Problems and Possible Options for Improving the Efficiency of Diesel Generation

N K Efimov¹,²,³, P F Vasiliev¹,²,³

¹Yakutsk, Russia
²Institute of Physical and Technical Problems of the North named after V.P. Larionov SB RAS - a separate subdivision of the FRC YSC SB RAS
³Department of Power Supply, Institute of Physics and Technology, North-Eastern Federal University named after M.K. Ammosova

E-mail: 626enk@mail.ru, Kb8@mail.ru

Abstract. The potential for improving the energy efficiency of diesel generation really exists and can be estimated in real money. Reducing the fuel component is one of the priority areas. This article discusses the problems and possible options for the modernization and reconstruction of diesel generation, including the positive experience of JSC Sakhaenergo of the Republic of Sakha (Yakutia).

1. Introduction

More than five thousand units of diesel generator sets, which generate 1.8 billion kWh per year, operate in the decentralized zones of power supply in Russia, while they consume about 1.2 million tons of diesel fuel per year. Their cost is more than 80 billion rubles according to an aggregate estimate. There is no such number of diesel power plants in any country in the world, as in 6 regions of the Far Eastern Federal District, where there are about 500 diesel generator power plants, with a fleet of diesel generator sets of more than 2000 units [1].

According to the conclusions of a number of scientific communities, the local electric power industry based on diesel-generator power plants existing in the North and the Arctic of Russia in the next fifty years has no alternative, due to the natural and climatic conditions. and sometimes exclude the use of renewable energy sources [2].

In the Annual Statistical Bulletin 2020, and BP published in the Statistical Review of World Energy 2020. Oil reserves in Russia are 107,200 million barrels, 14,700 million tons, which is 6.18% of world reserves. According to Forbes [3], BP [4], EREPORT.RU, and a simple arithmetic calculation, while maintaining the current level of consumption, the proven world reserves (about 1700 billion barrels, as of 2014-2015) would be enough about 50 years of production [5]. This indicator was 21 years for Russia in 2016 [6].

Thus, society is faced with a difficult task, a solution that is limited by time and technology.

The main factor in the economically justified introduction of renewable energy sources is the lack of confirmed scientific research on long-term monitoring of the natural and climatic conditions of the northern and arctic territories. It is important to note the high cost of equipment and the limited market
for its suppliers for the industrial production of "green" electricity of small and medium power, which negates the performance indicators of projects [2].

If the authors in the article "Problems and prospects of the electric power industry of the Arctic regions of Russia" in the journal "Problems of the modern economy № 1 (76) 2020". The solution to the problems was proposed through organizational transformations and the creation of a unified management system for the decentralized energy sector in the Arctic of Russia, then this article will consider possible options for the modernization and reconstruction of diesel generation.

There is no plant in our country to date, specializing in the development and production of diesel generators, as the main source of electricity generation on an industrial scale. There is a need to develop a new generation of generating sets with the highest efficiency. Diesel generators created by global manufacturers are based on diesel engines for marine drives adapted for power plants. There are no special designs for power plants [2].

At the same time, diesel generators operate in very large load ranges, they depend on the nature of the consumer, time of day, day of the week, seasonality, climate, etc.

For example, the loads in the DPP Saskylakh of Anabar REN in June: the minimum 267 kW and the maximum 487 kW, then in December 1190 kW and 1621 kW, respectively.

The cost of fuel increases significantly and differs in each station due to complex transport logistics, with seasonal supplies, which in some areas are two seasonal periods with many transshipments and long-term storage.

The analysis of the fuel cost by stations carried out by OJSC Sakhaenergo in 2018 showed that at the Sitta diesel power plant Kobyai electric grids amounted to 30,433.3 rubles per 1 ton of diesel fuel, excluding VAT, when, as in the Barylas diesel power plant, the Verkhoyansk electrical networks, this figure was 71235.1.

At the same time, the installed capacity of diesel generator sets, design features and uneven loading of equipment, depending on the main activity of the consumer, significantly affects the fuel consumption for the generation of 1 kWh electricity.

Specific consumption of natural fuel for the generation of 1 kWh amounted to 243.3 g / kWh in DPP Tiksi Bulunsky electrical networks and 1531.4 g / kWh in DPP Yuren Oleneksky district of electrical networks.

Based on the foregoing, the cost of production of marketable products by the stations of Sakhaenergo JSC is very different from each other and on average is more than 40 rubles per kWh, due to more efficient large stations.

This process was considered in great detail in the scientific article "Study of the regularities of the formation of graphs of electrical loads of decentralized consumers in the Republic of Sakha (Yakutia)", where the efficiency of fuel (energy) use in decentralized zones is 25.2% (excluding heat recovery). The largest losses are observed in diesel generators when generating electrical energy - 68.1%. Fuel consumption is 1.8% of primary energy for own and economic needs of the DPP. Losses of electrical energy are 4.9% in distribution networks on average for JSC "Sakhaenergo" [7].
If the DPP load lies in the range from 40% to 75% of the nominal value, it is considered optimal. If the load is less than 40% of the rated power, the diesel engine operates with increased specific fuel consumption. Loading of diesel power plants by more than 75% also leads to a decrease in the efficiency and excessive consumption of fuel. The influence of the ambient temperature, unregulated supply of the air-fuel mixture and other negative factors can reduce the efficiency of the engine by almost 30% [7].

Thus, the potential for reducing fuel consumption by up to 30% in the existing method of generating electricity.

All engine designers, in one way or another, are limited by such indicators as weight and size parameters, which influenced the traction characteristics of engines, depending on the engine torque, and subsequently limiting them to a small range of engine efficient operation.

From the above, it can be concluded that a special development of the engine for diesel generators is required.

The second direction of increasing the efficiency of diesel generators can be achieved through the use of a buffer storage. The reduction in fuel consumption is achieved due to the fact that the loading mode of the diesel engine is maintained at the level of the average load power. At the same time, in modes when the output power of the synchronous generator exceeds the current load power, excess energy is accumulated in the buffer energy storage, and in modes when the output power of the synchronous generator is less than the load power, energy from the buffer storage is transferred to the load. As a result, the diesel engine operates in a mode close to the nominal one, respectively, the fuel consumption decreases [8].

Experts have developed various methods of short-term accumulation of electricity in small volumes, which are of interest, but have not been brought to an industrial scale.

The need to preserve large volumes of electricity for a long time is becoming a priority task for power engineers around the world. The creation of energy storage devices capable of storing electricity in large volumes and long-term storage in containers for transportation by air, sea and land would radically change the economic situation in many hard-to-reach regions of the country.
It is not possible to use renewable energy sources, such as wind-solar power plants, as the main (basic or basic) energy source for industrial power generation without storage due to technological features and variability of weather conditions.

It is possible to use effectively wind-solar power plants in combination with diesel generators, without installing expensive energy storage units (storage batteries) according to the experience of JSC Sakhaenergo.

A decent fuel economy is achieved even with such a scheme in JSC Sakhaenergo.

The following is observed when the ratio of loads changes in the direction of increasing shares:
- diesel generator, increased fuel consumption due to going beyond the parameters of rated loads (40-75%);
- wind-solar power plants, disruption of the supply of electricity in case of a sharp change in weather conditions, which is not permissible.

Why was the share of 20-25% for the wind-solar power plant chosen? Firstly: any station operates with a share of the rotating power reserve, which is necessary to level the dynamic loads (starting torque of engines, hourly changes in consumption, etc.), this parameter is 20-25% of the power of the station for rural settlements; Secondly: the diesel generator works efficiently at rated loads of 40-75%.

A short-term operation with 10-15% of the nominal passport characteristic is provided in the diesel-generators when force majeure circumstances, a sharp increase of the load (short circuit on the line to trigger the automatic tripping of protection, etc.).

The wind-solar power plant becomes the main (basic) source under optimal weather conditions for its operation, thus, all the energy generated by it is transferred to the grid, and the role of "leveling" the dynamic loads is transferred to the diesel generator. JSC "Sakhaenergo" was able to obtain efficiency due to such a system when using solar power plants in a hybrid scheme, without expensive storage devices (accumulators).

If we consider the installation of storage devices on a diesel power plant (DPP), we would get a very efficient system.

Consider the efficiency of reducing the fuel component using the example of the Saskylakhskaya diesel power plant, which is equipped with modern diesel generator sets (DGU) and energy storage.

Figure 2. Load graph of Saskylakhskaya DPP.
The maximum load was reached in December and is 1621 kW, while the minimum was 1163 kW according to the load schedule of the Saskylakhskaya DPP.

It is necessary to take into account the charging and discharging times of the drive when using the drive, so that the charge volume is slightly higher than the discharge volume. The graph shows that the areas below and above the straight line are practically the same. In this case, the straight line corresponds to a load of 1430 kW. For these data, the composition of the equipment is selected, which should work around the clock without stopping in the nominal mode. In our case, the composition of the equipment is as follows: (SAT 3412STA) two units and DGR-520 one unit, with a total capacity of 1450 kW.

| №  | Unit type                        | Capacity kW |
|----|----------------------------------|-------------|
| 1  | (CAT 3412STA)                    | 465         |
| 2  | (CAT 3412STA)                    | 465         |
| 3  | ДГР-520                          | 520         |
| 4  | ДГР-520                          | 520         |
| 5  | ДГР-520                          | 520         |
| 6  | (CAT 3406C)                      | 175         |
| 7  | (CAT 3406C)                      | 175         |
| 8  | Cummins 600                      | 600         |
| 9  | Cummins 600                      | 600         |

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The following equipment compositions were selected without a storage device when operating according to the classical scheme: 1-7 hours Cummins 600 one unit, DGR-520 one unit and (SAT 3406S), with a total capacity of 1295 kW; 8-24 hours DGR-520 two units and Cummins 600 one unit, with a total capacity of 1640 kW.

The following happened when calculating fuel consumption:
- when working with storage devices - 8352 kg of diesel fuel;
- when working according to the classical scheme - 8866.8 kg of diesel fuel.

Fuel savings amounted to 514.8 kg per day, or 5%.

The savings can amount to 106.2 tons or 6.2 million rubles in the annual volume of fuel consumption equal to 2.124 thousand tons, with a fuel cost of 58247.08 rubles. per 1 ton, excluding VAT, in 2018 prices.

308 units of batteries with a capacity of 100 A * h are needed to ensure the necessary output by the storage device in the amount of 1697 kWh, which will amount to 5.5 million rubles at the cost of one AGM-type battery of 18 thousand rubles.

The project can pay for itself in a year, which can be considered very effective when the battery operates for 10-12 years.

In addition, all large thermal and power plants cannot respond to hourly and daily fluctuations in loads due to inertia, which also affects the installed capacity utilization factor (ICUF), which can be increased through the use of energy storage devices.

"A comprehensive plan of measures to improve the energy efficiency of the economy of the Russian Federation" was approved by the order of the Government of the Russian Federation dated April 19, 2018 No. 703-r, which provides for a decrease in the specific consumption of equivalent fuel (SCEF) for electricity generation in Russia to 280.1 g / kWh in 2025 and 255.6 g / kWh in 2030 [9].

The weighted average actual SCEF amounted to 309.8 g / kWh for electricity supply in the proportional method of separating fuel between types of products and 297 g / kWh in the mixed method at the end of 2020. The decrease in specific fuel consumption amounted to 24.6 g / kWh, or 7.4% of the
2010 level, which made it possible to reduce the fuel component of the cost of electricity by 49.2 billion rubles over the past 8 years [10].

According to energy experts, an efficiency of 100% will be achieved with a SCEF of 122.84 g/kWh, which is comparable to a "perpetual motion machine".

2. Conclusion

As can be seen from the above, the potential for improving energy efficiency really exists and can be estimated in real money. Reducing the fuel component is one of the priority areas for joint work of specialists from scientific communities and engineering and technical personnel of energy companies.

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