Proceedings of ASME Turbo Expo 2011
GT2011
June 6-10, 2011, Vancouver, British Columbia, Canada

GT2011-45563

OPERATING EXPERIENCE ON ADVANCED TECHNOLOGY AE64.3A GAS TURBINE

Federico Bonzani, Andrea Silingardi,
Laura Traversone,
Ansaldo Energia S.p.A.
Product Development
Turbomachinery
Via Lorenzi 8, 16162
Genova (Italy)

Luigi Di Pasquale

Ansaldo Energia S.p.A.
Production and Technology
Gas Turbine Engineering
Via Lorenzi 8, 16162
Genova (Italy)

ABSTRACT
The growth of power markets stresses the importance of optimizing power plant performance and boosts the need to improve and upgrade the existing power generation plants. In this framework, Gas Turbine with medium power output are regarded as strategic asset to gain competitiveness in energy business. In such a challenging scenario, the current version of the 50/60 cycles AE64.3A Gas Turbine has been upgraded by Ansaldo Energia, enhancing performances, operational and dynamic features. Therefore the unit is rated now 75 Mwe power output and 35.9% efficiency.

The upgraded AE64.3A along with the relevant generator and auxiliary systems in single shaft configuration, has been installed in the combined cycle generation plant of Vlore, on the Adriatic coast of Albania.

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

The paper will report the main feature of the engine highlighting the upgrade and present the operational experience gained during the commissioning phase.

INTRODUCTION
The growth of Power Markets stresses the importance of optimizing power plant performance and boosts the need to improve and upgrade the existing power generation plants. In this vein, Gas Turbine with medium power output are regarded as strategic asset to gain competitiveness in energy business. In such a challenging scenario, the upgraded version of AE64.3A ([fig.1] Gas Turbine has been delivered by Ansaldo Energia, enhancing performances, operational and dynamic features. This is a very important step in the power generation scenario since the termination of the license agreement with Siemens Power Generation. Therefore all the upgrades have been designed and manufactured in house.

.

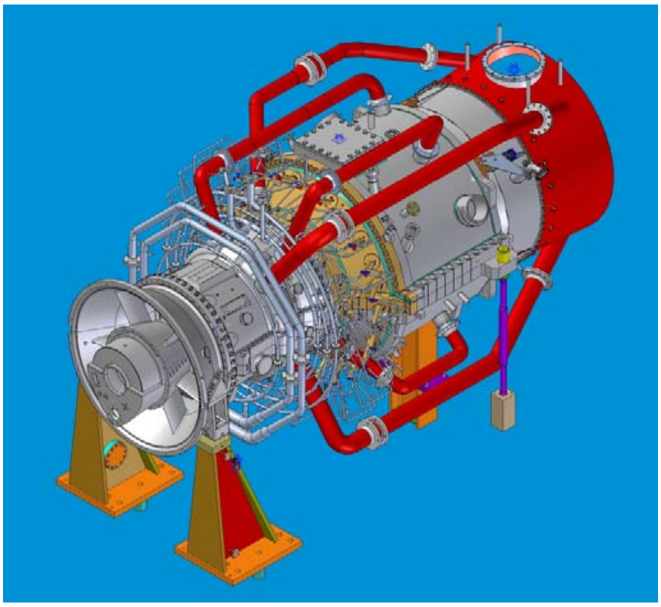

Fig. 1 AE64.3A GAS TURBINE

GENERAL DESIGN FEATURES

Machine body

The upgraded AE64.3A gas turbine is based on a mono shaft design: it includes a fifteen (15) stages axial compressor and a four (4) stages 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 turbines 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.

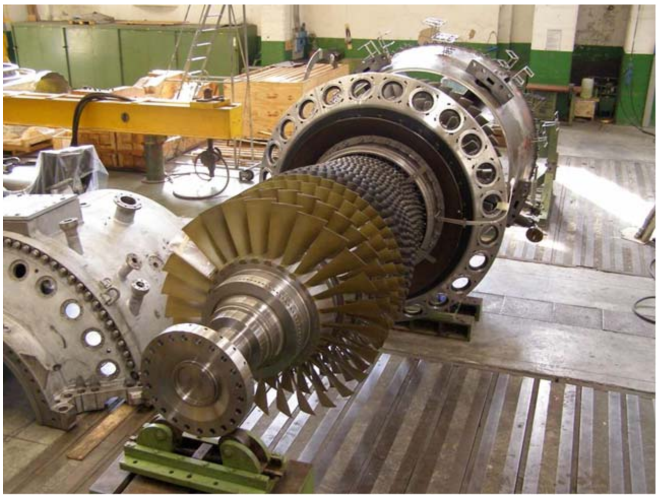

Fig 2. ROTOR VIEW FROM COMPRESSOR

The upgraded AE64.3A gas turbine design is based on the well known 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 withstood by the outer casing on which the thermal loads is low, while all thermal loads are withstood 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 upgraded AE64.3A gas turbine is equipped with an annular combustion chamber and 24 dry low NOx burners for both fuel gas and fuel oil operation.
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 arranged by heat shields made of metal tiles with a ceramic oxide layer on their surface.

Fig 3. ROTOR VIEW WITH ANNULAR COMBUSTION CHAMBER INNER SHELL

Burners

The AE64.3A burner [Fig. 4] is based on the hybrid (diffusion/premix) burner design principle, that is able to perform low NOX and CO emission 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.

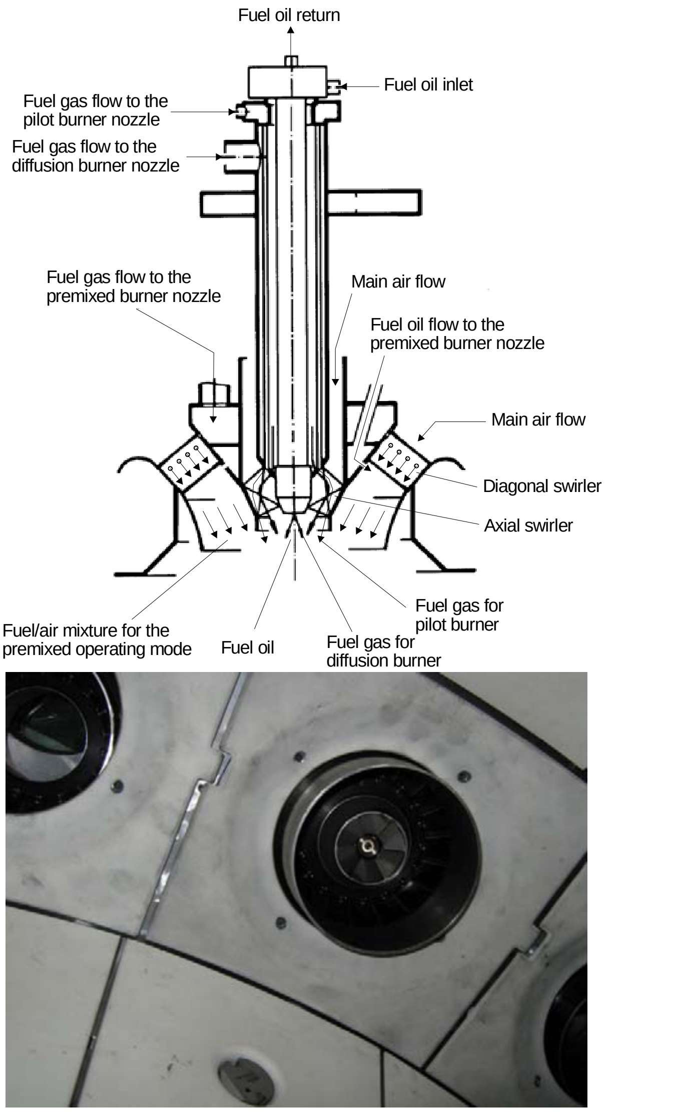

Fig 4. BURNER SCHEMATIC VIEW AND BURNER INSTALLATION ON COMBUSTOR CHAMBER

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.

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

GAS TURBINE UPGRADE

Significant improvement margins do exist to allow the performance increase of current gas turbine AE64.3A. Such performance increase has been making possible by deploying some of the design features of the higher rated and well provenAE94.3A(4) Gas Turbine.

The modifications brought in upgrading model of AE64.3A mainly consist of:

- ✓ Compressor upgrade as scaled down of well proven AE94.3A(4) model in order to allow, with an almost equal inlet and outlet cross section, a higher air flow rate and a improved surge margin.

- ✓ Casing and compressor bearing optimised to fit with the upgraded compressor.

- ✓ Turbine modified mainly as concerns the last stage, to increase the efficiency with a higher flow rate.

- ✓ Casing and arms supporting the turbine bearing optimized, with arms having airfoil profile instead of straight profile.

- ✓ Unchanged burners, taking into account that the latest evolutions of the HR3 burners.

- ✓ Other components modified due to what described above (e.g. the rotor, but also the outer casings, supports, etc.)

Figure 5 summarizes the main improvements on AE64.3A Gas Turbine. The upgraded components are the compressor (A), the thermal barrier coating on the turbine blades (B), the turbine cold end (C), and the last turbine stage (D)

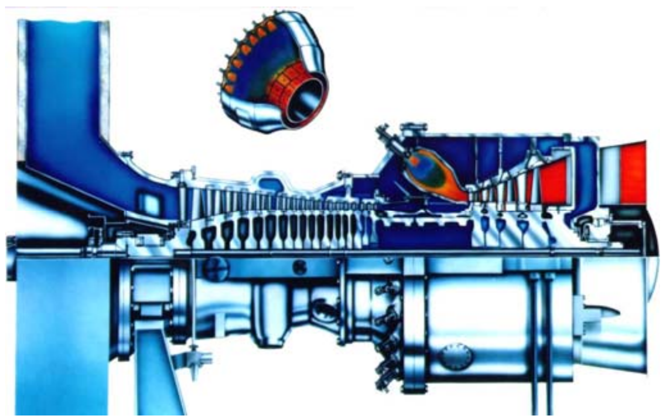

Fig 5. GAS TURBINE OVERVIEW

PERFOMANCES OF UPGRADED AE64.3A GAS TURBINE

Performance of a AE64.3A+ gas turbine are listed both in combined cycle arrangement (table 1) and simple cycle ISO condition (table 2).

Table 1: PERFORMANCES OF AE64.3A GAS TURBINE IN COMBINED CYCLE ARRANGEMENT

	Model of Gas Turbine	Frequency	Continous Output (MW)	Heat Rate (kj/kWh)	Efficiency %
1xV64.3A	1 x V64.3A	50/60	112	6698	53,75
2xV64.3A	2 x V64.3A	50/60	224	6689	53,82

ISO condition with
- Condenser vacuum = 0.035 mbar
- GT inlet pressure loss = 10 mbar ISO
- GT exhaust pressure loss = 30 mbar ISO

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

OPERATING EXPERIENCE: VLORE CCCP 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 6 km far away).

Fig 6. AERIAL VIEW OF BAY OF VLORE (ALBANIA)

The AE64.3A Gas Turbine for Vlore Project [fig. 7] has been delivered during July2008 and has started its commissioning in the beginning of 2010. In the following chapter, the main important operating condition tested in Vlore during commissioning are described in more detail.

Fig 7. AE64.3A+ GAS TURBINE INSTALLED IN VLORE SITE

The Gas turbine has been supplied in accordance to the standard and proven design of the manufacturer, optimising the need for burning fuel oil in continuous operation.
As a fact, one of the main operational feature of the AE64.3A installed in Vlore will be the continuous operation at Fuel Oil.

High technology instrumentation
Aiming to enhance its own field experience, Gas Turbine Engineering Department of Ansaldo Energia has decided to install additional instrumentation [fig. 8 and 9] for monitoring of the state-of-art AE64.3A Gas Turbine installed in Vlore.
The on-line monitoring system will be used to deeper investigate the GT operation at Fuel Oil during commissioning phase. The installation of the aforementioned additional

instrumentation in Vlore is a part of an internal R&D Project actually carried on by Ansaldo Energia GT Engineering Department. As a matter of fact, a AE94.3A(4) Gas Turbine installed in Vado Ligure (Italy) has been equipped with a similar set of instrumentation.

Fig 8. INSTRUMENT RACKS

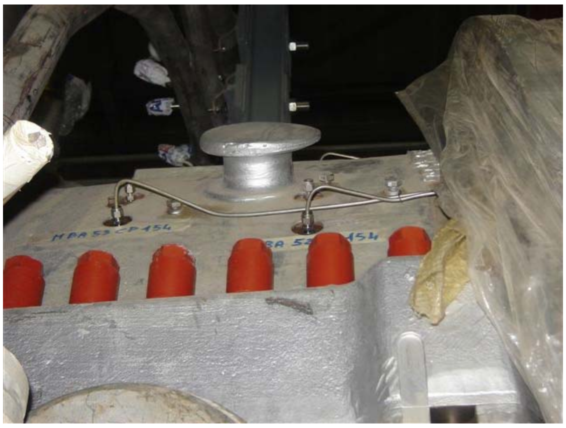

Fig 9. PRESSURE MEASUREMENTS ON AE64.3A INSTALLED IN VLORE

In particular, AE64.3A's body have been equipped with several measuring point: different stages of compressor, blow-off lines, combustion chamber, cooling lines, shaft and bearings. As a final result, all the measuring points result in a large set of temperature, pressure, vibration and positioning data.
The whole system is made up of the following packages: sensing, data acquisition, characterisation, condition monitoring and feature extraction packages.
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.

Start-up

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 by fuel oil pilot and once the engine has been started, it is ready to be synchronized. The load jump for synchronization is approx 5 MW.

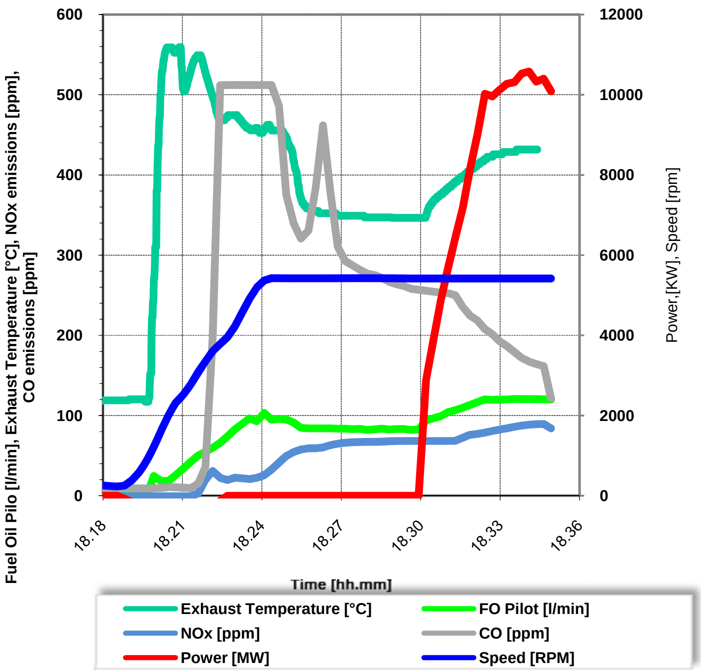

Fig 10. START-UP AND SYNCHRONIZATION

Change over

In fig 11 a change over from diffusion mode to premix mode operation is shown.
Among other permissive criteria, change over from diffusion operation to premix operation can only be performed in a certain range defined by values of turbine exhaust temperature and IGV position.
The load set point is frozen during all change over. In case of fuel oil diffusion operation with water injection before proceeding the water injection system must be switched off during 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. The innovative purging system allows to increase the purging water system and, by changing the connection point of the water into the fuel oil piping, to avoid that residual oil may come in contact with hot part of the burners. The improved system consists of a centrifugal pump which has a discharge pressure comparable with the pressure in the fuel oil lines, a control valve which is

used to regulate the correct water mass flow and a mixer which produces a water-oil emulsion in each phase of the purging. In this way it is possible to add the water to the oil before its disconnection and this constitutes a great advantage because when the oil operation is terminated the residual oil is pushed away without any interruption.

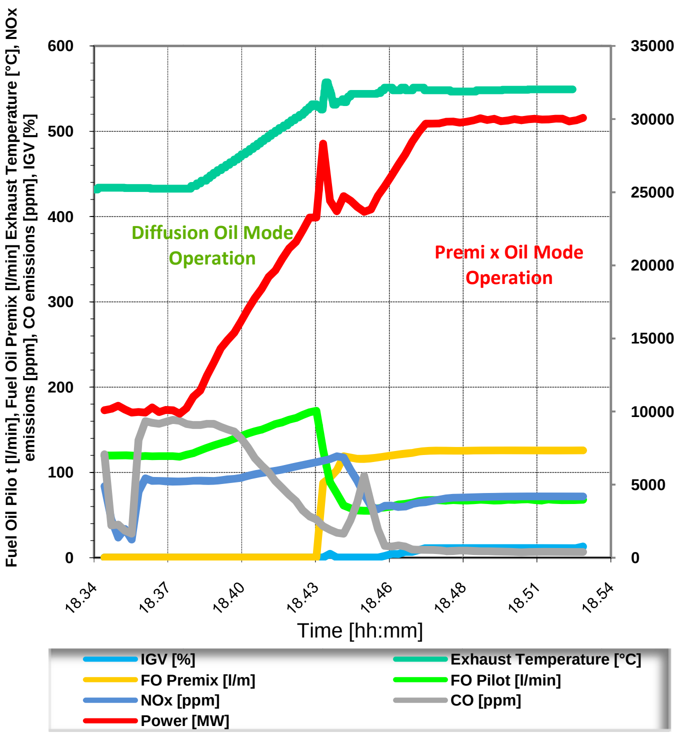

Fig 11. CHANGE OVER FROM DIFFUSION OIL TO PREMIX OIL

Load rejection

In fig 12 a 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. The operation has been successfully tested without any over and under frequency.

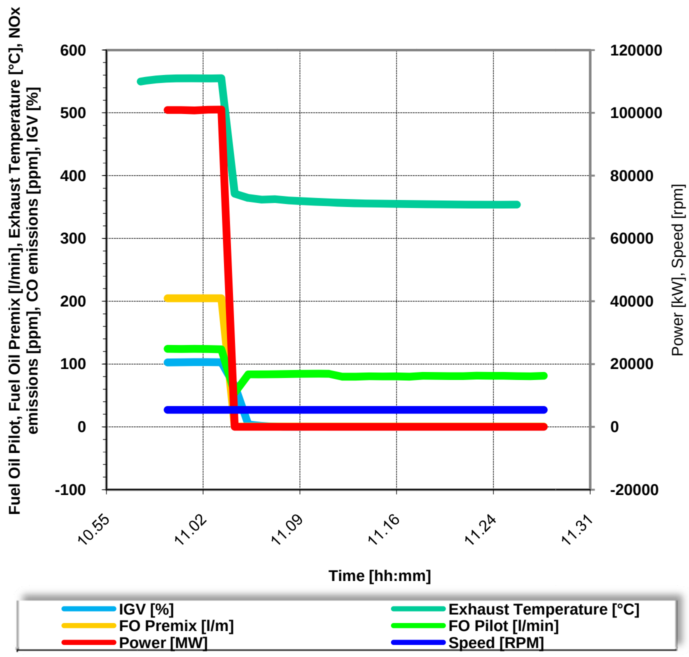

Fig 12. LOAD REJECTION FROM BASE LOAD

Base Load

In fig 13 the base load operation in fuel oil premix mode is reported. Power output is about 70 MWe with NOx emissions below 60 ppm with water injection and CO level negligible. Sensitivity analysis has been performed in order to assess the water to fuel ratio required to fit the contractual emissions requirements. The operation has been demonstrated very reliable in all the tested ambient conditions.

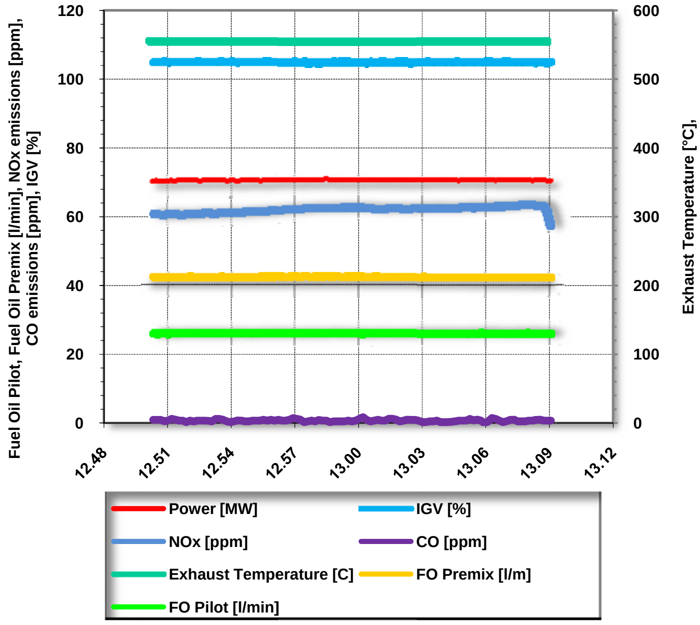

Fig 13. BASE LOAD IN FUEL OIL PREMIX OPERATION

CONCLUSIONS

The paper describes the features of the upgraded version of AE64.3A whose improvements have been carried out taking into account the design of the well proven AE94.3A. Compressor upgrade has been design by scaling down AE94.3A compressor thus taking care of the operational experience of the AE94.3A.
All operating conditions of the gas turbine has been successfully performed during the commissioning phase in Vlore Power Plant. Despite the dual fuel arrangement the engine has been operating in fuel oil mode while waiting for the new pipeline to gas supply. Up to now some thousand of equivalent operating hours have been cumulated demonstrating a successful performance.

AKNOWLEDGMENTS

The authors of this paper would like to thank all the colleagues because all of their support during the upgrade project. Their efforts and their suggestion made possible the successful performance of the upgraded AE64.3A.