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UGS as Effective Tool for Optimizing Technological Regimes and Investment Costs of New Export Pipelines

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Background

In the context of present geopolitical conditions Gazprom is aimed at the diversification of supply sources, routes and markets in order to further increase the efficiency of projects and their resistance to market fluctuations, and also to minimize risks concerned with market volatility. It will ensure the increase of logistical flexibility for implementing contract obligations, as well as risk management for mitigating adverse changes in any regional market.

Pipelines continue to deliver main gas volumes, and namely transportation is a priority in our investment program, particularly considering the fact, that gas delivery is a considerably more capital consuming process, than production itself.

Aim

As part of relevant Gazprom's strategy for securing reliability of gas export supplies to customers we take measures for developing underground gas storage (UGS) system along routes and within the territory of importing countries. The implementation of autonomous investment projects in the UGS sector reduces to a minimum the risk of storage capacities non-receipt in the period of peak gas demand.

Considering a significant capital intensity of pipeline systems costs optimization is vital. The UGS facility located in a high consumption region enables to reduce the diameter of supply pipelines assuming not maximum but average consumption volume, as a result, the load on gas compressor units and costs of production capacities buildup become materially lower.

UGS facilities operating jointly with a trunk pipeline are capable of mitigating sharp performance fluctuations unacceptable for technological equipment, by means of supplying extra amounts of gas to such storage facilities while seasonal or short-term demand drop to maintain a consistent gas supply via a gas pipeline. On the other hand, such storage facilities are aimed at increasing reliability of gas transmission systems and at uninterrupted gas supplies to final consumers.

Methods

Trunk pipeline system lag prevents from a prompt respond to a short-term increase of gas demand. Presence of storage facilities lets solve this problem and, finally, increase gas supply volumes.

Efficiency of the Unified Gas Supply System in relation to UGS facilities and export pipelines may be expressed in the following figures: costs for creating gas reserves in UGS facilities are two-three times lower compared to similar capacities in transportation. Specific capital expenditures for UGS facilities construction in Europe amount to EUR 100 – 130 /1000 m^3 today. Thus, each thousand cubic meters in UGS facilities provides for saving EUR 200 – 250, that is an UGS facility with the active capacity of 1 bcm provides for net saving of capital expenditures amounting to EUR 200 – 250 million. Besides, specific capital expenditures in making gas reserves become lower for UGS facilities and higher in a transportation system, with growing volumes of gas storage (Fig.1).

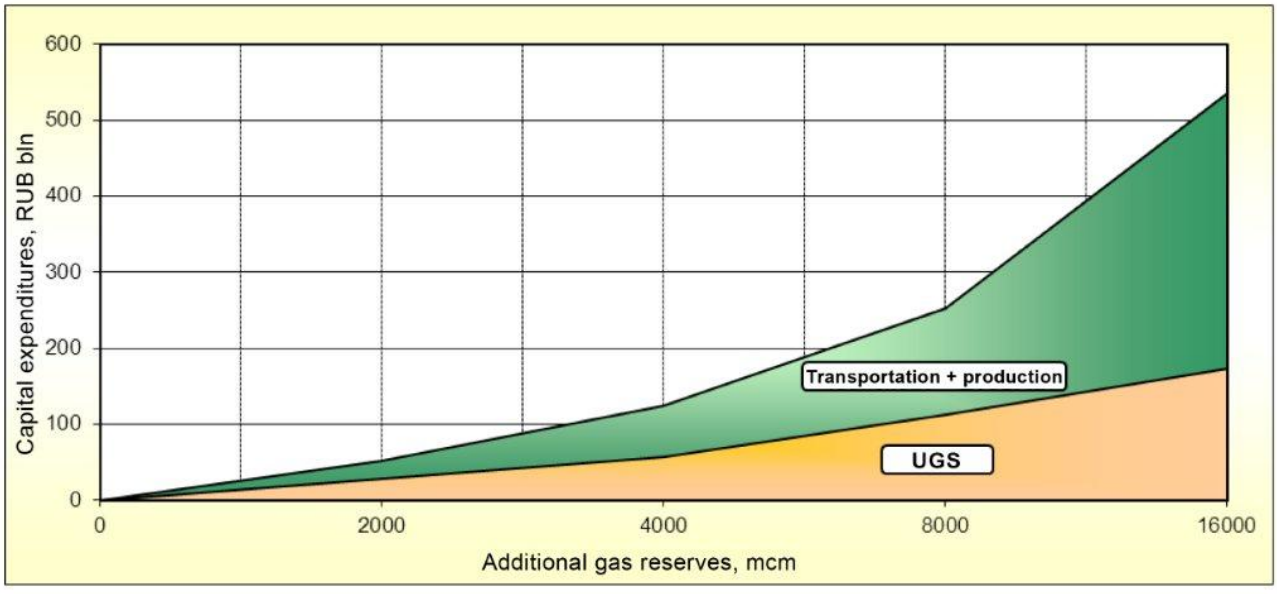


Fig.1 Efficiency of using UGS facilities in pipeline gas supply system

Gazprom Management Committee Directive No.5 dated January 27, 2011 "On building up Company's UGS capacities abroad" envisages Company's UGS capacities growth in foreign countries to achieving the active capacity of at least 5% of annual export supplies, with the priority of creating proprietary storage capacities.

Russian gas storage abroad is characterized by the following advantages:

- Improving reliability and continuity of gas export supplies,
- Reducing fines for short supplies,
- Emerging option of the participation in spot gas markets,

- Increasing gas export volume,
- Maintaining status of strategic supplier.

Recent years, following significant changes in the gas market the ability of vendors to provide flexibility and elasticity of supplies within the shortest period of time, is becoming increasingly important. In this regard, Gazprom consistently builds up the daily capacity of its UGS facilities abroad. Daily capacity of our European storage facilities is expected to reach 70 mcm, and in ten years we will be able to ensure approximately 100 mcm a day.

In 2014 the volume of Gazprom Group's gas sales to Europe is lowered almost by 10% after record indicators of 2013 (Fig.2). The reason is the reduction of gas demand in Europe by 11%, primarily due to the abnormally warm weather. Gas consumption in Europe fell in contrast with its growth in the previous period of time till 2008. This decline was subject to the growth of renewables and coal share in the fuel and energy mix of European countries. However, the review by the Oxford Institute for Energy Studies shows that gas demand will be minimal in 2020 (564 bcm), and then it will upsurge to 618 bcm in 2030.

Fig.2 Gazprom's gas supplies to Europe

Gas supplies from Russia are still reasonably the most beneficial for Europe and they do not have a viable alternative. LNG capacities are less than one-third loaded, and for facilities built in recent 10 years the average utilization coefficient came to only 15%.

In comparison with 2009, the European gas demand dropped by 8%, while potential gas volumes in UGS facilities grew by 16%. Such situation led to the temporary surplus of gas storage capacities and to the conservation of the least profitable storage facilities. However the role of storage facilities being a source of long-term and strategic reservation was not diminished. New functions related to unconventional energy sources also appeared. See the details below.

Nord Stream

The Nord Stream gas pipeline is a fundamentally new route for Russian gas exports to Europe. The target markets for gas supplies via Nord Stream are Germany, the UK, the Netherlands, France, Denmark and others. To secure reliability Gazprom changed gas supply routes to Europe with an aim to maximally load "northern" gas pipelines such as Nord Stream and Yamal – Europe and to decrease a transit through Ukraine. As a result, in 2014 the transit through Ukraine dropped by 28% to 62 bcm, and in 2015 Fitch expects its reduction to 50 bcm.

The new gas pipeline is extremely important for meeting the increasing natural gas demand in the European market. In this regard, back in December 2000 the European Commission had assigned the Nord Stream project the Trans-European Network (TEN) status. It means that the Nord Stream pipeline is a key project aimed at creating crucial cross-border transport capacities with a view to ensure sustainability and energy security in Europe. Presently, both strings of the pipeline are technically ready for the 100% throughput of 55 bcm.

In order to provide for the reliability and flexibility of export gas supplies to European customers via Nord Stream in the periods of increased demand, sharp cooling and repair works, as well as in contingency situations at gas transmission systems (GTS), 2.75 bcm of underground storage active capacity are required. To this effect the Rehden UGS facility (Germany) and the Bergermeer UGS facility (the Netherlands) were commissioned in 2014. In addition, the required level of daily throughput will be to a large extent provided by the constructed Katharina and Jemgum UGS facilities in the salts of Northern Germany.

Turkish Stream

In 2014, the forced decision was made to change the route of the South Stream project and redirect it to Turkey. While the strategic target to provide sustainable gas supply of southern Europe remains the same. Deepwater pipe laying operations will start in the Black Sea this autumn. In the end of 2016 Turkish Stream will transmit the first gas.

This new gas pipeline system meeting the most up-to-date environmental and technological requirements will significantly increase the energy supply security over the whole European continent. For the provision of supplying required gas volumes to the Turkish Stream gas pipeline, the extension of the gas transmission system within the RF territory is projected: the construction of additional 2,300 km of the linear part and 10 compressor stations with the total capacity of 1,473 MW.

The large-scale and complex gas transmission system will require the construction of UGS facilities. At present, possible UGS projects are intensively analyzed in relation to maintaining optimal operation modes of the constructed Turkish Stream gas pipeline. For that, Haidach (Austria) and Banatski Dvor (Serbia) UGS facilities under operation may be used. The projected Damborice UGS facility (the Czech Republic) is supposed to make a contribution. For balancing daily irregularities, the projected peak-shaving Tarsus UGS facility (Turkey) may be engaged.

Since the design capacity of the Turkish Stream gas pipeline equals 63 bcm per year, the additional capacity in terms of active storage volume reaches around 3.15 bcm for providing

its optimal mode of operation. In Southeastern Europe several UGS facilities are located, that may appear useful for optimizing the Turkish Stream operation mode. Primarily, it is Chiren UGS facility in Bulgaria with the active storage volume of 0.6 bcm and daily capacity of 4.3 mcm; Zsana UGS facility in Hungary with the active gas volume of 1.54 bcm and daily capacity of 24 mcm; new complex of Slovak UGS facilities, including Lab и Gajary-Baden facilities with the active storage volume of 2.3 bcm and daily capacity of 31.2 mcm.

Eastern Program

Russian plans include not only maintaining its interests at the European direction, but also strengthening its positions in the Asian gas market (Fig.3). Eastern Siberia and the Far East constitute 60% of Russian territory. Initially in-place gas reserves come to 52.4 tcm onshore and 14.9 tcm offshore in eastern Russia.

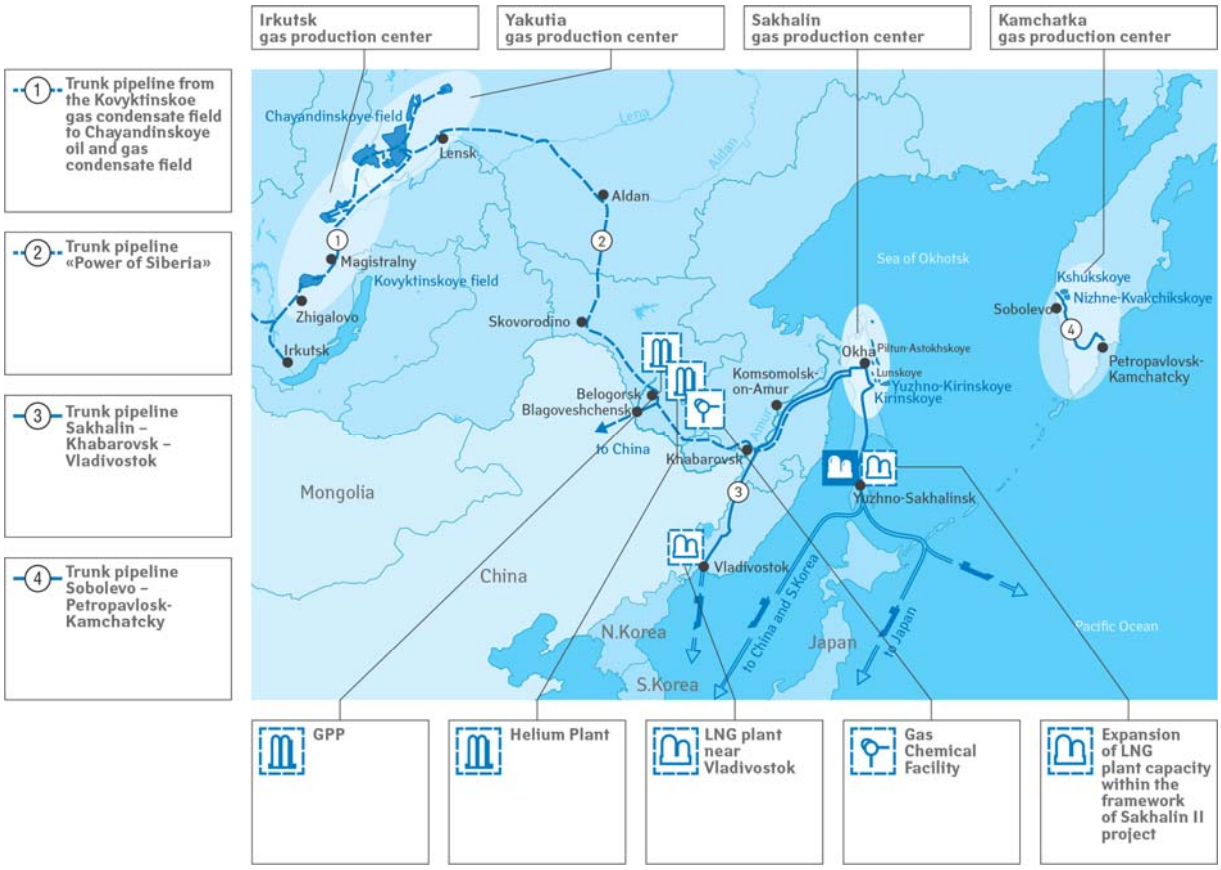


Fig.3 Gazprom's Eastern Gas Program

On May 21, 2014 Gazprom and CNPC signed one of the largest pipeline gas sales contract in the world. The contract is concluded for 30 years and envisages the supply of 38 bcm of gas per year to China. Within the contract period over 1 tcm of gas will be supplied.

The Power of Siberia gas transmission system (GTS) will become a unified gas transmission system for the Irkutsk and Yakutia gas production centers and will convey gas from these

centers to Vladivostok via Khabarovsk and to China. It will stretch for about 4,000 km and have the annual throughput capacity equaling 61 bcm of gas. In compliance with the contract liabilities Chinese customers will receive 38 bcm of gas per year.

UGS in China

New Gazprom's projects for supplying gas to People's Republic of China may be supported by constructing underground gas storage facilities in relation to finishing sections of the Power of Siberia and Altai trunk pipelines within China territory for securing reliability and flexibility of Russian gas export supplies, as well as the optimization of investment expenditures for their construction and operating modes. Considering the capacity of the Power of Siberia pipeline, its effective operation requires the construction of storage capacities for 1.9 bcm of gas next to the entry point in Northeast China. Northwest and Northeast China have mature fields available for the construction of UGS facilities. In China the UGS sector as the whole gas industry comes through the intensive growth stage, while Chinese and Russian specialists cooperate in relevant scientific and technical spheres. It will contribute to implementing the UGS facilities construction tasks.

For the first time in Russia as part of the Eastern Program the technology of membrane helium separation from natural gas on-site will be used. It will secure the transmitting via the gas pipeline the exact amount of helium to be demanded in the market, and collecting extra volumes in UGS facilities.

New Functions of UGS

Throughout almost 100 years, the operation of UGS facilities in porous medium and salt caverns successfully addresses traditional tasks related to maintaining flexible and secure gas supplies under conditions of irregular demand with various periodic trends, from seasonal to hourly.

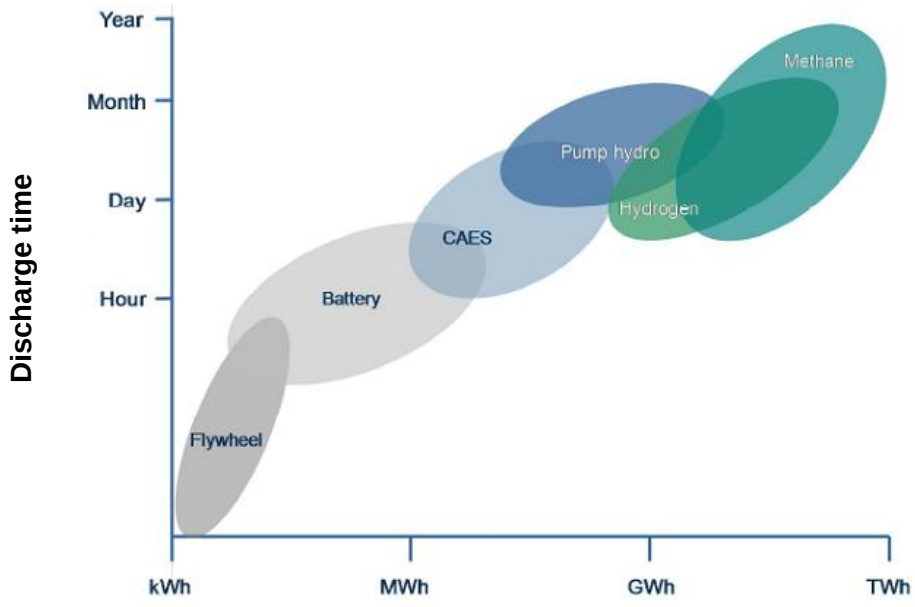
Over recent years in Europe as well as in China the program for development of renewables making it possible to reduce the share of coal, oil and gas consumption is being successfully implemented. However, the larger the share of renewables, the less the annual average utilization factor of thermal generation. Downturn of operational hours and growing irregularity of gas consuming generators load require the adaptation with the increasingly large role of UGS facilities.

Due to the high dependence of new resources on weather conditions and time of day it is necessary to develop the ways of generated energy storage for the stabilization of energy flow. The generated energy should be immediately fed into a power grid. As a result, demand and supply come to inconsistency as the storage of large energy amounts could not be supported by the power grids structure, their control, or even price policy.

Existing storage technologies include the following: water pumping with subsequent use of its energy of free fall; energy storage in the form of compressed air; production by virtue of surplus energy and following hydrogen and synthetic methane storage; other means of energy storage, such as inertia-type machines, batteries, condensers etc.

Underground "energy" storage facilities constitute a key element of this new energetic doctrine. In the market of underground gas storage services new areas of storage capacities

utilization are being shaped along with conventional tasks. They are giving rise to new functions of UGS facilities.



Source: International Gas Union

Fig.4 Efficiency of proposed 'Energy Storage' technologies

The scheme above (Fig.4) shows that compared to new technologies, natural gas is the most powerful, time proof and efficient way of energy transmission and storage today.

Results

Currently, 400 units with the total capacity of 125 GWh are built using pumped hydropower storage (PHS) technology for electricity storage. Average capacity of storage facilities varies from hundreds MWh to one GWh. For sure, this capacity level is completely insufficient. Besides, the storage facilities are featured by low efficiency along with high capital expenditures.

Compressed air energy storage (CAES) technology provides for even lower capacity level – two facilities with the total capacity of 0.7 GWh are constructed. The technology is not fully developed. Long-distance transmissions are impossible, in other words, everything should be in one point: energy source, energy consumer, underground storage facility. Low efficiency of the technology was supported by the fact that not a single commercial project was implemented in recent 30 years.

Methane/hydrogen fuel technology (Power2gas) features the characteristics that are the closest in efficiency to methane. At present, ideas of hydrogen fuel are developing most

intensively. However, in the underground storage sector these proposals faced nearly insurmountable obstacles:

- The way of H_2 interaction with insoluble minerals is not clear, presence of pyrite and sulfur minerals in salts or porous medium may lead to the formation of hydrogen sulfide;
- High permeability of H_2, also in cement, causes difficulties in providing the integrity of UGS facilities;
- Metal embrittlement as a result of hydrogen absorption requires non-standard solutions while developing equipment for storage facilities;
- Also hydrogen is aggressive toward synthetic elements of constructions (seals);
- In UGS facilities situated in porous media and salt caverns usually contain water, consequently, the acid formation will take place in the presence of water;
- Unfavorable processes are related to bacteriological biodegradation of hydrogen;
- As a result of hydrogen dissolution in water and in reservoir rock, hydrogen used as a cushion gas volume may be lost;
- Safety issues are related to extreme volatility and explosiveness of hydrogen;
- Time factor – when using existing hydrolysis units, it will take 15 years to fill with hydrogen the average cavern with the capacity of 50 mcm.
- Beyond technological problems regulative limitations take place, specifically European Standard EN ISO 6974 limits the content of hydrogen in natural gas transmitted via pipes with the value of 0.5%. The creation of new hydrogen transportation network implies huge investments, complicated approvals and negative public opinion.

Hence, the only area where hydrogen could successfully compete with methane is the production of natural gas motor fuel.

Other means of energy storage (inertia, batteries, condensers etc.) may enter the market only in the distant future, due to their efficiency level, price and technological development.

Transportation of electricity appears multiple times more expensive than transmission of gas.

Conclusions

Natural gas is the only existing option featuring the sufficient level of transformation and energy storage efficiency. More exactly, it is the Unified Gas Supply System (UGSS) – the unified system of transportation, storage and power generation (gas power stations). Only underground natural gas storage constitutes the reliable connection element between renewables, power grids and growing needs of energy consumers.

Summarizing the above, it is worth noting that regardless the apparent importance of UGS as an effective tool for commercializing the gas market, supporting renewables, as well as developing brand new areas in the energy sector, such as "energy storage" in pure form, today the main function of underground storage is still the provision of optimal and reliable operation of the gas supply and energy security system in vast regions on a continental scale.

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