Increasing efficiency of TPP fuel supply system due to LNG usage as a reserve fuel

E V Zhigulina¹, V G Khromchenkov¹, J Mischner² and Y V Yavorovsky¹

¹National Research University "Moscow Power Engineering Institute"
Russia, 111250 Moscow, Krasnokazarmennaya, 14
²University of Applied Sciences Erfurt
Germany, 99095 Erfurt, Altonaer, 25

Abstract. The paper is devoted to the analysis of fuel economy efficiency increase possibility at thermal power plants (TPP) due to the transition from the use of black oil as a reserve fuel to liquefied natural gas (LNG) produced at the very station. The work represents the technical solution that allows to generate, to store and to use LNG as the reserve fuel TPP. The annual amounts of black oil and natural gas that are needed to ensure the reliable operation of several power plants in Russia were assessed. Some original schemes of the liquefied natural gas production and storing as alternative reserve fuel generated by means of application of expansion turbines are proposed. The simulation results of the expansion process for two compositions of natural gas with different contents of high-boiling fractions are presented. The dependences of the condensation outlet and power generation from the flow initial parameters and from the natural gas composition are obtained and analysed. It was shown that the choice of a particular circuit design depends primarily on the specific natural gas composition. The calculations have proved the effectiveness and the technical ability to use liquefied natural gas as a backup fuel at reconstructed and newly designed gas power station.

1. Introduction
Natural gas is the main fuel for the majority of district-heating plants and thermal power plants at the European part of Russia. Black oil is usually used as the reserve fuel at TPP. It causes the expensive maintenance of black oil economy. Even while storing it is required to keep the black oil in fluid condition and because of that there is need of its constant heating and circulation all year round. Besides oil-fired boilers have lower efficiency than gas-fired ones due to sediments of combustion products at heat exchange surface areas, higher temperature of the exhaust fumes and etc.

Herewith the growing global demand for LNG promotes the interest growth to scientific researches in the field of new technologies of its production [1-3].

The current research presents the technical solution that allows to generate, to store and to use the liquefied natural gas as the reserve fuel at thermal power plants instead of black oil.

2. Application of turbo expanders at TPP
Gas fired boilers at TPP consume natural gas at low pressure level (a little more than 1 ATM.). At the same time the pressure of natural gas arriving at heat supply sources is about 0.5-1.2 MPa. The usage
of turbo expanders for capturing the energy that is otherwise lost in the gas pressure letdown process, allows you to produce power and to cool the gas deeply.

Natural gas delivered to consumers, is a mixture of hydrocarbons, with a predominant share of methane (50 - 99%), as well as nitrogen, carbon dioxide and others. Cooling the gas by reducing its pressure via the turbo expander will condense some high-boiling fractions of hydrocarbons.

Figures 1 and 2 contain the obtained diagrams of two compositions of real gas (from Ishimbay-Magnitogorsk pipeline and Moscow region gas networks) with different contents of high-boiling components (temperature - entropy and enthalpy - entropy). The gas composition influences much to the isobars course in the two-phase field. In this area where the isobars have knees in two-phase field (under the saturation curve) methane begins to condense.

![Thermodynamic diagrams of real natural gas (Ishimbay-Magnitogorsk pipeline).](image)

**Figure 1.** Thermodynamic diagrams of real natural gas (Ishimbay-Magnitogorsk pipeline).
The analysis shows that in the case of usage of the gas containing a lot of high-boiling fractions, it is possible to condense them even at atmospheric pressure at the temperature level of about -65°C, whereas in the case of gas with prevalent low-boiling fractions only the required temperature level is -130°C. This means that, the additional cooling of the gas should be done in order to obtain the necessary amount of liquefied gas. It will complicate the technological scheme.

3. Calculation of the developed schemes
In the course of conducting this study two original schemes were developed for LNG production and storing as a backup fuel at TPP [4-5]. The schematic diagrams are shown in figure 3. The calculation of the developed schemes was performed using the following data of Moscow TPP-23: the annual natural gas and black oil consumption, the composition and the technical characteristics of the main equipment.

The calculations were done using the comprehensive process modeling via Aspen Hysys. The calculations shows that it will take a little less than 9 months to accumulate the necessary amount of the reserve fuel [6].

This scheme cannot be used if work on natural gas with composition no. 2 consisting from 98% of methane. The problem is that the temperature level is not low enough for the methane condensation. So it was decided to use cold recovery, providing the preliminary cooling of the gas before the expander. The condensation outlet is almost 3 times bigger, then it was in the first scheme, so in this case the accumulation period of the reserve fuel is 3 months.
The calculations for nine different compositions of natural gas were done for estimation of the feasibility of the first scheme usage.

Figure 3. Schematic diagrams of scheme 1 (a) and scheme 2 (b).

1 - high pressure gas pipeline, 2 - throttle valve, 3 - bypass, 4 - low pressure pipeline, 5 - turbo expander, 6 - electric generator, 7 - separator, 8 - pump, 9 - storage tank, 10 - gasifier, 11 - to the consumer of natural gas, 12 - heat exchanger

Figure 4. Dependence of the condensate output on the total alkane percentage except methane in the initial gas.
Figure 4 shows the dependence of the condensate proportion from the separator on the total alkane percentage except methane in the initial gas for nine different natural gas compositions.

4. Conclusions
The possibility of liquefied natural gas usage as the reserve fuel at gas oil-fired thermal power plants and boiler plants in Russia is considered in the paper. The estimation of the annual amounts of black oil and natural gas that are needed to ensure the reliable operation of several power plants in Russia has been done. Fundamental technical solutions for reserving the necessary amounts of liquefied gas at TPP are presented. The evaluation confirms the effectiveness of the technical ability to use liquefied natural gas as a backup fuel reconstructed and newly designed gas power station. The calculations showed that the first scheme can be applied only when work on natural gas with a high content of high-boiling fractions (more than 4-6 %). The increase of pressure of natural gas in the high-pressure pipeline from 9 up to 12 atm leads to the increase of mass fraction of the condensate in the circuit 1 for 1.6%, and in the circuit 2 for 0.43%. The increase of the total mass fraction of hydrocarbons except methane involves a higher output of condensate (for example, when the total share of these components is increased for 1%, the output of the condensate increases at 0.2%).

References

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