Annex 1

Procurement and implementation of specialized High Level Applications for Modeling and Optimization of Natural Gas Transmission Processes in the System of the Gas Transmission System Operator of Ukraine

Scope of Work

1. **Software and licenses**

1.1 Provision of software and licenses for High Level Applications for Modeling and Optimization of Natural Gas Transmission Processes in the System of the Gas Transmission System Operator of Ukraine in accordance with the Technical Requirements described in Annex 4.

1.2 Bidder's proposal should contain all required licenses for proposed technical solution and take into account separation of DEV, QAS and productive environments as described in Annex 4. Such licenses should be supplied together with HLA's licenses. Virtualization platforms and workstations licenses are not required for this procurement.

2. **Implementation services**

2.1 Provision of Implementation services for proposed High Level Applications for Modeling and Optimization of Natural Gas Transmission Processes in the System of the Gas Transmission System Operator of Ukraine as per Annex 2.

2.2 ESP welcomes contractor to demonstrate from their experience recommendations to amendments to the scope for consideration to ensure the most effective implementation of the project.

2.3 Ensuring on-site availability of an expert in implementation modelling systems (with the C2 level of Ukrainian or Russian) who has participated in at least two implementations of a program for gas transmission network modelling or in implementing the SCADA system together with an integrated program for gas transmission network modelling. The expert should be available in the UAGTSO office in Kyiv for three days weekly, which are business days under the Ukrainian calendar (UAGTSO will provide the expert with a workplace in its office having access to the Internet, a printer and IT systems for the software to be implemented in compliance with safety regulation principles under the UAGTSO policies). Should epidemiological threats and, in particular, those related to COVID 19 or other circumstances occur, work may be performed outside the UAGTSO office and, under such circumstances, the contractor is obliged to provide the expert with relevant resources to perform remote work;

3. **Users training services as per 3.9 section of Annex 4.**

4. **Post-implementation support**

4.1 The warranty of proper functionality for the software or provision of technical support to the UAGTSO (customer) for five years following the warranty period

The primary standards for warranty and non-warranty service:

Criticality level	**Time to respond / start working at the information request**	**Time to provide a solution / stabilization**	**Time to solve the issue**
Criticality 1	30 min	8 hours	7 days

Criticality 2	60 min	1 day	14 days
Criticality 3	24 hours	14 days	21 days
Criticality 4	24 hours	21 days	-

All the time before business days in Ukraine during a business day 7.00 - 19.00 local time;

Proposal inclusions:
The contractor should provide a methodology and proposed technical solution.

The proposal should include recommendations for effective implementation and management of the project.

Monthly reports, and stakeholder communication plan should be provided for in the technical approach of the bid.

KPIs should be outlined for tracking and management. Potential challenges and risk mitigation planning should be mentioned in the proposals.

Past experiences should be presented in the following format:

Network Name	Year	Duration	Value	Parameters of Network*	Integration with SCADA (Y/N) – Name of SCADA

* number of kilometers , CSs, points of interaction etc.

Any questions regarding the objective, scope or deliverables should be clarified prior to the closing bid date.

Pre qualification Requirements

An original and/or an electronic copy and/or a scan of a Participant's Certificate (no particular form required) confirming that the Participant and/or its affiliate and/or other legal entity that, together with the Participant, is part of a single group/network and/or functions under a single trademark (brand), has performed similar contracts related to providing and/or developing and introducing online and offline modelling software, along with optimizing and tracking gas quality and consumer demand predicting, i.e. for a gas transmission system with the following complexity standards:

- the network length of no less than 3,000 km, high-pressure gas transmission pipelines with the operating pressure of over 26 bar;
- pipeline connections with at least two levels of operational pressure from 26 to 75 bar;
- at least 5 compressor stations with at least 20 gas-compressor units altogether;
- at least 1,500 gas transmission infrastructure facilities (such as valves, PRS, GDS, pipelines)
- These requirements are also relevant to any Participant who has been involved as a sub-contractor to perform (a) similar contract(s).

Annex 2

Phase	Activity	Input	Output
1) Inception	- Kick-off meeting; - Joint technical requirements analysis and solution demo meetings; - Development of the Detailed technical design documentation jointly with TSO project team according to the specifics of Winner's proposed software solution and in line with Technical Requirements; - Development of the Project Plan;	- Technical Requirements; - Technical proposal provided by the Bidder as part of the tender package; - Information from TSO based on Vendor's RFI;	- D1.1. Project charter, including team members responsibilities and project communication guidance agreed; - D1.2. Approved Report on the analysis of technical requirements and the planned method of implementation - D1.3. Approved Detailed Technical Design document; - D1.4. Defined register of changes to be implemented into the system; - D1.5. Approved Project Plan; - D1.6. Approved Testing methodology and plan;
2)System Preparation and FAT	Preparation of the system in accordance to Technical Requirements and Deliverables of the Phase 1. Execution of the FAT.	- D1.2. Approved Report on the analysis of technical requirements and the planned method of implementation; - D1.3. Approved Detailed Technical Design document; - D1.4. Defined register of changes to be implemented into the system; - D1.5. Approved Project Plan; - D1.6. Approved Testing methodology and plan;	- D2.1. Installation package is provided to the TSO; - D2.2. System documentation, installation and user manuals are provided to TSO; - D2.3. Licenses are provided to the TSO according to the agreement conditions; - D2.4. Approved FAT Testing scenarios and protocols

3) System installation and configuration based on selected balancing zone (Pilot)	-Support of TSO project team during system installation on the TSO infrastructure; - Support of TSO project team during preparation of all required master data (including migration tools from existing TSO systems) for selected pilot balancing zone; - Configuration of on-line and off-line models, including linepack calculations, gas leakage detection and forecasts functionality for selected pilot balancing zone (on the basis of replacement data entered into the system from the existing UAGTSO systems); - Configuration of the reports and HMI's for the selected pilot balancing zone according to the Detailed Technical design documentation (D1.4); - Execution of Functional testing (including required data preparation).	- D1.2. Approved Report on the analysis of technical requirements and the planned method of implementation - D1.3. Approved Detailed Technical Design document; - D1.4. Defined register of changes to be implemented into the system; - D1.5. Approved Project Plan; - D1.6. Approved Testing methodology and plan; - D2.1. Installation package is provided to the TSO; - D2.2. System documentation, installation and user manuals are provided to TSO; - D2.3. Licenses are provided to the TSO according to the agreement conditions;	- D3.1. System is fully configured for selected pilot balancing zone; - D3.2. Functional testing protocols signed; - D3.3. Register of changes defined based on functional testing results;
4) Integration with other systems and data sources	Configuration of integration and data exchange with the systems/sources listed in Annex 3 (based on the Technical requirements and Detailed technical design documentation):	- Technical Requirements; - D1.3 Approved Detailed Technical Design document;	- D4.1. Data exchange and integration between proposed solution and systems/sources listed in Annex2 configured (Budget should separate D4.1a and D4.1b, as with new SCADA and without new SCADA respectively)

5) System roll-out	- Support of TSO project team during preparation of all required master data (including migration tools from existing TSO systems) for all TSO objects in accordance with Technical Requirements, Detailed technical design and the results of Pilot; - Support of TSO team during configuration of on-line and off-line models, including linepack calculations and gas leakage detection functionality, for all TSO objects in accordance with Technical Requirements, Detailed technical design and the results of Pilot; - Support of TSO project team during configuration of the reports (dispatching journal, balances reports) and HMI's based on data from all TSO objects in accordance with Technical Requirements, Detailed technical design and the results of Pilot; -Fixing deficiencies identified during functional testing (D3.3.)	-- D1.2. Approved Report on the analysis of technical requirements and the planned method of implementation - D1.3. Approved Detailed Technical Design document; - D1.4. Defined register of changes to be implemented into the system; - D1.5. Approved Project Plan; - -D3.1. System is fully configured for selected pilot balancing zone; - D3.2. Functional testing protocols signed; - D3.3. Register of changes defined based on functional testing results;	- D5.1. System is fully configured according to Technical Requirements and Detailed Technical Design documentation
6) -Final user acceptance and integration testing	- UAT testing; - Integration and data exchange testing.	- Technical Requirements; -D1.3. Approved Detailed Technical Design document; - D4.1. Data exchange and integration between proposed solution and systems/sources listed in Annex 3 configured -D5.1. System is fully configured according to Technical Requirements and Detailed Technical Design documentation	- D6.1. Approved UAT testing scenarios and protocols; - D6.2. Integration testing scenarios and protocols;
7) Go-live	-Fixing deficiencies during UAT and integration testing (D6.1. D6.2) - Go-live decision	- D6.1. UAT testing protocols; - D6.2. - Integration testing protocols	- D7.1 Deficiencies resolved; - D7.2 Go-live decision made - D7.3 Final Report – Summary of works and acceptance

Annex 3:

#	System / Integration point description	System / Integration point name	Integration point status	Probability that item will be confirmed for integration / data exchange configuration after completion of detailed technical design	Database details	Virtualization
1	New SCADA system	N/A	To be implemented during the course of the project	High	Historian DB to be defined when solution will be selected	Yes
2	Pipeline integrity management system	PIMS	Existing system	Medium	Oracle	Yes
3	Metering data polling system	Gas Metering Data Hub (GMDH)	Existing system	High	Oracle	Yes
4	Daily balancing platform	iPlatform (SAP based solution)	Existing system	High	Oracle	Yes
5	Legacy ERP	SAP ERP (ECC 6.0 version)	Existing system	High	Oracle	Yes
6	New ERP system	SAP S/4 HANA	Existing system	High	SAP HANA	Yes
7	Dispatching analytical system (regime's journal, physical balance, real-time data received from existing ClearSCADA systems	OAS GTP	Existing system	High	Oracle DB	Yes
8	Online modelling system	KIM	Existing system	Medium	Oracle DB	Yes
9	Meteorological resource	N/A	Existing data exchange point	Medium	N/A	N/A
10	External data sources (adjacent TSO's, UGS, upstream, DSO's)	N/A	Existing data exchange point	High	N/A	N/A

Annex 4:

TECHNICAL, QUALITATIVE AND QUANTITATIVE CHARACTERISTICS OF THE PROCUREMENT ITEM

"Software Package for Operational Supervisory Control, Simulation and Optimization of Natural Gas Transmission Processes" for Gas Transmission System Operator of Ukraine, LLC

ABBREVIATIONS

ACU air cooling unit
GPU gas pumping unit
GDS gas distribution station
GTS gas Transmission System
MCC main control center
HLA high-level applications - software package for operational supervisory control, simulation and optimization of natural gas transmission processes
CS compressor station
LOSS line operations supervisory service
UAGTSO Gas Transmission System Operator of Ukraine, LLC
OS operating system
SW software
BCC backup control center
DBMS database management system
PCP physical and chemical parameters of gas
DPC data processing center
API application programming interface
GMDH Gas Metering Data Hub
PIMS pipeline integrity management system
SCADA Supervisory Control and Data Acquisition

CHAPTER I
Applications:

General purpose of the software package for operational supervisory control, simulation and optimization of natural gas transmission processes - high-level applications (hereinafter the HLA) is providing high-level analytical support of operational supervisory control to ensure

- reliable and optimal functioning of the gas transmission system of Ukraine;
- reliable and uninterrupted transmission of natural gas to consumers in Ukraine and European countries;
- the fastest possible supervisory control of the gas transmission system (GTS) mode of operation and physical balancing of the system;
- comprehensive control and regulation of natural gas quality in the system's gas pipelines

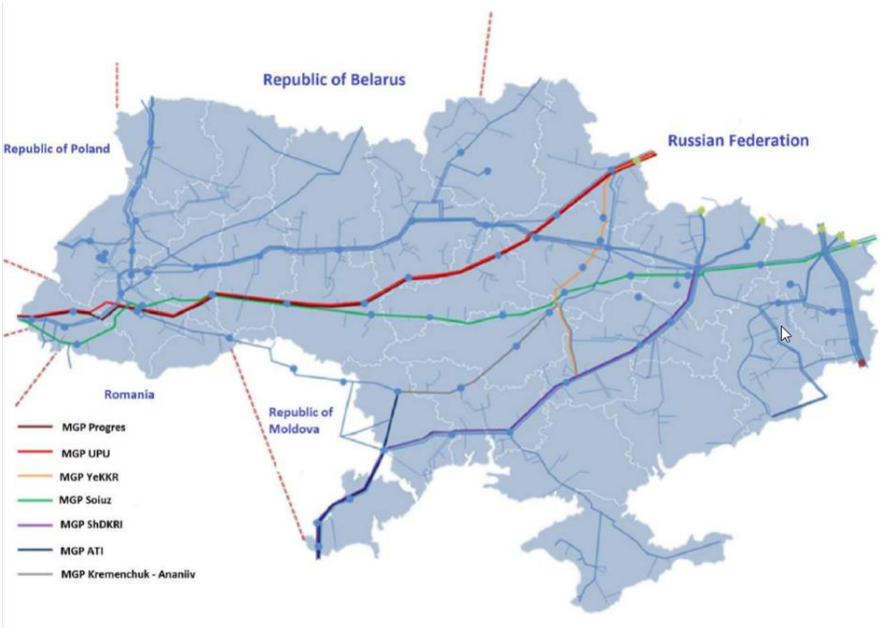
to improve

- Transparency
- Reliability
- Efficiency
- Safety
- Threat resiliency

Description of the Gas Transmission System of Ukraine

The gas transmission system of Ukraine is reliable, multifunctional and one of the largest such systems in Europe. It has connection points with the Russian, Belarusian, Polish, Slovak, Hungarian,

Romanian and Moldovan gas transmission systems, which indicates a high level of its integration into the European gas transmission system. Overall, the gas transmission system of Ukraine provides access to various sources of gas including domestically produced gas, imported gas and gas from underground gas storage facilities, which facilitates the transmission/transit of natural gas by various routes to European countries and is a guarantee of energy security for Ukraine and Europe as a whole.
Below is the basic structural scheme of the GTS of Ukraine:



Quantitative parameters of the GTS of Ukraine are shown below:

GTS PARAMETER	UNIT OF MEASUREMENT	VALUE
Length of gas pipelines, of which	km	33,383
main gas pipelines		20,938
branch gas pipelines		12,141
gas distribution pipelines		304
CS number	unit	57
number of CD		86
number of GPU		524
number of GDS		1,389
number of GMS		69
number of LVS		1,419
Installed capacity of CS	MW	4,580
Maximum rated capacity for simultaneous operation	MW	3,208

CHAPTER II
Technical Specifications

These technical specifications apply to the software package for operational supervisory control, simulation and optimization of natural gas transmission processes for Gas Transmission System Operator of Ukraine, LLC (UAGTSO)

The technical requirements for the architecture and functionality of HLA modules described in the document should provide analytical support for operational supervisory control, whose structure includes:

- The main control center (MCC) which is divided into four supervisory control zones;
- The backup control center (BCC), which is structurally identical to the MCC;

- 13 Line operations supervisory services (LOSS), making up the second tier of supervisory control;
- Site LOSS units, representing the lowest tier of supervisory control.

Exercises immediate control of the following facilities:

- Compressor stations (CS);
- Line valve stations;
- Gas metering stations;
- Gas distribution stations (GDS);
- Gas pressure reduction sites;

and engages in operational interaction with:

- Operators of adjacent gas transmission systems;
- Operators of gas distribution networks;
- The operator of underground gas storage facilities;
- Gas producers;
- Direct consumers connected directly to the GTS pipelines.

HLA software (SW) should enable the company to perform the following tasks:

- real-time dynamic simulation and forecasting of non-stationary modes of gas transmission;
- solving gas transmission problems under normal system operation conditions, incl. calculation of optimal stationary modes of transmission taking into account the consumption of fuel gas or electricity by gas compressor stations;
- solving system control problems in emergency situations;
- local optimization of gas compressor stations' operations;
- determination of long-term and short-term operational plans, including input data-based calculations on the performance of gas pipelines and submitted nominations;
- solving problems of transmission during scheduled repairs;
- metering gas outtake in energy units of measurement (kWh, GCal) using the function of tracking parameters (PCP) of gas;
- identifying losses, detecting gas leaks, gas pipeline ruptures;
- supporting online control decisions based on the hydraulic model data;
- analyzing the state of telemetry systems based on the comparison of the data of the mathematical model with the data of the real process received from the SCADA;
- monitoring motion of cleaning and diagnostic devices;
- calculation of gas stock in the pipeline;
- forecasting changes of gas stock in the pipeline;
- forecasting network balance;
- forecasting demand;
- training of control personnel.

1. General requirements

Characteristic	Requirement
Integration interaction with software products of third-party developers using standard data sharing means.	Integration with the proposed new SCADA system (to be implemented during the course of the Project) and data exchange with existing systems: the OAS GTP operational supervisory control database, which includes real-time data obtained from existing SCADA systems of the UAGTSO (DBMS Oracle), GMDH (DBMS Oracle), PIMS, SAP ERP and SAP S/4 HANA, and meteorological services
Quantitative characteristics of the simulation object	Entry points: about 200 Exit points: about 2,000 Topological sections of pipes: over 12,000

	Branches: over 5,000 Valves: over 5,000 Regulators: about 30 Compressor stations: over 50 GPU: about 300
Master data	Ability to enter/import data through user interface, API, structured files, etc. on topology and network characteristics and technological equipment of the GTS
Scalability	In case of increasing needs for the number of simulations performed simultaneously, it should be possible to increase the computational performance of the simulation by scaling up the server resources.
Methodological documentation	The following should be provided: Methodology of Calculation of Linepack and Linepack Flexibility, Methodology of Reconstruction of Gas Quality, Methodology of Calculation of Technical Capacity of Network Entry/Exit Points.
Language of documentation	Ukrainian, English
Access to the Software Product modules	Simultaneous work with offline simulation modules by at least 50 users (up to 25 of them active, the rest in viewing mode). Access to the archive of modes and analytical reporting based on it and read-only access to online simulation - unlimited.

The HLA solution should be integrated with the new SCADA system, which will be implemented in GTSOU in parallel with the HLA software, and provide the fastest possible access to real-time data and archive data.

The proposed SW should be scalable, feature expandable functionality and be updatable without configuration changes and with version tracking.

The proposed SW should allow the user to create network models and provide simulation support to the development of the UAGTSO network by in-house specialists on their own without additional payments and involvement of the manufacturer's specialists.

2. Functional requirements

High-level applications for pipelines should be based on a hydraulic model (dynamic real-time model), taking into account network configuration (lengths, diameters, roughness, pipeline altitude profile, etc.), devices (valves, regulators, GPU, ACU) and measured process parameters (pressure, temperature, flow, gas composition), as well as their limitations and characteristics.

The main task of the GTS model is to raise the level of awareness of network operators about the parameters of transportation and the nature of the processes occurring in the pipelines. Due to this, a critical condition is the use of a modern mathematical model, developed and tested by the experience of customers with similar GTS's.

- The mathematical model of the pipeline network should be formed by the most accurate equations of physical processes. The use of simplified and statistical models is not allowed.
- The model should be robust under all operating conditions of pipelines and infrastructure elements.
- The results of the model's operation should be provided in the form of time trends and longitudinal profiles, presented in graphical and tabular forms. The profile representation should be implemented at least for the following parameters: pressure, temperature, flow rate, density, gas composition components, speed, hydraulic resistance coefficient.
- The model should be reliable enough to perform calculations for pipelines with large altitude differences, regular changes in gas composition and changes in diameter.

- The system should be able to model a wide range of physical and operational conditions of the pipeline based on information obtained from the SCADA and the GMDH gas metering system.

The Software Product should ensure the simultaneous operation of the following functional modules (names and number of modules are recommendations only, provided that the Software Product provides all the functions set by these Technical Requirements):

Simulation Offline module - designed to simulate GTS processes (dynamic and stationary) without reference to the current state of the network and allows one to analyze and study past modes, form long-term forecast modes, simulate and plan repairs and network development.

Simulation Online module - designed to simulate the dynamics of GTS processes in real-time and expands the basic functions of offline simulation, allowing one to perform: cyclic reconstruction of the current state, cyclic simulation of short-term forecast, current and forecast balancing, gas leakage detection, tracking the passage of pistons;

Controller Simulator model - designed to train controllers on simulated standard and emergency processes with the provision of the maximum possible similarity with real processes and operating interfaces.

Online and offline simulation should enable the calculation of the following GTS parameters:

- linepack and linepack flexibility;
- gas balance for individual balance sections, zones, transport corridors and the entire GTS;
- process parameters (pressure, temperature, gas quality) for all nodes, branches, and control points of the network;
- dynamics of PCP change by pipes and mixing processes in units, calculation of gas quality parameters at all exit points;
- coordinates of operating points of injectors on their characteristics: flow-pressure, polytropic efficiency, and capacity;
- energy performance of engines and fuel gas consumption, the intensity of emissions of polluting combustion products;
- technical capacity of entry and exit points;
- conditions and coordinates of possible condensation of moisture and formation of hydrates.

High-level applications should allow several simulation options to work simultaneously, each of which simulates either the entire GTS or individual balance zones or transport corridors for different forecast options and in online and offline simulation modes.
Multi-user access to each of the parallel simulation options should be provided.

Simulation data are stored in a database with labeling (input data, results). The results of online simulation of the current state and the calculation of the forecast model adopted for implementation are transmitted to SCADA for display at the operational level and for further processing (for example, sending an alarm when limits are reached).

2.1. Requirements for the Simulation Online module

The simulation should be based on a dynamic hydraulic model using as an initial state either archived process state (pressure, flow, gas composition, temperature) from the historical SCADA database or the current state of the network obtained by the online simulation module or the saved state obtained as a result of a previously conducted offline simulation.

Offline simulation of the technological process of the GTS should enable:

- Analyzing possible options for the network's operation and optimization of the network mode;
- Analyzing network capacity limitations when planning repairs;
- Simulating development or optimization of the network;

Offline simulation should support dynamic and static simulation. The dynamic model should enable simulation of long-term transition processes to optimize the control sequence. Static simulation should enable high-speed calculations of stationary network modes.

The module should enable the following calculations:

2.1.1 Calculation of gas dynamics in pipelines.

It should be based on a numerical solution of the system of partial differential equations that describe the basic laws of conservation of momentum and mass - Newton's equations of motion and the equations of continuity. The calculation should take into account thermal dynamics and changes in gas composition.

2.1.2 Taking into account thermal dynamics

The thermal dynamics of the following processes should be taken into account:

- the Joule-Thomson effect;
- temperature increase during compression in injectors
- temperature decrease in cooling devices;
- transverse heat transfer, including the transfer between the pipe and the ground, taking into account the dynamics of soil heating after the CS is switched on and the reheating of gas from the ground after the CS is stopped.

2.1.3 Tracking the gas PCP

It is necessary to track the physicochemical parameters of gas properties for gas pipelines with sources of natural gas which have different compositions and volatile compositions over time. The module should simulate the mixing of natural gas flows of different quality and the dynamics of the progress of quality changes through pipelines.

The results of the module's work are calculated values of the components of the composition and derived parameters of the gas along the pipelines and at all exit points, as well as proportional values of the amounts of gases coming from several sources and durations of their receipt.

2.1.4 Tracking the risk of liquid condensation and hydrate formation

The function should control the conditions of liquid condensation and hydrate formation and signal the approach to these conditions based on a reconstruction of the gas PCP and the calculated thermodynamic state of the gas in each topological element of the network.

2.1.5 Valve calculation

Valve station operations should be calculated for the following basic operation modes:

- the valve is closed (zero flow);
- the valve is open (zero pressure drop);

- the valve is partly open (non-zero pressure drop);
- the valve is opened by means of (opening) the bypass valve.

2.1.6 Regulator calculation

The function should enable setting the values of the following parameters:

- inlet/outlet gas pressure;
- pressure change;
- gas flow;

The temperature at the exit of the regulator should be calculated (the Joule-Thomson effect). More accurate calculations of thermal dynamics should take into account the heating of the gas before throttling on the GDS.

Depending on the percentage of its opening, the operation of a regulator should be simulated as a control valve with a defined characteristic. The function should enable setting the control point.

The calculation of the flow through the regulator in the partially open state should be performed as a function of the inlet pressure, outlet pressure and the position of the valve.

2.1.7 Compressor station calculation

The function of compressor station calculation should be described at two levels:

- as an external description of the station;
- as described based on characteristics of the station's equipment;

Both approaches should simulate local regulation operations setting the values of the following parameters:

- inlet/outlet pressure;
- gas flow;
- compression degree;
- productivity maximum;
- without regulation (set speed of compressor rotation).

The external description level should simulate the compressor station in the simplest way (by setting the degree of compression) to enable rapid approximate calculations, without taking into account the internal structure of the station and the characteristics of its units.

Three levels of the CS model should be implemented:

- unlimited – should use any operating point with only a gas flow limited only directionally and technological limits of inlet and outlet pressures;
- generalized – should use the operating area limited as in the unlimited model, as well as by the maximum degree of compression, capacity, and volumetric flow;
- limited – should use all technological limitations of GPU concerning both the compressor and the engine;

The level of description based on the characteristics of in-station technologies should simulate the compressor station in the detail necessary to control the system and consist of the following components:

- injector;
- drive (gas turbine, electric drive, gas motor drive);
- gas cooling unit.

The description should offer both the nameplate characteristics of the equipment and a possibility of supplementing them with the characteristics developed on the basis of actual measurements. The

function should enable one to combine and configure joints of elements of station equipment (in a parallel or sequential manner) subject to rules on load distribution and internal control (application of switching) at the station.

It should be possible to input the normalized characteristics of the injectors (flow-pressure, polytropic efficiency and internal capacity). Simulation modules should use the normalized characteristics in calculations according to the methodology set out in Collection of Centrifugal Natural Gas Injector Specifications (Mingazprom SSSR, Moscow, 1985) [«Альбом характеристик центробежных нагнетателей природного газа», Мингазпром СССР, Москва, 1985].

2.1.8 Calculation of technical capacity of entry and exit points

The calculation should determine the technical capacity of each entry and exit point based on the state of the network and the simulated operation mode according to the criteria of the minimum possible pressure and the maximum possible flow rate.

2.1.9 Stationary state calculation

The stationary simulation module should enable reliable and fast calculation of the system's stationary modes of operation. The module should retain the functionality of the dynamic module with modifications for the stationary calculation.

The function should be completely identical with the function of calculating the dynamics concerning the initial data and working with the results of calculations. The module should enable output and formation of data in the table form in a format convenient for the transfer of results into a standard spreadsheet environment (eg. EXCEL).

2.1.10 Optimization of network mode

The optimization of the network mode should determine, for the set requirements for transportation and switching of the network, the conditions of stationary state for optimal operational (pressure, flow) and economic (energy efficiency parameters of GPU) characteristics of gas pipeline operation. It should ensure set values for compressor shops, compressor units, and regulating valves for which energy needs or energy costs should be minimized.

2.1.11 Optimization of operating points

The module should enable the calculation of the optimal stationary mode of operation of the gas transmission system for the set configurations of compressor stations and the set distribution of gas transmission flows (in the set state of shut-off valves) on the gas transmission system as a whole. The module should set operating points for all compressor stations and regulation units, at which the cost of energy used to operate all compressor stations, should be minimal. The calculation of the optimal mode should take into account all the conditions of the CS' own operating limitations and pressure limitations at any point of the pipeline's linear part.

2.1.12 Option optimization

The function should enable one to search for the best combination of configurations of individual stations based on the analysis of the results of operating point optimization for a package of several dozen-configuration options.

2.1.13 Planning pig run

The Simulation Offline module should be equipped with a function of planning utility and inspection pig runs. It should enable simulation of movement of at least four pigs at a time.

2.2. Requirements for the Simulation Offline module

To simulate the dynamics of technological processes of the GTS in real-time, **the Simulation Online module** should perform the reconstruction of the current state and the following functions:

- cyclic simulation of the future;
- calculations of forecast demand;
- pig tracking;
- gas leak detection;
- identification of systematic measurement errors;

Online simulations are subject to all requirements for the simulation of gas dynamics and thermodynamics of technological processes, tracking the PCP of gas, simulation of valves, regulators, compressor stations, control of moisture condensation and hydrate formation conditions, formulated in paragraph 2.1.

Online simulation is performed to predict the state of the network by simulating it based on the reconstructed state of the network and the changes envisaged as a result of the new transmission requirements. The system should provide at least a forecast for the current gas day and a further forecast for the next 72 hours. Simulation results are uploaded to the SCADA system.

Cyclic functions should work automatically, without user intervention. The results of the cyclic reconstruction should be displayed for the elapsed time period, and it should be possible to link them with the trend obtained from the last launch of the forecast simulation of the future.

2.2.1 Current state reconstruction

The current state reconstruction module should use all process data to reconstruct the current state of the system. The module should also perform the reconstruction using the topologically minimal amount of process data (without adjusting the intermediate nodes).

The reconstruction result should be uploaded to the SCADA system.

In case of deviation from the existing technological condition (for example, detection of faulty readings of devices, discrepancy of quality of gas), an alarm signal should be sent.

The current state reconstruction module should work continuously or cyclically depending on the principle of its implementation. For systems that implement cyclic reconstruction, its frequency should be adjustable. The minimum available period should not exceed 3 minutes.

2.2.2 Network line pack

Simulations should calculate the line pack and line pack flexibility in the pipelines taking into account the pressure, temperature, gas composition, and network configuration. Means of structuring the line pack by the balance zones of the GTS and transport corridors should be available.

2.2.3 Balances

To generate operational (online), hourly, and daily physical balances, the system should read instantaneous, hourly, and daily gas metering data from the GMDH database, using the configuration master data of the central catalog of gas metering devices.

All types of balances are calculated for the configured set of balance subsystems and the entire GTS.

Online balances are calculated automatically with an adjustable frequency, and the results are recorded in a trend archive.

Hourly balances are automatically calculated every hour with an adjustable shift from the hourly grid. It should be possible to recalculate them as required both for a given hour and for each hour of a given time interval. The results of the calculation are recorded in the historical archive. The data

model and scripts should support the call-back paradigm for automatic recalculation of balances when the source data is adjusted.

Daily balances are automatically calculated daily with adjustable calculation time. It should be possible to recalculate them as required both for a given day and for each day of a given multi-day interval. The results of the calculation are recorded in the historical archive. The data model and scripts should support the call-back paradigm for automatic recalculation of balances when the source data is adjusted.

Monthly balances are calculated as required based on daily data.

Yearly balances are calculated as required based on monthly data.

2.2.4 Demand forecasting

Online forecast simulation should take into account expected consumption depending on the weather forecast using a regression model of demand based on current and historical data on weather conditions and demand. The forecast should support the determination of demand for at least 72 hours. Demand forecasting should also be available as a separate forecasting service for up to two weeks without network simulation.

2.2.5 Cyclic simulation of the future

The future simulation module should be linked to the state reconstruction. The forecast dynamics of the system process should be calculated to a precision of several hours, based on the result of the state reconstruction, the values of the submitted nominations and the intraday demand forecast. The depth of future simulation should be adjustable. It should not exceed 72 hours.

The results of the calculation should illustrate the development of the network in the future, taking into account all the projected changes in supply and outtakes, as well as all planned actions of the control staff during the forecast period.

It should enable the user to perform test calculations of control options and implement future simulation manually.

It should enable one to compare the expected changes in the GTS mode with the actual changes during the day, and thus allow one to assess the need to adjust the transmission tasks in real time to transmit daily volumes according to the current nominations.

All limitations contained in the task and limitations imposed by the actual technical condition of the gas transmission system facilities (updating according to the technical capabilities of the system) should be taken into account.

The system should provide for control of technological limitations, signaling of them being reached in the forecast processes and determination of the time they were reached.

2.2.6 Forecasting gas network balance and linepack

The forecast network balance is calculated on the basis of nominations and demand forecasting in the process of cyclic simulation of the future and results in a forecast of network line pack and pressure distribution along gas pipelines. Based on the required pressure distribution, the deployment of compressor capacity and engine fuel demand is calculated, which is also taken into account in the balance. If, as a result, the linepack exceeds the limit values, the need to purchase missing volumes of gas or sell its surplus is established.

2.2.7 Pig movement tracking

The Simulation Online module should be equipped with a tracking function for utility and inspection pigs. The standard interactive interface of the software package should allow for calling the pig tracking function and setting parameters for at least four pigs that are in the process of cleaning (inspection) at the same time. The online system should display their current position and speed and estimate the time until their passage of the specified locations (posts) on the pipelines or the time of arrival at the reception chamber.

In the case of devices stopping in the pipeline, the system should have a mechanism for identifying the coordinates of the stop with an error of not more than 200 meters.

The system should implement an algorithm for the identification and adaptation of the slip coefficient of cleaning and inspection devices.

2.2.8 Tracking substandard batches

Substandard batches of gas may be received by pipeline systems.

All anomalies should be identified and displayed on the tracking screen.

The system should use the current pipeline flow, line capacity, and other data to calculate the arrival time for each anomaly.

2.2.9 Gas leak detection

The software package should include, as a stand-alone module of the online system, the function of detecting gas leaks from the pipeline. Detection should be based on measurements provided by the SCADA system (flow, pressure, temperature) and on a dynamic network model. The following methods of leak detection should be implemented depending on the availability and quality of measurements:

- balance method;
- method of real-time monitoring of the parameters of transition processes;

The module should determine the time, size, and location of the detected leak.

The module should enable one to run different methods of leak detection and provide different characteristics for different segments of the pipeline.

The balance method of leak detection should be based on gas balance with real-time compensation of transition processes, tracking the change of the line pack with high accuracy.

The leak detection module should include an automatic friction coefficient adjustment function (or an appropriate setting parameter for this leak detection method) to compensate for simulation errors due to unmeasured or unpredictable factors.

To prevent erroneous alarm actuations, the leak detection module should have automatic adjustment of the input quality control parameters and the state of the pipelines. The user should be able to regulate parameter values manually as well. Automatic control parameter settings should be optimized during the configuration phase to minimize false alarms.

The leak detection module should use at least five integrated data accumulation time intervals to detect leaks to ensure the fastest possible detection of large leaks (short filtration period) and the most efficient detection of small leaks (long filtration period).

The gas transmission network operator should be able to assess any suspicious leakage condition to ensure its actual presence before reporting it as a confirmed alarm signal. To meet this requirement,

the system should implement several levels of warnings. Alarm management should be designed so that the average number of false alarms is less than one per month.

Target parameters of leak detection efficiency:

- Minimum detectable leak: 1.0% of the nominal flow.
- Leak detection time for a leak which is 2% of the nominal flow: 30 minutes
- Leak detection time for a leak which is 5% of the nominal flow: 7 minutes

The GTSOU understands that these operating parameters depend on the accuracy of field devices and the overall performance of the SCADA system. Thus, the bidder should include in the scope of offered services a preliminary analysis of the characteristics of leaks detected by the proposed system with a description of the assumptions made for the theoretical study and the correlation between the time of leak detection and the leak size. The results of such an analysis should be as close as possible to the above-desired performance parameters, or even better than them.

2.2.10 Identification of systematic measurement errors

The function should identify the systematic measurement error based on the processing of time series of measurements and simulation calculations. Corrections should be calculated for individual measured pressure points and for supplies, outtakes and hydraulic resistance in individual areas. The analysis of the results should show the magnitude and location and estimate the priority of adjustment of measuring instruments.

2.3. Requirements for the Controller Simulator module

The Controller Simulator module should provide training of control personnel on realization of standard system operation scenarios and emergency situations.

The module should be implemented as a stand-alone set not connected to the existing gas pipeline control system to avoid erroneous control of the real technological process. Simulator workstations should be located in a separate room and not in the existing control room.

The simulator set should consist of a dynamic offline simulation module, which realistically simulates the process of gas transmission that is identical to the real process and provides to a separate SCADA server the same set of process data as in the operating system. The simulator should also include an online simulation module, identical to that in the operating system, to reproduce the diagnostic functions of the simulation system in emergency situations.

For group and remote training, the simulator set should provide a full-fledged web interface with the ability to control the simulated technological process via the SCADA as in the operating system, and have additional instructor controls to create emergencies including depressurization, an emergency stop of a compressor, unauthorized switching of a valve, hydrate formation, etc.

The simulator should implement scenarios that support the roles of the instructor and examinee. The instructor should have tools for determining and manipulating training scenarios.

The simulator should have the means to automatically record and archive training sessions with the ability to reproduce them for analysis.

The simulator should have a program methodological component for automation of the training process, training evaluation, etc.

3. Non-functional requirements.

The Software Product should have a client-server architecture. The client should be implemented as a software application and/or web client. It should have at least a bilingual interface (Ukrainian and

English). Active Directory authorization and role model distribution of user access rights should be enabled.

3.1. General requirements.

- Architecture of high-level applications – Client-server.
- The server part of the HLA should meet the following conditions:
    - support of the x86-64-compatible CPU architecture;
    - installation on the OS Microsoft Windows Server 2012 x64 and newer versions or the latest versions of Oracle Linux x64;
    - support for virtualization systems, at least for Microsoft Hyper-V and VMware;
- The server part of the HLA must contain a relational database for archiving actual and simulated modes, calculation data, etc. The size of the database should not be subject to license restrictions. The database must be software accessible for reading and recording at the levels of model, scenarios, scripts and through the API. If a database license is required, it must be provided as part of the system delivery
- The client part should be in the form of an application and/or web-client and meet the following conditions:
  for an application:
    - full implementation of all functional requirements;
    - installation on a workstation based on the OS Microsoft Windows 10 x64 and newer versions;
    - do not use the system directories of the OS when installing the application and in further work.

  for a Web client:
    - implementation of functional requirements of the execution mode (web implementation of editing and configuration of models and other functions of the design mode is not required);
    - Support for the latest versions of Microsoft Edge, Chrome, and Firefox browsers.
    - Installing additional extensions in browsers is not desirable.
- The system's graphical interface must support monitors with a resolution of at least 4K Ultra-HD.
- The HLA should have duplicate productive environments in the MCC and BCC, an environment for development and testing and a Controller Simulator.
- Cyclic online state reconstruction and cyclic reconstruction of the future should constantly operate In productive environments in the MCC and BCC according to the scheme of the simple independent reserve. Simultaneous offline simulation sessions in productive environments should be run following the principle of load balancing between the MCC and BCC. The redundancy architecture should face no barriers or restrictions due to the implementation of license protection.
- The HLA should function 24/7/365;
- Support for the HLA transition to daylight saving time and leap year.
- The HLA must work with a new SCADA system installed in two locations (the main and backup DPC). The HLA must work with an active SCADA site and automatically switch between sites when their roles change. The full system functionality and access to all data collected by the HLA should be maintained in both locations.

The simulation server should provide the following multi-user tools:

- models and model data should be stored on the server;
- multiple users can simultaneously connect to the same model to work together;

- users with the appropriate rights should be able to work directly with the main models on the server and update them for use by other users.
- users should be able to create their own working copies of master models to run simulations on their workstations.
- projects that contain models may be designated as public or private. Public access projects are available to other clients on the network, while private projects are only available to the client application;
- models should be password-protected so that only users with the appropriate permissions can access or modify the models;
- model configurations should be locked (operating settings can be changed, but pipeline and station configurations cannot), and the locked state should be password-protected.

The supply package should include all necessary server and client software with an unlimited license period. The server software should allow real-time data processing on the main and backup servers with support for standby backup. Client software should allow simultaneous access to the system from at least 50 independent client stations. The software should enable unlimited access by WEB-users in the mode of examining the simulation results, and its own system of widget configuration which targets GTSOU users included in the Active Directory.

3.2. Requirements for user interface

The system should provide a multi-window multi-document graphical interface with the ability to organize documents and quickly navigate between them (such as a stack of bookmarks). Displaying tables, mnemonic aids, and trends in one session with an arbitrary location and scaling (at least 20 items). Saving the custom configuration, composition, and location of windows on the screen for the quick formation of the workspace when logging in.

The user interface should provide for different types of information presentation and management of the software package operations.

3.2.1 Network interface

The network is the main type of interface that displays a scheme of the pipeline system and is the main means of navigating between models and editing.
It should offer convenient means of scaling and navigating the scheme.

The Network interface should be synchronized with other interfaces. It should include context menus and tools for manipulating scheme objects.

The package should include means of consolidating the representation of the network (simplification of topology, aggregation and virtualization of inputs and outputs) and programming meta-instructions for configuring gas transmission schemes and modes.

3.2.2 Map interface

The map is a supplementary type of interface that displays a pipeline system scheme on a cartographic background with the topological elements of the network linked to the geographic coordinates. This type of interface has the same navigation and control contextuality requirements as the Network interface.

3.2.3 Report interface

The report interface is used to view, export, and print user-selected simulation parameters. Reports should be customizable for data and display format. They should offer data search and sorting options. The user should be able to select items for reports in the scheme or the record editor, using the standard selection options in the spreadsheet.

It should include a report designer enabling one to create one's own reports, which can include graphics, mnemonic schemes, and other forms that are related to the model data.

3.2.4 Tables

For comfortable control of the technological mode (a set of technological parameters both measured and calculated for the selected system objects) and operational balancing, it should be possible to create the following tables:

- vector of parameter values (current instantaneous)/(for the nearest past hour of the current day)/(for the selected hour of the selected day);
- matrix of hourly parameter values (for each hour of the current day)/(for each hour of the selected time period);
- matrix of hourly parameter values (for the selected hour of the day for the selected multi-day period);
- vector of daily parameter values (for the nearest past day)/(for the selected day);
- matrix of daily parameter values (for each day of the current month)/(for each day of the selected month)/(for each day of the selected multi-day period);
- vector of balance data (current online balance)/(for the nearest past hour of the current day)/(for the selected hour of the selected day)/(cumulative from the beginning of the day);
- matrix of balance data (for each hour of the current day + cumulative from the beginning of the day)/(for each hour of the selected day + daily);
- matrix of balance data (for each day of the current month + cumulative from the beginning of the month)/(for each day of the selected month + monthly);
- matrix of balance data (for each month of the current year + cumulative from the beginning of the year)/(for each month of the selected year + yearly);
- The tables should meet the following requirements:
- automatic updating (supplementing) of parameters in the forms as new values enter the database or existing data are adjusted.
- color mnemonics of warning and alarm systems should apply to tabular forms. In addition, tables should be equipped with the means to create additional mnemonic schemes based on the results of time series analysis.

To create and edit tables and process data in the archive, the following is required:

- tool (designer) for building free-form tables using SQL queries to the database and/or the API. Such tables are stored in the system as separate objects with their properties. Each such table can be displayed in a user client or user group client according to the user's roles;
- enabling the user to manually change the data in the table, simultaneously entering this data in the database of the historical archive. Such actions should be archived and logged;
- search in the database of the historical archive for the modes which would satisfy the user-formulated conditions concerning the chosen objects and parameters for the time interval defined by the user. Such search should have at least 20 parameters. The search results (the set of vectors of parameter values that satisfy the search criteria and the corresponding timestamps) together with the search criteria should be displayed in a table which can be printed and exported to xls format. It should be possible to name and store search queries. The selection of objects for the search terms should have elements of a quick contextual search of the database of objects presented in the form of a list of options that satisfy the entered fragment of the identifier or the mask. For each object that has been a search criterion at least once, a cache of the terms used should be kept for quick selection among them.
- ability to create scripts for calculating analytical objects and integrate data processing applications;

- construction of trends for any actual or calculated parameter, change of scale and time interval;
- automatic updating of parameter values on visual forms of documents as new values arrive in the database. Values that reach the set limitations should be color-coded.

3.3. Information security requirements.

The set of measures to ensure information security should include:

3.3.1 User authentication:

- HLA integration with the Microsoft Active Directory corporate system.
- The HLA should support the creation of its own local accounts with the following characteristics:
    - setting the password validity duration;
    - the user's ability to change their password;
    - determining the maximum allowed quantity of incorrect login attempts;
    - locking the account upon reaching the set quantity of incorrect login attempts;
    - determining the time interval after using up the allowed quantity of incorrect login attempts for automatic unlocking of the account;
    - determining the criterion of password complexity;
    - passwords should not be displayed or transmitted inside the HLA and stored explicitly.
- The HLA administrator's ability to lock and unlock accounts

Providing users with access to the HLA:

- A user is granted access to the HLA only after successful authentication of their account.
- The distribution of user access rights concerning data, individual functions and components of the HLA is carried out according to their individual roles.
- If a user's session stays inactive for a certain period of time, the HLA should automatically close the session. The inactivity period is determined individually for each account.
- When the user takes active action, the HLA should require confirmation of action.

3.3.2 Data protection:

- Data transmission between server and client components of the HLA and between it and other systems should be encrypted.
- The HLA, including database servers, should consist of two interchangeable geographically distributed components between which the data is replicated. Each component may be either active or passive. One component works in the active mode and implements all the functions of the HLA, while the other part is in the passive mode. The component that is in passive mode can be turned off for hardware maintenance, OS and HLA upgrades. In the event of a failed update of the HLA or its components, the HLA should perform a rollback to the previous state.
- The HLA should support automatic and manual switching between active and passive components. HLA client software should automatically recognize the switch and reconnect to the active HLA component.
- Ability to duplicate database servers on each geographically distributed component of the HLA.
- The HLA architecture should provide for data backup and recovery.
- Both active and passive HLA components are subject to data backup.

3.3.3 Audit and monitoring:

- The HLA should enable audit settings for authentication, user and administrator actions. Audit objects should be registered in a separate electronic log or database. The registration record should contain at least the following fields: date; time; account name; IP address and network name of the computer from which the login is performed; the name of the HLA module in which the user is currently performing actions; user action description; whether the action was successful or not. The log should be available for reading, viewing, analysis, storage and backup only to HLA administrators and information security staff;
- The HLA should constantly perform self-diagnostics and monitor the performance of its components, databases, and communication channels with other systems. The monitoring result is recorded in a separate electronic log or database. The monitoring log should be available for reading, viewing, analysis, storage and backup only to HLA and system administrators. Emergency alerts should be duplicated to Email;
- Different personalized accounts with appropriate roles are used for administration, monitoring, and audit.

3.4. Information communication requirements.

The HLA should contain a module of information communication with other information systems with the following properties:

- Automatic generation of data files according to customer templates and their recording on a network resource for transmission by corporate transportation services.
- Automatic reading of data files received through corporate transportation services and their loading into the HLA according to customer-programmed algorithms.
- Task scheduler to automate file exchange and messaging.
- Data exchange via the API and xml file exchange with the SAP system (the ERP and Operator Information Platform).
- Data exchange via the API with the SCADA (in the server redundancy architecture).
- Data exchange via the API with the GMDH.
- Data exchange via the API with the OAS GTP database.

3.5. Change management requirements

At least 10 simultaneous connections to the development and testing environment. The development and testing environment should provide for coordinated simultaneous group editing and testing of models, scenarios, scripts, and other project components and their uploading to a productive online system. Uploading changes to the productive system should not interrupt the online simulation process.

3.6. Hardware resource loading requirements

The required calculation speed, performance of the HLA, as well as the capacity of the server equipment is determined at the stage of working design. The HLA supplier should provide its methodology of calculating the required computing power for the HLA depending on the length of the simulated pipelines, the number of local facilities, and the desired calculation speed.

The supplier must offer a hardware configuration for the servers and client workstations. The software in combination with the recommended hardware must have the following loading values:

- server and workstation processor loading: no more than 50%;
- usage of random access memory in the normal operation mode: no more than 50%;
- hard drive usage
    - at servers: no more than 75%;

- at workstations: no more than 50%;

3.7. Requirements for language support.

- Support for Cyrillic encodings UTF-8 and Windows-1251.
- Ability to choose the interface language between Ukrainian and English.

3.8. Requirements for documentation.

The HLA documentation should contain at least:

- IT system solution concept.
  - System architecture.
  - Sizing.
- Process documentation.
- Technical documentation:
  - Infrastructure;
  - Communication scheme;
- Documentation for users.
- The Controller Simulator documentation.
- Engineering documentation:
  - Creating own macros, procedures, applications, etc.
  - Documentation and the SDK for the API.
  - Creating pipeline network schemes, configuring their properties, linking them to data, etc.
- Documentation for system administrators:
  - Deployment scheme;
  - Installation and configuration (it should describe the configurations of components for each environment – production, testing, products, the Controller Simulator);
  - Backup and restore;
  - Emergency action plan
- Documentation for the HLA administrator.
- Documentation of logging and monitoring.
- Audit documentation.
- Detailed database specification.
- Documentation on the methodology and process of transition from the development environment to the testing environment and from the testing environment to the productive one.

Implementation concept:

- Full functional system description.
- Proposal for integration with other systems.
- Approach to testing, implementation and production; user training.
- Proposal for the overall technical infrastructure of the system.

All documentation should have the following structure:

- Name of the document.
- Number (including version) and date.
- Summary.
- Description of the contents of the document.
- Approval procedures and persons approving it on behalf of both parties.

Documentation should be provided in Ukrainian and English. All documentation should be submitted in electronic form, which will allow its audits to be tracked.

3.9. Requirements for user training.

The Contractor should provide all necessary HLA training services to system administrators, HLA administrators, database administrators, user action auditors (information security service), software engineering service's employees, users, etc.

Training should be conducted individually for each category.

Training documentation and the training itself should be conducted in Ukrainian or (with the prior consent of the Customer) in English.