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IMPROVEMENT OF APPROACHES TO DISPATCH CONTROL ON THE MAIN HIGH-PRESSURE GAS PIPELINES TO ENSURE RELIABILITY AND SAFETY OF NATURAL GAS SUPPLY

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Ensuring of reliability and effectiveness of gas supplies by the main high -pressure gas pipelines

Ensuring of reliability and economic security of gas supply by the main high-pressure gas pipelines

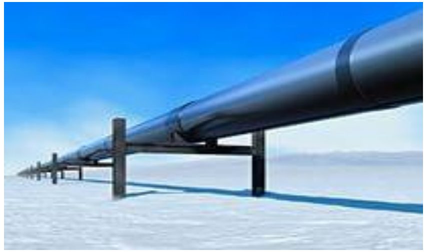
Efficient dispatch control

Control of technological parameters of main gas pipelines´ operation

Automation of dispatch decisions support

Physical and mathematical simulation of gas flow parameters in the main gas pipelines

Formation of response scenarios to minimize technological and economic consequences of contingencies, and to ensure efficient and safe gas pipelines functioning by the transient regimes

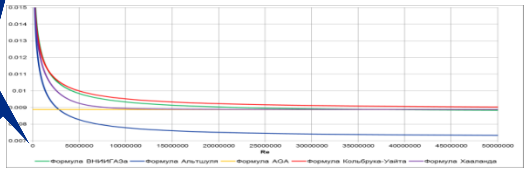


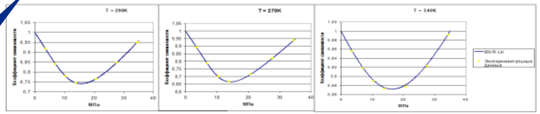
Gas flow model for the main high-pressure gas pipelines

The usage of complete one-dimensional equations of gas dynamics permits to execute the computations with high accuracy and in real-time mode

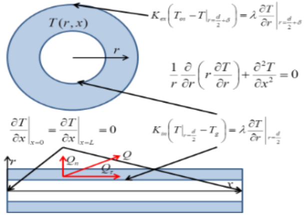
$$\begin{cases} \frac{\partial}{\partial t}(\rho\upsilon)+\frac{\partial}{\partial x}(\rho\upsilon^2)+\frac{\partial p}{\partial x}+\rho g\sin\alpha+\frac{1}{4r}\xi\rho\upsilon|\upsilon|=0 \\ \frac{\partial\rho}{\partial t}+\frac{\partial}{\partial x}(\rho\upsilon)=0 \\ \frac{\partial}{\partial t}\left(\rho\varepsilon^{(\text{уд})}+\rho\frac{\upsilon^2}{2}+\rho gH\right)+\frac{\partial}{\partial x}\left(\rho\upsilon\left(\frac{\upsilon^2}{2}+h^{(\text{уд})}+gH\right)\right)=-\frac{Q}{F} \end{cases}$$

The model has a great flexibility and permits to use different formulas for hydraulic resistance computations, as well as various state equations to compute gas properties

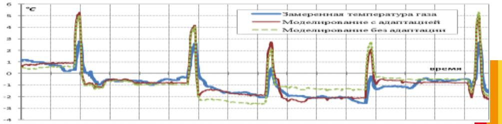




The axisymmetrical model of environment´s description is used, this model takes into account the heat flow´s longitudinal components, as well as the proper heat capacity of gas pipeline´s walls

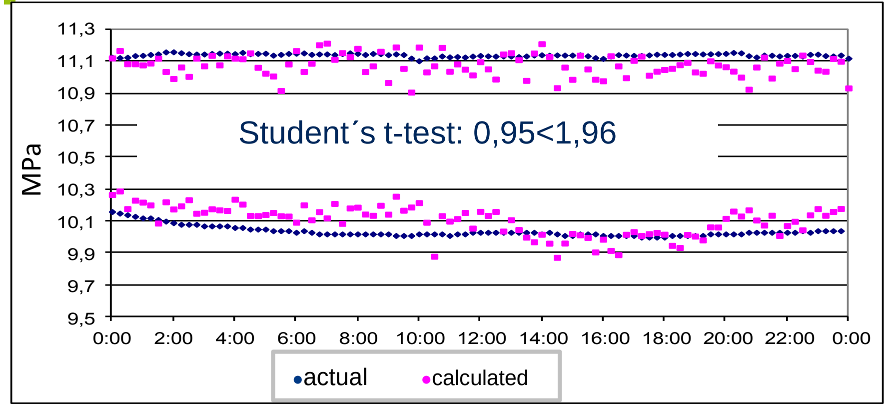


The block of model´s regular adaptation to the real objects is provided for in the model, based on the identification of nonmetering parameters



Evaluation of model´s adequacy, concerning the real main high-pressure gas pipeline (steady regimes)

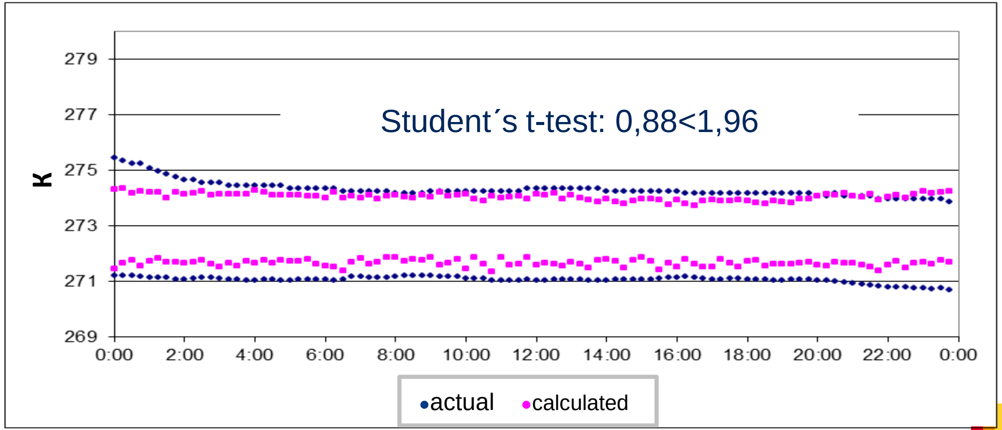
Pressure at the end of gas pipeline



Boundary conditions

Pressure and temperature at the entrance of the pipeline section, flow rate over the pipeline section

Temperature at the end of gas pipeline



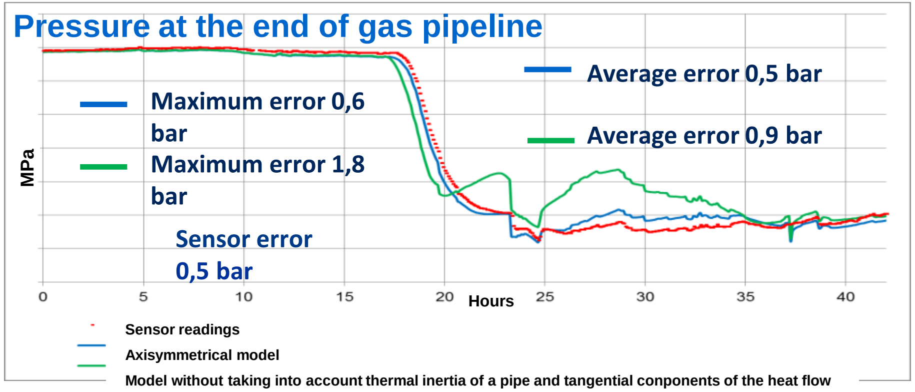
Student´s t-test

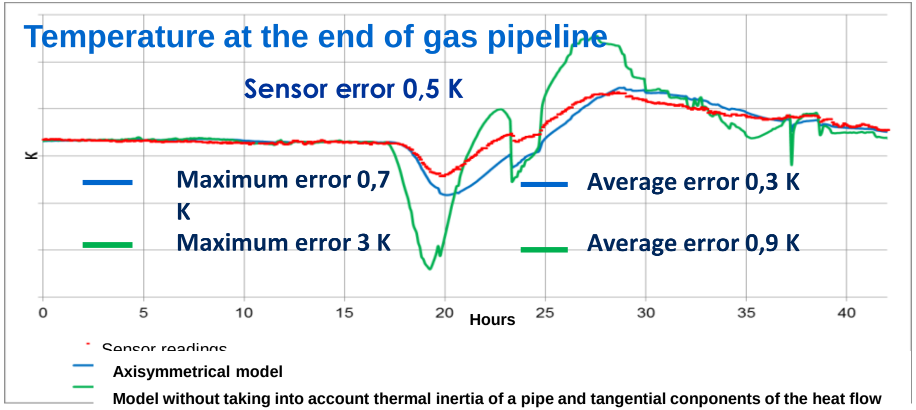
$$t_{St} = \left| \frac{\left(\Phi_{calc} - \Phi_{\exp}\right)\left(\Lambda\right)^{0.5}}{\sigma} \right| < t_{table}\left(\theta, \Lambda - 1\right)$$

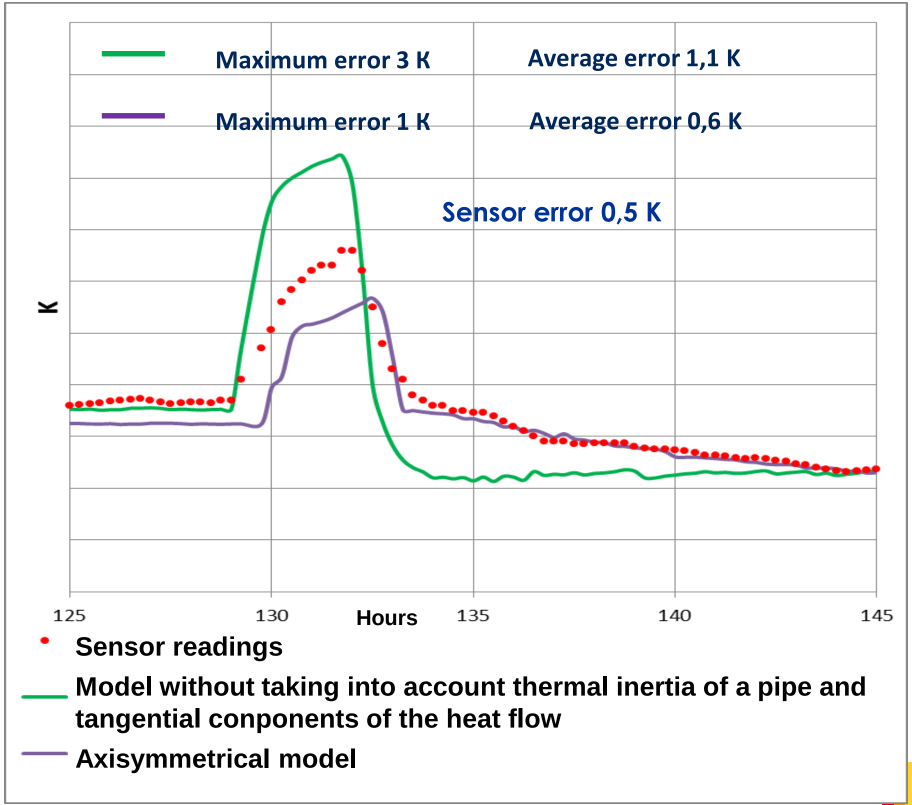
$\Lambda - 1$ – degree of freedom

θ – significance level

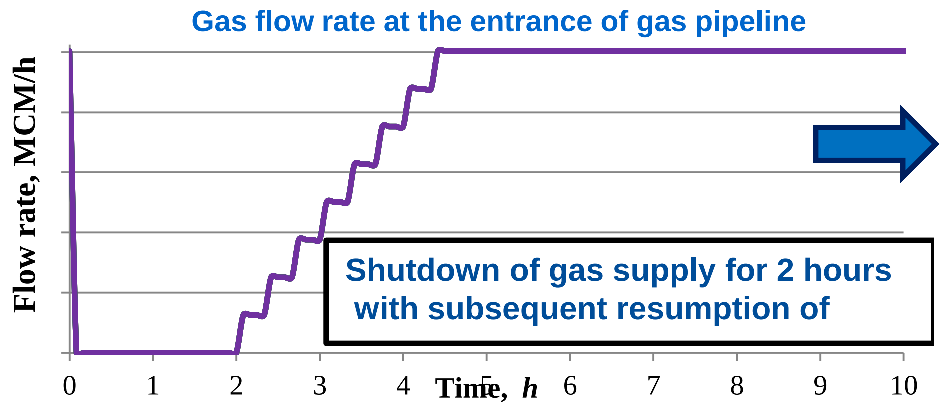
Evaluation of model´s adequacy, concerning the real main high-pressure gas pipeline (unsteady regimes)





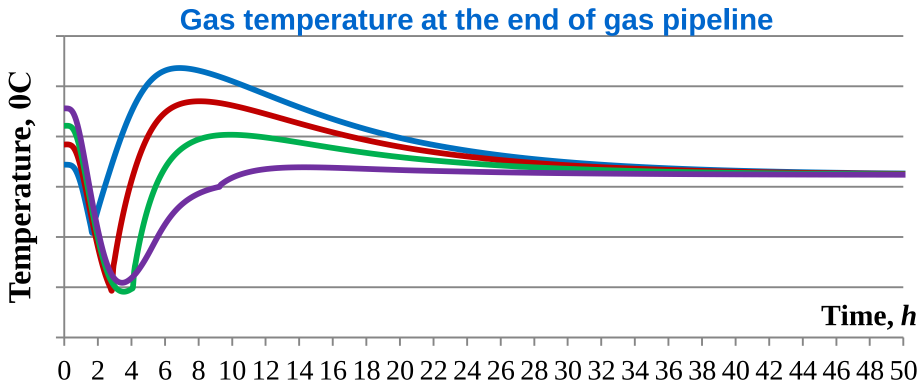


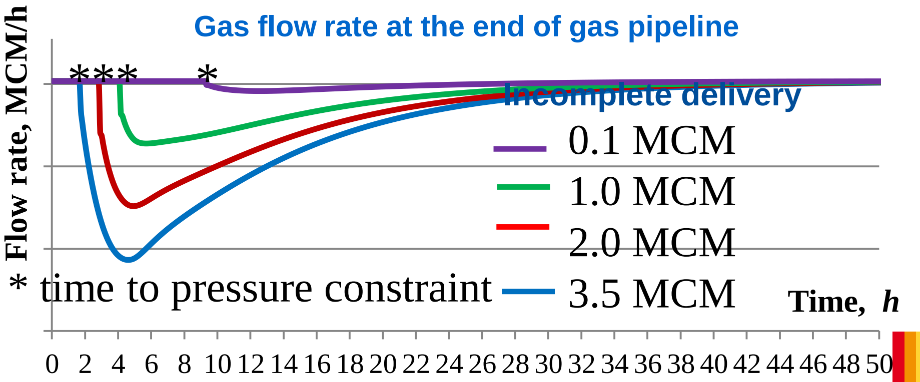
Simulation of contingency to determine the most efficient control over the transient regime: shutdown and subsequent resumption of gas supply at the entrance to gas pipeline



Possible managerial decisions to reduce penalties for incomplete delivery:

1. Stop gas extraction for 2 hours (incomplete delivery of 4,3 MMCM)
2. Make use of gas reserve in the pipeline to minimize gas incomplete delivery
3. In the case of planned shutdown, it is reasonable to raise previously the pressure in the pipe up to the maximum acceptable
4. It is economically unreasonably to maintain constantly the maximum pressure in the pipeline in the case of contingency (overrun of fuel gas)





Simulation of contingency to determine the most efficient control over the transient regime: shutdown of gas supply at the entrance to gas pipeline and subsequent response by the reduction of gas extraction

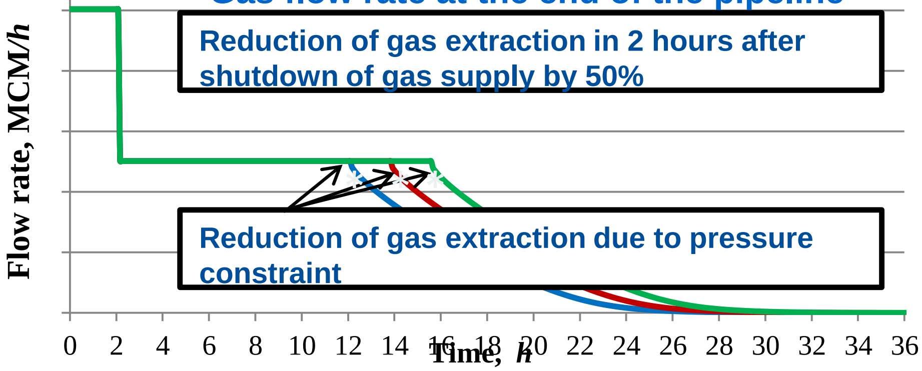
Possible managerial decisions to reduce penalties for incomplete delivery :

1.Stop gas extraction

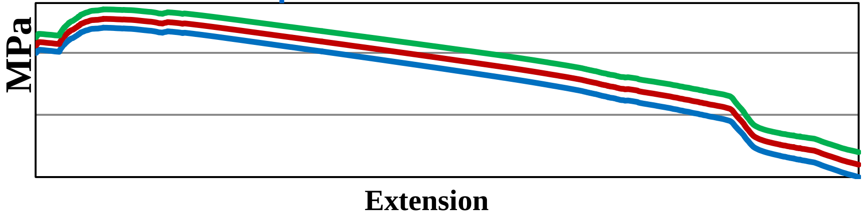
2.Partially reduce extraction, using gas reserve in the pipeline to minimize incomplete gas delivery

3. In case of a planned shutdown, it is reasonable to raise previously the pressure in the pipe up to the maximum

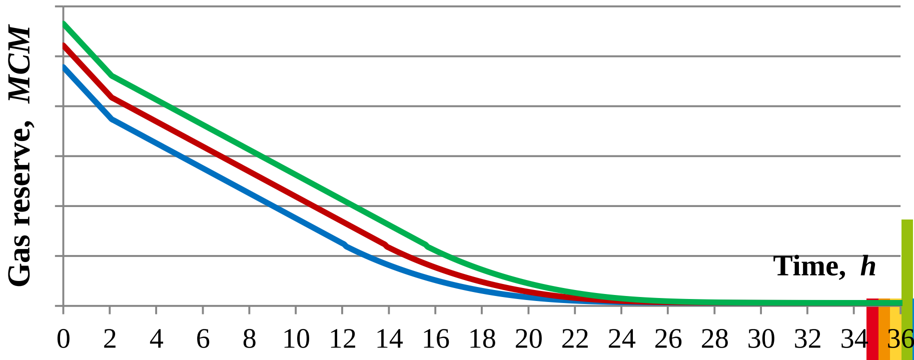
Gas flow rate at the end of the pipeline



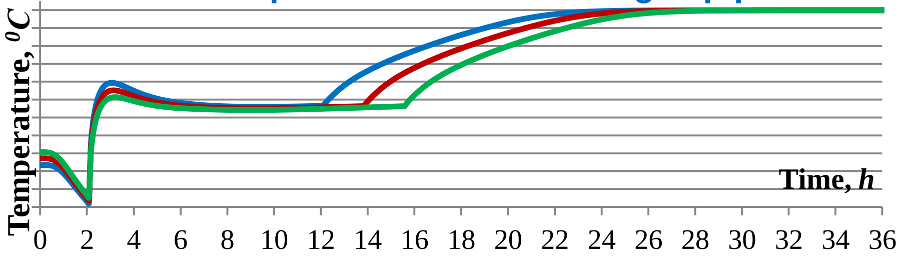
Initial pressure´s distributions



Gas reserve in the pipeline

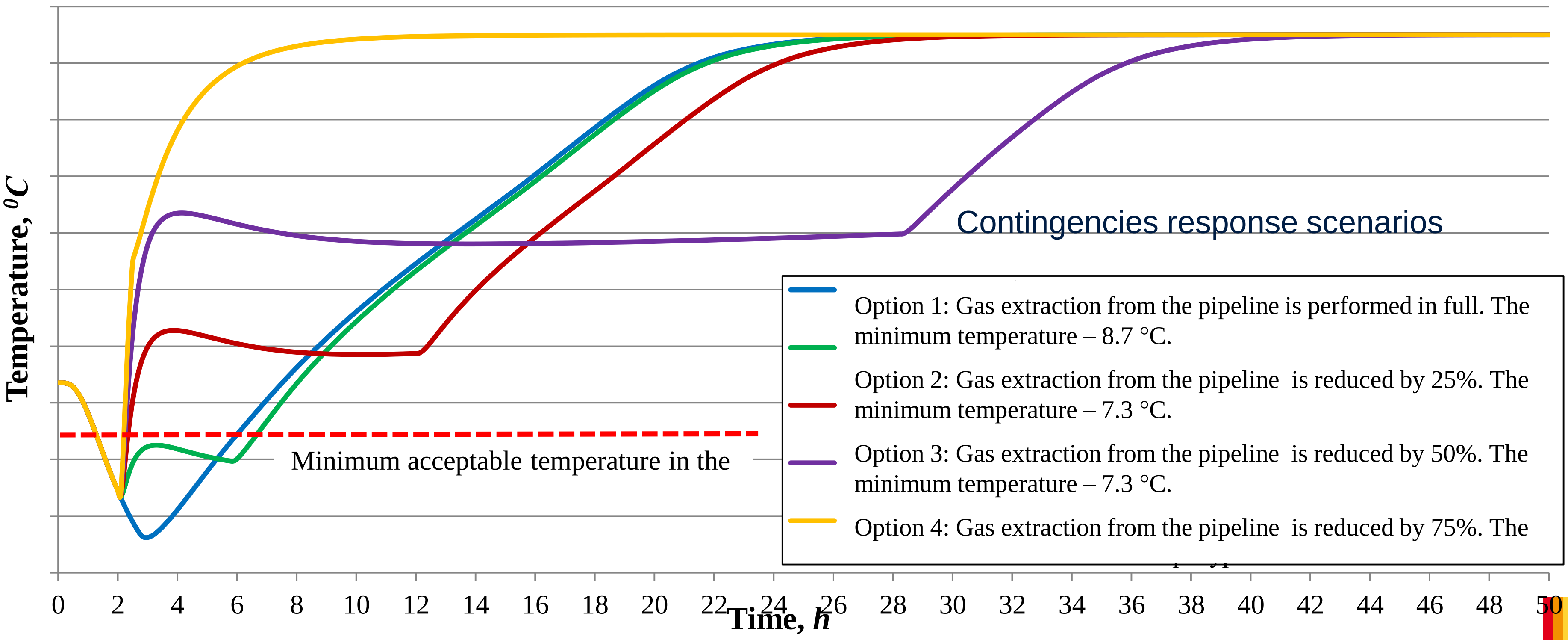


Gas temperature at the end of gas pipeline



Determination of dynamics and control of minimum temperature in gas pipeline

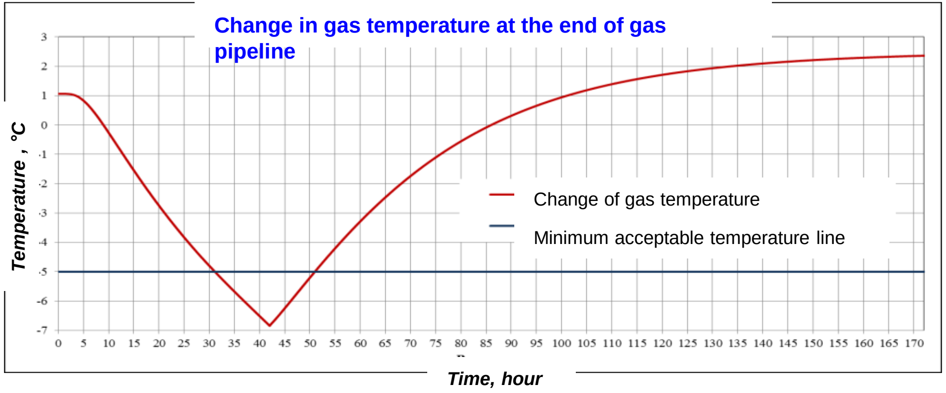
Dynamics of minimum gas temperature in the gas pipeline for various response scenarios to reduce gas extraction

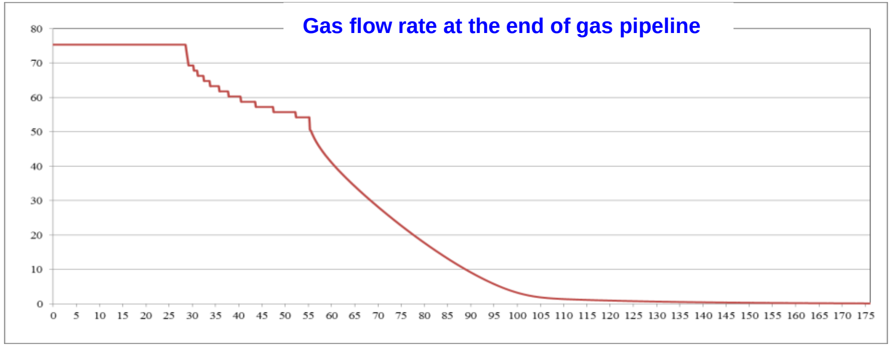


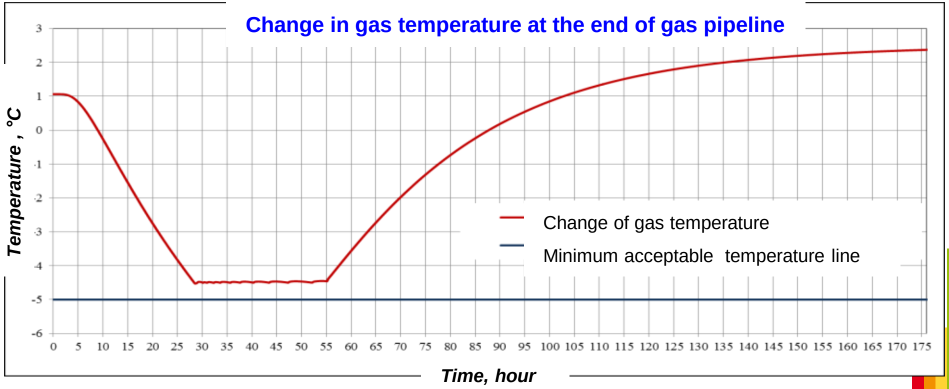
Dispatch decisions support during the contingencies to minimize the potential ecological damage: control of the minimum temperature constraint of the pipeline´s surface with the subsequent selection of the control action

Without control action: the temperature at the end falls lower than the minimum acceptable value for 20 hours

With control action: by the reduction of gas extraction the temperature doesn´t fall below the constraint

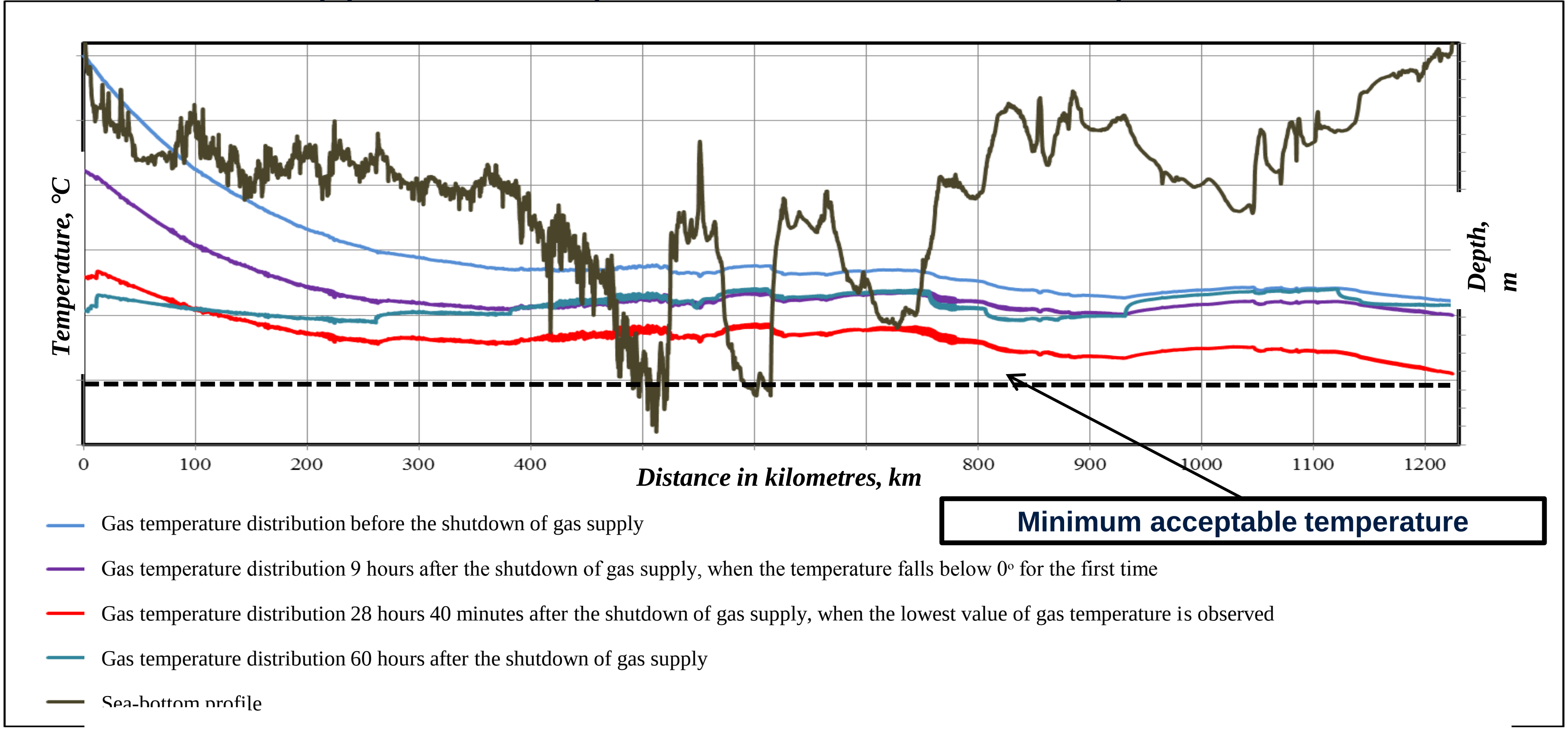






Dispatch decisions support during the contingencies: control of the minimum gas pipeline´s wall temperature to minimize ecological penalties

Gas pipeline´s wall temperature's distributions in different points of time



Conclusion:

1. Due to the principle of minimization of adopted simplifications by the description of gas flow through the pipeline, the developed physico-mathematical model has high accuracy in computations of gas flow parameters' distributions, which are necessary for dispatching decision-making support and formation of response scenarios for the contingencies.
2. The usage of axisymmetric model of environment´s description made it possible to precise significantly the computation of technological gas flow parameters in the up-to-date main high-pressure gas pipelines at the expense of account of important physical effects, which have been neglected by the simulation of main gas transport until now.
3. The application of methods of regular model´s adaptation to the real gas pipelines not only raises the accuracy of operational flow parameters computations, as well as permits to get the additional information about the simulated object and to take into account the systematic sensors' errors of flow parameters measurements.
4. The developed model could be used as the dispatch decision-making support and formation of response scenarios which are necessary to prevent the consequences of potential contingencies, to except the potentially dangerous regimes of gas pipelines functioning and to ensure the most effective regimes of shutdown and startup of gas pipelines during planned repair works.

The simulation results permit to create the contingencies event log in order to ensure the sustainable operation of high-pressure gas pipelines, as well as the reliability of gas supply. From the economic point of view, such approaches permit to select the most efficient way from one gas pipeline operation's regime to another, to reduce possible penalties for incomplete gas deliveries to the consumers, by minimizing the operation time of gas pipeline in off-design conditions or in the case of a downtime, as well as minimize the ecological risks and penalties, related to the significant change of gas pipeline surface's temperature by the transient regimes.

Thank you fo attention!

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