construction work was restricted as well because of reasons elaborated upon below.

The implications of the third and fourth points are shown in the following Figures. Figure 1 shows the interior of the turbine hall with the old FT8-train at the 10 m level platform. This elevation was previously dictated by the equipment of the helium turbine. The blue coloured enclosure contains the FT8 gas turbine, the red coloured structure in the foreground is the old generator that had to be removed, both because of its age (over 125,000 operating hours) and the fact it was oversized for the new turbine. Even with the FT8 the generator operated in part-load and with the new gas turbine this would have dropped to less than 20% of nominal generator load. In the background the steam turbine can be discerned. This remains at the site and uses steam generated by burning biomass, especially woodchips. The original crane is still located in the building. Because this was designed with much heavier and larger equipment in mind, handling the new components was not an issue.

The overall phasing of the work is detailed in Table 2 (see also Figure 5). This shows, in a simplified way, the planning involved in the brownfield installation and some associated challenges. One example is the delivery schedule of the gas turbine that required a revision of the normal workflow at erection sites and the split in the sequence of the mechanical work.

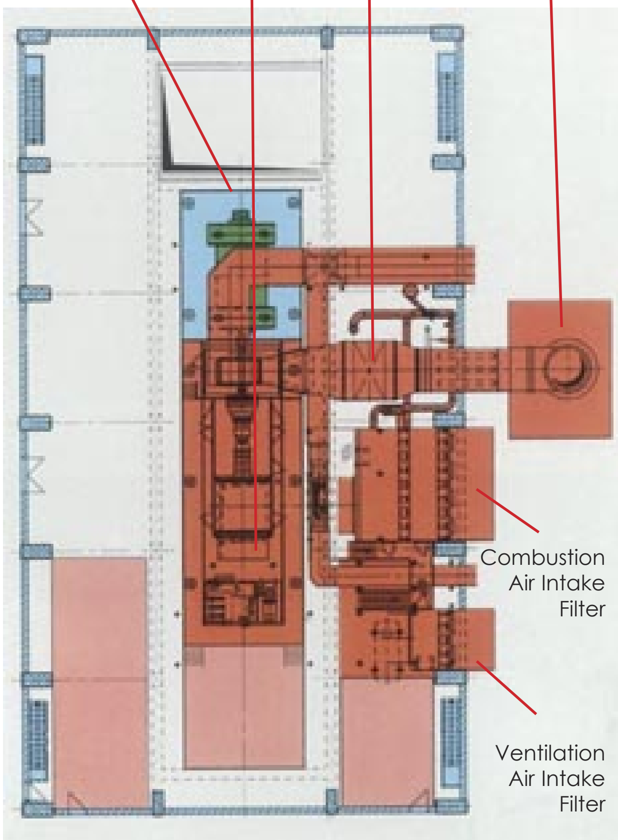


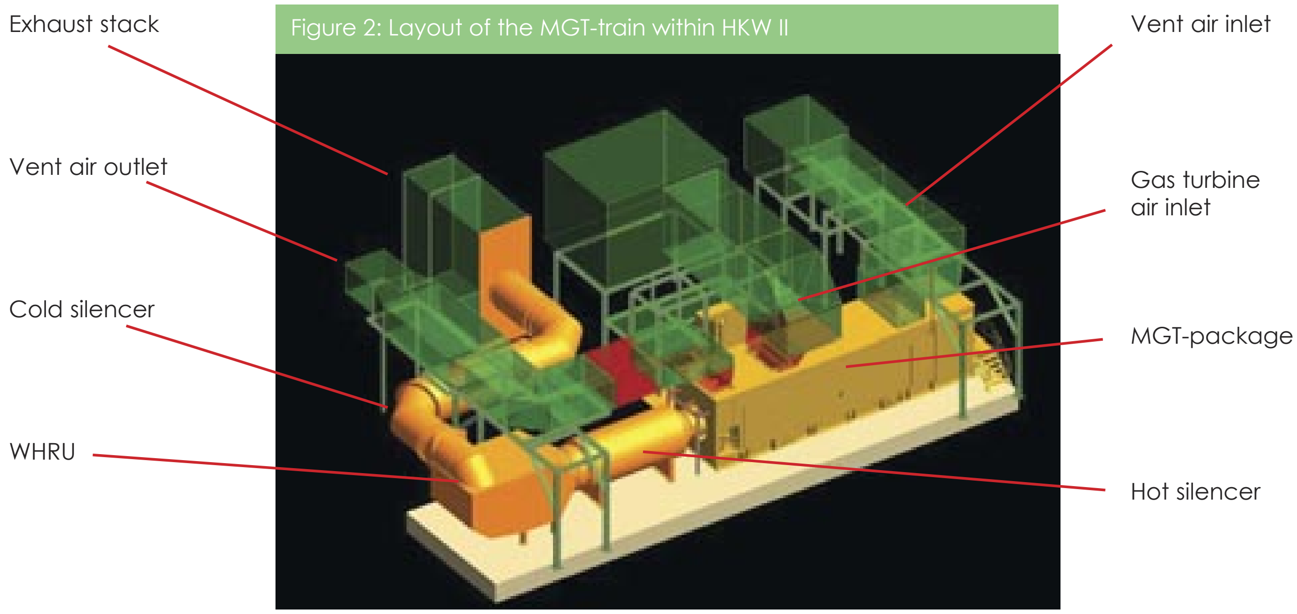
Figure 1: The FT8-Package in power plant HKW II of evo (left) and general layout of the train (right, after [6])

Table 2: Phases of the Installation Procedure

Phase 1: Dismantling of the old GT	Includes all other piping and machinery that will be replaced
Phase 2: Installation of the new steel base frame for the machinery and package	Base frames for the GT and the WHRU, includes installation of package w/o GT
Phase 3: Installation of the exhaust gas system	Silencers, WHRU, exhaust gas duct
Phase 4: Installation of air ducting	Between package and existing equipment
Phase 5: Installation of interconnecting piping	Between WHRU and existing equipment as well as between GT package and utilities tie in points
Phase 6: Electrical installation	Cabling; simultaneous installation of all insulations of piping and ducting
Phase 7: Mechanical completion	Finalization of piping, ducting etc. w/o GT
Phase 8: Installation of the new GT	Includes connection to the air ducts
Phase 9: Mechanical finalization	Connection of the GT to the exhaust gas duct
Phase 10: Commissioning	All systems installed and tested

A rendering of the layout of the new train and auxiliaries is depicted in Figure 2. All components in yellow were replaced, the ones in green were refurbished. Because the old ducting was designed for a larger turbine with different flanges, some adapters needed to be replaced. These were designed by MAN and are depicted in red. The new package was positioned thus that the old connections of the air intakes for the turbine but also the venting air for the package could be used. The outlet of the venting air was similarly refurbished. The outlet silencer was positioned downstream of the package, followed by the hot water boiler (quadrangular structure).

Figure 2: Layout of the MGT-train within HKW II



The hot water boiler needed to be replaced and was delivered preassembled to the site. It is of the water-tube type and can generate slightly more than 200 tonnes of hot water per hour. It has a hot water temperature between 80°C and 120°C and a return temperature between 50°C and 70°C (nominally 60°C). The exhaust gas temperature at the outlet of the boiler is approx. 82°C. Contrary to the previous installation, where the turbine would be fired with liquid fuel occasionally during the first years after installation, only high-quality natural gas, and in future possibly hydrogen, are used. Therefore, sulphuric acids are not a limiting factor for the temperature at outlet of the exhaust stack.
Downstream of the boiler an exhaust gas damper is installed which prevents a natural convection air flow through the turbine and boiler after shutdown.
In order to use the existing exhaust stack, the exhaust gases need to be ducted through two 90° bends, as can be seen in Figure 2. The stack itself was nearing the end of its operating permit. Therefore, it was inspected and renovated resulting in a 10-year extension of the permit.

Not shown in Figure 2 but of some importance are the inlet air treatments. Temperatures can drop to

Figure 3: Turbine hall after the removal of the old train

well below 5°C in winter in Oberhausen, necessitating an anti-icing system. This, too, was already in place and was designed to heat up the inlet air by up to 10°C for the larger FT8. The smaller mass flow of the new turbine meant that the air can be heated to a temperature that is nearly twice as high as before.

A connection to the natural gas grid at a pressure level of 42 bar existed at the site to supply the FT8 with fuel. The specifications for MGTs required a pressure level of only 24 bar(g) and therefore the pressure regulator was replaced.

Special care needed to be taken regarding noise emissions. The buildings are situated between an industrial site with office buildings and a densely populated residential area. Therefore, stringent legal regulations are not only in place for exhaust gas emissions but for noise as well. All of these were contractually safeguarded. The sound power levels were fixed at 67dB(A) at the in- and outlet of the package venting system and only 65dB(A) at the oil vapour extraction. These extremely low levels required several silencers to be installed. In the exhaust gas stream, a hot silencer is installed upstream and a cold silencer downstream of the heat exchanger. In addition to the silencers, the piping and ducting was cladded in insulation to reduce noise emissions even further.

Figure 3 shows the turbine hall after the old train was completely removed. Some of the piping and ducting that needed to be revamped as a matter of course was temporarily removed for ease of installation of the new components. The steam turbine can be seen in the far right behind the screen.

The gas turbines are normally delivered as a package with pre-mounted units on a steel machinery base frame with an enclosure, complete with ancillary equipment (gear box, starting system) and auxiliary systems such as the lubrication system, the fuel gas skid and the fire detection and suppression system as well as the control unit. In this case, as is the norm for indoor installations, the inlet and exhaust system modules are integrated in the building. This does not pose a problem because the package is divided into two sections: one that contains the turbine, ancillary and auxiliary equipment and one that contains the in- and outlet systems. Therefore, no modifications are needed when the former is installed indoors without the latter.

The installation of the package is shown in Figure 4. All grey struts in the wall of the building are load bearing and could therefore not be removed. Because of this the individual sections of the package had to be brought into the building through a break-through in the wall measuring approx. 9.5x4 m². As can be seen, the different parts of the machinery base frame were mounted first, followed by a base frame with pre-mounted load gear, but without the generator or gas turbine. The duration of the operation was slightly less than 10 hours [7].

The generator was delivered within days of the machinery base frame (but through the normal entrance gate) since it cannot be installed in or removed from the package easily. Afterwards, the enclosure of the gas turbine, piping and ducting were installed. The gas turbine was delivered some time after the package [7]. This did not pose a problem because the package as well as peripheral equipment and ducting are designed in a way that the gas turbine can be exchanged within 48 hours for servicing.

The main stages of the installation at HKW II are shown in Figure 5. Here, the exhaust gas silencer is still wrapped in black foil and the boiler is without insulation (the red structure in the background of the second image).

Figure 4: Installation of the gas turbine package at HKW II (continues on p16)

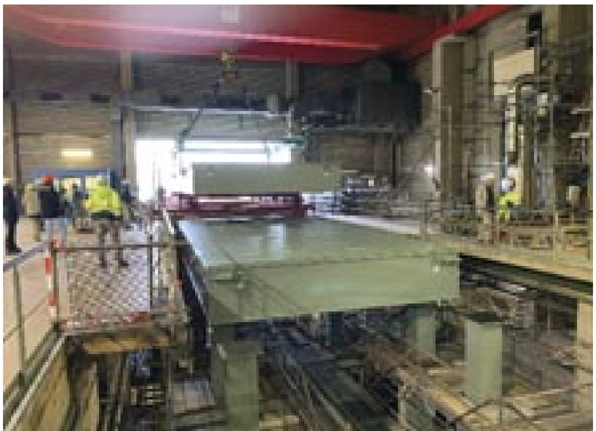
7:00 h: crane is being erected

9:00 h: 1st base frame is lifted

Figure 4: Installation of the gas turbine package at HKW II (continued from p15)

10:00 h: and brought into the building

11:00 h: 2nd base frame is lifted



12:00 h: and brought into the building

14:30 h: GT-package is lifted

16:00 h: …. and brought into the building

16:45 h: GT-package has arrived at its position

Figure 5: Stages of the completion of the installation of the gas turbine package at HKW II

The enclosure being erected

The installed exhaust gas silencer and boiler

The core engine being hoisted to the platform

The gas turbine is installed

The insulation is applied & cabling conducted

Package installed & awaiting systems checks

Operational Experience

The plant came online during the annual heating period that starts in October and normally ends in April. Because of the long and cold winter 2020/2021, it ran much longer than scheduled in the first half of 2021.

Since the official takeover the plant by the utility and being strategically planned and operated by a power plant optimisation system, the gas turbine has successfully accumulated 2458 operating hours and 62 starts (as of 31/08/2021). Most of the time the plant runs at full load and contributed significantly to the power and district heating supply in Oberhausen. Overall, the MGT8000 presents itself as very reliable and good-natured. Despite strong changes in the electric output (0.5 MW to 9 MW in under 5 minutes),

Figure 6: Boroscopy photos after approx. 4000 EOH.

the thermal output is adjusted reliably and calmly. As mentioned above, the heat load can be kept at a fairly constant level and even in part load the plant provides a decent heat output.

The cooperation between *evo* and MAN has proven to be pleasant since the start of the project. This also applies to all suppliers throughout the erection and commissioning phase. At regular quarterly meetings operational experience and operational data are discussed and analysed. Therefore, deviations can be recognised early. In case questions or problems arise, solutions can be provided quickly by service department from MAN via remote access or at site.

The boroscope inspection after approx. 4000 equivalent operating hours accumulated at the *evo* site and MAN's test rig showed the engine to be in excellent condition, see also Figure 6. The pictures show the inlet of the compressor, the combustion chamber and the transition duct / NGV interface.

Fuel Flexibility in the Context of Hydrogen Combustion

Low emissions of nitrogen oxides (NO_X), carbon monoxide (CO) and carbon dioxide (CO_2) are among today's top priorities for gas turbine manufactures, with legal regulations being tightened continuously. MAN guarantees emissions of less than 18 mg/Nm^3 (9 ppmv) NO_X, 20 mg/Nm^3 (16 ppmv) CO and 20 mg/Nm^3 (28 ppmv) UHC for both natural gas and hydrogen combustion. This is well below the limits stipulated in the latest version of the German Federal Emission Control Act from July 2020 (§33, BImschV).

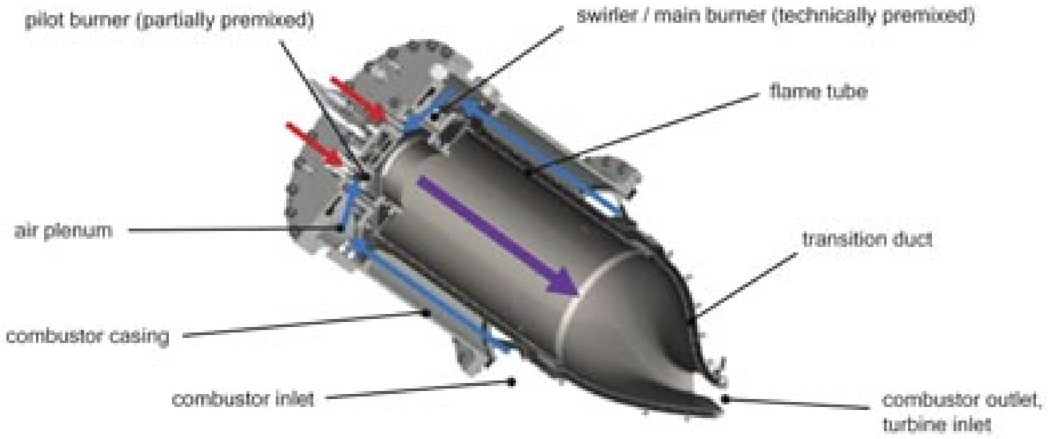
The first generation of dry-low emission Advanced Can Combustor (ACC) combustors was developed by MAN for the THM gas turbine family to comply with the even stricter emission targets. The MGT gas turbine series features the second generation of ACC. This design enables the engines to achieve emissions lower than current legal requirements and the predicted more stringent future ones in European as well as non-European markets.

The main parts of the ACC are named in Figure 7. Blue arrows indicate compressor airflow, red arrows show gaseous fuel flow, and the purple arrow indicates exhaust gases after combustion. The flame is stabilized in the region of the area jump between swirler and flame tube.

On customer site the installed MGT single-shaft gas turbine achieved single-digit NO_X and CO emissions (<10 ppmv) for loads between 60% and 100%. Fuel flexibility in the classical sense, i.e. the capability to burn both gaseous and liquid fuels, is of ever less importance in most developed countries. The *evo*, for example, originally used the dual-fuel capability of the FT8, but the fuel tanks have been long since decommissioned [8] and no such operation is planned for the new equipment. Fuel flexibility is important from another perspective, though, as deliberations are under way for blending hydrogen into the natural gas grid to achieve a certain level of decarbonisation. This is currently limited by the hydrogen compatibility of general consumers connected to the gas grid. MAN addresses this ongoing discussion by allowing a 20%$_{Vol}$ hydrogen share (plug and play ready) in the fuel gas supply of every new standard MGT power generation package, i.e., no adaptations to the package or turbine are needed for this hydrogen content. This hydrogen share would reduce the CO_2 emissions by approximately 7% relative to the volumetric emissions of burning high quality natural gas. It is important to underline that the pollutant emissions are not negatively affected by these levels of hydrogen blending.

Before an even higher hydrogen content can be considered, the whole power plant layout needs a thorough review in terms of piping materials, sealing, instrumentation and safety devices. However, the biggest challenge from a technical standpoint is the low emission combustion of pure hydrogen in gas turbines. Nonetheless, a combustion system for the low emission combustion of 100%$_{Vol}$ hydrogen will be available for customers between 2025 and 2030, depending on actual demand. Once hydrogen will be available in large enough quantities, a retrofit of the combustion and fuel distribution system as well as some package safety and instrumentation elements will be sufficient to switch to a full hydrogen mode without any change in efficiency or power output. This was another key aspect in the decision of *evo* to install the gas turbine at this site.

Figure 7: 3D cross-sectional view of the can combustor assembly of the MGT ACC system.



Summary and Conclusion

Because of climate change a considerable regulatory pressure exists to reduce or eliminate CO_2-emissions. This can be achieved by significantly expanding the amount of electricity generated by renewables, but as these are intermittent by nature, some means of stabilising the power grid is required. Modern gas turbines quickly and reliably deliver electrical power and heat that can contribute to this stabilization at lowest emissions. They are also well suited to contribute to decarbonisation especially as substitution for older (simple cycle) gas turbines or coal-based energy supply. The continuous development of fuel flexibility makes gas turbines a future-proof investment. In general, it saves costs to implement new core components like gas turbines in brownfield sites because existing buildings and infrastructure can be re-utilized. The challenges associated with this kind of project are also primarily related to exactly this re-utilization, though. These have been discussed in detail with the example of a joint project by the local utility in Oberhausen, the *evo*, and MAN Energy Solutions SE. This example shows that, with good preparational work and measured engineering decisions, such a project can be finished in time and on budget.

The uncertainties related to future fuels or fuel mixtures require a significant flexibility in the combustion system. This includes minimizing the number of modifications needed to switch between fuels, be it gaseous and liquid or between fuels with different heating values and levels of reactivity. Modern MAN combustion systems can provide this.

The project discussed here proved to be a defining factor in the decision of another German municipal utility to order four MGT8000 gas turbines for a brownfield application.

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Bibliography

[1] H. Huitenga and E. Norster, *“Development Approach to the Dry Low Emission Combustion System of MAN Diesel and Turbo Gas Turbines,”* in ASME Turbo Expo, Düsseldorf, Germany, 2014.

[2] C. Steinbach, F. Liu, A. Spiegel and T. Pöhler, *“Operating Experience with MGT6000 GT’s at SAIC Volkswagen Combined Heat and Power Plant in Shanghai,”* 2021. https://www.man-es.com/energy-storage/solutions/combined-heat-and-power

[3] R. Krewinkel, U. Orth, D. Viereck and S.-H. Wiers, *“MAN Industrial Gas Turbines for Clean and Flexible Power – Solutions for International Power Generation Markets,”* Paper 625 *Power Engineer*, vol. 22, no. 3, pp. 7-14, 2018.

[4] N.N., *“EIB Group Climate Bank Roadmap 2021-2025,”* 2020.

[5] K. Saidi, H. Hoops, U. Orth and S.-H. Wiers, *“Hybrid Trigeneration Concepts for Power, Steam and Hot Water Production,”* Paper 629 *Power Engineer*, vol. 23, no. 1, 2019.

[6] N.N., *“Integration of 25MW Gas Turbine into Existing Power Station,”* 1996.

[7] N.N., *“Zukunftsweisende evo-Gasturbine für Oberhausen,”* 2020. [Online]. Available: https://www.youtube.com/watch?v=U2GL8K806RA. [Accessed 23 6 2021].

[8] N.N., *“Energiewende lokal: Ein Heizöltank wird Wärmespeicher,” evo*, [Online]. Available: https://www.youtube.com/watch?v=qf0PijsWreo. [Accessed 23 6 2021].