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Feasibility of Replacing the Fuel Oil Economy of the Reserve Fuel of the TPP With the LNG Economy on the Example of Pervomaiskaya CHPP-14 of PJSC "TGC-1"

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ABSTRACT
One of the feasible essential things of the technological structure of thermal power plants running on liquefied natural gas is the economy of reserve fuel. The traditional reserve type of fuel in the Russian Federation is heating oil of the M-100 brand. The backup fuel at these power plants is practically not used. Due to the Physical-chemical properties of fuel oil, energy resources are spent on maintaining the economy of reserve fuel in reserve, which increases the cost of electric and thermal energy produced at the liquefied natural gas. In this research paper, the possibility of increasing the efficiency of power plants using fuel oil and diesel fuel as backup fuel by transferring Combined heat and power plant to storage is investigated. This research paper shows that with the combined use of fuel oil and diesel reserve fuel in the economy, the zone of lower operating costs when converting to LNG will be achieved at an annual consumption of reserve fuel, and when using only fuel oil at the power plant, the zone of lower operating costs when switching to LNG will be at an annual consumption of reserve fuel of no more than 7000 tons of conventional fuel per annum.

Keywords: *Liquefied natural gas, Reserve fuel, Fuel oil, Diesel, Economic efficiency.*

1. INTRODUCTION

The important thing of the technological construction of thermal power plants (TPP) running on natural gas is the economy of reserve fuel. The traditional reserve type of fuel in the Russian Federation is heating oil of the M-100 brand. For example, for the combined heat and power plant (CHPP) of PJSC Territorial generating company number 1 (TGC-1), this fuel is installed as a reserve for all power plants in St. Petersburg. The reserve fuel at these power plants is little used [1]. At the same time, due to the Physical-chemical properties of fuel oil, energy resources (steam, electricity) are spent in reserve to maintain the economy of reserve fuel (RF), which increases the cost of electric and thermal energy produced at the CHPP [2]. As solutions to this problem, it is possible to transfer power plants to reserve fuel, which does not require significant energy resources for its maintenance. A possible explanation could be the storage of diesel fuel [3]. However, diesel fuel is quite expensive to operate and requires a high initial filling, heating fuel lines, and more costly dual-fuel gas turbine power plants (GTPP) in modern combined-cycle power plants. One of the promising types of RF at thermal power plants can also be liquefied natural gas (LNG). In different years, the authors noted the possibility of transferring the CHPP from fuel oil to alternative fuel [4–9]. To date, Russia has a broad base and prerequisites for using LNG in the country's economy. The use of LNG instead of fuel oil as RF in thermal power plants has environmental and economic advantages over diesel fuel and fuel oil in the case of LNG shipment to a third-party consumer [10]. The above discussed the urgency of this problem. To assess the feasibility of replacing the existing RF storage with an LNG storage, a technical and economic assessment of the effectiveness of solutions is necessary. Due to the features of the cost of energy resources and individual characteristics of the economic

functioning of power plants, a particular justification is required for each energy facility.

In this research paper, we investigated the possibility of increasing the efficiency of power plants using fuel oil and diesel fuel as RF by transferring liquefied natural gas to storage.

Pervomaiskaya CHPP-14 of PJSC "TGC-1" was chosen as the object of the study. This CHPP has power steam, hot water boilers with fuel oil as reserve fuel, and combined-cycle power units with GTPP have diesel fuel as a backup. Backup diesel fuel requires high operating costs, namely: heating of pipelines (electric heating is used at the research facility), monthly fuel quality control after the expiration of the five-year warranty period of storage [11], as well as additional maintenance costs for dual-fuel gas turbines (if they are available at the facility). Thus, the transition to single-fuel burners in GTPP and LNG storage as RF can increase the economic potential of solutions.

2. METHODS AND MATERIALS OF THE STUDY

The study is carried out by a comparative technical and economic assessment of the effectiveness of solutions following the methodology of reducing the cost of maintaining existing storages of diesel and fuel oil reserve fuel and comparable fuel-liquefied natural gas. The practical value of the work lies in obtaining a specific result for the object of research, as well as in getting an area of efficiency of the transfer of the economy of the Reserve fuel to the use of LNG, which is of general importance and allows you to use the results of the work when assessing the prospects for translation at other facilities. The purpose of the study. Assessment of the feasibility of replacing the RF storage at CHPPP-14 with an LNG storage by comparing the operating costs of the existing RF and an alternative LNG storage.

To achieve the results of this research work, it is required to solve the following tasks:

1. Analysis of the existing thermal scheme of the CHPP and the structure of electricity and heat production. From the analysis, it is necessary to draw a conclusion about the required volume of tanks for liquid fuel.

2. Estimation of operational costs for maintaining the reserve fuel reserve at CHPP-14 in a state of readiness based on the reporting data on the costs of fuel oil resources of previous years.

3. Estimation of operating costs for alternative fuels with savings of liquefied natural gas.

4. Conclusions about annual savings when switching to alternative backup fuel.

The existing fuel economy of Pervomaiskaya CHPP-14 includes:

I. Fuel oil production storage No. 2 (FOPS-2).

II. Fuel oil production storage No. 3 (FOPS-3).

III. Production of diesel fuel and fuel oil with a tank storage.

The equipment of the FOPS-3 fuel oil storage includes:

I. Reinforced concrete fuel oil storage tanks, construction volume 10000 m3 - four pieces.

II. Two fuel oil heaters PM-10-120.

III. Condensate collection tank.

IV. Pumping equipment.

Production of diesel fuel and fuel oil and tank storage equipment includes:

I. Diesel fuel drain trestle (six lower diesel fuel drain devices and one combined device).

II. Railway trestle for draining fuel oil (six lower devices for draining fuel oil).

III. Overpass for unloading and refuelling diesel fuel.

IV. Flyover for draining fuel oil.

V. Two diesel fuel tanks, construction volume 5000 m3.

VI. Two fuel oil tanks, construction volume of 1000 m3.

VII. Production of diesel fuel and fuel oil building, including:

• fuel oil pumping station: pumping equipment, fuel oil heaters (main and circulation circuits), filters;

• pumping station for diesel fuel: pumping equipment, diesel fuel heaters (main and circulation), filters;

• pumping station for automatic fire extinguishing of diesel fuel tanks.

FOPS-2 equipment includes:

I. Reinforced concrete fuel oil storage tanks, construction volume of 5000 m3 – two pieces.

II. Three fuel oil heaters PM-10-120.

III. Two drain and refuelling railway overpasses.

IV. Two receiving tanks with a capacity of 200, 400 m3.

V. Pumping equipment.

Fuel oil plant No. 2 has been decommissioned; technological pipelines have been blocked.

The gas-consuming equipment of CHPP-14 includes 4 AE64.3A gas turbine units, 2 E-50 steam boilers and 5 KVGM-120 hot water boilers. The gas costs for the gas-consuming equipment of the power plant are shown in the given Table 1.

Table 1. Gas-consuming equipment of the CHPP

Unit name	Quantity, pcs	Gas consumption per 1 unit, [thousands of normal cubic meters per hour]	Total gas consumption, [thousands of normal cubic meters per hour]
GTU AE64.3A	4	23.0	92.0
KVGM-120 hot water boilers	5	14.8	74.0
Steam boilers E-50	2	4.0	8.0
Total	-	-	174.0

The reserve fuel reserve at CHP-14 is approximately 23000 tons, 18000 tons of fuel oil and 5000 tons of diesel. Thus, the calorific value of the entire reserve fuel economy is about 32,000 tons. For an alternative economy of RF, considering the calorific value of LNG, the mass of RF is approximately 20000 tons (47600 m^3).

The operating costs of the current economy of the Reserve fuel can be divided into fixed costs and variable costs. The main fixed prices of the current fuel economy of the CHP-14 include:

I. steam costs for heating fuel during its storage and when maintaining the economy in the “hot reserve” mode;

II. electric energy costs for the drive of fuel oil pumping pumps and heating of diesel fuel lines.

The main variable costs of the current economy of the Reserve fuel include:

I. fuel costs when working on reserve;

II. the cost of steam for reheating the fuel entering the combustion chamber when the fuel economy is in operation;

III. the cost of electricity to drive the fuel supply pumps when the fuel economy is in process.

Table 2. Prices For Energy Resources

Energy Resource	Price per unit	Source of references
Electricity	1.12 [Rubles/kWh]	[1]
Thermal energy	760.70 [Rubles/GCal]	[12]
Fuel oil M-100 (with VAT%)	9886.00 [Rubles/ton]	[13]
Diesel fuel EURO (with VAT%)	31508.00 [Rubles/ton]	[14]
LNG (with VAT%)	14985.00 [Rubles/ton]	[15]

All the above costs can be represented in fuel, steam, and electric energy costs. To assess the operational costs of maintaining the RF reserve in a state of readiness, the prices of energy resources were clarified in the given Table 2, and a technical and economic calculation was performed.

3. RESULTS

According to the technical and economic calculated results, the values of the total operating costs were obtained depending on the consumption of conditional RF in the given Table 3.

As an alternative solution to reduce the operating costs of reserve fuel, consider the option of replacing the existing fuel economy with an LNG economy. The equipment of the LNG storage includes:

I. LNG storage tanks.

II. Set of evaporators.

III. Cryogenic pumping station.

IV. System of collection and condensation of selected natural gas by high-pressure installations with refrigerant-freon.

V. LNG filling and receiving station.

LNG regasification systems can be divided into systems with atmospheric evaporators and systems with steam evaporators of LNG. To replace the fuel economy of the Pervomaiskaya thermal power plant, an option with steam evaporators of LNG is being considered due to dense urban development.

Table 3. The costs of energy resources for maintaining the existing economy reserve fuel in a state of readiness in kind and value terms, depending on the annual consumption of conditional reserve fuel.

Reserve fuel consumption, [Ton of conventional fuel/year]	100	100000
Variable cost of reserve fuel	-	-
Heat costs for fuel reheating, [GCal]	4.04	4039.96
Electricity Costs, [kWh]	4258.19	4258191.16
Heat costs for fuel reheating, [thousand rubles/year]	3.07	3073.20
Electricity costs, [thousand rubles/year]	4.77	4769.17
Fuel costs, [thousand rubles/year]	1038.95	1038947.20
Total variable costs, [thousand rubles/year]	1046.79	1046789.57
Fixed costs of reserve fuel storage	-	-
Steam consumption, [Ton/year]	47981.00	47981.00
Heat consumption, [GCal/year]	33401.00	33401.00
Electricity energy consumption, [thousand kWh/year]	4399.16	4399.16
Heat costs, [thousand rubles/year]	2554940	25549.40
Electricity energy costs, [thousand rubles/year]	4927.06	4927.06
Total fixed costs, [thousand rubles/year]	30476.46	30476.46
Operating costs, [thousand rubles/year]	31523.25	1077266.03

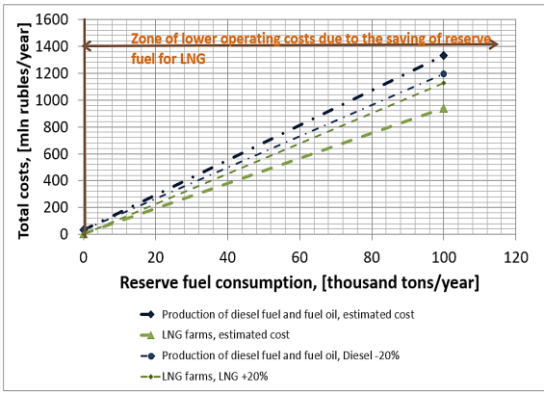

Figure 1 Operating costs for reserve fuel to the price of fuel for LNG storages and the production of diesel fuel and fuel oil at CHPP-14.

The fixed costs of an alternative economy of reserve fuel include electric power costs for the collection and condensation of LNG vapour. Variable costs include fuel costs of the backup fuel, thermal energy costs for LNG evaporation and gas heating, and electricity costs for gas transportation to the combustion chamber. The total costs of alternative fuel economy of reserve fuel are presented in Table 4.

For CHPP-14, when switching to LNG, the economy of the Reserve fuel will be more economical. Savings are achieved at any consumption of conventional fuel. With the consumption of reserve fuel in 2016–2020, the annual savings in operating costs on the alternative economy of the Reserve fuel will amount to approximately 28 million rubles. For a simple payback period of 10–15 years, the cost of switching to LNG should be 280–420 million rubles.

A technical and economic calculation was carried out to determine the sensitivity of the result to the conjuncture of energy prices (Figure 1). If the price of fuel oil, diesel, or LNG deviates by 20 %, the option of a fuel economy with LNG has lower costs for backup fuel than the existing option. The main reason for the weak sensitivity of the annual savings of the transition to LNG to the fuel price is the presence of rather expensive diesel fuel at CHPP-14.

Table 4. The costs of energy resources for maintaining the LNG economy of reserve fuel in kind and value terms, depending on the annual consumption of conditional reserve fuel

Reserve fuel consumption, [ton of conventional fuel/year]	100	100000
Variable cost of reserve fuel	-	-
Heat costs for fuel reheating, [GCal]	8.70	8700.84
Electricity Costs, [kWh]	0.03	3.07
Heat costs for fuel reheating, [thousand rubles/year]	6.62	6618.73
Electricity costs, [thousand rubles/year]	0.03	3.44
Fuel costs, [thousand rubles/year]	930.92	930918.80
Total variable costs, [thousand rubles/year]	937.57	937540.97
Fixed costs of reserve fuel storage	-	-
Electricity energy consumption, [thousand kWh/year]	2920.00	292000
Heat costs, [thousand rubles/year]	0.00	0.00
Electricity energy costs, [thousand rubles/year]	3270.40	3270.40
Total fixed costs, [thousand rubles/year]	3270.40	3270.40
Operating costs, [thousand rubles/year]	4207.97	940811.37

In such a way, the main reason for the weak sensitivity of the annual savings of the transition to LNG to the fuel price is the presence of rather expensive diesel fuel on the existing RF CHPP-14 storage. The area of efficiency of LNG compared with only fuel oil reserve fuel is located at the consumption of reserve fuel of no more than 7000 tons of conventional fuel per annum (Figure 2).

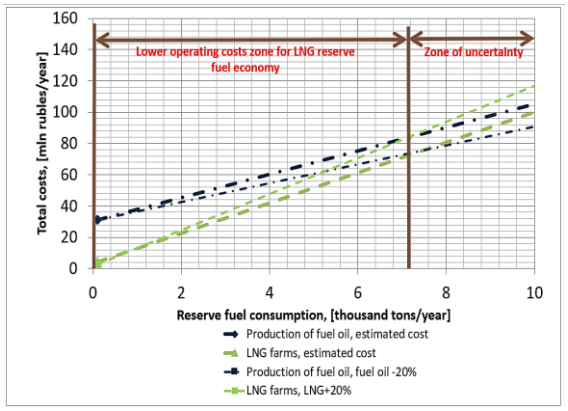

Figure 2 Operating costs of fuel oil reserve fuel and LNG economy reserve fuel to the price of fuel.

The area of efficiency of LNG in comparison with the fuel oil industry is located when the consumption of RF is no more than 7000 tons of conventional fuel per annum (Figure 2). When the consumption of RF is 7000 tons of conventional fuel per annum, but less than 37000 tons of conventional fuel per annum, there is a zone of the uncertainty of operating costs for the economy of RF (Figure 3.). When the consumption of RF is more than 37000 tons of conventional fuel per annum, there is a zone of efficiency of fuel oil. For a power plant with a fuel oil economy of the reserve fuel and a small average annual consumption of reserve fuel, the reduction in operating costs for the economy of the Reserve fuel during the transition to LNG is explained by a large number of fixed costs for storing fuel oil and maintaining it in the "hot reserve" mode. For power plants with a fuel oil economy of the reserve fuel and a large average annual consumption of the Reserve fuel, the inefficiency of replacing the economy of the reserve fuel with fuel oil for LNG of the Reserve fuel is explained by the lower price of a ton of conventional fuel oil compared to LNG.

4. CONCLUSION

Replacing the reserve fuel economy of Pervomaiskaya CHPP-14 of PJSC TGC-1 with an LNG economy will reduce operating costs for the annual consumption of reserve fuel. With an average annual consumption of reserve fuel, the annual savings will be about 28 million rubles.

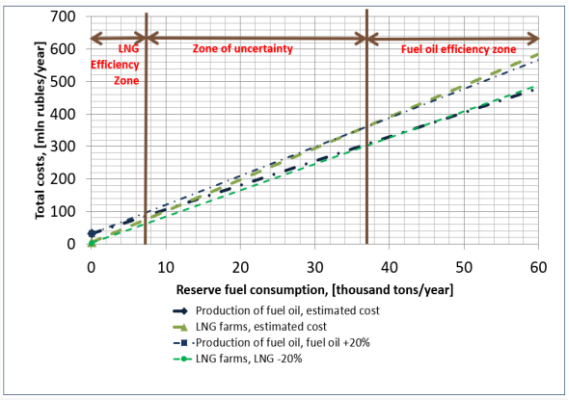

Figure 3 Operating costs of fuel oil reserve fuel and LNG economy reserve fuel to the price of fuel (continuation of the graph).

The area of efficiency of transferring power plants to the LNG reserve fuel economy includes power plants with fuel oil and diesel reserve fuels and power plants with diesel reserve fuel only, regardless of the annual consumption of reserve fuel, as well as power plants with fuel oil only with an average annual fuel oil consumption of no more than 7000 tons of conventional fuel per annum.

AUTHORS' CONTRIBUTIONS

All authors have contributed equally to this study. All authors read and approved the final manuscript.

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