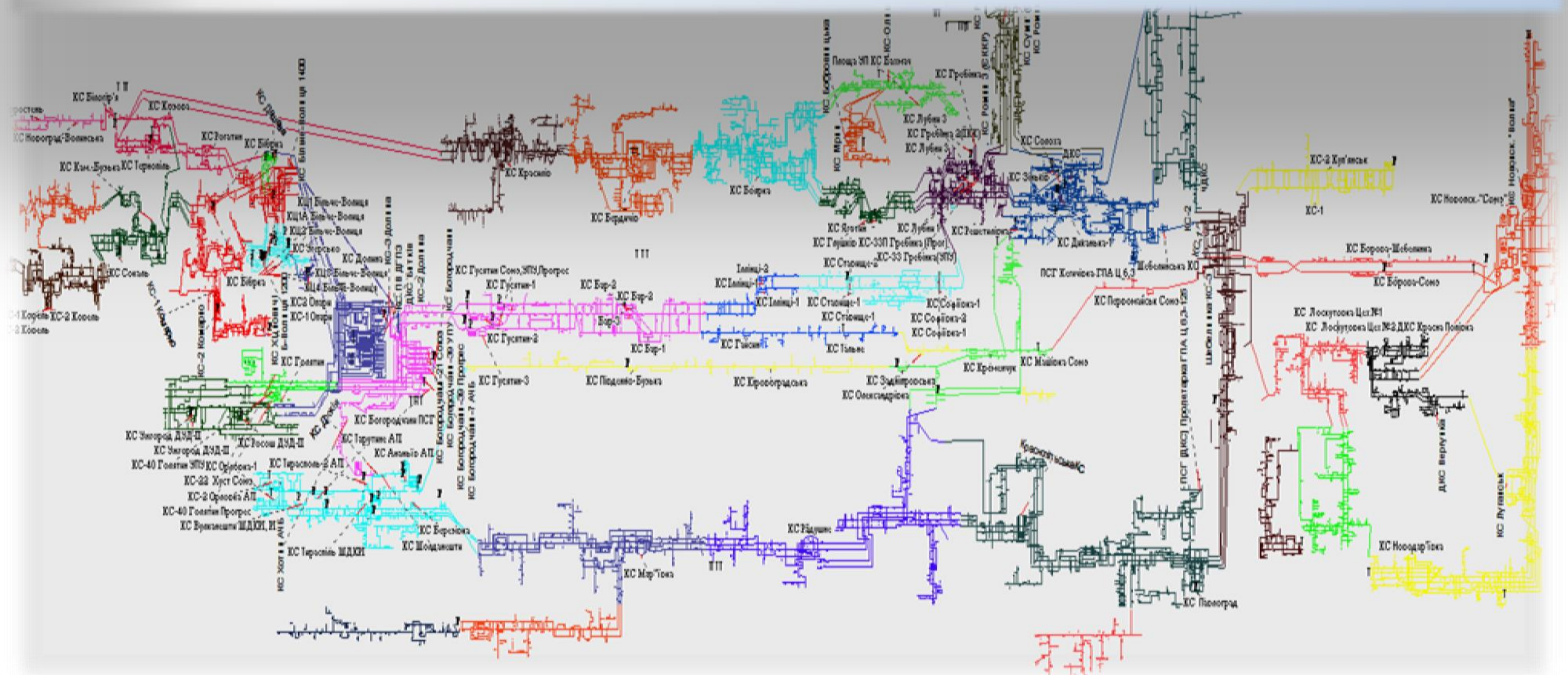
Mathematical Centre Ltd.

mathcenter.com.ua
company@mathcenter.com.ua

SOFTWARE COMPLEXES FOR MODELLING, PLANNING AND MANAGING GAS FLOWS IN GTS



The objectives:

To provide the guaranteed and qualitative implementation of natural gas transporting, storing and distributing with minimal energy and fuel costs

The functions of software complex:

Modeling the processes of gas dynamics within the transporting facilities of GTS and filtration processes in porous beds of underground gas storages

Optimal planning the flow regimes meeting given criteria

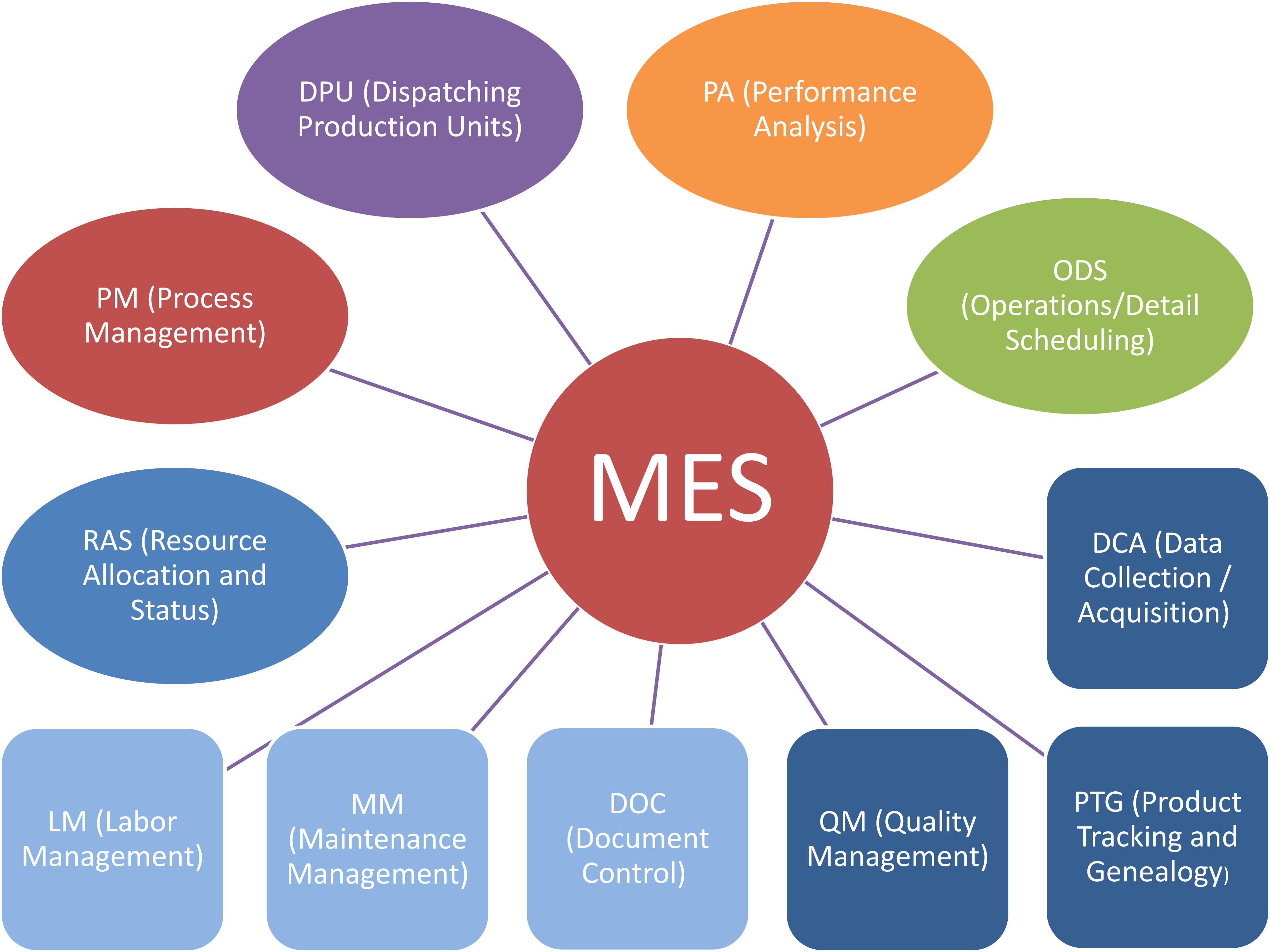
Calculation of non-stationary regimes for gas transporting and storing during given periods subject to operating conditions of GTS engineering facilities

Calculation of parameters for live optimal control of technological processes of gas transporting and storing

Monitoring GTS and its facilities

The software complexes are based on the fundamental mathematical problems that have been solved:

- Numerical solution to dynamic problems for gas flows in a curvilinear pipeline built on uneven terrain
- Numerical solutions to stationary and non-stationary problems for gas flows in distributive gas networks of given topography
- Numerical solutions to problems for GTS regimes optimization
- Finding control parameters for optimal gas transporting under conditions of unsteady gas flows
- Numerical solutions to gas filtration problems in heterogeneous porous media
- Finding filtration parameters in porous underground storages under conditions of replacing natural gas by inert gas


MES
DPU (Dispatching Production Units)
PA (Performance Analysis)
PM (Process Management)
ODS (Operations/Detail Scheduling)
RAS (Resource Allocation and Status)
DCA (Data Collection / Acquisition)
LM (Labor Management)
MM (Maintenance Management)
DOC (Document Control)
QM (Quality Management)
PTG (Product Tracking and Genealogy)

RAS (Resource Allocation and Status)

PM (Process Management)

DPU (Dispatching Production Units)

PA (Performance Analysis)

ODS (Operations/Detail Scheduling)

Facilities

Main information objects

- GIS
- gas distribution station
- CNG FILLING STATION
- Gas fields
- lock and regulating valves

Objects of modelling

- sectors of gas pipelines
- wells
- Borehole bottom
- Gas compressor units

Systems of hydraulically connected objects

- distributive networks
- cable-collector systems
- compressor shops and stations
- one and multistrand main gas pipelines
- facilities of air cooling
- underground gas storages facility (UGS)
- groups of technologically joint UGS

Physical processes accompanying gas transportation

Groups of processes	Processes	Mathematical models
Thermodynamic	heating / cooling	equations of state of a gas mixture
		equations of state of a metal
	compression / expansion	equations of state of a gas mixture
	strain / stress	equations of state of a metal
	thermal expansion	gas equations of state
		equations of state of a metal
	blending component	equations of state of a gas mixture
Gasdynamic	mass transfer	mass balance equations
	momentum transfer	impulse balance equations
	transfer of angular momentum	moment of impulse balance equations
	transfer of energy	energy balance equations, equations of heat transfer, kinetic and potential energy
Diffusion, filtrational	diffusion component	diffusion equations, thermal diffusion, mechanic diffusion
	filtering components and mixtures	filtration equations
Chemical and phase transformations	formation of chemical compounds	
	condensation and evaporation	
	burning	
Elastic, thermoelastic		
Wave		
Aging, degradation		

Tasks. Main gas pipelines

RAS (Resource Allocation and Status)

PA (Performance Analysis)

- hydraulic and temperature calculation of main gas pipelines;
- identification of the actual coefficients of hydraulic resistance and efficiency (in stationary and non-stationary cases on annual data);
- calculation of the coefficient of a gas - environment heat transfer (in a stationary case on considerable intervals of time);
- calculation of clearing piston speed in a gas pipeline section;
- calculation of time and volume of gas bleeding through a candle;
- calculation of accumulated gas volume in a gas pipeline in the conditions of its non-stationary movement;
- calculation of temperature mode parameters of gas transportation in the conditions of non-stationary processes (in three-dimensional statement);
- assessment of gas losses in gas pipelines sections(to find and prove standard data);
- finding of gas leakages location (to investigate calculation accuracy);
- calculation of hydrate formation zones and volumes of necessary methanol.

RAS (Resource Allocation and Status)

PM (Process Management)

PA (Performance Analysis)

The problems. Compressor stations

Computation of operation regimes for compressor units, workshops, multi-shop compressor stations containing compressor units of different type

Computation of fuel and energy expenses for compressor unit and compressor station for given operational regimes

Computation of optimal operational regimes for multi-shop compressor stations

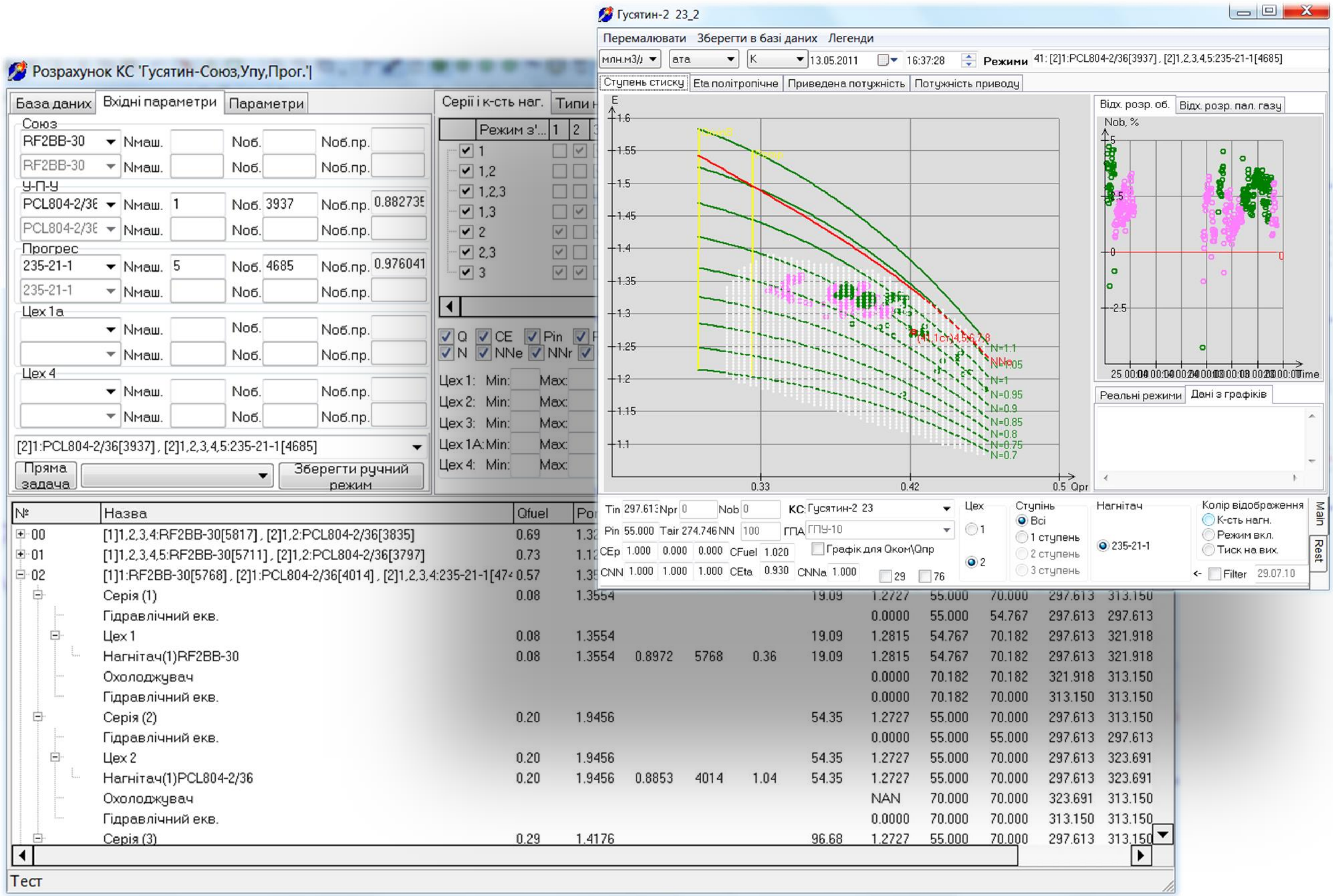
Computation of working characteristics of compressor units and drives based on measured data

Thermo-hydraulic calculation of compressor stations with the use of their detailed flowgraphs

Restoration from archives and displaying the data on previous operational regimes for selected compressor unit or compressor stations station

Identification of the state of compressor units and compressor stations

Computation of optimal operational regimes for multi-shop compressor stations



The system problems. Underground storages

RAS (Resource Allocation and Status)

PM (Process Management)

DPU (Dispatching Production Units)

PA (Performance Analysis)

ODS (Operations/Detail Scheduling)

- Thermo-hydraulic calculation of the system “porous bed – pipeline”
- Solving direct and inverse problems for planning of technological regimes
- Finding time periods of gas pumping/extraction into/out the storage without use of compression stations
- Identification of underground gas storages parameters
- Calculation of compressor stations with gas turbine and piston-type compressors
- Forming optimal admissible operational regimes for gas storage facilities
- Determination of gas-bearing beds storage capacity and parameters of the cross-flows between the beds
- Throughput computation for technological objects of the system “porous bed – pipeline”
- Finding of peak operation parameters in the domain of variable pressure in the pipeline
- Optimal planning the storage operation during given periods of gas pumping/extraction

Tasks of UGS facility

UGS Porous bed:

Calculation of gas parameters throughout filtration area

Calculation of heterogeneous porosity, permeability, gas concentration rates of gas storage reservoirs;

Calculation of geometrical, geological and accumulated parameters of gas storage reservoir

Borehole bottom:

Calculation of filtration rates of borehole bottoms;

Calculation of density of envelop column perforation;

Exploration of borehole bottom using hydrodynamic methods;

Borehole:

Calculation of flow rate, hole mouth; borehole bottom pressure;

Calculation of impact of additional perforation of a hole on it’s flow rate;

Calculation of impact parameters of open borehole bottom on horehole flow rate

Strapping of hole mouth:

Constracting hydraulic equivalent of hole mouth strapping

Cable collector system (CCS)

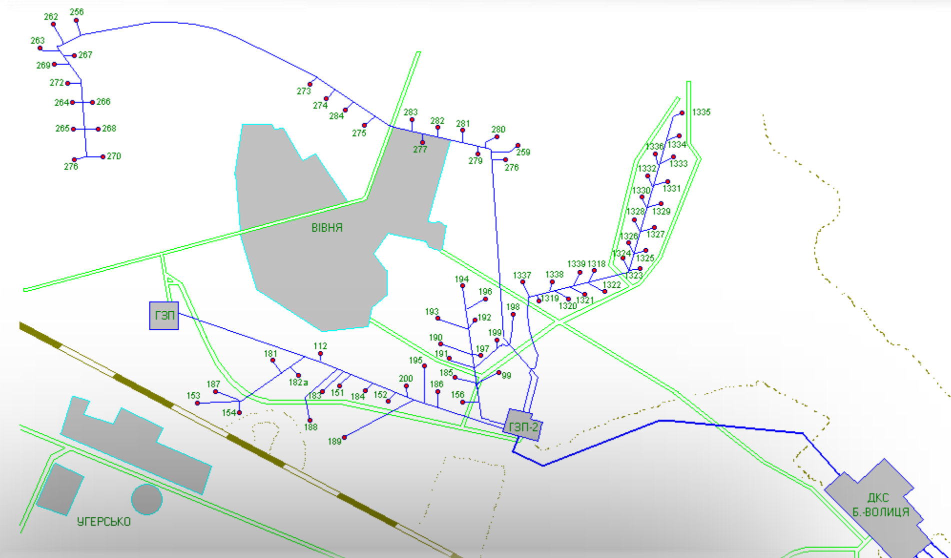
Considering all possible solution of setting pressure and flow rate

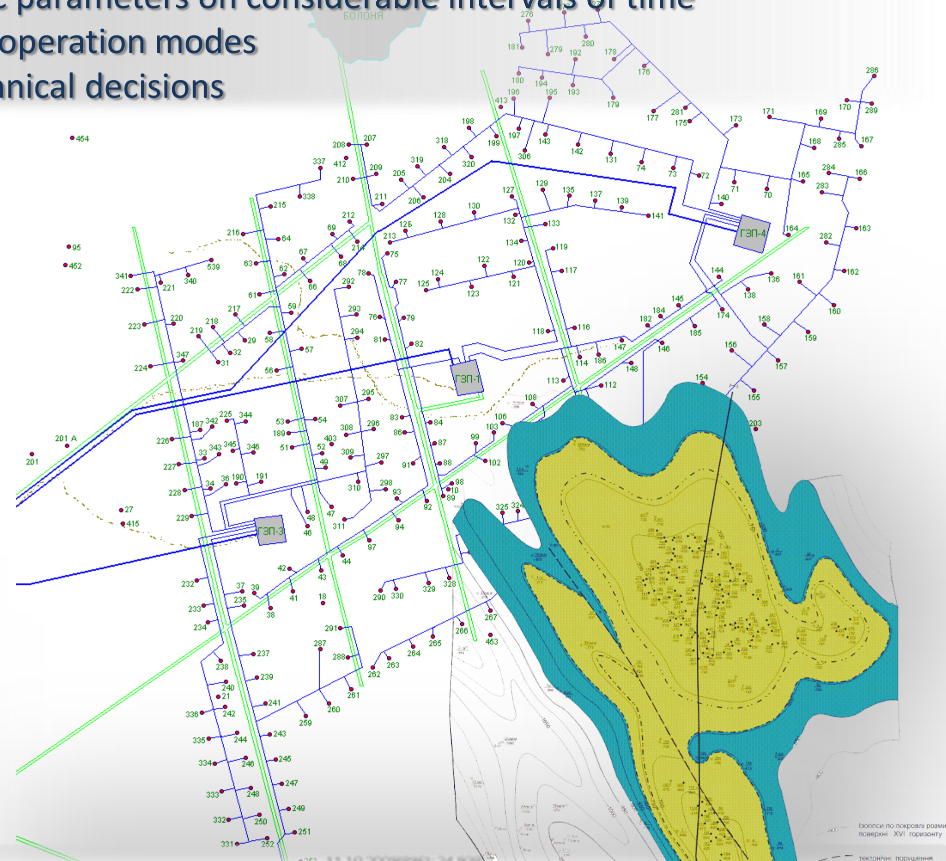
RAS (Resource Allocation and Status)

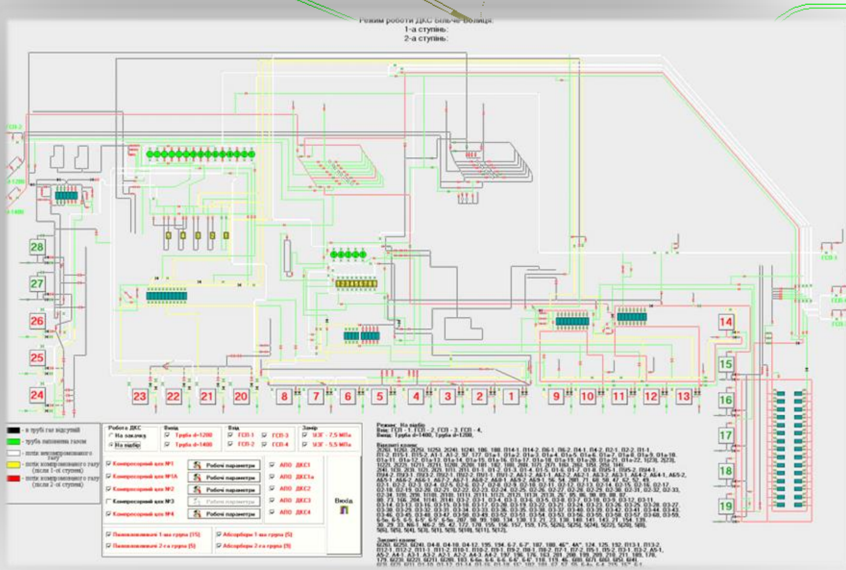
PA (Performance Analysis)

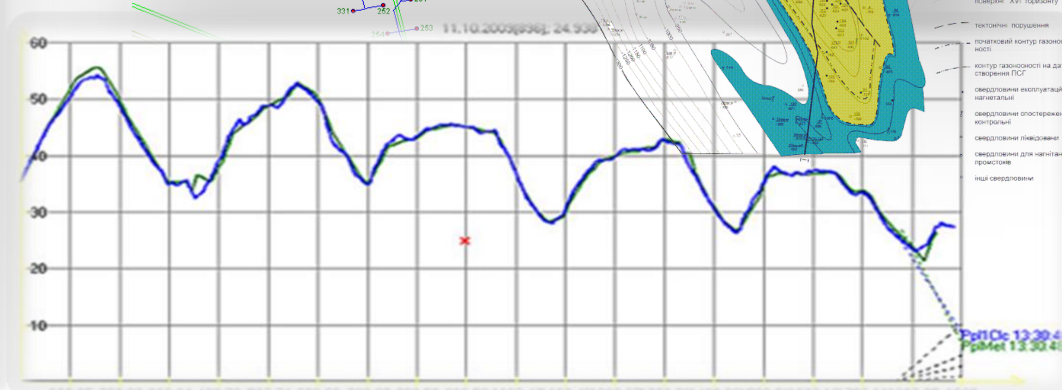
Modeling operation of USF

Planning of optimum work
Studying of dynamics of behavior of filtrational and gasdynamic parameters on considerable intervals of time
Studying and development of new technological decisions and operation modes
Economic assessment of introduction of new scientific and technical decisions









PM (Process Management)

DPU (Dispatching Production Units)

PA (Performance Analysis)

ODS (Operations/Detail Scheduling)

Groups of technological connected gas storages

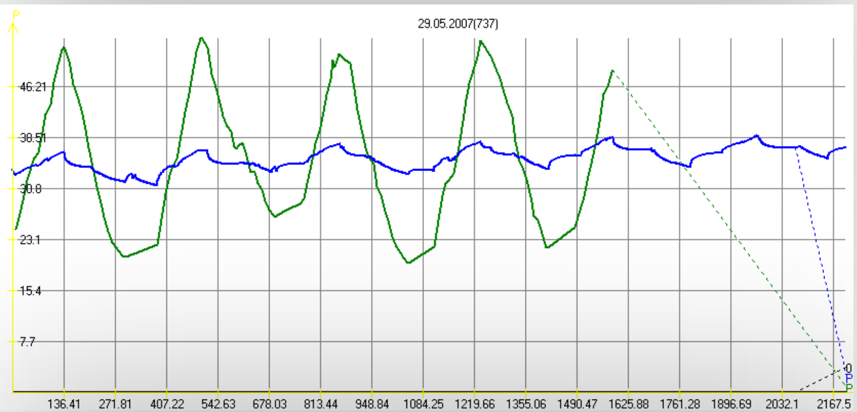
Finding peak capacity for all CS as gas flow rate, fuel gas and pressure in the main pipeline in the area of designed and actual operating modes of UGS

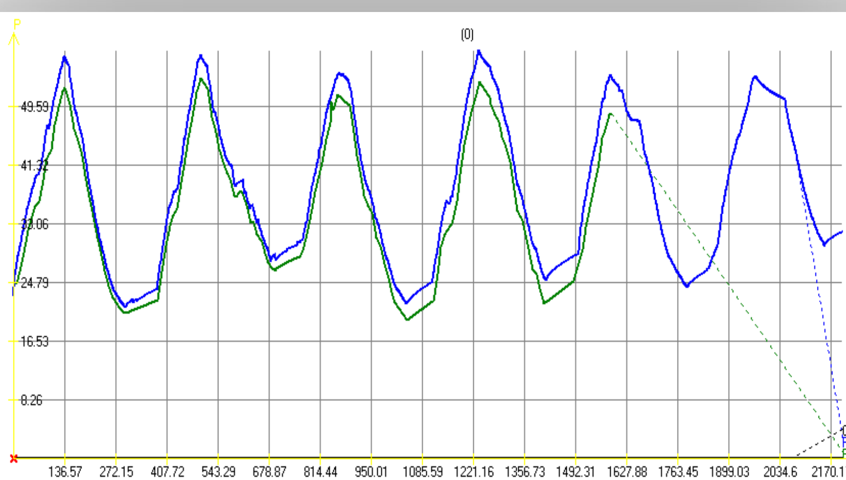
Optimum gas distribution for storing amout GS with total maximum capacity ensured when gas extraction at given period of time;

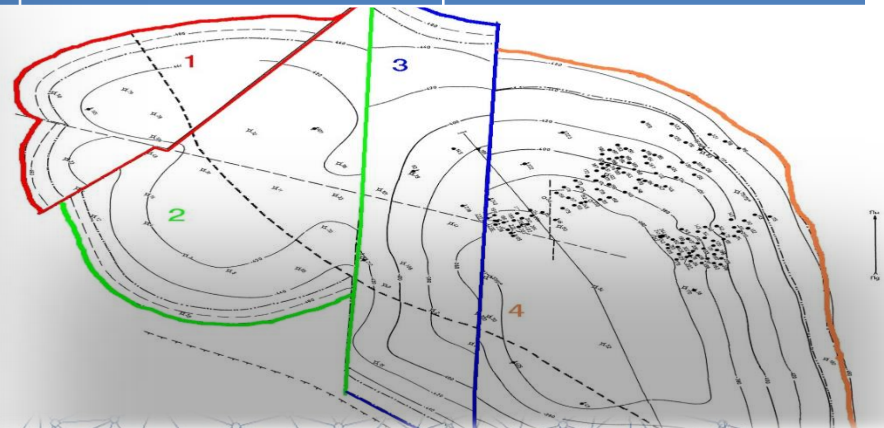
Optimum planning of gas extraction from GS with maximum capacity of gas storages in the process of extraction or maximum peak capasity of active gas availible

Replacement of cushion gas by Nitrogen

	End of the second season	End of the third season	End of the fourth season
After pumping	29,75	23,97	27,44
Without pumping	27,77	21,16	23,47
Pressure difference	1.98	2.81	3.97







Description of GS mode software

The speed of filtrating process modeling is ensured by the methods of work with sparse matrixes;

Hydraulic calculation of technological gas gathering complex facility chain is ensured by the methods of solving of diverse nonlinear equations;

Taking into account of hydraulic iteration of all objects involved in gas pumping? Storage and extraction;

Automation of forming models for various modifications of equipment, changing states of technological facilities modernization and upgrade of certain facility and GS as a whole;

Adaptation of models of facilities to changeable operating modes and its hydrodynamic states;

Multiple operation calculation in search of optimum operation modes at considerable period of time and necessary compare analysis of possible GS upgrade options

Gas hydrodynamic connections considered with all facilities involved in gas extracting and pumping;

Automation of process of adopting models of system facilities;

Normative requirements of GS operation modes is taken into account;

Provides for possibility to make a compare analysis of the efficient using of different facilities in a course of GS modernization and upgrading

Gas transmission system

RAS (Resource Allocation and Status)
PM (Process Management)
DPU (Dispatching Production Units)
PA (Performance Analysis)
ODS (Operations/Detail Scheduling)

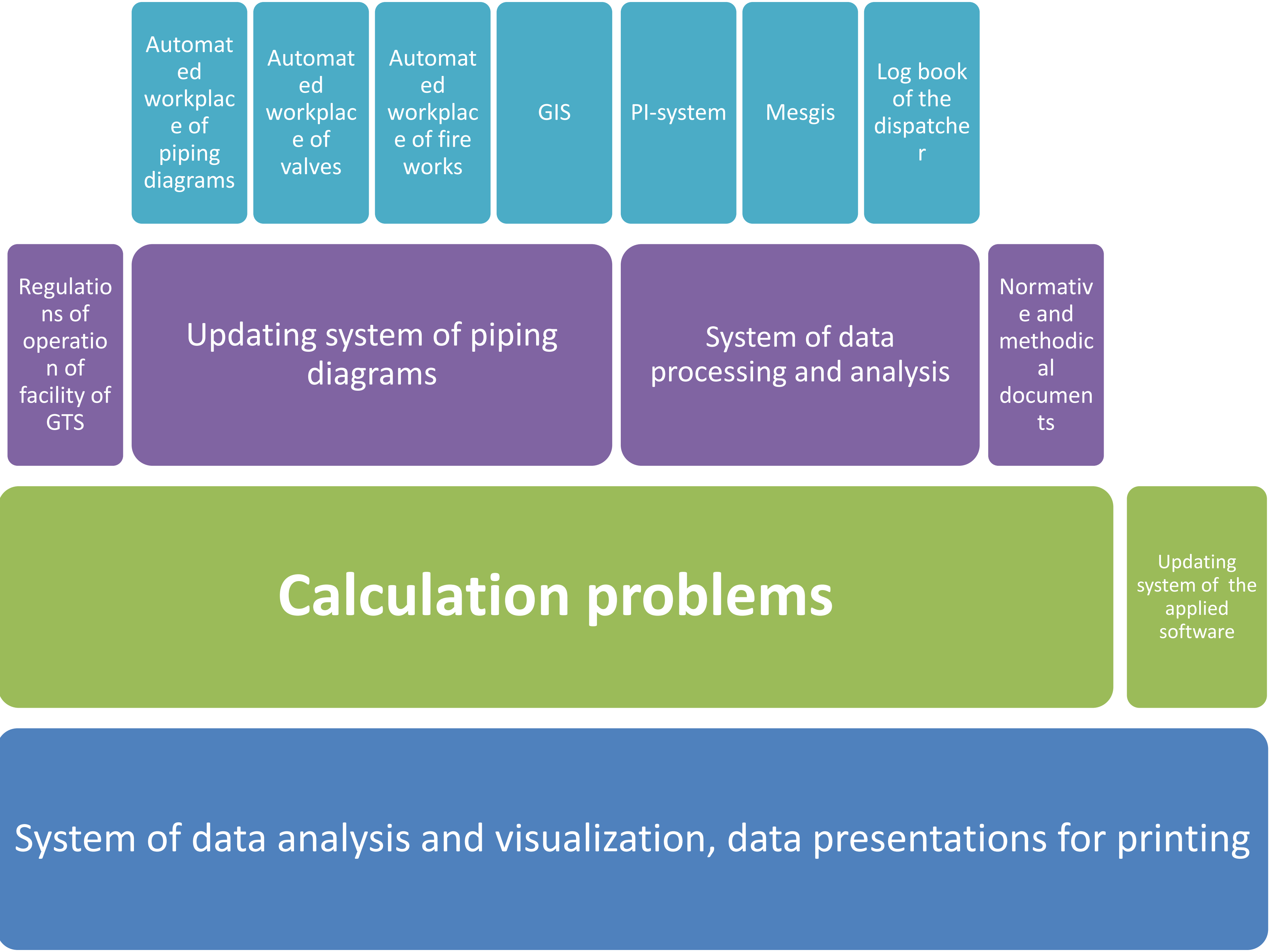
- calculation, optimum planning and forecasting of gas transmission system operation in the conditions of stationary and non-stationary gas movement;
- calculation of optimum parameters of control by gas flows in GTS;
- building according to the measured data of hydrodynamic characteristics of facilities;
- monitoring of facility operation influencing gas distribution in GTS (automated workplace fire works);
- calculation of control parameters by a thermal mode of gas transportation;
- forecasting of caloric content of gas in the given GTS's consumption;
- creation of the automated system of rating selection of energy saving projects for introduction at JSC Ukrtransgas enterprises (power audit);
- calculation of free capacities taking into account component composition of gas (gas caloric content);
- development and adaptation of existing logistic systems, for ensuring effective interaction of dispatching service of gas importer and exporter countries;

RAS (Resource Allocation and Status)

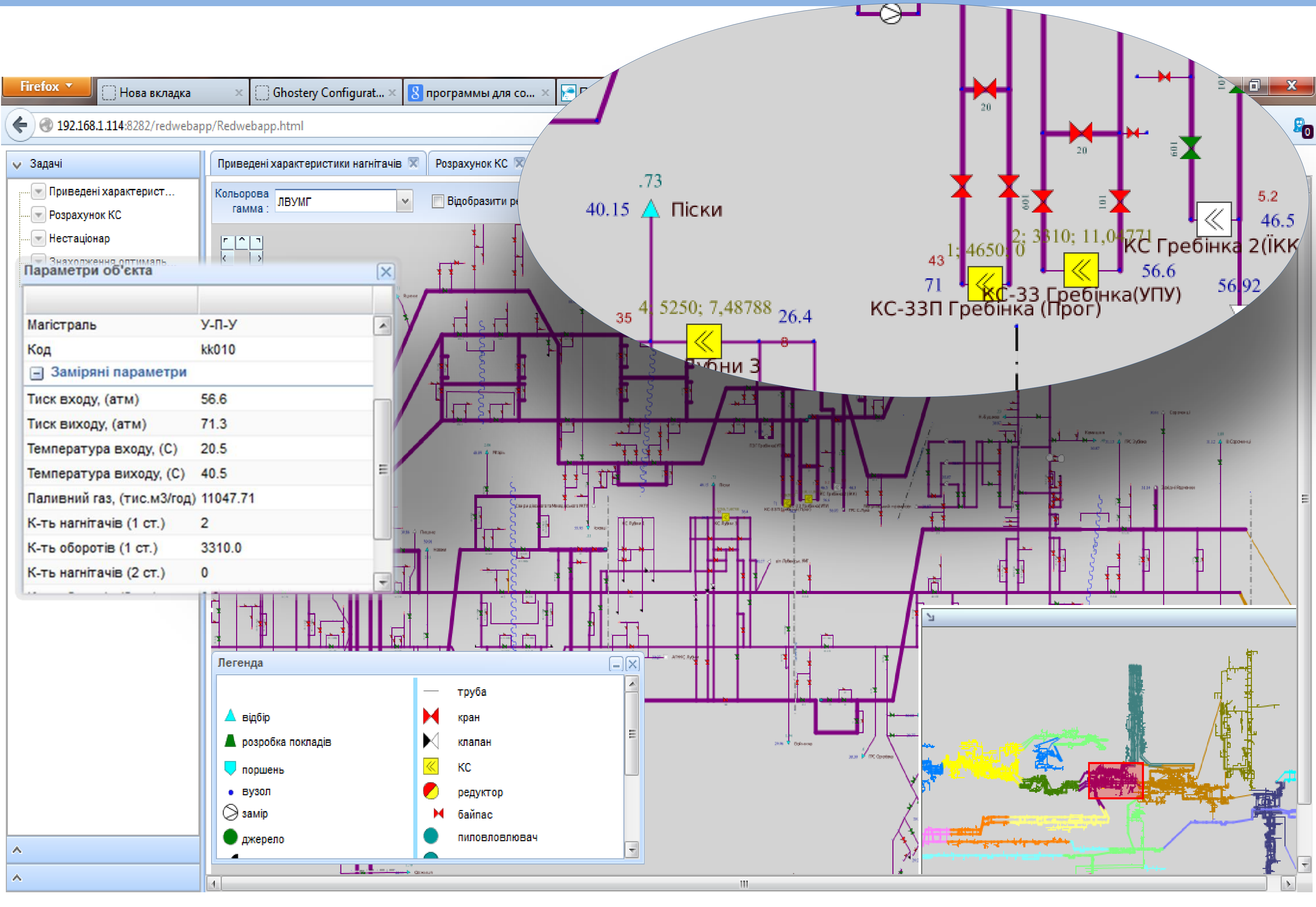
ODS (Operations/Detail Scheduling)

Information support

- operative updating of information support of problems;
- information support of long-term planning of modes;
- information support of operational planning of modes;
- information support of problems of operative finding of control parameters of gas dynamic processes;
- operative forecasting of gas consumption and optimum operational control of UGS;
- calculation of optimum gas extraction from storages with continued support of their total peak capacity


Automated workplace of piping diagrams
Automated workplace of valves
Automated workplace of fire works
GIS
PI-system
Mesgis
Log book of the dispatcher
Regulations of operation of facility of GTS
Updating system of piping diagrams
System of data processing and analysis
Normative and methodical documents
Calculation problems
Updating system of the applied software
System of data analysis and visualization, data presentations for printing

On-line software complex



Realized functionality in WEB

graphic of reduced characteristics of superchargers;

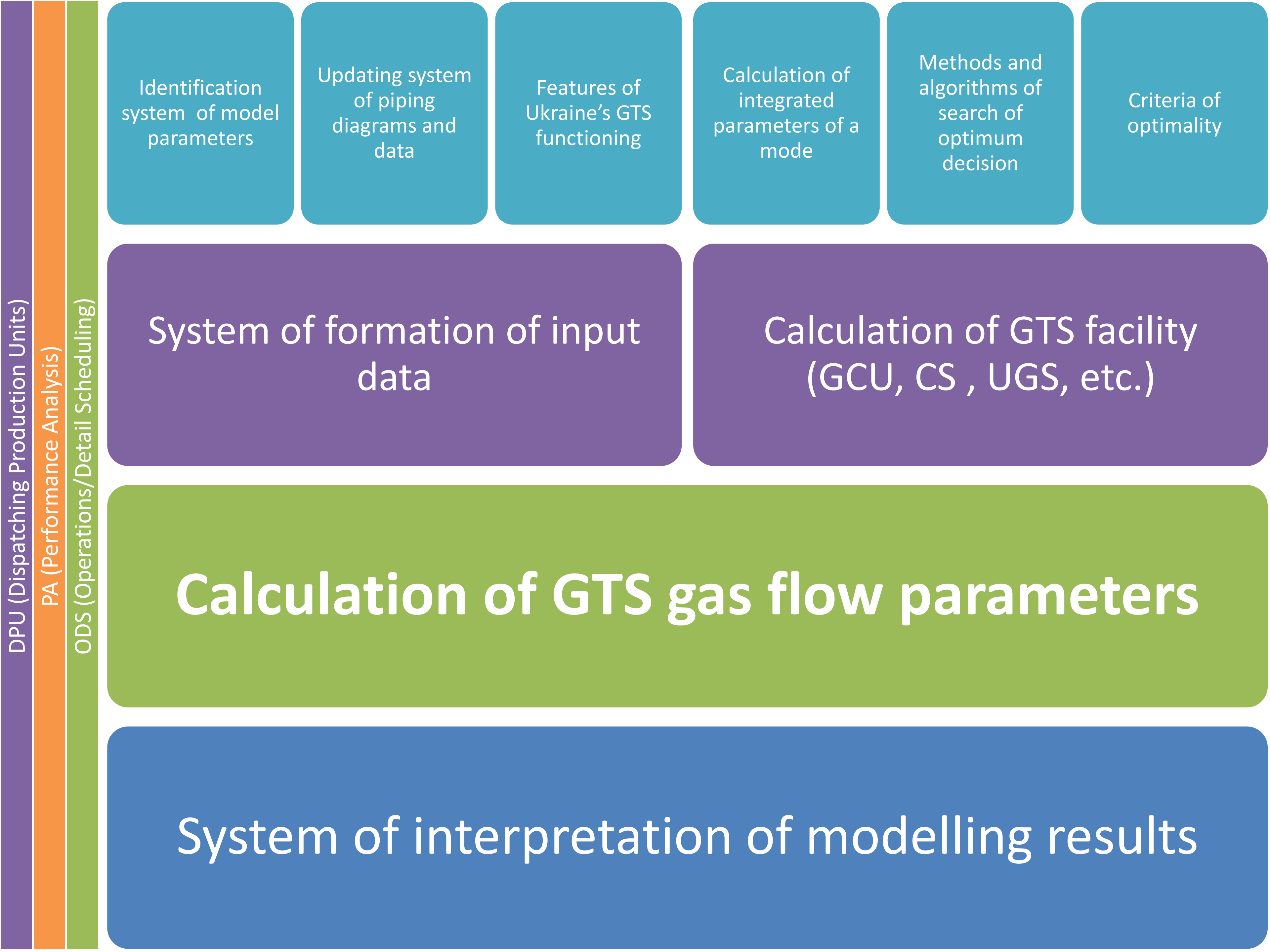
calculation of multi shop CS with polytypic GPA;

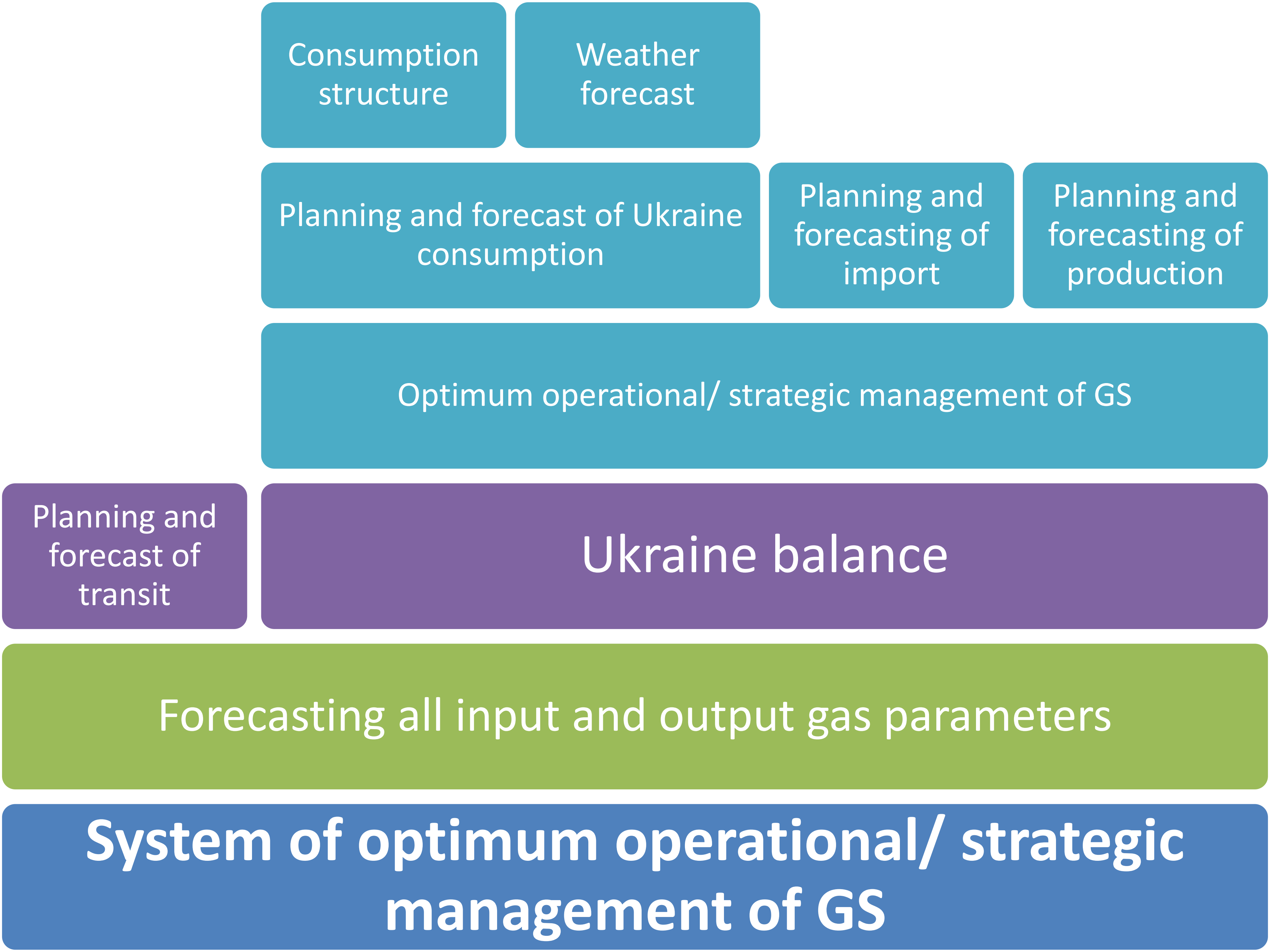
non-stationary calculation of gas pipeline sectors;

optimum planning of GTS operating modes;

Piping diagram of GTS and system of information updating;

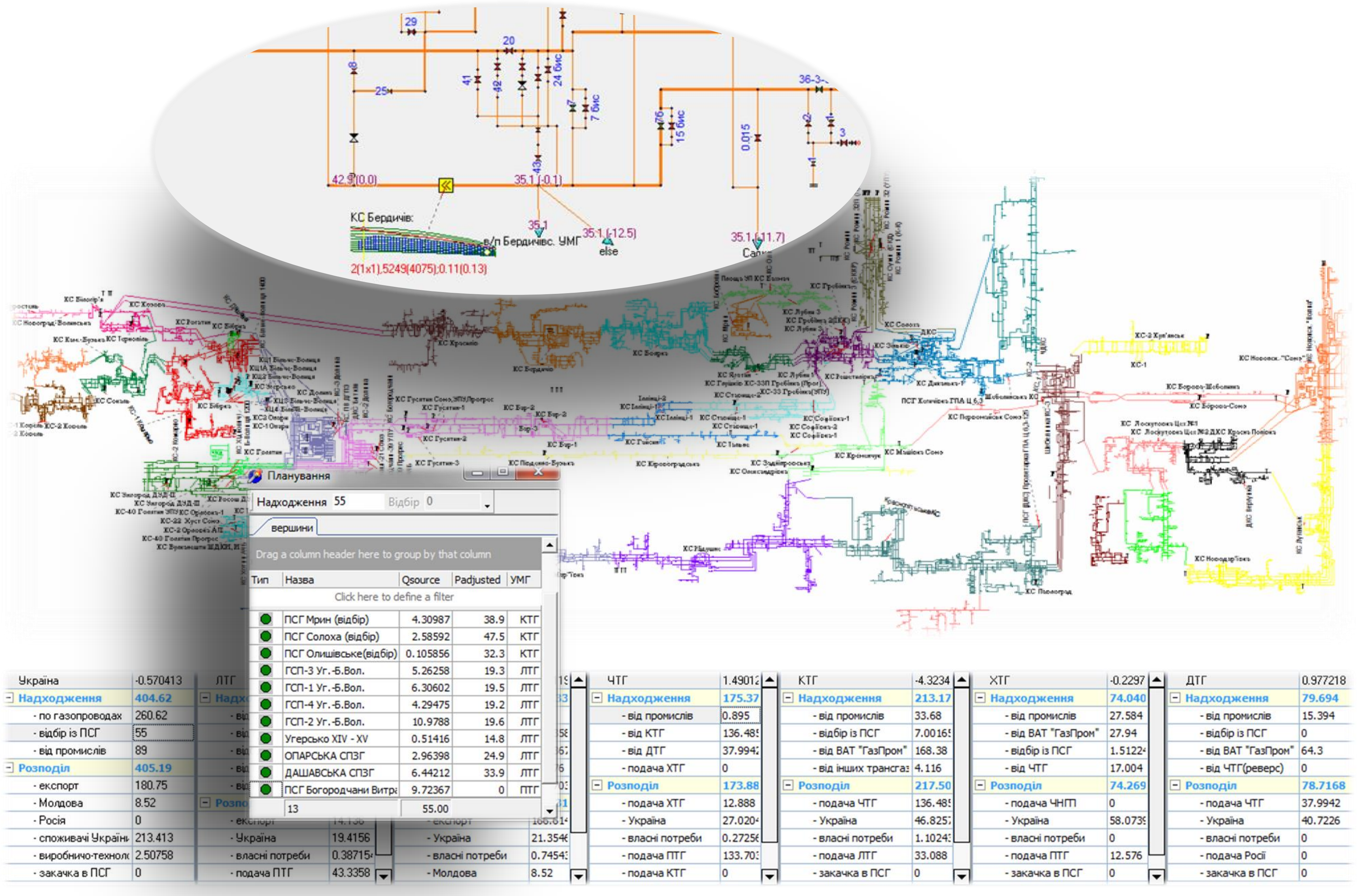
loading, processing and display of data with an automated workplace of the dispatcher and PI-system


DPU (Dispatching Production Units)
PA (Performance Analysis)
ODS (Operations/Detail Scheduling)
Identification system of model parameters
Updating system of piping diagrams and data
Features of Ukraine's GTS functioning
Calculation of integrated parameters of a mode
Methods and algorithms of search of optimum decision
Criteria of optimality
System of formation of input data
Calculation of GTS facility (GCU, CS , UGS, etc.)
Calculation of GTS gas flow parameters
System of interpretation of modelling results

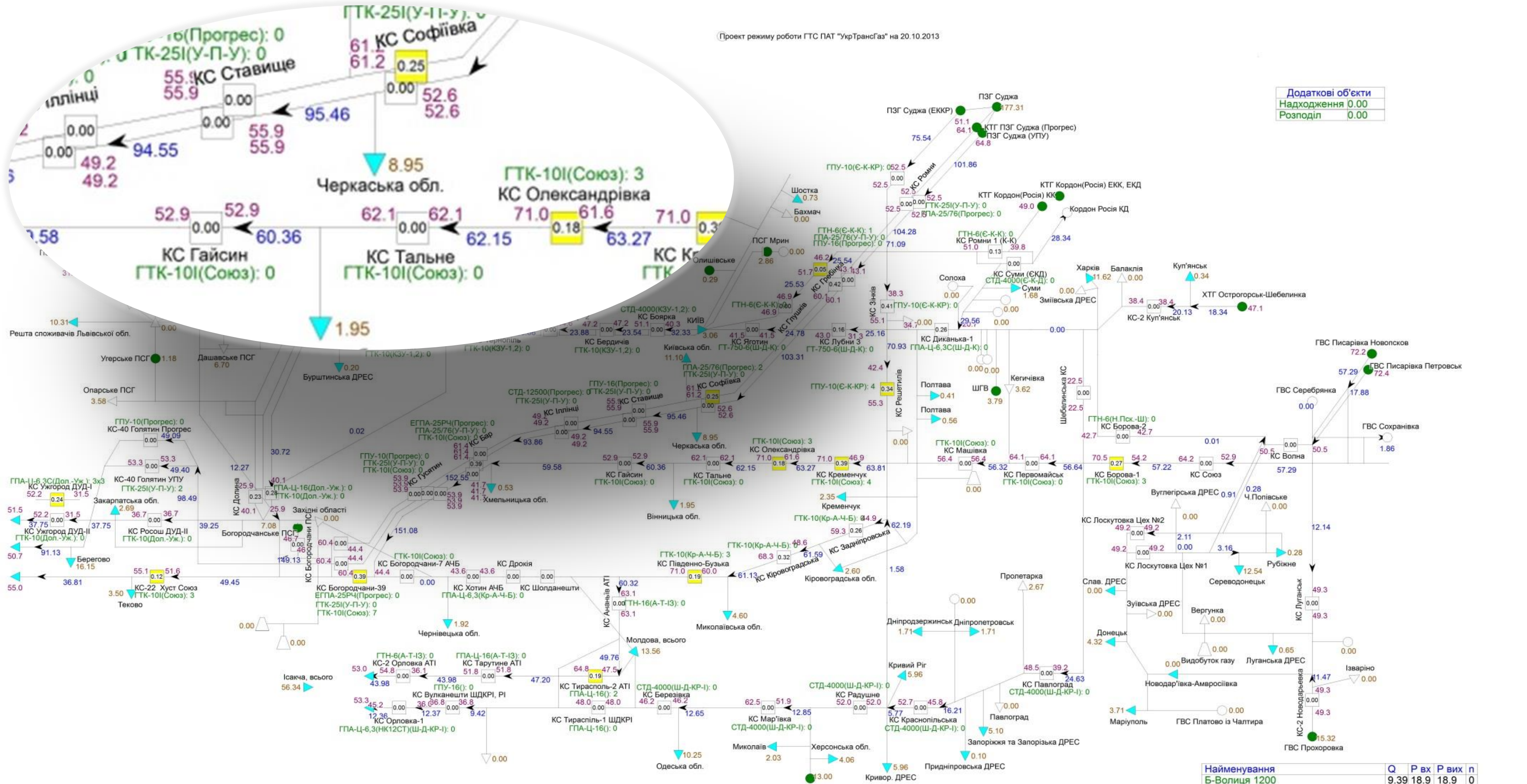


Consumption structure
Weather forecast
Planning and forecast of Ukraine consumption
Planning and forecasting of import
Planning and forecasting of production
Optimum operational/ strategic management of GS
Planning and forecast of transit
Ukraine balance
Forecasting all input and output gas parameters
System of optimum operational/ strategic management of GS

Planning operational regimes of GTS



Flow chart of Ukrainian GTS. Calculated operational regime of GTS



Україна		
Надходження	466.85	Q /міс.
- по газопроводах	315.08	9452.32
- відбір з ПСГ	58.62	1758.60
- від промислів	93.15	2794.52
Розподіл	472.61	
- еспорт	250.48	7514.43
- Молдова	9.79	293.79
- Росія	0.00	0.00
- споживачі України	206.57	6197.22
- вироб-технол. потреби	5.76	172.75
- закачка в ПСГ	0.00	0.00

ГВС	
Надходження	0.00
Розподіл	253.99
- ГВС Дроздовичі	12.30
- ГВС Ужгород	165.69
- ГВС Берегове	16.15
- ГВС Текове	3.50
- ГВС Орловка	56.34

ЛТГ	
Надходження	76.61
- Від промислів	13.57
- Від Белтрансгаз	0.00
- Відбір з ПСГ	42.11
- Від КТГ	20.93
- Від ПТГ(закачка)	0.00
Розподіл	75.28
- Експорт	12.30
- Україна	21.72
- вл. потреби	0.38
- Подача ПТГ	40.89
- Закачка в ПСГ	0.00

ПТГ	
Надходження	274.79
- Від промислів	1.00
- Від ЛТГ	40.89
- Відбір з ПСГ	7.08
- Від ХТГ	12.79
- Від ЧТГ	213.03
Розподіл	270.34
- Експорт	238.18
- Україна	20.92
- Вл. потреби	1.45
- Молдова	9.79
- Закачка в ПСГ	0.00
- Подача ЛТГ(закач)	0.00
- КС Тарутіно	0.00

ЧТГ	
Надходження	240.10
- Від промислів	1.56
- Від КТГ	181.25
- Від ДТГ	57.29
Розподіл	235.68
- Подача ХТГ	0.00
- Україна	20.68
- Вл. потреби	1.97
- Подача ПТГ	213.03
- Подача на ДТГ(реверс)	0.00

КТГ	
Надходження	246.22
- Від промислів	33.75
- Відбір з ПСГ	3.14
- Від ВАТ "Газпром"	205.71
- Від інших трансгазів	3.62
Розподіл	249.89
- Подача ЧТГ	181.49
- Україна	45.51
- Вл. потреби	1.96
- Подача ЛТГ	20.93
- Закачка ПСГ	0.00
- Курська обл.	0.00

ХТГ	
Надходження	48.64
- від промислів	25.82
- від ВАТ "Газпром"	18.34
- відбір з ПСГ	2.67
- від ЧТГ	1.82
Розподіл	71.25
- подача ЧНГП	0.00
- Україна	54.84
- вл. потреби	0.00
- подача ПТГ	12.79
- закачка в ПСГ	0.00
- Подача КТГ	3.62

ДТГ	
Надходження	108.48
- від промислів	17.45
- відбір з ПСГ	0.00
- від ВАТ "Газпром"	91.03
- від ЧТГ(реверс)	0.00
Розподіл	100.19
- подача ЧТГ	57.29
- Україна	42.91
- вл. потреби	0.00
- подача Росії	0.00
- закачка в ПСГ	0.00

Найменування	Q	P вх	P вих	n
Б-Волиця 1200	9.39	18.9	18.9	0
КС Більче-Волиця 1400	0.00	18.8	38.9	0
КЦ2 Більче-Волиця	0.00	0.0	0.0	2
КС Угерсько	1.18	16.8	41.5	7
КЦ1 Більче-Волиця	0.00	0.0	0.0	2
КЦ3 Більче-Волиця	0.00	0.0	0.0	0
КЦ1А Більче-Волиця	0.00	0.0	0.0	2
КЦ4 Більче-Волиця	0.00	0.0	0.0	2
КС Дашава	6.70	14.2	28.3	1
КС-1 Опари	0.00	0.0	0.0	4
КС2 Опари	2.95	0.0	41.7	0
КС Богородчани ПСГ	0.00	0.0	0.0	0
КС Мрин	2.62	40.8	40.8	0
КС Бобровницька	0.00	0.0	0.0	1
КС Солоха	0.00	34.7	56.3	6
ПСГ Кегичівка ГПА Ц 6,3	0.00	61.6	61.6	0
ПСГ [ДКС] Пролетарка ГПА Ц 6,3-125	2.67	28.0	48.5	1
ДКС Красна Попівка	0.00	49.7	49.7	0
ДКС Вергунка	0.00	51.4	51.4	0

Кількість діб у розрахунковому періоді - 30

Тиски вказані в атн, обсяги газу - млн.м3/добу

20.10.2013 10:45

Characteristic of the program module - calculation of stationary modes

model of a gas transmission system includes all facilities which are presented on piping diagrams;

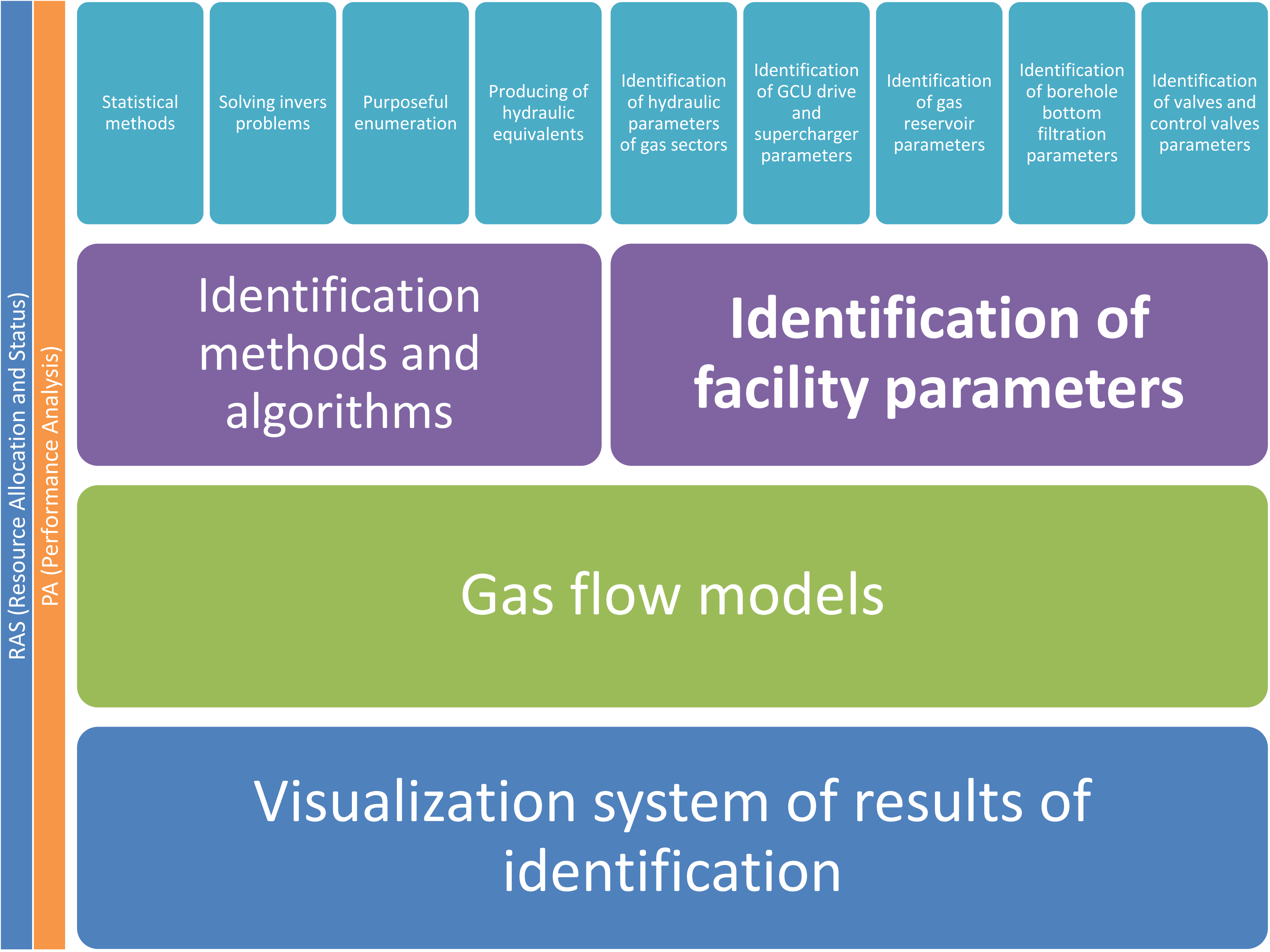
methods of decision search aren't attached to type of mathematical representation of facility models and various options of specification of compressor station models;

inclusion in the GTS model of facilities of discrete action (for example, irreversible valves) is possible;

fast convergence of a method is provided at inclusion in model of tens of thousands of facilities at method start from zero initial conditions;

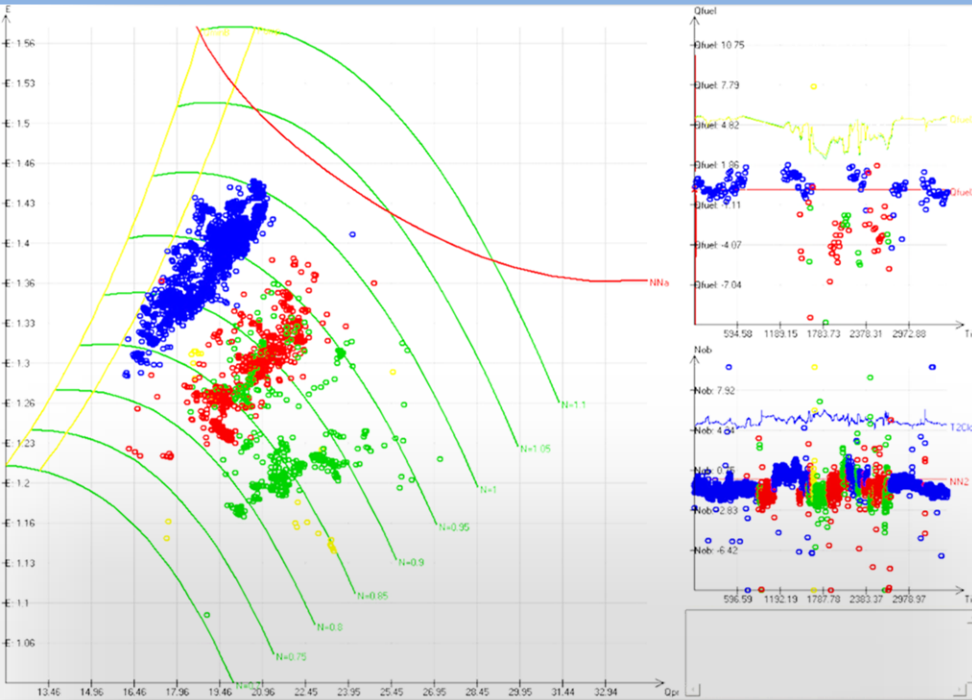
optimization of flow distribution and multishop CS is connected to polytypic GCU;

methods of identification of parameters of models work in the conditions of incompleteness of data



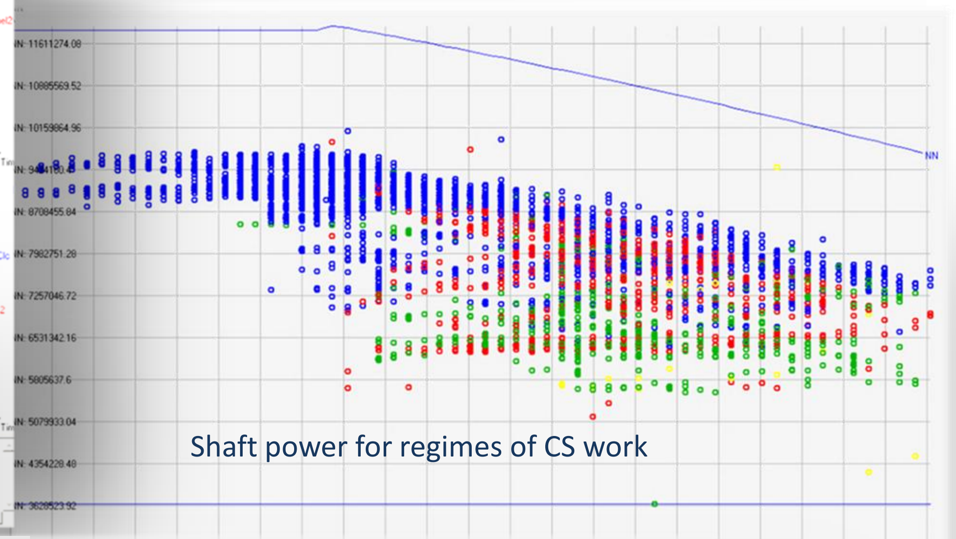
RAS (Resource Allocation and Status)
PA (Performance Analysis)
Statistical methods
Solving invers problems
Purposeful enumeration
Producing of hydraulic equivalents
Identification of hydraulic parameters of gas sectors
Identification of GCU drive and supercharger parameters
Identification of gas reservoir parameters
Identification of borehole bottom filtration parameters
Identification of valves and control valves parameters
Identification methods and algorithms
Identification of facility parameters
Gas flow models
Visualization system of results of identification

Computation of parameters of compressor stations



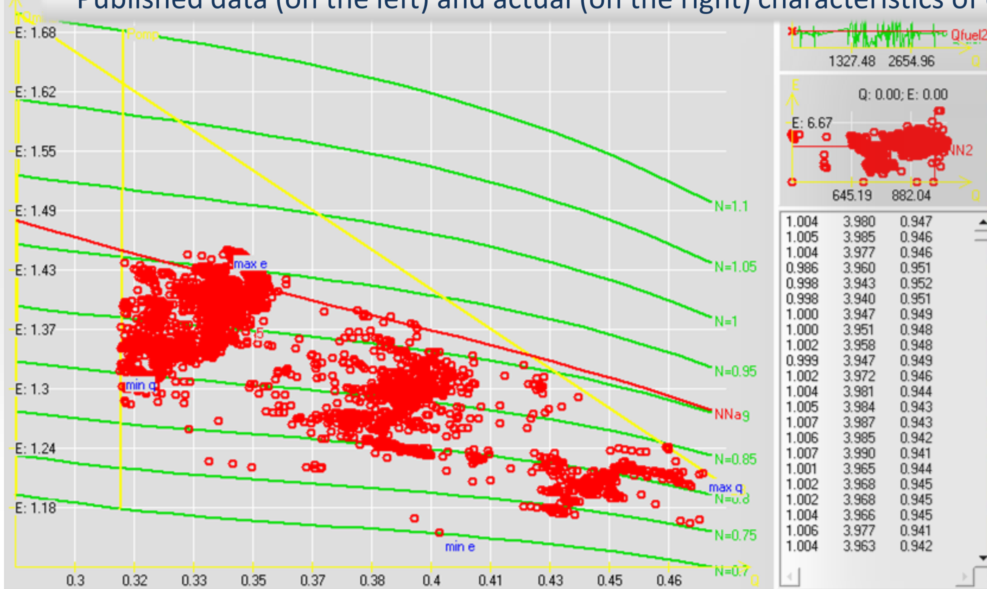
Analysis of work supercharger CS Borova (RF2BB-30) during year 2007 (about 3600 work points)

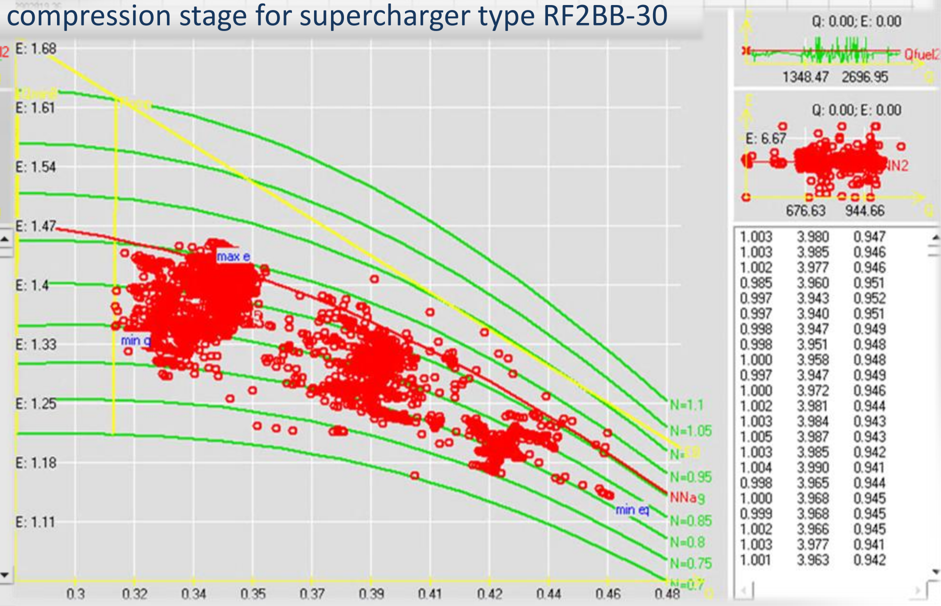
blue points – regime of 5 GPU , red points –regime of 4 GPU, green points – regime of 3 GPU, yellow points – regime of 2 GPU.



Shaft power for regimes of CS work

Published data (on the left) and actual (on the right) characteristics of compression stage for supercharger type RF2BB-30





RAS (Resource Allocation and Status)

PM (Process Management)

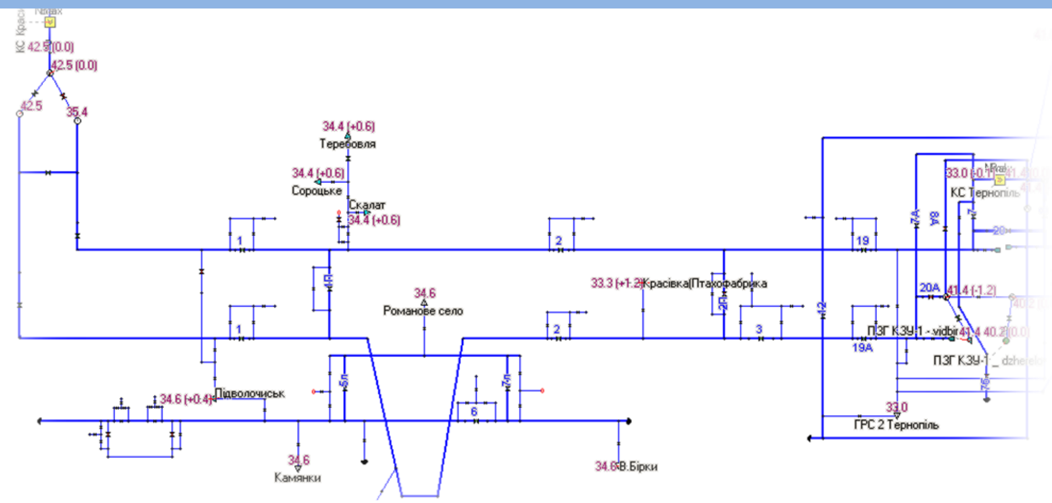
PA (Performance Analysis)

ODS (Operations/Detail Scheduling)

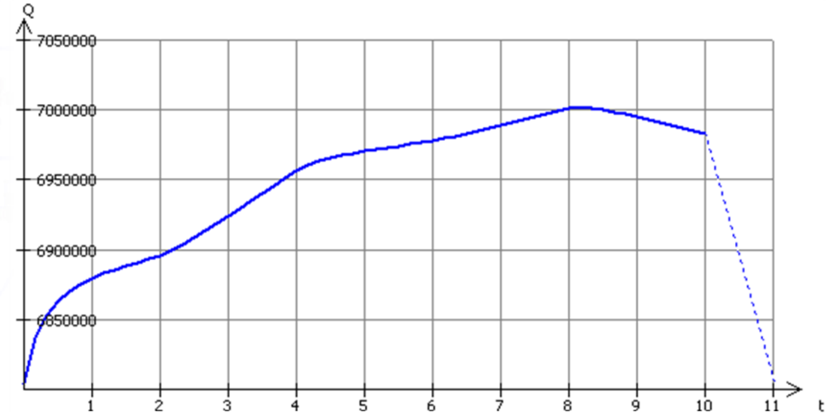
Results

- the volume of the accumulated gas in system and in any allocated subsystems;
- dynamics of change of volumes of the accumulated gas in any allocated subsystems;
- commodity transport work (CTR) for the allocated subsystems and consumers of gas;
- fuel – energy resources on CTR unit for the allocated subsystems and gas consumers;
- balance, gas imbalance;
- the analysis of efficiency of use fuel – energy resources on a mode;
- calculation of caloric content of gas for each consumer;
- calculation of free capacities taking into account component composition of gas (gas caloric content).

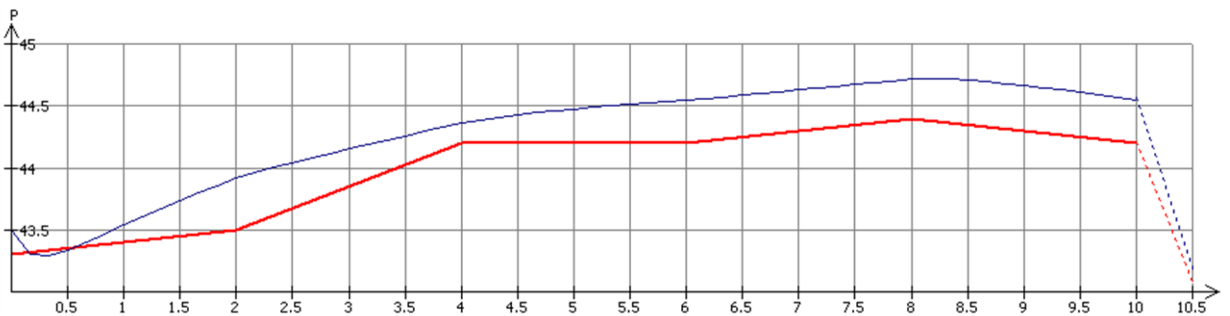
Calculation of non-stationary modes



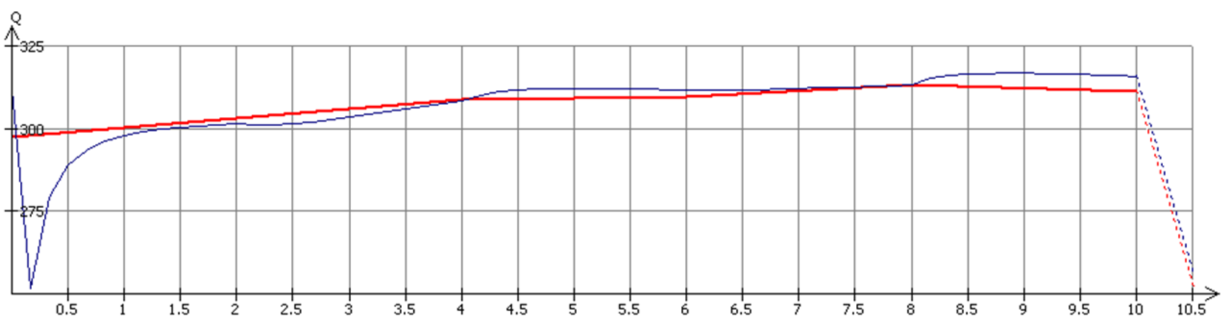
The piping diagram of a sector of the KS gas pipeline Krasilov – KS Ternopol



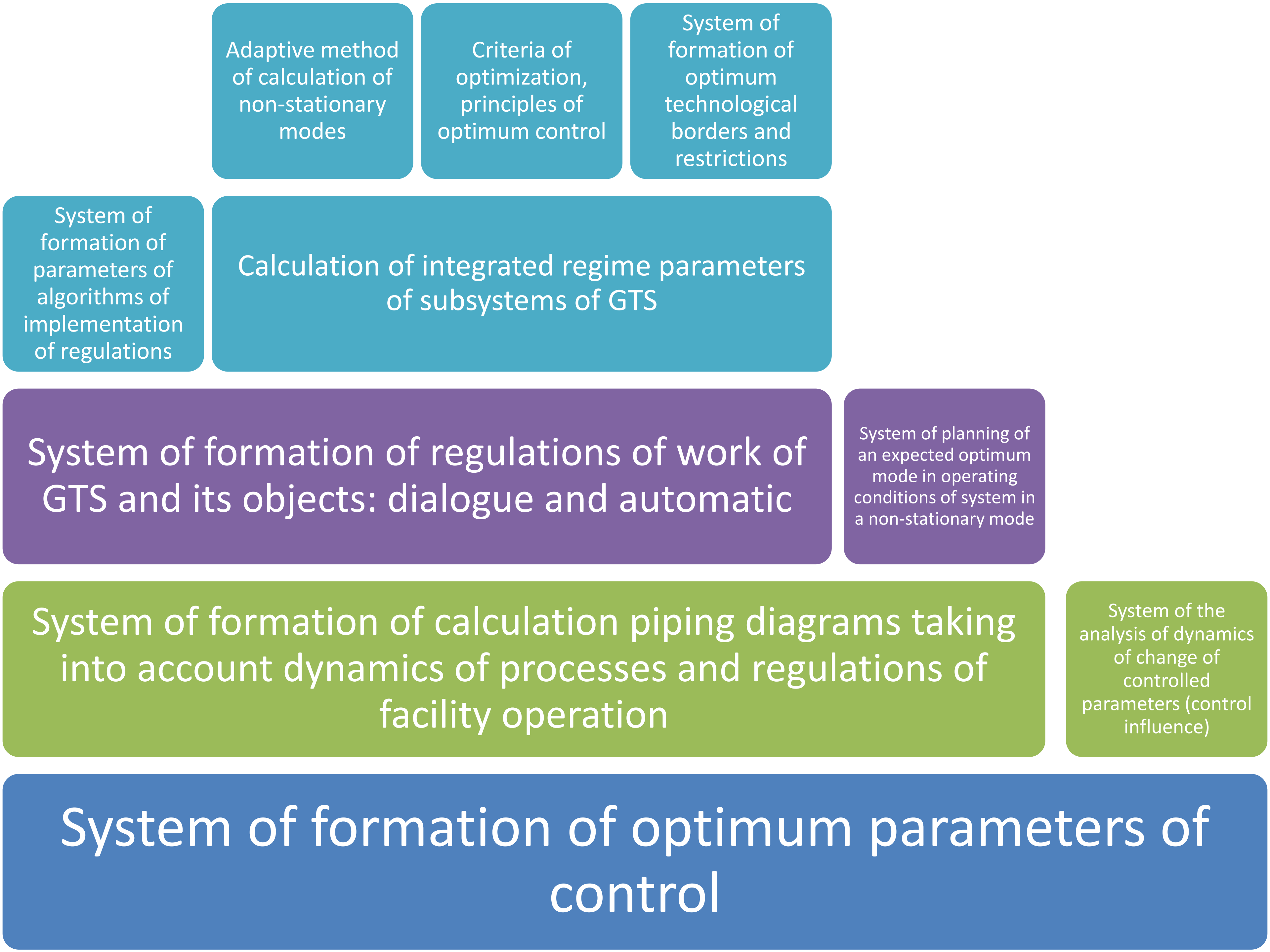
The graphic of change of volume of the accumulated gas in system (calculated)



Graphics of change of pressure of KS gas Krasilov (the red – measured, blue – calculated)



Schedules of change of a consumption of KS Ternopol gas (the red - measured, blue - calculated)

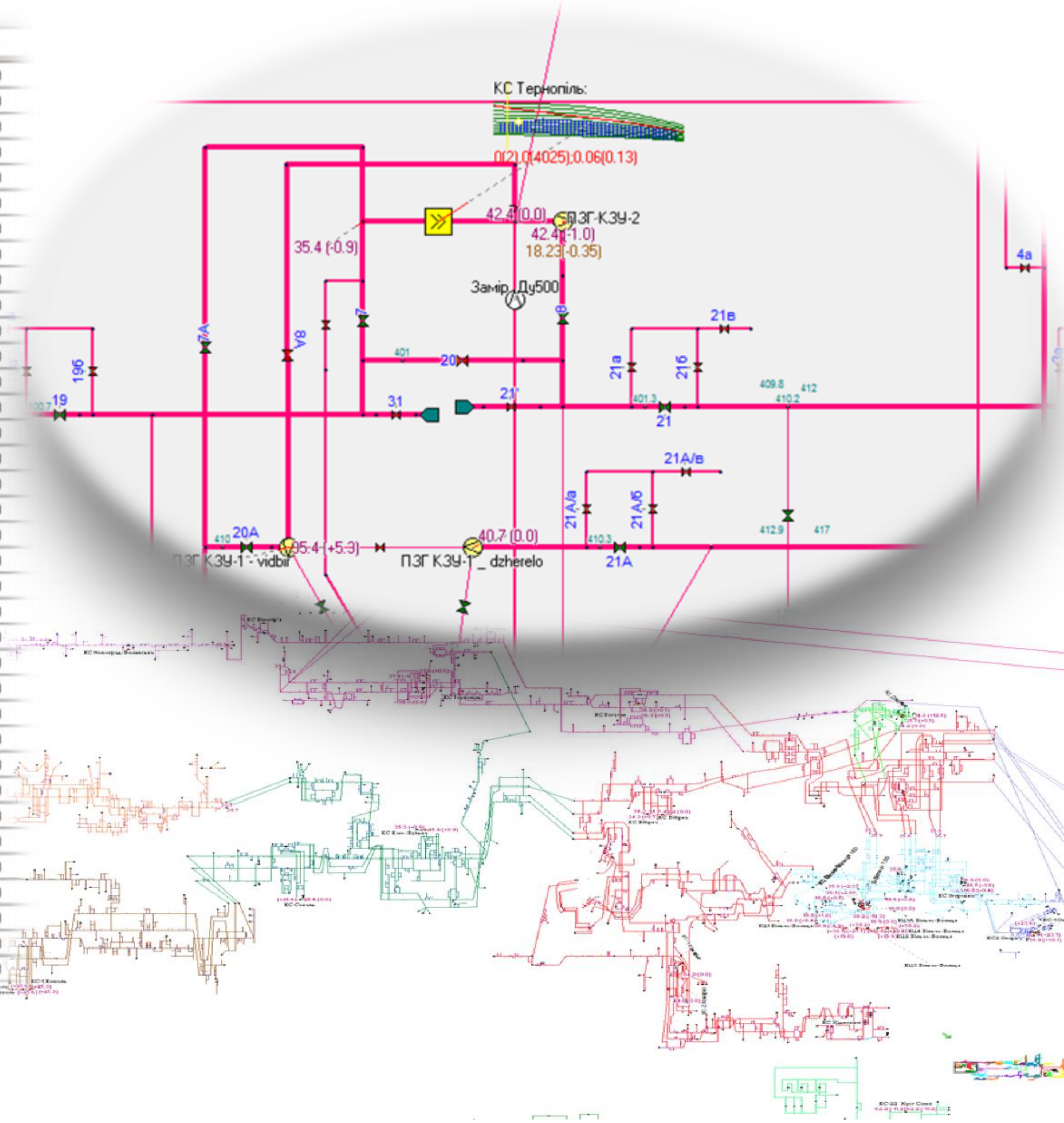


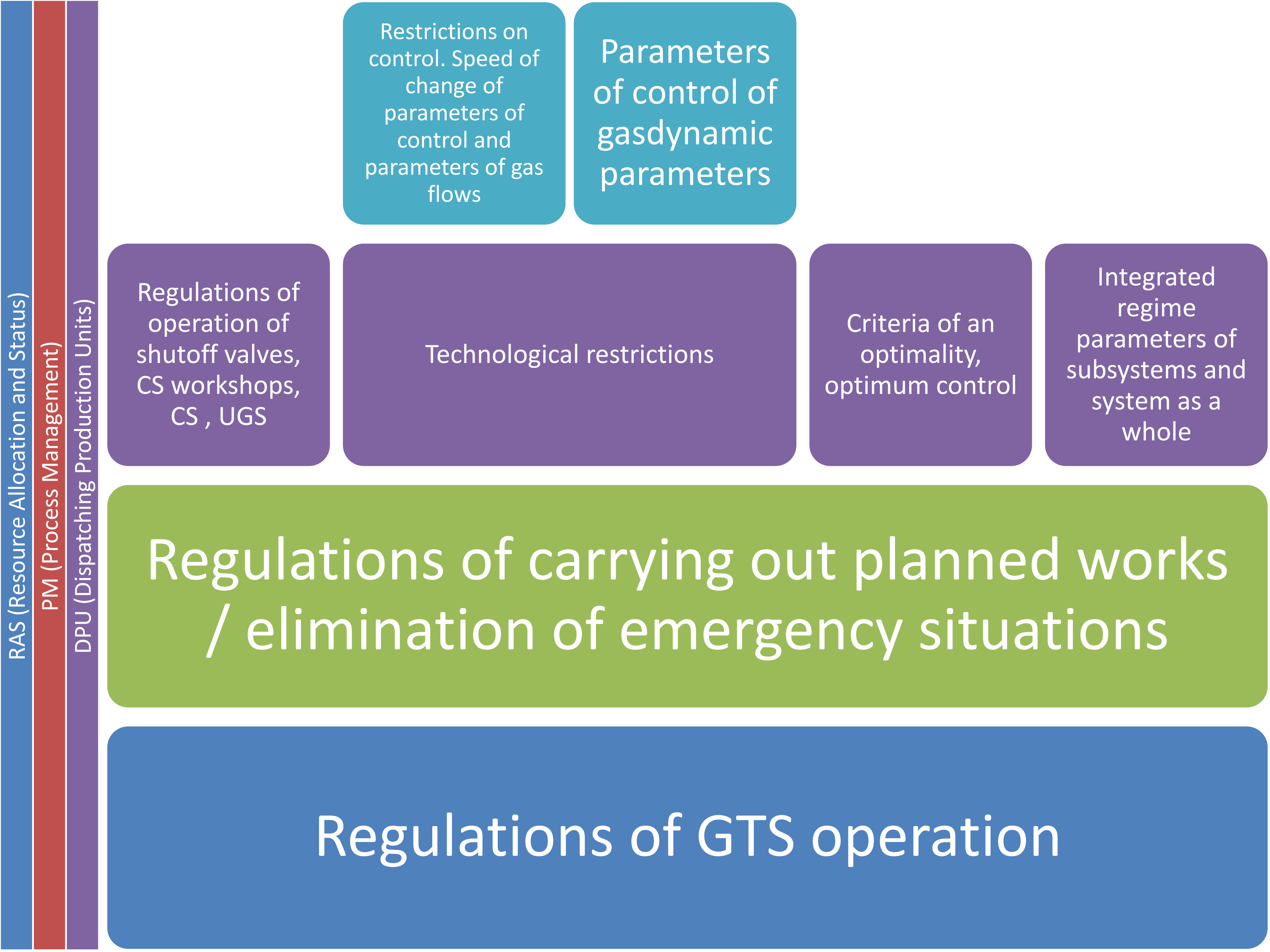
Adaptive method of calculation of non-stationary modes
Criteria of optimization, principles of optimum control
System of formation of optimum technological borders and restrictions
System of formation of parameters of algorithms of implementation of regulations
Calculation of integrated regime parameters of subsystems of GTS
System of formation of regulations of work of GTS and its objects: dialogue and automatic
System of planning of an expected optimum mode in operating conditions of system in a non-stationary mode
System of formation of calculation piping diagrams taking into account dynamics of processes and regulations of facility operation
System of the analysis of dynamics of change of controlled parameters (control influence)
System of formation of optimum parameters of control

Calculation of non-stationary modes

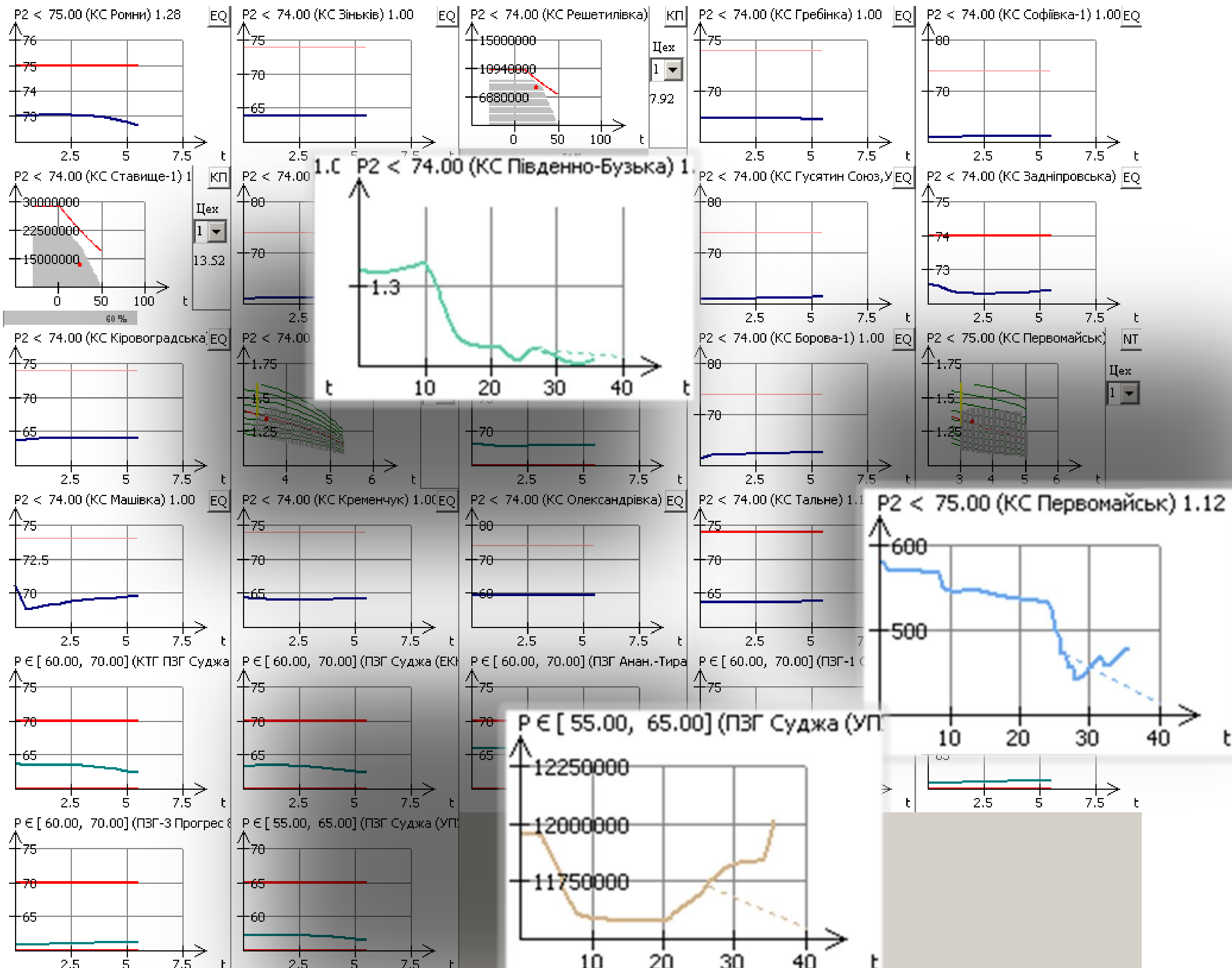
Click here to define a filter

В.п. Рів	wl030	-0.0139999993	-0.0120000005	Q	03.11.2012	00:00:00
АГНКС ТОВ "АРЕТІ"	al054	-0.0060000002	-0.0049999999	Q	03.11.2012	00:00:00
КС Тернопіль	kl011	1.40350881889	1.38938049064	E	03.11.2012	00:00:00
КС Бібрка	kl044	1.34890969767	1.37658226186	E	03.11.2012	00:00:00
КЦ2 Більче-Волиця	kl064	17.7600001464	18.0479997070	Q	03.11.2012	00:00:00
КС Більче-Волиця 1400	kl068	17.7600001464	18.0479997070	Q	03.11.2012	00:00:00
КЦ1А Більче-Волиця	kl063	17.7600001464	18.0479997070	Q	03.11.2012	00:00:00
ПЗГ Кобрин	zl021	15.5280005859	15.6000001464	Q	03.11.2012	02:00:00
Надх. від ПрикарпатТГ	zl053	-17.472000585	-16.776000439	Q	03.11.2012	02:00:00
ПЗГ Мозир	zl091	9.64799978027	9.81600029296	Q	03.11.2012	02:00:00
КС Красилів	kk015	3.06974542236	2.84584943847	Q	03.11.2012	02:00:00
КС Тернопіль	kl011	1.38938049064	1.39732141830	E	03.11.2012	02:00:00
КС Бібрка	kl044	1.37658226186	1.40384609506	E	03.11.2012	02:00:00
ПЗГ Кобрин	zl021	15.6000001464	15.4800004394	Q	03.11.2012	04:00:00
	zl041	-11.232	-11.208000585	Q	03.11.2012	04:00:00
Надх. від ПрикарпатТГ	zl053	-16.776000439	-16.728000292	Q	03.11.2012	04:00:00
ГСП-1 Уг.-Б.Вол.	pl014	5.59199992675	5.832	Q	03.11.2012	04:00:00
ГСП-4 Уг.-Б.Вол.	pl017	5.47199989013	5.49599996337	Q	03.11.2012	04:00:00
ГСП-3 Уг.-Б.Вол.	pl016	6.98400021972	7.15200007324	Q	03.11.2012	04:00:00
	gl061	1.03200001831	1.10399999084	Q	03.11.2012	04:00:00
	gl061	-1.0320000183	-1.1039999908	Q	03.11.2012	04:00:00
Б.-В. 1400	kl068a	18.0479997070	18.4799997070	Q	03.11.2012	04:00:00
ЛТГ БВ 1200	kl068b	-18.047999707	-18.479999707	Q	03.11.2012	04:00:00
ПЗГ Мозир	zl091	9.81600029296	9.86399978027	Q	03.11.2012	04:00:00
КС Тернопіль	kl011	1.39732141830	1.38116593232	E	03.11.2012	04:00:00
КС Бібрка	kl044	1.40384609506	1.41935483870	E	03.11.2012	04:00:00
КЦ2 Більче-Волиця	kl064	18.0479997070	18.4799997070	Q	03.11.2012	04:00:00
КС Більче-Волиця 1400	kl068	18.0479997070	18.4799997070	Q	03.11.2012	04:00:00
КЦ1А Більче-Волиця	kl063	18.0479997070	18.4799997070	Q	03.11.2012	04:00:00
ПЗГ Кобрин	zl021	15.4800004394	15.7199998535	Q	03.11.2012	06:00:00
	zl041	-11.208000585	-11.255999414	Q	03.11.2012	06:00:00
Надх. від ПрикарпатТГ	zl053	-16.728000292	-16.344000439	Q	03.11.2012	06:00:00
	gl061	1.10399999084	1.08	Q	03.11.2012	06:00:00
	gl061	-1.1039999908	-1.08	Q	03.11.2012	06:00:00
ПЗГ Мозир	zl091	9.86399978027	9.76800014648	Q	03.11.2012	06:00:00
КС Тернопіль	kl011	1.38116593232	1.37837834819	E	03.11.2012	06:00:00




RAS (Resource Allocation and Status)
PM (Process Management)
DPU (Dispatching Production Units)
Restrictions on control. Speed of change of parameters of control and parameters of gas flows
Parameters of control of gasdynamic parameters
Regulations of operation of shutoff valves, CS workshops, CS , UGS
Technological restrictions
Criteria of an optimality, optimum control
Integrated regime parameters of subsystems and system as a whole
Regulations of carrying out planned works / elimination of emergency situations
Regulations of GTS operation

Formation of parameters of management



The characteristic of the program module - calculation of non-stationary modes

the GTS mathematical model for calculations of non-stationary modes includes models of all objects which are presented on detailed piping diagrams;

speed and stability of a method are provided with algorithm of modification of the piping diagram according to parameters (they can be changed);

the method works taking into account previously created regulations and taking into account available technical and technological restrictions;

method adaptive to the speed of change of gasdynamic parameters;

in a mode of manual control of gas-flows all key parameters of control of compressor stations - productivity, turns of centrifugal superchargers, input and output gas parameters, etc. are available to the user;

before carrying out modeling it is provided indentification of system to a non-stationary mode

The characteristic of the program module - formation of parameters of gas-flow control

controls it is formed in the conditions of achievement of technological limits, borders of areas and corridors of change of controlled parameters;

technological borders are formed on the basis of the forecast of inflows, consumption of gas and criteria of optimum control;

possible options of operation - in an automatic and in a dialogue mode with a choice of options;

the automatic mode forms regulations of operation of compressor stations independently;

the optimum multiple parameter trajectory of movement of gasdynamic processes is formed by algorithm of optimum planning of a mode on the basis of expected information;

speed of transitional non-stationary processes is regulated by the speed of change of parameters of gas on system inputs and outputs

Optimization potential

№	Factor	Optimization potential to (%)	
1	Redistribution of volumes of the accumulated gas which is available in system, between separate subsystems, including its change	5	
2	Timely transition from two - three-staged gas compression on one-two step compression of gas	23	
3	Redistribution of flows between shops of multishop CS	6 - 8	
4	Redistribution of flows of gas between the main gas pipelines	3 - 4	
5	Minimization of quantity of working GCU	3 - 11	
6	Redistribution of a consumption of gas between the same GCU	1	
7	Control of a temperature mode of transport of gas – AC (air cooler) gas cooling. Control of fans - quantity and rotation frequency within a year (the economy during certain periods is possible behind the electric power)	5 - 10 50	**the increase in capacity of the main gas pipeline to 3% is possible**
8	Threads of gas pipelines on pass		

Projected developments

- to construct peak regime parameters of UGS operation in the field of change of pressure in the gas main (for operational control of UGS);
- advance and operational planning of UGS operation by various criteria (optimum and peak capacity) for the set period of gas extraction- pumping;
- calculation of parameters of a temperature mode of transportation of gas in the conditions of non-stationary processes (in three-dimensional statement);
- development of a program complex for control of a thermal mode of transportation of gas;
- calculation – forecasting of caloric content of gas on the given GTS sector;
- calculation of free capacities taking into account component composition of gas (gas caloric content);
- logistic systems for ensuring effective interaction of dispatching services of the countries of importers and exporters of gas;
- assessment of losses of gas on sectors of gas pipelines (to prove real and to create standard data);
- development of a software for control of joint operation of UGS and GTS;
- development of a software for carrying out calculations of parameters of a gas-liquid flows in pipelines at stationary and non-stationary operating modes with pressure to 30 MPas;
- development of economical and technological model and software for optimization of financial and material resources for ensuring effective operation of system of transportation and gas storage;
- development of the automated system of rating selection of energy saving projects for implementation at JSC Ukrtransgaz enterprises;
- economical and technological optimizing problems of reconstruction of GTS.

PROBLEMS FOR DISCUSSIONS

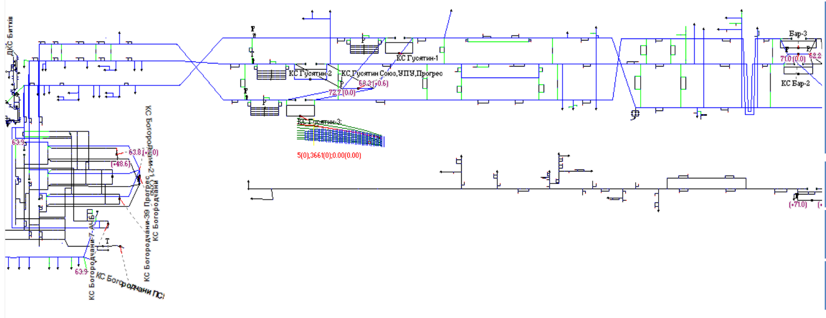
Optimization, optimum planning and optimum control of gasdynamic and filtrational processes. Criteria of an optimality, principles of optimum control and their realization in actual practice uncertainty

Imbalances, standards, techniques and metrology. Existing area of uncertainty. Problems of accuracy of measurement, calculations and modeling

System assessment of quality of a mode. Comparative analysis of modes

Optimum control of resources in order to ensure the reliability of transportation and gas storage. Estimation of degradation processes. Planning of modernization, reconstruction and projecting scenarios of gas transmission system operation

Applications of the software complexes



Суммарная производительность по трем нитям (млн.м3/сутки)	Расход топливного газа (параллельно работающие цеха)(млн.м3/сутки)	Расход топливного газа (один цех на проход) (млн.м3/сутки (снижен. расходов в %))
180	0,42	0,38 (11%)
210	0,53	0,50 (6%)
230	0,67	0,66 (2%)

Численные эксперименты проведены на программном комплексе для оценки эффективности использования агрегатов фирмы WARTSILA по топливному газом по сравнению с существующими агрегатами, при заданных давлениях на входе и выходе ДКС. На выходе ДКС принималось 5.5 МПа.

Отбор газа (млн. $м^3$)

Дни	Q_1	Q_{1p}	Q_2	Q_{2p}	%
10					
20	102,2	0,14			
30	106,8	0,18	100	0,27	164%
40	106,7	0,21	100	0,29	144%
50	106,5	0,26	100	0,34	140%
60	106,4	0,29	100	0,38	138%
70	106,3	0,32	100	0,46	154%
80	106,2	0,35	100	0,63	193%
90	102,8	0,36	100	0,66	186%
100	108,6	0,42	100	0,68	177%
110	101	0,42	100	0,71	172%
120	107,1	0,47	100	0,74	169%
130	100,8	0,47	100	0,77	165%
140	106,3	0,52	100	0,83	169%
150	102,4	0,62	100	0,85	139%

Дни	Q_1	Q_{1p}	Q_2	Q_{2p}	%
10	124,6	0,12			
20	127,8	0,23	122	0,32	145
30	128,9	0,33	122	0,44	139
40	127,7	0,43	122	0,8	194
50	128,5	0,57	122	1,04	191
60	123,8	0,73	100	0,8	136
70	113,2	0,78	100	0,91	131
80	101,6	0,78	95	0,95	131
90	95,1	0,78	89	0,97	132
100	81,5	0,73	81	0,95	131
110	70,9	0,63	66	0,76	130
120	66,9	0,63	61,5	0,72	125
130	57,3	0,63			
140	47,8	0,52			
150	43	0,47			
160	38,2	0,42			
165	38,2	0,42			

Нагнетание газа(млн. $м^3$)

Main results of GTS

1 . The offered mathematical model of the gas transmission system which includes all facilities which are involved in transportation and gas storage.

2 . Methods of the solving of systems of the polytypic nonlinear equations which solutiions satisfy to technological limits of operation of the main facilities which are involved in gas transportation.

3 . The algorithm of hydraulic calculation of multishop compressor stations with polytypic gas-compressor units (GCU) that allowed to consider individual characteristics of each GCU and to carry out the analysis of influence of change of regime parameters of each GCU on CS operating mode as a whole.

4 . The algorithm of finding of optimum regime parameters of the gas-flows, considering the size of the total accumulated gas in GTS and in its parts.

5 . Methods of identification of model parameters and technological condition of facilities that allowed to consider aprioristic uncertainty of conditions of their functioning and to provide the necessary accuracy of planning of parameters of operating modes of GTS.

6 . Problems of calculation of non-stationary modes of movement of gas with an accuracy, commensurable with an accuracy of measurement of regime parameters for sectors of gas pipelines which pass on a rough country are solved.

7 . Methods of optimization of difficult gas transmission systems are developed, methods and the principles of optimum control by gas-flows in GTS in the conditions of non-stationary modes are developed and realized.

8 . The applied software which provided high level of automation of process of the solution of regime and technological problems.

9 . There passes approbation system of formation of parameters of optimum control of gas-flows, taking into account existing degree of uncertainty, as on input parameters, and parameters of a condition of facilities.

Main outcomes of UGS

Development of non-stationary models and analytical and numeric methods of calculation and analysis of gas dynamic and filtration processes of at GS technological facilities

Receiving nonlinear shed characteristic of beds and borehole bottoms

Exploring impact of parameter of perforation canals and holes with open borehole bottom on GS operation;

Exploring of correlation of geometric, collectors and filtration properties with boreholes and beds operating technological modes with the effect of major factors taken into account;

Solving a whole rang of direct and inverse operation problems

Comprehensive, numerical GS research using measure data covering many years has shown that in many cases earlier interpretations of bed parameters did not agree with actual parameters.

Developed iteration procedures ensured sufficient accuracy of calculation of shared parameters(pressure, permeability etc.) and control with sufficient accuracy parameters of material balance of GS bed. At present two dimension gas filtration model in porous heterogeneous beds is sufficient enough in terms of accuracy and efficiency of calculation problems.

The research has shown that:

for most boreholes the ratio of quality of reservoir opening is well below one;

there is a potential to increase the productivity of certain boreholes due to additional perforation and drilling of a borehole bottom;

In general the potential to increase the productivity of storage reservoir does not always depend on the potential to increase productivity of boreholes;

there is top limit to economic expedience of increasing density of perforation canals of boreholes;

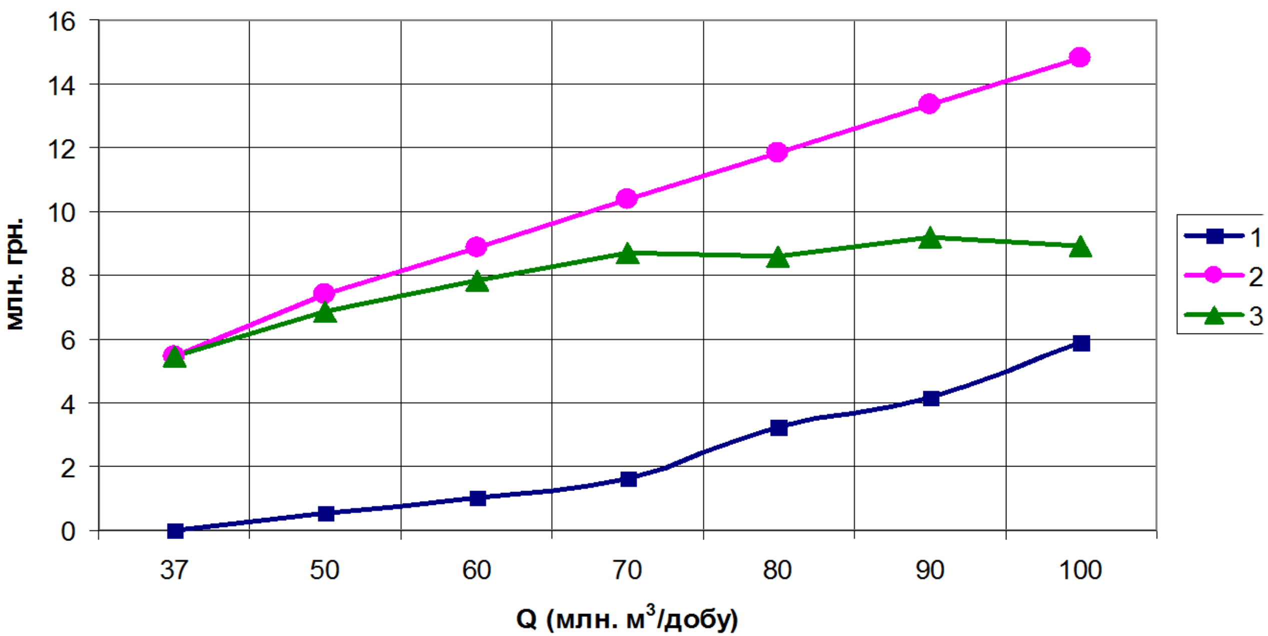
the flow rate of a given borehole significantly depends of the open filtration area;

for certain boreholes, drilling borehole bottom area within horizontal boundaries may result in a 2.5 – fold increase in flow rate on average;

the total affect of increasing of productivity of UGS with open borehole bottoms may amount to up to 25 % of the UGS productivity established on the basis of theoretical calculation;

open borehole bottom yields on average a 15% increase in UGS peak capacity and 20% reduction of total gas withdrawal time, with no higher energy expenditures incurred.

Examples of application of software



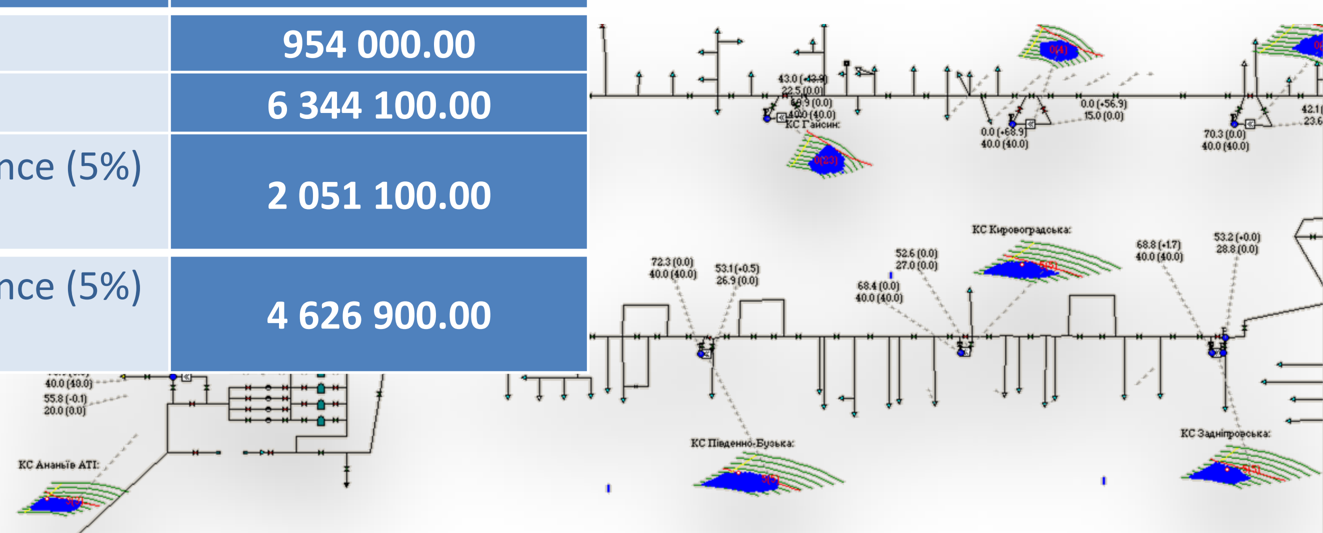
Graphics of dependence of cost of fuel gas and gas pipeline productivity.

1 - costs of transport

2 - transit costs

3 - difference between the second and the first graphics (profit)

ACTIONS	EFFECT (UAH)
Supercharger replacement	**954 000.00**
GCU replacement	**6 344 100.00**
Increase in pressure on CS entrance (5%) and supercharger replacement	**2 051 100.00**
Increase in pressure on CS entrance (5%) and GCU replacement	**4 626 900.00**



Characteristic of object of research

DESCRIPTION OF GAS-TRANSSMISION SYSTEM AC UKRTRANSGAS			
PARAMETERS OF GTS		UNITS	AMOUNT
LENGTH OF GAS PIPELINES, INCLUDING		th. km	38.579
• main gas pipelines			22.148
• branch pipelines			13.363
• distribution pipelines			3.068
gas-transmission system:		bcm/y	
• input capacity			287.7
• output capacity			178.5
• including to the countries of Europe			142.5
• to the countries of the CIS			36.0
NUMBER OF THE COMPRESSOR STATIONS (COMPRESSOR PLANTS)		units	72 (110)
NUMBER OF GASCOMPRESSOR UNITS		units	702
NUMBER OF UNDERGROUND GAS STORAGE FACILITIES (UGSF)		units	12
UGSF TOTAL WORKING CAPACITY		bcm	30.95
NUMBER OF THE GAS-DISTRIBUTION STATIONS (GDB)		units	1 449

Mathematical model of storage reservoir – gas main system

Model of gas flow in pipeline

$$P(x)=\varphi_1\left(P_{i,}T_i,q_{ij},D_1,\lambda_{ij},x\right) \quad T(x)=\varphi_2\left(P_i,P_j,T_i,q_{ij},D_2,K_T,x\right)-(i,j)\in M \quad T_i\le T_{\max} \quad P(x)\le P_{\max}(x)$$

Model of gas flows passing through compressor station

$$P_j=\varphi_3\left(q_{ij},T_i,P_i,D_3,G,\bar{n}\right),T_j=\varphi_4\left(T_i,P_i,P_j,D_4,\eta\right),Q_i^-=\varphi_5\left(P_j,T_j,D_5,K_S,N\right)-(i,j)\in L$$

$$q_{\min}\le q_{ij}\le q_{\max} \quad n_{\min}\le n\le n_{\max} \quad T_j\le T_{\max} \quad N\le N_{\max}$$

Local resistance model	$P_j-P_i=\Delta P=\varphi_6\left(\rho,\nu,D_6\right),T_j=\varphi_7\left(T_i,\Delta P,D_{di},D_7\right),(i,j)\in K$
Reducer model	$q_{ij}=\varphi_8\left(P_i,P_j\right)=\begin{cases}P_i\ge P_j,q_{ij}=Q\\ P_i<P_j,q_{ij}=0\end{cases},(i,j)\in R_Q$
Flow regulator model	$q_{ij}=\varphi_9(\Delta P),\Delta P=P_i-P_j \quad (i,j)\in R_q$
Valve model	$q_{ij}=\varphi_{10}\left(P_i,P_j\right)=\begin{cases}q_{ij},P_i>P_j\\ 0,P_i\le P_j\end{cases},(i,j)\in R_p$
Mass balance equation	$\sum_i m_{ij}+\sum_k m_{jk}=0,\ j\in V$
Constitutive equation of gas mixture	$P\sum_k V_k=\sum_i x_i(PV)_i+\sum_j\sum_k x_jx_kF_{jk}(T,\rho),PV=Rf(T,\rho)$
Heat balance equation	$T_J\sum_k q_{jk}-\sum_i q_{ij}T_i=0,\ j\in V$
Model of storage reservoir with lamped sources	$\varphi_{11}\left(x,y,p,T,\rho,h,k,m,\alpha,\Gamma,\{x_i,y_i,q_i\}\right)=0$
Borehole bottom model	$\varphi_{12}\left(p_{\text{пл},i},p_{\text{виб},i},q_i,A_i,B_i\right)=0$
Models of separator, dust collector and other facilities	$\varphi_{13}\left(F,\Delta p,q_{ij}\right)=0$

Gas inflow to borehole bottom

$$-d\left(\frac{p}{p_0}\right)^2 = \frac{\mu}{\pi h k p_0}\ \frac{q_0}{F}\ dF + \beta \frac{\rho_0}{\pi p_0 dh}\ \frac{q_0^2}{F^2}\ dF,$$

$$\beta = \frac{12 \cdot 10^{-5} d^3}{m k^{3/2}}$$

Borehole bottom is characterized by k_b parameter of borehole bottom opening and $k_{пл}$ parameter of adjoining reservoir

$$p_{пл}^2 - p_b^2 = A q_0 + B q_0^2,\ A = \frac{A_1}{k_{пл}} + \frac{A_2}{k_b},\ B = \frac{B_1}{k_{пл}^{3/2}} + \frac{B_2}{k_b^{3/2}}$$

$$A_1 = \frac{\mu p_0}{\pi h_x} \ln \frac{R_k h}{R_c h_x}$$

$$A_2 = \frac{\mu p_0}{\pi h_x} \ln \frac{R_c}{r_{k1} l_{k1} n_{01} + r_{k2} l_{k2} n_{02}}$$

$$B_1 = 12 \cdot 10^{-5} \frac{\rho_0 p_0}{2\pi^2 h_x} \frac{d^2}{m} \left(\frac{1}{R_c h_x} - \frac{1}{R_k h}\right)$$

$$B_2 = 12 \cdot 10^{-5} \frac{\rho_0 p_0}{2\pi^2 h_x^2} \frac{d^2}{m} \left(\frac{1}{r_{k1} l_{k1} n_{01} + r_{k2} l_{k2} n_{02}} - \frac{1}{R_c h_x}\right)$$

Finding pressure distribution p(x, y, t) in gas storage reservoir

Equation of gas filtration in porous medium

$$\frac{\partial}{\partial x}\left(\frac{kh}{\mu z}\frac{\partial p^2}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{kh}{\mu z}\frac{\partial p^2}{\partial y}\right)=2mh\left(\frac{\partial}{\partial t}\frac{p}{z}+2qp_{am}\right)$$

Gas balance conditions

$$Q_{зап}=\frac{T_{am}}{P_{am}}\int_0^F\int_0^h\frac{p\,m}{T\,z}dF\,dh\approx\frac{T_{cm}}{p_{cm}}\frac{\overline{p}}{\overline{T}\,\overline{z}}\overline{m}\,\overline{h}\,F$$

Withdrawal density can be found

$$q=\frac{1}{V}\sum_{i=1}^{I}q_i\delta\left(x-x_i^0\right)\delta\left(y-y_i^0\right)\delta\left(z-z_i^0\right)\left[\eta\left(t-t_{1i}\right)-\left(t-t_{2i}\right)\right].$$

Boundary condition for filtration equation

$$\Gamma=\Gamma_1\cup\Gamma_2$$

Dirichlet condition

$$p(\overline{x})=p_1,\quad \overline{x}\in\Gamma_1$$

Neumann condition

$$\Phi p(\overline{x})=0,\quad \overline{x}\in\Gamma_2$$

$$\Phi p\overset{def}{=}\frac{k\cdot h}{\mu\cdot z}\frac{\partial p}{\partial x}\nu_x+\frac{k\cdot h}{\mu\cdot z}\frac{\partial p}{\partial y}\nu_y;\ \nu_x=\cos(\nu,x),\ \ \nu_y=\cos(\nu,y)$$

Main Goals

1. Calculation of pressure distribution in gas storage reservoir

2. Identification of storage reservoir parameters

3. Finding boundaries of nitrogen penetration when not mixed with natural gas

4. Calculation of nitrogen concentration when mixed with natural gas

5. Gas and water filtration around concentrated sources created by horizontal and vertical boreholes (water cone inflow)

6. Gas filtration in water pressure mode (Finding penetration of edge water in the gas-bearing area. Piston like ejection of gas by water)

7. Finding unknown parameters of gas sources using known concentrations of hydrocarbon available in water, on the ground surface and in the air

Distribution of active gas among gas storages

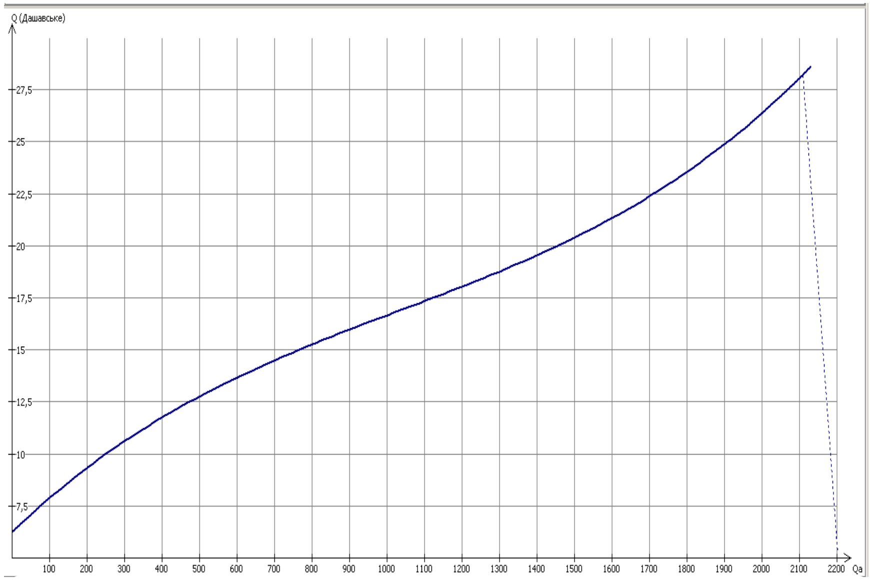


Figure 1. Peak capacity function Dashava UGS

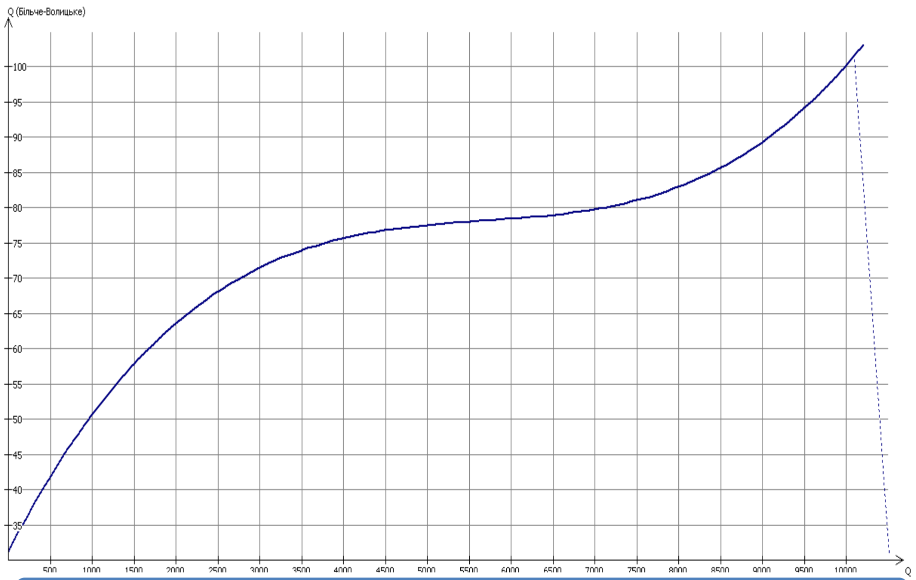


Figure 2. Peak capacity function Bilche-Volytcya UGS

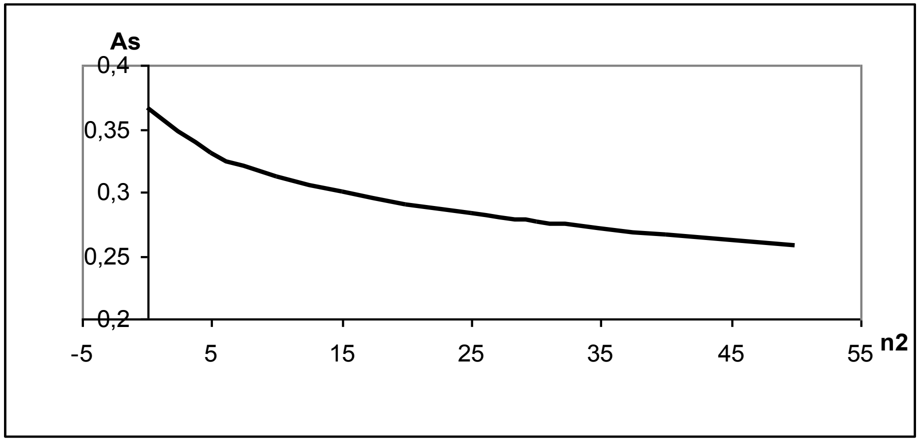
Optimum distribution of 12545.00 mln. m3 of gas among 5 UGS

Назва ПСГ	C1*x^3	C2*x^2	C3*x	C4	Загальний об'єм	Активний об'єм	Розв'язок	Піковість	Піковість (розв)
Більче-Волицьке	2,30089194740863l	-3,92197191505239	0,023117487088071	31,2377622377604	10200	0	6386	31,2377622377604	78,8456538653109
Угерське-14-15	-1,16913362190966	1,74104873688454l	0,00051800051800l	3,91188811188811	1230	0	980	3,91188811188811	10,1367685698438
Угерське-16	3,45609083288052l	-7,36517642849631	0,00510187538845l	11,3132867132868	1989	0	1989	11,3132867132868	21,2666666666664
Дашавське	3,23629816871344l	-1,00573895455874	0,01722898905997!	6,25734265734256	2130	0	2130	6,25734265734256	28,6000000000002
Опарське	-3,98405926595767	2,97899494342125l	0,00793256023381!	3,9986013986014	1195	0	1060	3,9986013986014	11,0092356341701

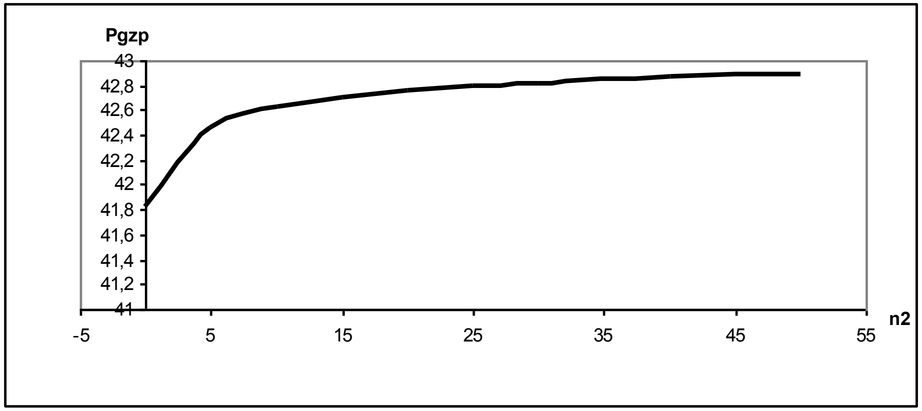
Total peak capacity: 149,8 mln. m3 / day

Effect of additional perforation

1. Dependence of increase in average input pressures at gas collection points Pgzp and the density of additional perforation n2



2. Dependence of average value of filtration coefficient A and the density of additional perforation n2



3. Dependence of average value of filtration coefficient B and the density of additional perforation n2