Increasing The Use Of Natural Gas On Motor Transport By An Efficient Location Of The NGV RS (On The Example Of Tyumen)

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Abstract. This article is devoted to increasing the use of natural gas on the basis of an efficient territorial and quantitative location of natural gas refuelling stations (NGV RS). The key factors which can affect it are offered. On the basis of the chosen factors on the example of Tyumen the option of a territorial location of 4 NGV RS capable to satisfy the demand for natural gas by motor transport in the short term is considered. Increased use of natural gas (NG) on motor transport allows to reduce the negative impact on the environment from harmful substances emitted with exhaust gases.

1. Introduction

In April 2016 many countries signed the Paris agreement to which the 21st conference (COP 21) preceded at the end of 2015 to the United Nations Framework Convention on Climate Change. This paper discusses the problem and importance of decreasing carbon dioxide in the atmosphere to slow the growth of global warming, since 2020. The purpose of this conference was to sign the international agreement on maintaining the average temperature increases of the planet to less than 2 °C, applicable to all countries. The agreement will replace one of the first global documents to regulate the negative impact of humans on the environment, the Kyoto Protocol (COP 3), which was accepted in Japan in 1997. The Paris Protocol was already appended by 175 countries, including Great Britain, China, Russia, the USA, France, etc., thus confirming the importance of environmental issues and climate change around the world.

At the same time, it is known that one of the main anthropogenic sources of environmental pollutants is motor vehicles, with over 1 billion vehicles worldwide and steady growth in this number each year.

One way to reduce the harmful effects of vehicles is to use more environmentally-friendly alternative energy sources, such as natural or oil gas, biofuels, electricity, hydrogen, etc. Application of these types of fuel is already widely used in various countries.

In Russia, the most urgent is the use of natural gas (NG). The country has the world’s largest reserves of this fossil (24.6%) and is the second-largest producer worldwide (18%) [1]. Also on state and regional levels a number of legislative initiatives which in the near future have to increase consumption of NG on the motor transport in compressed (CNG), and liquefied (LNG) states is...
accepted. Countrywide construction of NGV RS has to play a leading role in increase of this hydrocarbon consumption.

For example, according to the program for the construction of compressed natural gas refueling stations (CNG RS)s and liquefied natural gas refueling stations (LNG RS)s developed by PJSC "Gazprom" and LLC "Gazprom gas fuel" it is planned to construct in Russia 2158 CNG RSs and 462 LNG RSs until 2030 [2]. This program also includes transferring 524 thousand vehicles to NG. The program contributes to the environmental and economic efficiency of vehicles use, increases energy security of the country and corresponds to the Russian state program "Energy efficiency and the development of renewable energies" from 15.04.2014, № 321 (edition. Resolutions of the Government of the Russian Federation from 09.10.2015 № 1079; from 07.12.2015 № 1339; from 25.05.2016, № 464) and the order of the Government RF № 767-r "On regulation of the relations in the sphere of the use of gas motor fuel, including NG as motor fuel" from 13.05.2013.

On the base of analysis of the submitted documents it is possible to note the next highlights. The purpose of the "Energy efficiency and the development of renewable energies" Program (an edition from 07.12.2015 No 1339) is – reliable providing the country with fuel and energy resources, increase in efficiency of their use and decrease in anthropogenic impact of fuel and energy complex on the environment. The aim of the subprogram "Development of the gas industry" is – the development of the gas industry, effectively providing the gas demand of the domestic market and the accomplishment of contract commitments on supply of NG for export, increasing the production and exports of LNG, the increase in the volume and depth of processing of raw material gas in the framework of diversification and leaving from export and raw model of an industry. A target indicators are including: a consumption of the compressed gas on to the motor transport work and the number of NGV RSs.

In the order of the Government RF No 767-r "On regulation of the relations in the sphere of the use of gas motor fuel, including natural gas as motor fuel" the harmonization of legal acts of the Russian Federation in the field of standardization with the relevant international documents in the sphere of the use of NG as motor fuel is offered; expediency of development of the technical regulation of the Customs Union in the sphere of use of NG is proved.

It is entrusted to develop a set of measures by 2020 in territorial subjects of the Russian Federation to bring the level of NG use on the public motor transport and transport of road municipal services in the following proportions: 1. In the cities with population more than 1 million people – to 50% of the total number of vehicles. 2. In the cities with population more than 300 thousand people – to 30% of the total number of vehicles. 3. In the cities and settlements with population more than 100 thousand people – to 10% of the total number of vehicles.

It is offered to develop the decrease mechanism (zeroing) of an import customs duty rate on the components required for the production of vehicles, using NG as motor fuel, as well as equipment and machinery, used for refueling vehicles with NG.

It is noted about the development of offers on subsidizing of the transfer of vehicles to NG in order to update the bus fleet, vehicles of road municipal services, etc.

On the basis of the submitted documents it is possible to conclude that growth of number of NGVs and gas NGV RSs will promptly grow in the nearest future. However today, for example, NGV RSs are concentrated generally in the European part of Russia and their quantity obviously insufficiently for growth of gas fuel consumption. Thus, expansion of NG use on the motor transport in eastern regions of the country is very urgent.

In this work we consider only one kind of NGV RSs – CNG RSs.

2. Increase in level of NG consumption on the motor transport
2.1 The factors influencing a numerical and territorial location of CNG RSs

Issues prospects for the NG use on road transport by the construction and infrastructure development of CNG RSs in the world and Russia are in many papers [3-15, etc.]. Also in sources [2, 4-8, 10] it is
noted that in the combustion process of NG in the engines the smaller number of harmful substances emitted in comparison with traditional liquid motor fuels is allocated.

From the technical point of view weak branching of the CNG RSs in east Federal Districts of the country is possible to explain with several reasons among which the main ones:

1. Weak branching (or total absence) the gas transportation system in Eastern Siberia and in Far East. As is well-known the main part of the gas transportation system of the country is located in the western, central and southern parts, and also in the Urals. And supply of RSs with NG requires existence of the gas pipeline.

2. The significant extent of the specified FDs territory and the resulting problematic nature of the creation of so-called "blue corridors" (i.e., vehicles moving in different settlements and using NG mainly). As noted by professor Ya. S. Mkrtychan [12], the distance between CNG RSs should be in the range of 70–250 km.

However in view of the continuing arrangement of a number of new gas fields (Chayandinskoye, Kovyktinskoye, Kshukskoye, Nizhne-Kvakchikskoye, Sakhalinskoye, etc.), construction of the "Force of Siberia" gas transportation system and by commissionings of gas pipelines "Sobolevo — Petropavlovsk-Kamchatsky", "Sakhalin — Khabarovsk — Vladivostok", etc. it is possible to conclude that problems with gasification of the East are intensively solved. This may help, in the short term, increase the level of NG consumption by motor transport in these regions.

Thus, to determine the required number of the CNG RSs in the cities and their territorial location it is offered to consider a number of factors:

1. Branching of the gas transportation system in the settlement (the number and a territorial location of gas distribution stations (GDS) and gas control points (GCP), length of gas pipelines and their capacity, distance from the main highways).
2. The fire safety requirements regarding remoteness of the CNG RSs from various objects of city infrastructure [16].
3. The number of the large highways passing through the settlement.
4. The number of potential motor transport which can be converted to run on CNG.
5. The availability and geographical location of existing CNG RSs.

2.2. Calculation of the CNG RSs optimum number and their territorial location on the example of Tyumen

In this work expansion of NG use by rational territorial and quantitative construction of the CNG RSs is considered on the example of the city of Tyumen.

The choice of the city of Tyumen is caused by the fact that the city is one of the largest transport hubs of the Ural Federal District. Through the city there passes one of two existing highways connecting the east and west of the country, and also its northern oil and gas areas – Khanty-Mansi Autonomous District and Yamalo-Nenets Autonomous District. Since 2016 the city of Tyumen is also included in the "Reduction of greenhouse gas emissions from motor transport in the cities of Russia" project. The project is directed to decrease in emissions in the atmosphere of greenhouse gases by means of improvement of planning and management of an urban transportation by creation of effective systems of monitoring and promotion of environmentally friendly transport modes. Project implementation will be enabled at the expense of the Ministry of transport of the Russian Federation and the United Nations Development Programme with the assistance of the Global Environment Facility.

As of August, 2016 in Tyumen operates one CNG RS, located in 12 km from the downtown. Let's choose the optimum number of the CNG RSs for Tyumen taking into account the above factors.

NG is supplied to the south of the Tyumen region from its northern regions on the main gas pipeline "Urengoy - Chelyabinsk I", "Urengoy - Chelyabinsk II". In the city operates 2 GDS, about 30 GCP, the total length of gas pipelines more than 1000 km, and volume more than 1 million m³ of gas a day (daily from compressor station-11 for the needs of Tyumen served 1 million m³ of gas) (figure 1). In view of extensive branching of gas pipelines it is possible to locate the CNG RS in many of its
parts. However according to [16, 17] the location of the CNG RS in the central parts of the city is almost impossible.

As a rule, diameter of gas pipelines from GDS to GCP is 120 mm, and from GCP to consumers of 35 mm. Pressure in gas pipelines inside the line from GDS to GCP makes 0,6 MPas, and after GCP to consumers, as a rule, moves under pressure of 0,05 MPas.

As presented in RD 3112199-1095-03 [18] and the order of the Government of the Russian Federation № 767-r in case of intercity transportations it is the most effective to use CNG first of all by buses of various capacity and transport of road municipal services.

When choosing a CNG station locations in the city of Tyumen it is offered to consider the territory adjacent to the following city highways:

P402 (Tyumen – Yalutorovsk – Ishim – Omsk) – adjacent to the south-east, on the way to the city and is called the Yalutorovsky tract.

P351 (Tyumen – Ekaterinburg) – adjacent to the west, on the way to the city and called Moscovsky tract.

P404 (Tyumen – Tobolsk – Surgut – Nefteyugansk – Khanty-Mansiysk) – adjacent to the east, on the way to the city and called Tobolsky tract.

Tyumen – Kurgan – adjacent to the south, on the way to the city and called Chervishevsky tract.

On these highways there passes a large number of transit vehicles, which potentially can also refuel at CNG RSs of the city of Tyumen.

Regarding determination of quantity of the potential vehicles which can be transferred to NG it is possible to note the following:

1. According to [19] transport service of the population in the city of Tyumen are carried out by 1162 units. The number of high-capacity buses M3 is 593, M2 – 569 units.

2. According to [20] for the main contract organizations of Tyumen 624 units of road municipal services vehicles are available. And in case of force majeure circumstances, the city administration signed contracts with a number of the organizations having the road and municipal services vehicles in number of 503 units.

That is 2289 units of vehicles in total. At the same time to select the optimal performance of CNG RS it is necessary to know their total daily CNG consumption. Fuel consumption is calculated on the example of the most characteristic brands of the cars which are operated in the city of Tyumen. Buses
of the class M3 (MAZ-206) 20 m³/100 km in city conditions. M2 Bus (Peugeot Boxer) consume about 11 m³/100 km. Fuel consumption of the combined road machines (ED-405AG) makes about 50 m³/100 km.

At the same time it is known that in the city of Tyumen each bus provides about 150 kilometers per day, and the road municipal services vehicles about 100 km.

Thus, knowing an approximate day run and an expense of CNG we will determine daily fuel consumption of the vehicle fleet (by modes of transport) as follows:

\[ Q_{\text{day}} = 0.01 \times H_s \times A \times L_m, \quad (1) \]

where \( H_s \) – the base rate of NG consumption on a vehicle mileage, m³/100 km; \( A \) – number of vehicles, units; \( L_m \) – day mileage of 1 vehicle, km.

Define daily fuel requirement of M3 buses:

\[ Q_{\text{day-M3}} = 0.01 \times 20 \times 593 \times 150 = 17790 \text{ m³}. \]

Define daily fuel requirement of M2 buses:

\[ Q_{\text{day-M2}} = 0.01 \times 11 \times 569 \times 150 = 9388.5 \text{ m³}. \]

Define daily fuel requirement of the road municipal services vehicles:

\[ Q_{\text{day-RMS}} = 0.01 \times 11 \times (624+503) \times 100 = 12397 \text{ m³}. \]

Next, we’ll define the total daily fuel demand of the fleet:

\[ Q_{O} = Q_{\text{day-M3}} + Q_{\text{day-M2}} + Q_{\text{day-RMS}}. \quad (2) \]

Substituting the values we get:

\[ Q_{O} = 17790 + 9388.5 + 12397 = 39575.5 \text{ m³}. \]

The received values represent only 4% of total daily quantity of the NG consumed by the city of Tyumen.

Except the considered transport potentially it is also possible to transfer to CNG the vehicles serving trade enterprises, private and office cars.

Further we will choose the CNG RS of necessary performance taking into account 4 large highways passing through Tyumen and the general potential day need for CNG. According to the classification performance of CNG stations, they are usually divided into 500, 250, 125 and so on of conventional refueling. Conventional refueling is the number of cargo vehicles refuels per day at the rate of 55 m³ on 1 vehicle. For example, daily performance of CNG RS-250 and CNG RS -125:

\[ P_{\text{CNG RS-250}} = 250 \times 55 = 13750 \text{ m³}. \]

\[ P_{\text{CNG RS-125}} = 125 \times 55 = 6875 \text{ m³}. \]

Thus, at the maximum daily requirement of CNG 39575.5 m³, calculated using the formula 2, it is enough to construct 2 CNG RSs – 250, and 2 CNG RSs – 125:

\[ P_{\text{CNGRS total}} = (250 \times 2 + 125 \times 2)55 = 41250 \text{ m³}. \]

The following places of CNG RSs location are offered:

1. On departure from Tyumen on the highway P402 near the TEC-2 (CNG RS-125).
2. On departure from Tyumen on the highway P351 next to the s. Derbyshy (CNG RS-250).
3. On departure from Tyumen on the highway near the P404 s. Yar (CNG RS-250).
4. On departure from Tyumen on the highway "Tyumen – Kurgan" near the village Patrushevo (CNG RS-125).

Schematically the location of the offered CNG RSs in Tyumen is shown in figure 2:
3. Conclusions
The proposed location of the CNG RSs can satisfy the demand for NG as a city car owners and transit transport. The important point is that refueling stations it is offered to locate close to the city limits, in order to reduce the vacant run, and that their location corresponds to the fire safety requirements in terms of distance from the buildings and infrastructure. During the maximum operation of all 4 CNG RSs a load on gas transportation network will increase slightly – by only 4%. Respectively, there is no need to reconstruct it. However for supply the gas to the CNG RS it is necessary to equip additionally the gas transportation system with separate GCP. The rational territorial and quantitative location of the CNG RS in the city of Tyumen can lead to growth not only NG buses and road municipal services vehicles, but also NG cargo transport, and cars. In the long term the given CNG RSs can become a part of the All-Russian (connecting the western and eastern regions of Russia, and also Northern territories of Western Siberia) and international (connecting territories of Russia, Kazakhstan and China) "blue transport corridor". Increased use of NG will reduce environmental pollution by harmful substances emitted with exhaust gases.

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