MODERN CONCEPTION OF THE HYDROTRANSPORT SYSTEMS PROGRESS IN THE SEA MINING

G.G. Pivnyak, *Professor, Academician of the National Academy of Sciences of Ukraine, Rector of National Mining University, Ukraine, phone: +38(056)7446219, +38(0562)464062, e-mail: rector@nmu.org.ua*

E.A. Kyrychenko, *Professor, Department of Mining Mechanics, National Mining University, Ukraine, phone: +38(0562)469982, e-mail: kirichenko@front.ru*

V.P. Franchuk, *Professor, Head of the Department of Mining Machines and Engineering, National Mining University, Ukraine, phone: +38(0562)474553, +38(0562)469000, e-mail: franchuk@nmu.org.ua*

A.I. Yegurnov, *PhD, President of Ana-Tems Ltd., e-mail: yegurnov@yahoo.com*

V.E. Kyrychenko, *PhD, Department of Automatics and Computer Systems, National Mining University, Ukraine, phone: +38(066)7730887, e-mail: duff_kirichenko@rambler.ru*

The actuality to develop the Experimental Automatic Control System (EACS) of sea mining enterprise (SME), together with sea equipment and technology for deep-water mineral deposits development, is shown. The necessity to take into consideration influence of modern EACS SME on parameters of equipment and technology for deep-water deposits development is grounded, although the back influence is evident. The strategy and basic principals to project the EACS SME, having as a part developed functional scheme of submarine equipment control subsystem, that complexly reflects the processes of mineral extraction from sea-bottom and their transportation to carrying vessel, are offered. This scheme is based on usage of functional model of technological equipment for bottom block and hydraulic lifting with high speed, that allows to enhance efficiency of submarine equipment work by optimization, regulation and stabilization of parameters, and also by concordance of elements working modes of the complex. The patented method to start up and stop the submerged equipment of SME, having increased reliability and efficiency in conditions of high depth, inscribes naturally in the scheme ideology. The set of scientific research programs is developed, which can be used as the basis to create the program calculation complex to control the main technological processes of SME. The presented elaborations are the basement to develop the technical task for projecting of Experimental ACS of sea mining enterprises.

Each year the reserves of many non-ferrous metals, being extracted from continental deposits by traditional method, are steady decreasing. The modern stage of development of oceans mineral potential is connected with experimental output of Ferrimanganese concretions (FMC). So, the projects to create the efficient methods and media to develop deep-water deposits are going to be of the most importance.

The article deals with **actual problem** of sea mining enterprises (SME) creating, which operation is mainly connected with multipurpose work of technologists, engineers and specialists in the field of control systems. The functioning of such complexes implies usage of unique high technology equipment in conditions of great depths. The efficiency of such equipment is basically determined by control technology. Today definite progress can be noticed only in the field of technical media development (hydraulic lifting systems and, partly, seabed harvesters). But low research activity is focused on forming requirements from the side of technologists and engineers to the control system, being developed.

However, questions of EACS SME development are actual even today, because their realization influences sufficiently the level of sea equipment and technology, also it requires more intellectual efforts and time. Based on experience in this field of many years, the authors suppose, that EACS's SME are needed to be projected in the same time with development of technology and equipment, because its functionality and architecture will stress considerably on compatibility of units and aggregates being planned for application. In the other words, even if structure of ACS does not determine design of aggregates and functional units, but it influences at least their type, dynamic characteristics and, also, methods and parameters of adjusting.

The authors are convinced of, that technology, equipment and control system should correspond to the level of certain stage of deep-water mineral deposits development. They also should be taken into consideration only within **system approach**, when the parameters of every indicated direction set strict limitations on characteristics of the other ones. This statement points to the necessity of

coordination (taking into consideration the formulated requirements and limitations) on the international level of efforts by developers of different countries and national agencies, specializing in the certain direction, that will allow to increase the efficiency of fulfilled research through minimization of waste time and work.

ACS equipment should include above-water part, set on a vessel, and submarine part, set on elements of SME submerged structure. Besides, media providing testing of units, aggregates and devices of ACS on the stages of installation and operation should also be included in the control system. Today it is difficult to designate the terms of ACS putting to practical application. At the same time, new, qualitative and suitable in expansion solutions, which usage in ACS will entice developers to refuse previously selected equipment to the benefit of modern samples, arise every year in the automation media market. This situation may sufficiently limit development of ACS, because exchange of one technological element will lead to change or readjusting of elements getting in contact with it. So, it is necessary to follow module criterion, apart from supporting criteria of development being set de facto (in order to provide full needed functionality and reliability). The sense of such approach is to present ACS as a quite big number of interacting subsystems with high level of autonomy, in order to minimize influence of changes, being made in structure of any subsystem, on adjacent subsystems.

It is stressed in the article on development of experimental ACS (EACS) of sea mining enterprise, which will allow, in addition to experimental extraction of FMC, to work through problem aspects, to verify working ideas and hypotheses, also to compare the efficiency of contesting solutions.

EACS SME is intended for control of equipment to give a workout to mining technology, for reaching and supporting of FMC extraction technological parameters, for creating conditions of SME safe operation in all working modes and carrying out pull-down and restorative works. EACS SME is unique and non-linear system with great inertia of controlled processes [1]. EACS structure is highly complicated by realization in it a big quantity of adaptive models and algorithms of processes prognostication at speeded time scale. Besides, stabilization schemes of controlled processes and concordance of functional elements control parameters must be engaged in EACS [2].

In general view EACS SME may consist of a central coordinating subsystem (while realizing a centralized control approach) and following basic subsystems, interacting with it [3]:

- subsystem of Seabed harvester (SH) movement control;
- SH navigation subsystem;

- mining-preparation-lifting of FMC control subsystem;
- local systems of technological equipment control;
- subsystems of measuring information processing;
- subsystem of technical media diagnostics;
- subsystem of mineral dressing;
- subsystem of wastes collecting;
- subsystem of raw loading on ore transportation vessels.

The authors of article believe, that despite of the final architecture, EACS SME must obligatory include two connected subsystems: "central coordination subsystem" (CCSS) and FMC "mining-preparation-lifting control subsystem" (MPL SCC).

CCSS in intended for the overall coordination and concordance of all technological links work. Physically this subsystem is based on computational net, disposed on a vessel, including Database control subsystem(-s) (DBCS) for collecting and processing of information, going from other subsystems; operator terminals; programmed CAE-complex, realizing the speeded time models of interacting subsystems. The authors group is engaged in designing of that CCSS part, which is connected directly to MPL SCC. In particular, the computational net is presented by several computers of x86 and ARM architecture, connected by Fast Ethernet protocol. MySQL is used as DBCS. The data exchange with MPL SCC is fulfilled by ModBus protocol. The data is formed in XML-lines, in which the calls of server procedures by SOAP technology are built-in. The basis model "Dynamics of multiphase mixes movement", created and verified by authors in SolidWorks medium, forms the base of developed program complex, realizing the speeded time models. Today we have a basis model and also several models of speeded time for MPL SCC realized as add-in modules to SolidWorks system, and besides as independent databases, working separately from SolidWorks.

MPL SCC is responsible for processes control of mining, preparation for lifting and hydraulic lifting of FMC on a base vessel. The preparation to lifting includes washing off silt, crushing to optimal sizes and pumping over FMC through a flexible pipeline into a bunker-dozer, disposed on a technological platform. The common influence of FMC mining, preparation and lifting parameters has caused exactly the expediency to single out the **minimal configuration** of submarine equipment in SME structure, the control of which should be made by MPL SCC. It consists of the following:

- self-propelled seabed harvesters with based on them equipment for washing off sea-bottom sediments and FMC crushing to optimal sizes [3];
- pipe for pumping over FMC through a flexible pipeline (FP) into a bunker-dozer (BD);

- BD with screw feeder and its auxiliary equipment, placed on technological platform;
- airlift or pipe hydraulic transportation system.

MPL SCC is intended for coordination of FMC mining, preparation for lifting and hydraulic lifting processes of FMC, technological equipment diagnostics, technological processes parameters control, technological equipment start-up and stop control, interaction with central coordination subsystem, technological process protocolling, operative analysis of production situations and giving recommendations on repair-restoration arrangements.

The structural scheme of suggested MPL SCC, having maximum favourable conditions for ACS (being the most problematic link) efficient work as a principle while providing coordination and concordance of all technological links, is shown on figures 1 and 2 [4]. Idea of the structure is distribution of functions and elements of MPL SCC to three hierarchical levels, where the results of upper level work are transmitted to the lower ones as mode parameters and limitations.

The problems of probable production situations analysis, diagnostics of efficiency and control of technological equipment reliability, regulation of production processes parameters are being solved within the developed structure, in order to minimize energy consumption and stabilize equipment rational working modes.

The 1st level. Response on outside commands of Central coordination subsystem (CCSS)

| MPL SCC parameters adaptation to change of the whole working time of submarine equipment. | Reconfiguration and adjusting of MPL SCC parameters while obtaining the corresponding command from CCSS |

⇩

The 2nd level. Control of reliability and efficiency

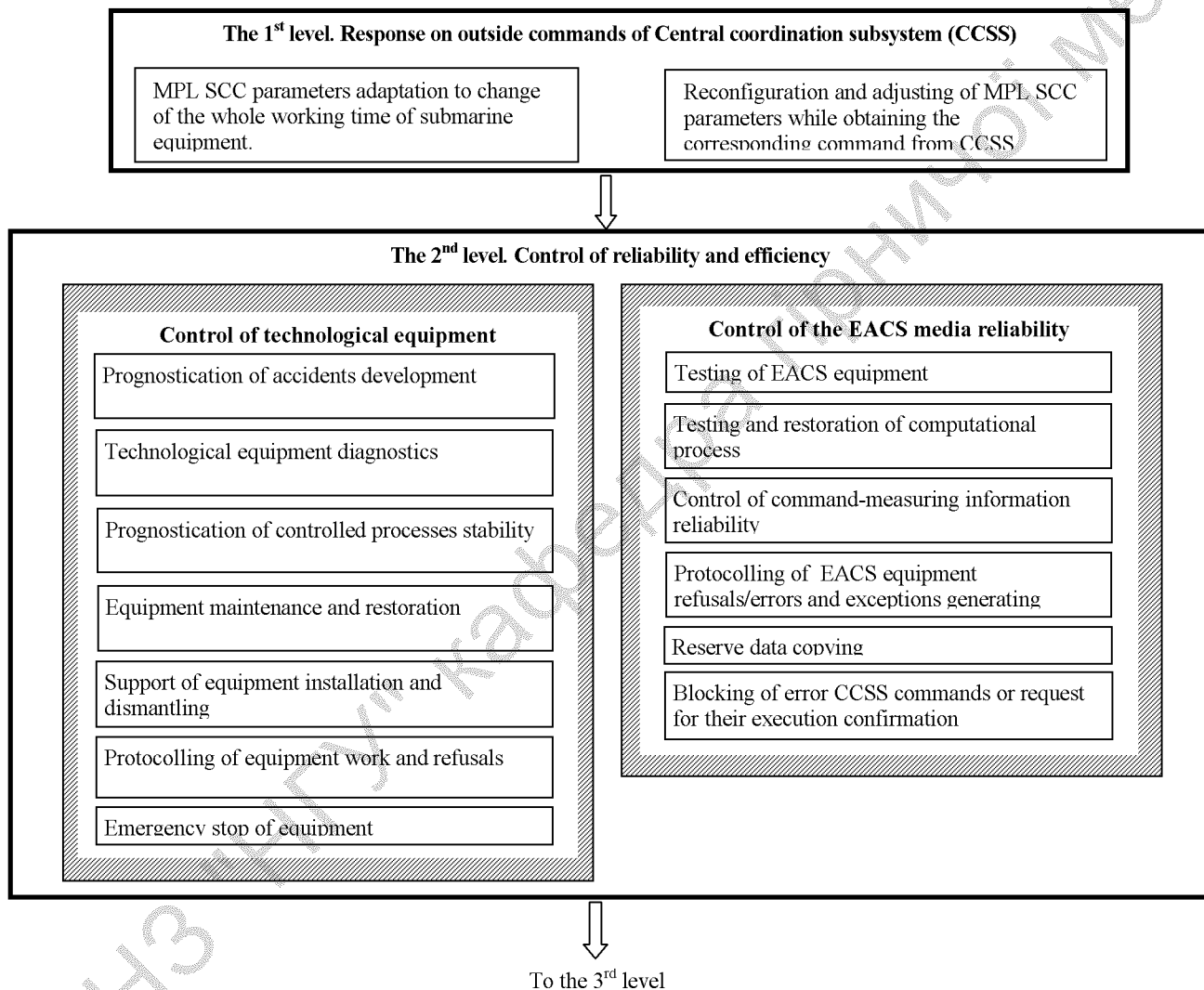| Control of technological equipment	Control of the EACS media reliability
Prognostication of accidents development	Testing of EACS equipment
Technological equipment diagnostics	Testing and restoration of computational process
Prognostication of controlled processes stability	Control of command-measuring information reliability
Equipment maintenance and restoration	Protocolling of EACS equipment refusals/errors and exceptions generating
Support of equipment installation and dismantling	Reserve data copying
Protocolling of equipment work and refusals	Blocking of error CCSS commands or request for their execution confirmation
Emergency stop of equipment	

⇩

To the 3rd level

Figure 1. Consolidated structural-functional scheme of MPL SCC of experimental ACS of sea mining enterprise. The first and the second levels

The most of the second and the third blocks of presented scheme are developed by creating of main module net of command-measuring controllers (CMC), being based on microprocessors of ARM architecture. CMC provide control of computational circuits and sensors, also they make measuring transformations and two-direction transmitting of measuring information by connection lines [5].

Originally, CMC development fulfilled based on 16-digit RISK-microcontrollers made by Amtel and Microchip. But they were replaced by modern ARM-compatible chips made by Texas Instruments, Motorola и XScale companies, because the last ones have wider means for energy consumption and productivity regulation, adjusting, program code adaptation etc.
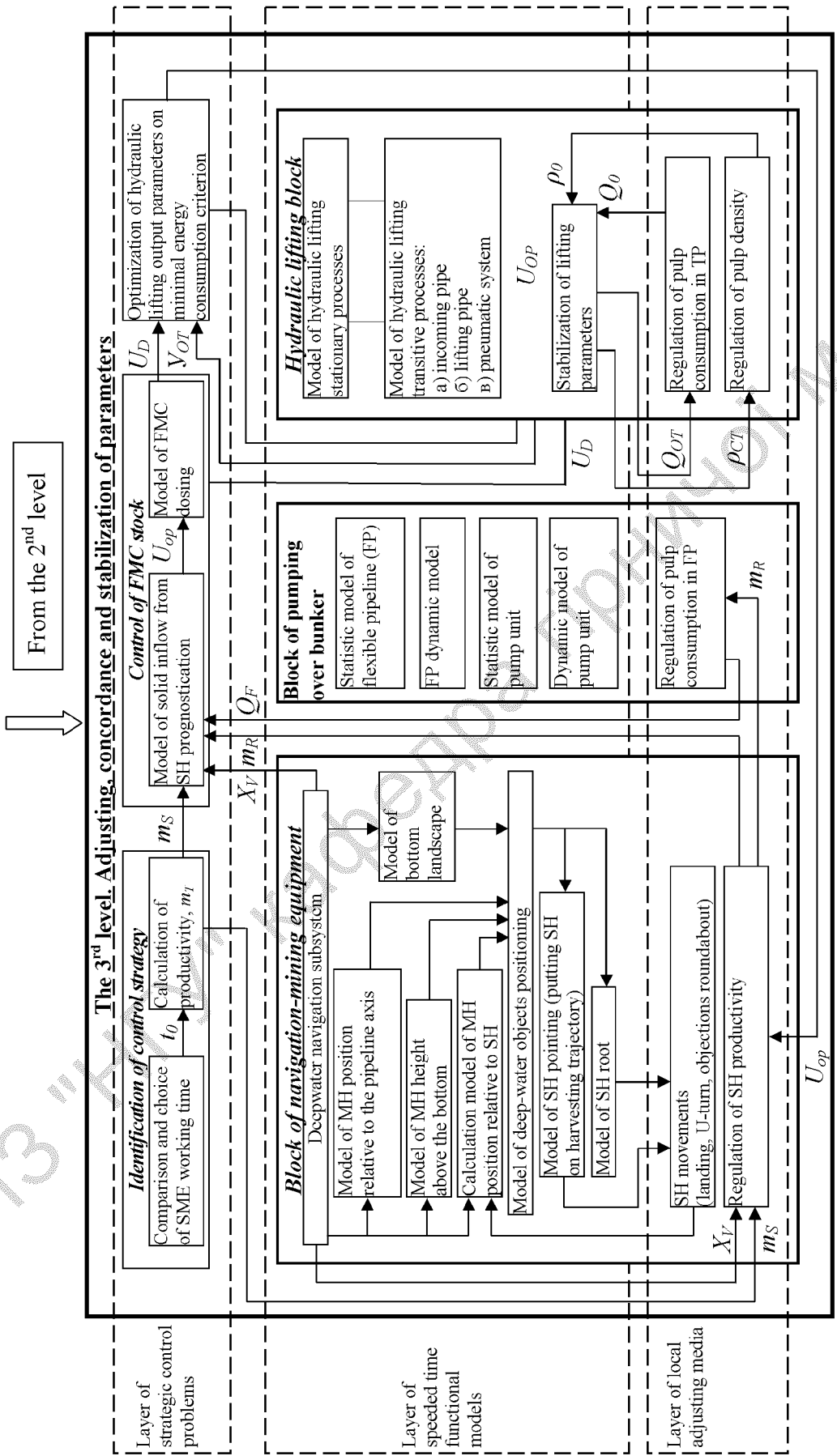
Figure 2. Consolidated structural-functional scheme of MPL SCC of experimental ACS of sea mining enterprise. The third level.

The 3rd level. Adjusting, concordance and stabilization of parameters

Identification of control strategy

- Comparison and choice of SME working time
- Calculation of productivity, m_I

Control of FMC stock

- Model of solid inflow from SH prognostication
- Model of FMC dosing

Optimization of hydraulic lifting output parameters on minimal energy consumption criterion

Hydraulic lifting block

- Model of hydraulic lifting stationary processes
- Model of hydraulic lifting transitive processes:
  a) incoming pipe
  б) lifting pipe
  в) pneumatic system
- Stabilization of lifting parameters
- Regulation of pulp consumption in TP
- Regulation of pulp density

Block of pumping over bunker

- Statistic model of flexible pipeline (FP)
- FP dynamic model
- Statistic model of pump unit
- Dynamic model of pump unit
- Regulation of pulp consumption in FP

Block of navigation-mining equipment

- Deepwater navigation subsystem
- Model of MH position relative to the pipeline axis
- Model of MH height above the bottom
- Calculation model of MH position relative to SH
- Model of bottom landscape
- Model of deep-water objects positioning
- Model of SH pointing (putting SH on harvesting trajectory)
- Model of SH root
- SH movements (landing, U-turn, objectionis roundabout)
- Regulation of SH productivity

Layer of strategic control problems

Layer of speeded time functional models

Layer of local adjusting media

From the 2nd level

U_D, Y_{OT}, U_{OP}, ρ_0, Q_0, U_D, Q_{OT}, ρ_{CT}, Q_F, X_V, m_R, m_R, m_S, t_0, X_V, m_S, U_{op}

Besides, progressive programming technologies as JIT-compilation are fully being supported by Java and Net-compilers for ARM processors. Development of software for CMC based on the managed-code has allowed to save time by possibility of efficient and freely adopting of JIT-code on x86-compatible personal computers. CMC programming was carried out using C++ language, as the most flexible for this range of problems. The written programs have high level of universality, because of being compiled, whether to machine code for processors of x86 and ARM architecture or to JIT-code of Microsoft Net Framework database, almost without changing of initial code. The data exchange between CMC is fulfilled by ModBus и ProfiBus protocols. ModBus is the most suitable due to its work over TCP transport protocol, that simplifies adjusting of distributed CMC in laboratory conditions.

Let's proceed to description of each level. The first block is formed by "MPL SCC parameters adaptation to change of the whole working time of submarine equipment" block and "Reconfiguration and adjusting of MPL SCC parameters while obtaining the corresponding command from CCSS" block. The first block is intended for readjusting of technological process in accordance with new time duration of SME work, which may be changed in connection with emergency situation of global nature, for example, storm-warning. Tactic goals of EACS may be changed depended on mining complex working hours, that will influence first of all operation of MPL SCC. The second block serves for transmission and low-level execution of CCSS definite commands spectrum. For instance, refer to switching between the complex productivity mode, having minimal energy consumption, and maximum productivity mode.

The second "Control of reliability and efficiency" level solves the problems of control and prognostication of efficiency of technological equipment and EACS functional elements [6]. Information on condition and working modes of units and aggregates is transmitted here from all command-measuring controllers MPL SCC. At the second level the blocks are divided into two groups: "Control of technological equipment" and "Control of EACS media reliability". Here condition and functionality of equipment are determined by special tests, also equipment efficiency and reliability indexes are forecasted.

The results of reliability and efficiency control problems solution are returned to CCSS for their visualization on operator terminals as recommended instructions on equipment maintenance and reservation. Also the results are transmitted to the third level as working modes limitations. The work of "Prognostication of accidents development" block is periodical request for information on technological equipment reliability, which is presented as input data for algorithms and models of SME equipment efficiency and reliability forecasting. Diagnostics of technological equipment (see corresponding block) is fulfilled by measuring circuits of EACS SME. Diagnostic information is transmitted to CCSS and is represented on operator terminals. It is also written to special databases and used in automatic circuits of response on equipment refusal. The "Prognostication of controlled processes stability" block is grounded on models work in speeded time. The "Equipment maintenance and restoration" block may be used both in automatic and automatized modes. Maintenance is mainly carried out by equipment lifting up to the ocean surface, using widely automatized means of installation and dismantling, included in the described subsystem. Restoration of equipment is generally fulfilled by aggregate method.

There is a necessity to control EACS own means, apart from SME units and aggregates efficiency control. Blocks of the second group are used for this purpose. The process of EACS equipment testing is periodic transmitting of test-letters to remote command-measuring controllers and following analysis of their execution. The "Testing and restoration of computational process" block refers mainly to software. Purposes of the block are computational resources control, quality of links between components, and also taking measures to restore EACS functionality after system falling out of steps. The "Control of command-measuring information reliability" block is densely connected with two above described blocks. Reliability of command-measuring information may be broken by interferences of different nature, erasing during information transmitting in long connection lines. Usage of coding stable to interference is provided in this block to prevent distortion of information. Reserve copying of experimental, intermediate and primary data is carried out automatically with set periodicity, that allows to restore efficiently the computational process in the case of calculation system damage.

The third level is divided on three layers of problems according to frequency and priority of their solution [7]. The first layer includes problems of control strategy identification, FMC stock control and throughput parameters optimization on minimal energy consumption criterion. The problem of strategy identification includes determination of whole working hours of SME submerged part (T_{tot}), taking into consideration economic profitability and different time limitations. The productivity on solid part is determined based on just mentioned (m_S). The control of solid material stock in technological lines is intended to provide stable, uninterrupted FMC supply to lifting from interrupted, irregular FMC feeding by SH. It is solved with help of a bunker-

dozer, local regulation systems and, also, usage of prognostication models of solid inflow from SH and FMC dozing into transport pipeline (TP).

It is necessary to note, that "bunker-free" technology may be more efficient in some cases during mining of poor mineral deposits, due to less technological operations number, apart from impossibility of lifting throughput parameters optimization [8].

The "Hydraulic lifting block" includes the "Stabilization of lifting parameters" and "Regulation of pulp consumption in TP" sub-blocks, which are based on "Stationary and transitive lifting processes" models. The models of speeded time are realized integrated in CCSS program CAE-complex, as mentioned above.

"Model of hydraulic lifting transitive processes" is used to determine the parameters of non-stationary modes within the patented automatized method of SME submarine equipment start-up and stop [2]. Start-up and stop of Deepwater airlift hydraulic hoist (DAHH) are fulfilled on mixer of optimal submerging depth, when reaching coordination of transitive modes parameters of hydraulic lifting elements with bottom block working characteristics, in accordance with the developed method.

The method has the following benefits:

- realization of DAHH start-up immediate on the mixer, which submerging depth corresponds to the maximum efficiency factor in the working mode;

- control of DAHH start-up process is carried out in automatized mode in complex with transitive modes in mining equipment elements of bottom block;

- reliability of start-up procedures and stability to different disturbances are guaranteed;

- DAHH start-up duration is provided taking into consideration daily task of mineral raw materials lifting.

The method is realized according to algorithms given on figures 3 and 4, being bound to position of lock-regulation fitting (figure 5).

The following is taken as the initial condition before the start-up: SH is ready on the initial position; the compressor is switched off; the screw and HS pump drives are switched off; slide-valve V_3 is shut off.

The principle of developed start-up procedure includes preliminary pressure decreasing in the mixer through the following operations execution. The compressor is switched on and water is pushed out pipelines through the lower TP section having opened slide-valves V_1 and V_2. The slide-valves V_1 and V_2 are shut down and air flow is redirected through force air pipeline to the mixer. V_3 is opened, leading to depressurizing of TP and so decreasing of pressure in the mixer, being followed by

compressed air feeding into it. Next the slide-valve V_2 is opened and the airlift begins to work in stable (established) mode.
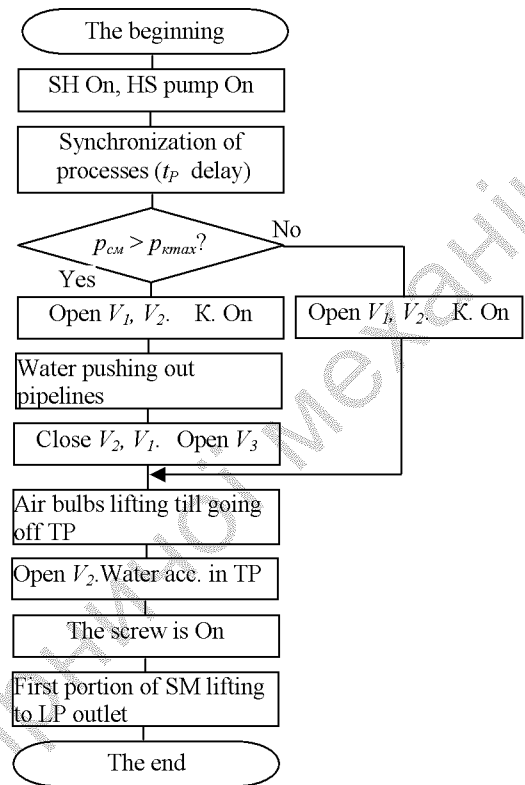

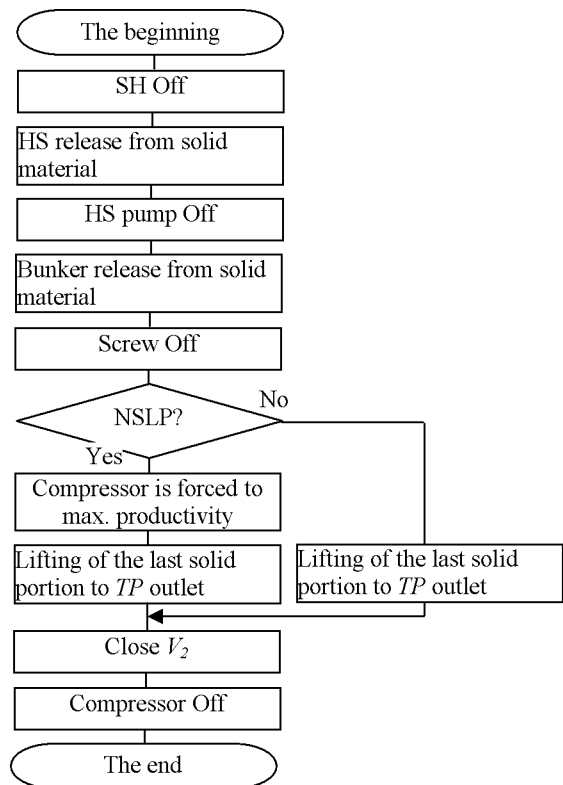Figure 3. Algorithm of SME submarine equipment start-up
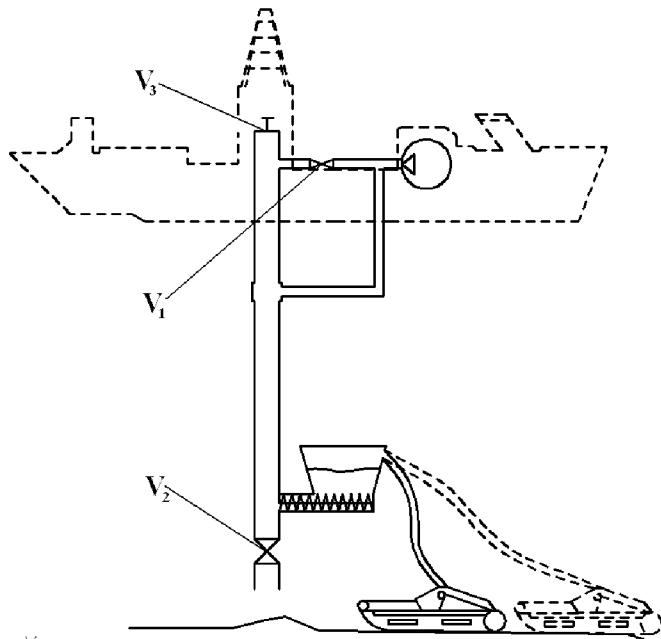

Figure 4. Algorithm of SME submarine equipment stop

Figure 5. Position of lock-regulation fitting of hydraulic lifting

Parallel execution of operations on raw material preparation and transportation is provided in order to decrease the start-up duration. Process of the bottom-block preparation for transportation includes accumulating in BD of some FMC amount (M_a) to the moment when the airlift is ready to transport the pulp. Duration of the airlift preparation process may be, according to preliminary estimation, whether less or equal to the bottom block preparation process. So, the "delay duration" t_Π, on which one need to shift the beginning of the airlift start-up relative to the beginning of the bottom block start-up, is calculated in the algorithm.

$$t_P = \frac{M_a - m_B}{\dot{m}_{BPR}} - t_\kappa - t_e - t_v ,$$

where $\dot{m}_{BPR}$ – medium mass throughput of the bunker filling with solid material; m_B – mass of solid material in the bunker; t_κ – duration of water pushing out from pipelines through the lower TP section; t_e – duration of water acceleration in feeding pipe; t_v – total duration of slide-valves switching.

Not less important benefit of the developed method is a possibility to use "The next start light procedure" (NSLP). The sense of NSLP is to stop submarine equipment in such a way, that pressure in the mixer is less than the maximum pressure created by compressor. It will allow to fulfill the next start-up through light procedure (direct feeding of compressed air to the mixer without preliminary procedure of water pushing out TP). It is made by shutting down V_2 slide-valve before compressor switching off during stop procedure, that leads

consequently to reducing the water column height in TP, and, so, pressure decreasing in the mixer.

The problem of decreasing of transitive processes duration in sea mining equipment elements has been solved within the developed method, due to simultaneous carrying out of hydraulic lifting and bottom block start-up operations and also realization of the next start light procedure.

Now return to MPL SCC scheme. The question of the given blocks on all levels requires taking into detailed consideration. On the first level, the duration of work within twenty-four hours of SME submerged part t_1 is determined, being limited by solution results of "MPL SCC parameters adaptation to change of the whole working time of submarine equipment" and "Reconfiguration and adjusting of MPL SCC parameters while obtaining the corresponding command from CCSS" problems. On the second level, t_2 time within current twenty four hours is determined, being limited by the problems of reliability control and efficiency. Obtained t_1 and t_2 values are directed to a comparison block, where one takes the lesser of values. After that the hour's productivity on solid material m_S is calculated based on daily economic profitability.

So determined value m_S is transmitted to SH productivity regulation block, having this parameter as basic one. Inside this block, m_S is conformed to the observation vector X_V, coming from the Deepwater navigation subsystem (DNSS), defining landscape features and density of concretions bedding. DNSS is a separate subsystem, interacting with MPL SCC, and it is going to be developed within separate research work in the nearest future. Real productivity m_R , generally being different from the given productivity, is calculated based on shift of concordance of m_S and X_V. The problem of SH root forming is solved in the same time with SH productivity control, providing maximum full extraction from current zone. Information vector X_{SH}, including SH movement characteristics (speed, direction etc) is provided as back connection in order to increase the precision of navigation model functioning. The value of current real productivity m_R is measured and transmitted then to the pulp regulation block in FP and to the model of solid material inflow from SH, because, as mentioned above, SH productivity regulation block can not provide guaranteed given productivity m_S. The pulp regulation block in FP, in cooperation with static and dynamic FP and pump unit models, provides necessary throughput of FP for FMC pumping over bunker. The model of solid inflow from SH prognostication is formed from combination of m_S, m_R, X_V parameters and the current pulp throughput in flexible pipeline Q_{FP}. Information vector X_{PR} (prognosis of solid material stock in bunker-dozer) is transmitted to FMC dozing model, where, based on $X_{\Pi P}$ and information of solid material stock in

bunker-dozer, setting values of test stock within limitations of medium productivity, such values of stock and productivity are calculated, that provide uninterrupted operation of hydraulic lifting, if solid material inflow from SH is varied. The outlet of FMC dozing model, within which the optimization problem of pulp transportation parameters is solved on criterion of minimal energy consumption, is U_{DZ} vector, defining limitations on current productivity of hydraulic lifting.

Control vector U_{DZ} is transmitted to the block of hydraulic lifting parameters stabilization and, in the same time, during solving of the optimization problem, is transformed to corrective vector U_{OP}, which is also transmitted to the stabilization block. The information on energy consumption of hydraulic lifting and its working mode current parameters is transmitted from local regulation system to the block of throughput parameters optimization. Optimizer, setting test values of throughput parameters (throughput and density of hydraulic mix), determines such their values, when the energy consumption of lifting process is minimal. The correction of these parameters, taking into consideration U_{DZ} and U_{OP} vectors with following transmitting to blocks of pulp throughput and density regulation as control signals, is fulfilled. U_{OP} vector is also transmitted to SH productivity regulation block for the following changing of SH productivity, in case if hydraulic lifting, working in optimal mode, does not provide transportation of required pump amount.

DIRECTION OF FURTHER RESEARCH ACTIVITY AND CONCLUSIONS

The subject of further research work is revision of missing modules of program-calculation CAE-complex and its beta-testing in different hardware configurations of central coordination subsystem of experimental ACS and submarine equipment control subsystem of sea mining enterprise.

Presented materials give just part of information on wide range of problems, connected with projecting and operation of sea mining enterprises. The group of authors, working in this direction for more than 30 years, is aware of complexity and many aspects of set problems, and also of many stages of their solution. But the authors think, that publishing of intermediate results is made at the proper time, because, by analogy with space equipment development, theory of this question should take the lead over practice. Besides, theoretic works have been powerful stimulus for practical realization of some design ideas, taking into consideration thorough study of complex physical phenomena. The authors group has in total more than 150 inventions in the field of sea mining industry, confirmed but patents of Ukraine and other

countries. In particular, hybrid sets of principally new type, combining advantages of pump and airlift versions, feature enhanced technical-economic results, use efficiently energy accumulated by ocean and low-temperature potential of deep water. There are inventions, apart from hydraulic transport questions, in the fields of mineral dressing, using alternative sources of energy and reducing of technogeneous influence of industrial plants on submarine flora and fauna with purpose to minimize ecological damage [8].

REFERENCES

1. Pivnyak G.G., Kyrychenko E.A., Franchuk V.P. 2008. Problems of deep-water hydraulic lifting of solid mineral resources. New technologies in mining 21st World mining congress, Krakow, 2008, pp. 49-57.
2. Patent. 2346161 RF, E21C50/00, E21C45/00, F04F1/20. Way of start and stop sea airlift and the system for its realization. Pivnyak G.G., Kyrychenko E.A., Evteev V.V., Shvorak V.G., Kyrychenko V.E. Published: 10.02.2009, Vol. 4.
3. Kyrychenko E.A., Samusya V.I., Kyrychenko V.E. The technology of polymetallic concretions extraction and transporting. Innovations in Non-Blasting Rock Destruction, Freiberg 2008, pp. 169-178.
4. Kyrychenko E.A., Franchuk V.P., Egurnov A.I., Shvorak V.G. 2008. Parametre's optimisation of the firm material hydrotransportation on the basis of economic-mathematical modelling. Mechanical engineering and XXI-st century technosphere: Works of XV international scientifically-technical conference in Sevastopol. Vol. 2. pp. 81-85.
5. Kyrychenko E.A., Samusya V.I., Kyrychenko V.E. 2008. Features of the experimental automated control system development for sea-mining enterprises. Scientific articles collection of National Mining University №30. pp. 112-120.
6. Kyrychenko E.A., Samusya V.I., Kyrychenko V.E. 2008. Block-hierarchical approach to development of the control technology for deep-water mining enterprises. Mining electromechanics and automatics №80. pp. 101-109.
7. Kyrychenko E.A., Samusya V.I., Kyrychenko V.E. 2008. Development of strategy and main principles to manage the technological equipment of the sea-mining enterprises. Scientific bulletin of National Mining University №10. pp. 78-83.
8. Site of the article authors group: http://hydrotransport.inf.ua.