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IMPROVEMENT AND OPERATING EXPERIENCE OF THE AE64.3A GAS TURBINE INSTALLED IN CCPP OF VLORE

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Professional paper

The aim of this paper is to make a short presentation of the improvement and optimization of the Gas Turbine in the design phase and also show the results achieved during the commissioning and the performance test in the Vlore PP. All the time this gas turbine operated on distillate fuel oil and this made it a prototype and its operating experience unique. The AE64.3A+ burner is based on the hybrid (diffusion/premix) burner design principle that enables it to perform low NOx and CO emission and stable and reliable combustion of fuel gas and fuel oil. The AE64.3A+ gas turbine is installed in the CCPP of Vlore and after the commissioning tests, carried out in the June 2010, continued to operate with a high performance due to the optimization made during the design phase.

Keywords: *gas turbine, hybrid burner, combustion chamber, loads rejection*

Plinska turbina AE64.3A instalirana u termoelektrani Vlore - poboljšanje i radno iskustvo

Stručni članak

Cilj je ovoga rada ukratko predstaviti poboljšanja i optimizaciju plinske turbine AE64.3A u projektnoj fazi i također rezultate dobivene ispitivanjem tijekom puštanja u pogon u termoelektrani Vlore. Cijelo je vrijeme ova plinska turbina radila na destilatu goriva i tako postala prototip, a njeno radno iskustvo jedinstveno. Gorionik AE64.3A+ zasniva se na hibridnom (difuzija/gotova smjesa) principu projektiranja koji mu omogućuje nisku emisiju NOx i CO te stabilno i pouzdano izgaranje i pogonskog plina i goriva. Plinska turbina AE64.3A+ instalirana je u termoelektrani Vlore i nakon ispitivanja tijekom probnog rada u lipnju 2010 nastavila je raditi s velikom učinkovitošću zahvaljujući optimizaciji u fazi projektiranja.

Ključne riječi: *plinska turbina, hibridni gorionik, komora izgaranja, odbacivanje opterećenja*

1 Introduction

The growth of power markets stresses the importance of optimizing power plant performance and creates the need to improve and upgrade the existing power generation plants. Thus a gas turbine with medium power output is regarded as a strategic asset in gaining competitiveness in energy business.

In such a challenging scenario, a new state-of-the art AE64.3A (hereinafter defined as AE64.3A+) (Fig. 1) gas turbine has been developed by Ansaldo Energia, enhancing performance, operational and dynamic features.

2 AE64.3A+ gas turbine

The AE64.3A+ gas turbine is a single shaft, cold end drive, annular combustor, heavy-duty gas turbine designed for 50 Hz operations. The gas turbine is suited to run in base load operation and can be used both in open cycle and in combined cycle operations.

2.1 General design features of AE64.3A+

Machine body

The AE64.3+ gas turbine is based on a mono shaft design: it includes fifteen (15) stages axial compressor and a four (4) stage axial turbine having a common rotor. The rotor (Fig. 2) consists of a front shaft section, fifteen (15) compressor blade disks, a central hollow shaft section, four (4) turbine blade disks and a rear shaft section, all held together by a single central tie bolt with a clamping nut at the turbine end. Each disk of the rotor has radial Hirth teeth on both sides; the Hirth serrations provide radial alignment between the rotor sections, ensuring torque transmission and allowing free relative radial expansion and contraction. Such a construction is of particular significance for the life of the rotor parts in response to changes in the operating conditions and in the temperature distribution in the rotor; it is the reason for the short start-up and loading/unloading times of the AE64.3A+ gas turbine and for their problem-free operation under all steady-state and non-steady-state rotor temperature conditions.

The rotor resulting from such a construction is a self-supporting drum with low weight and high stiffness; therefore it can be supported by only two bearings, one at the front shaft section and one at the rear shaft section. This eliminates the need for an additional bearing between the compressor and the turbine. The bearing at the compressor end is a combined journal and thrust bearing designed to accommodate the axial thrust of the rotor.

The two bearings are located outside the pressurized region of the gas turbine, providing the basis for constant good alignment and excellent running qualities.

All the turbine stator vanes and rotor blades are air-cooled, with the exception of the last stage ones. Cooling air is provided at different pressure and temperature levels by compressor extraction, in order to provide the best possible cooling effect and, at the same time, to provide optimal unit thermal performance.

The cooling air, after flowing through blades and vanes, discharges into the hot gas stream.

The AE64.3A+ gas turbine design is based on the two-shell design principle from the section of the compressor stage 10 to the turbine outlet, together with the combustion chamber. On the contrary, the casing from the compressor inlet to the section of the compressor stage 9 is featured by the single-shell design principle.

The major advantage of the two-shell design principle is that the mechanical and thermal loads on the casings are clearly separated; all mechanical loads due to internal pressure are taken by the outer casing on which the thermal loads are low, while all thermal loads are taken by the inner casing on which the mechanical loads are low.

The generator is driven from the compressor (cold) end and it is coupled via a gear box to the gas turbine shaft. This facilitates the connection of an optimum-geometry exhaust gas diffuser and a low-loss exhaust gas train to a heat recovery boiler without significant changes in direction.

Combustion chamber

The AE64.3A+ gas turbine is equipped with an annular combustion chamber and 24 dry low NO_x burners for both fuel gas and fuel oil.

The combustion zone (Fig. 3) is wrapped around the gas turbine first stage inlet section.

The combustion chamber is mounted inside the centre section of the outer casing.

The combustion chamber casing is formed by low alloy steel cast shells, which are completely enveloped by the compressor discharge air. They are thus not exposed to the local variations in temperature of the surface in contact with the hot gas. The surface exposed to the hot gas is formed by heat shields made of metal tiles with a ceramic oxide layer on their surface.

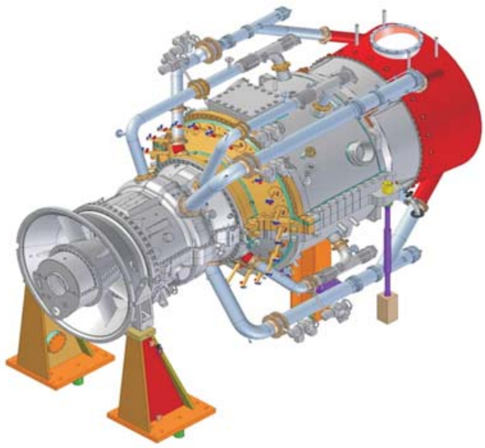

Figure 1 3D Model of a V64.3A+ Gas Turbine

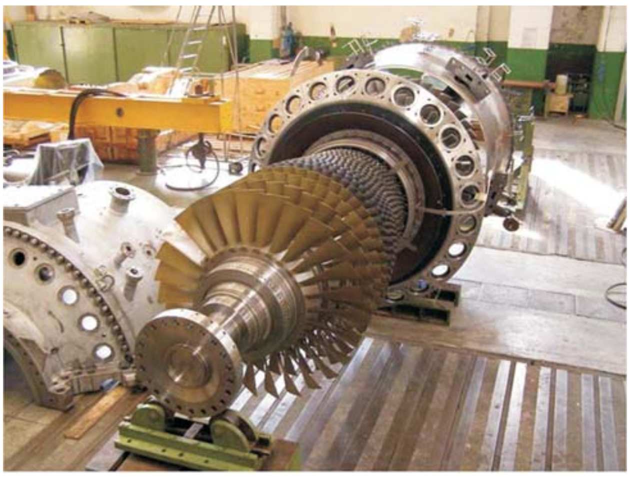

Figure 2 Rotor view from compressor

Burners

The AE64.3A+ burner is based on the hybrid (diffusion/premix) burner design principle, that is able to perform low NO_x and CO emissions and stable and reliable combustion with fuel gas and fuel oil.

The burner aerodynamics is given by 2 concentric, co-rotating swirlers (axial and diagonal) and the burner consists of an unchanged central diffusion burner suitable for operation with fuel oil and gas. This diffusion burner also contains the pilot burner for premix gas operation.

The premix gas distributing pipes are integrated into the swirl generating blades. This minimizes the danger of local auto-ignition and improves the mixing with the air incoming to the diagonal swirler.

Figure 3 Rotor view with annular combustion chamber

The premix oil operation mode is achieved by means of suitable oil nozzles downstream the diagonal swirler blades: the oil jet is atomized by the incoming air and the droplets vaporize and mix with air before the outlet.

The hybrid burner combustor combines all the advantages of optimal combustion, including:

- low NO_x and CO emissions
- low pressure loss
- high operating flexibility
- fully symmetrical design
- optimal size and number of burners
- compact design with good accessibility.

3 Design evolution of AE64.3A+ gas turbine

Significant improvement margins do exist to allow the performance increase of gas turbine AE64.3A, so to achieve what will be hereinafter defined as AE64.3A+.

Such performance increase is operatively feasible by introducing on the previous model AE64.3A, in a more or less extended way, some of the features of the higher rated AE94.3A(4) gas turbine.

The modifications made in changing AE64.3A to AE64.3A+ chiefly consist of:

- Compressor redesigned to allow, with an (almost) equal inlet and outlet cross section, to have a definitely higher air flow rate and a surge margin as much improved.
- Casing and compressor bearing redesigned for both mechanical and fluid-dynamic reasons.
- Turbine modified mainly as concerns the last stage, to increase the efficiency of flow rate.
- Casing and arms supporting the turbine bearing redesigned, with arms having airfoil profile instead of straight profile.

- Combustion chamber modified as concerns both the geometry (turbine interface).
- Unchanged burners, taking into account the latest evolutions of the HR3 burners.
- Cooling air system of the turbine modified both for the presence of a redesigned compressor and also for an additional air bleed inside the rotor.
- Other components modified due to what is described above (e.g. the rotor, but also the outer casings, supports, etc.)

Fig. 4 resumes the main improvements on AE64.3A+ Gas Turbine:

a) Increase of compressor mass flow
b) Optimization of last turbine stage
c) Optimization of turbine cold-end
d) Burner improvement
e) TBC (Thermal Barrier Coatings) on turbine stages.

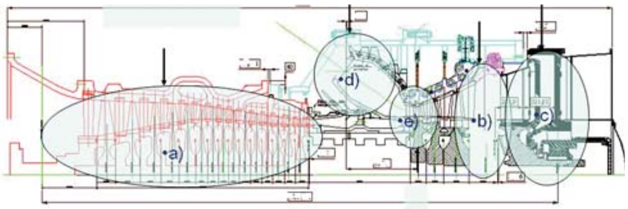

Figure 4 Main areas of improvements on a AE64.3A+ gas turbine

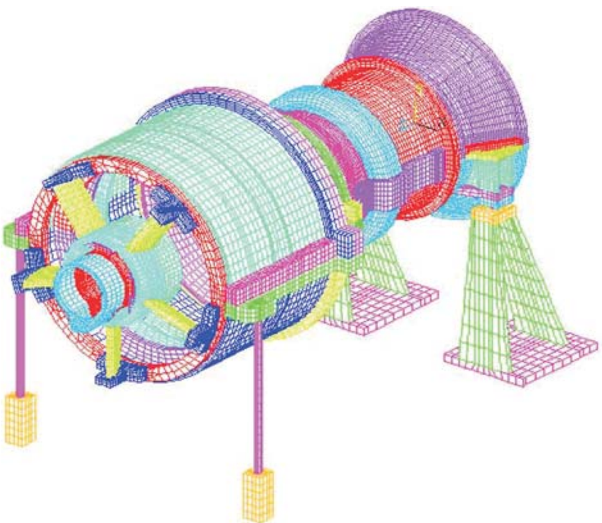

Figure 5 3-D meshed model of a AE64.3A+ gas turbine

4 Performance of a AE64.3A+ gas turbine

In Tabs. 1 and 2 performances of a AE64.3A+ gas turbine are listed both in COBRA (Combined Brayton Rankine) cycle arrangement (Tab. 1) and in ISO condition (Tab. 2).

Table 1 Performances of AE64.3A+ Gas Turbine in different cycle arrangement

Model of gas turbine	Frequency Hz	Continuous output MW	Heat rate kJ/kWh	Efficiency %
1xV64.3A	50/60	112	6698	53,75
2xV64.3A	50/60	224	6689	53,82

Table 2 Performances of AE64.3A+ gas turbine, ISO condition

Thermodynamic Data Iso Base Load	V64.3A
Turbine Inlet Temp. acc. to ISO2314 , °C	1190
Pressure Ratio	16,7
Power Output at generator terminal , MW	75
Efficiency at generator terminal	35,9
Exhaust Gas Mass Flow, kg/s	213
Exhaust Gas Temperature , °C	574

ISO condition with:

- Condenser vacuum = 0,035 bar
- GT inlet pressure loss = 10 mbar ISO
- GT exhaust pressure loss = 30 mbar ISO.

5 Vlore CCPP (Combined Cycle Power Plant) Project

The Power Plant of Vlore (Albania) is a Combined Cycle based on one dual fuel gas turbine model Ansaldo AE64.3A+, one horizontal fired HRSG, triple pressure sections without reheater, one Ansaldo Energia steam turbine rating approx 30 MWe with water cooled condenser. The plant site is located on a six hectare green field site adjacent to the offshore oil tanker terminal located on the Adriatic coast north of the Port of Vlore approximately six km from the Port of Vlore (Fig. 6).

The AE64.3A+ gas turbine for Vlore Project (Fig. 7) was delivered during July 2008 and started its operation in the beginning of 2010.

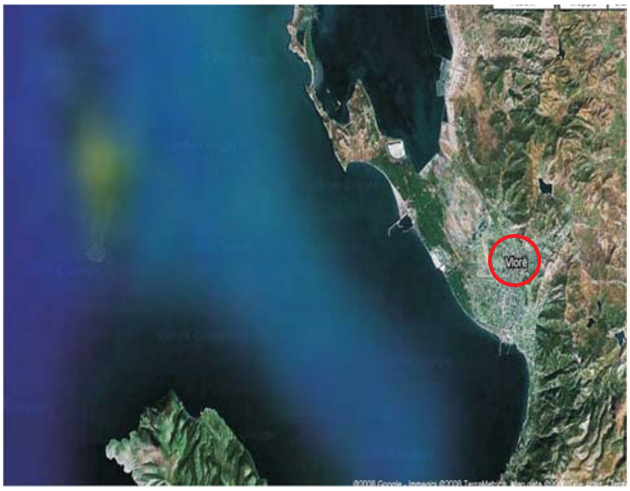

Figure 6 Aerial view of the bay of Vlore (Albania)

Figure 7 AE64.3A+ gas turbine installed in the Vlore site

The gas turbine was supplied in accordance to the standard and proven design of the manufacturer, optimizing the need for burning fuel oil in continuous operation.

As a fact, one of the main operational features of the AE64.3A+ installed in Vlore will be the continuous operation on Fuel Oil.

6 High-technology additional instrumentation for the Vlore Project

Aiming to enhance its own field experience, Gas Turbine Engineering Department of Ansaldo Energia decided to install additional instrumentation (Fig. 8 and Fig. 9) for monitoring of the state of the art AE64.3A+ gas turbine installed in Vlore.

The on-line monitoring system will be used to deeper investigate the GT operation on fuel oil during commissioning phase.

In particular, AE64.3A's body was equipped with several measuring points: different stages of compressor, blow-off lines, combustion chamber, cooling lines, shaft and bearings.

As a final result, all the measuring points resulted in a large set of temperature, pressure, vibration and positioning data.

The whole system is made up of the following packages: sensing, data acquisition, characterization, condition monitoring and feature extraction packages.

Figure 8 Instrument racks in Vlore for additional instrumentation

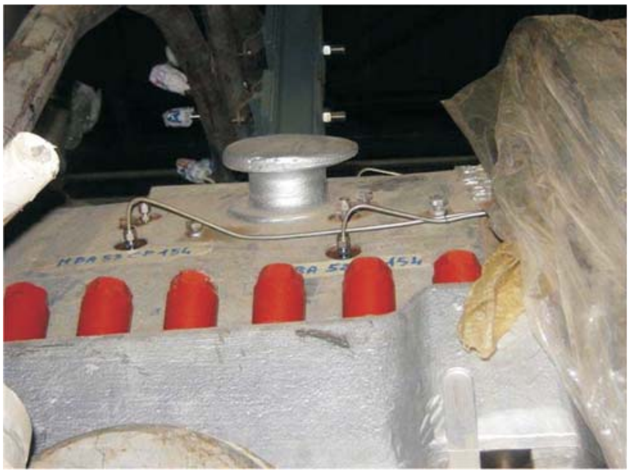

Figure 9 Pressure measurements on AE64.3A+ installed in Vlore

Several signal processing methods, namely, cross-correlation, resample, short-time Fourier transform and statistical process control, are developed to extract several values considered highly representative of GT operation.

7 Operating experience

The AE64.3A+ installed in Vlore started its commissioning at the beginning of 2010.

In the following, the main important operating conditions tested in Vlore during commissioning are described in detail.

All pictures from 10 to 12 are directly taken as screenshots from GT control system during relevant tests performed on site. Standard KKS (identification system for power station) tag for key features is in evidence.

In Fig. 10 a start-up and synchronization is represented. In the start-up process, the fuel oil flame is ignited by an ignition flame produced by propane gas coming from the ignition gas system. The Start-Up is performed in Diffusion mode and once the GT has been started, it is ready to be synchronized. The load jump for synchronization is approx 5 MW.

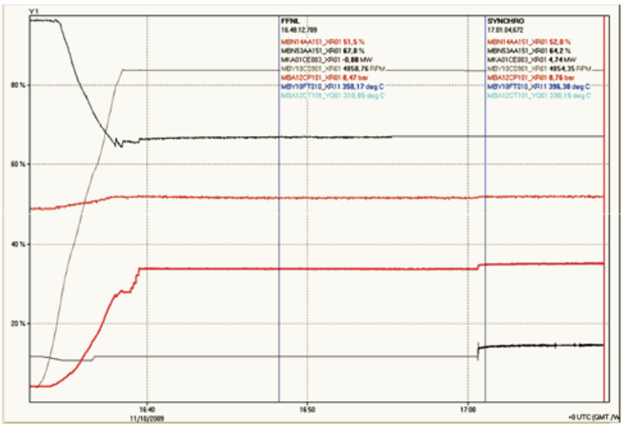

Figure 10 Start-up and synchronization

In Fig. 11 a change over from diffusion to premix flame is shown.

Among other permissive criteria, the change over from diffusion operation to premix operation can only be performed in a certain range defined by the values of the turbine exhaust temperature and IGV (inlet guide van) position.

The load set point is frozen during complete change over. In case of fuel oil diffusion operation with water injection, before proceeding the water injection system must be switched off during the change over. To prevent fuel oil cracking, a water emulsion system, together with a lower pressure purging system provides flushing water in sufficient capacity and at a sufficient pressure to premix nozzles.

Finally, in Fig. 12 the load rejection performed from base load is included.

In general, starting from any condition, in case of load rejection the water injection is tripped. The fuel oil premix mode system is even tripped and the GT remains in stable diffusion dry mode.

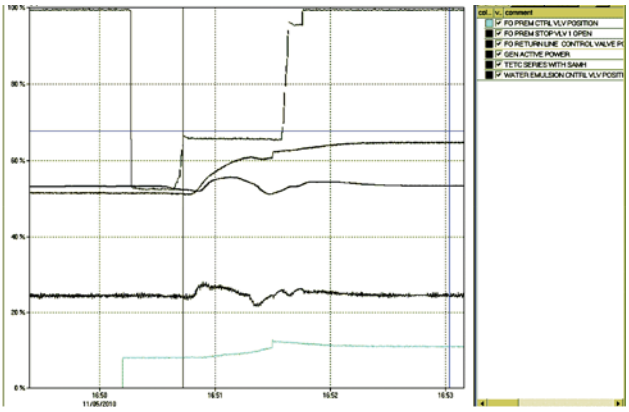

Figure 11 Change over from diffusion oil to premix oil

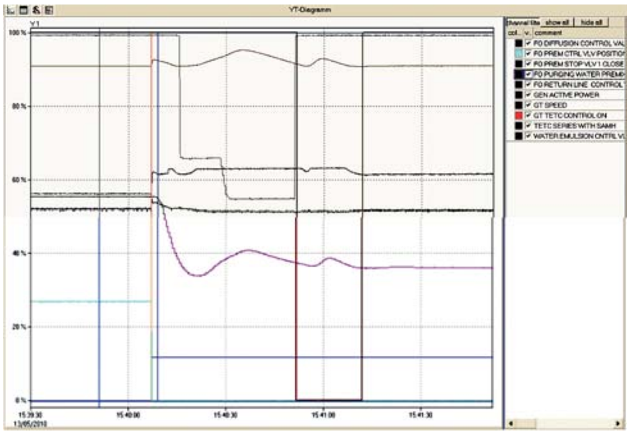

Figure 12 Load rejection from base load

8 Conclusions

On the basis of its operating experiences and taking into account specific needs of its customers, Ansaldo Energia has upgraded its medium-rated-power AE64.3A gas turbine with several improvements, enhancing performances and operational features as follows:

- The output power from 67,5 to 75 MW
- Efficiency from 35,1 to 35,9 %
- Fuel consumption from 4,58 to 4,64 kg/s
- Exhaust gas mass flow from 193 to 213 kg/s.

All operating conditions of the GT were successfully tested during commissioning phase in the Vlore Power Plant.

In the light of this scenario, Ansaldo Energia AE64.3A gas turbine can be undoubtedly regarded as an excellent choice for energy power market according to its engineering guiding principles and its operational and dynamic features.

9 References

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