Source: Konkov V., Bursau M. Several Aspects of Automation of Energy Supply Systems in Precast Concrete Buildings. Contemporary Issues of Concrete and Reinforced Concrete: Collected Research Papers. Minsk. Institute BelNIIS. Vol. 9. 2017. pp. 42–59. https://doi.org/10.23746/2017-9-3

DOI: 10.23746/2017-9-3

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SEVERAL ASPECTS OF AUTOMATION OF ENERGY SUPPLY SYSTEMS IN PRECAST CONCRETE BUILDINGS

НЕКОТОРЫЕ АСПЕКТЫ АВТОМАТИЗАЦИИ СИСТЕМ ЭНЕРГОСНАБЖЕНИЯ В ЗДАНИЯХ ИЗ СБОРНОГО ЖЕЛЕЗОБЕТОНА

ABSTRACT

The background of this article is formed by the results of studies carried out by authors in areas of design, construction and operation of smart buildings and installations.

It was found that the reasonably configured structure of a smart building provides acquisition of objective information about the condition of building utilities (including energy supply systems) and their operation, optimisation of utilities equipment control, making it possible to reduce total expenses and provide opportunities for making prompt decisions in case of onset of emergencies and their timely localisation.

The major components of a smart building are specified: elements responding on presence or absence (activity or inactivity) of smart building users and on variation of environment parameters; automatics tools regulating the parameters of a smart building in accordance with the results

of analysis of environment condition and variations of environment parameters; smart building self-regulation algorithm focused on improvement of comfort and safety for its users.

The utilities are defined forming the unified information network: automated building control system; structured cabling system; cable conduit system and actuators; balanced energy supply system; air conditioning and ventilation system; automated water supply system; automated heat supply and energy saving system; local computer network; private automatic branch exchanges (PABX); community antenna television (CATV); automated lift equipment system; electric clock system; local broadcasting, warning and emergency evacuation system; building security system.

The studies carried out made it possible to specify the recommended list of utilities for buildings and installations for which the unified automated building control system application is reasonable; the major functions of these systems including the energy supply systems; major components of the automated building energy supply system, technical and process-related requirements for it; energy consumption groups in the building energy supply system, corresponding to their usage conditions; basic performance characteristics of components of the automated energy supply system described in the requirements specification (power consumption, operating mains voltage, heat release, electromagnetic compatibility of equipment etc.); specific features in automation of energy supply systems in precast concrete buildings; basic performance characteristics of peripheral data display devices providing generation of emergency alarm; requirements for arrangement of electric power supply for the devices within the unified automated building control system, taking into consideration the arrangement of the secure electric power supply system and installation of backup power supply units.

The gained results make it possible to design automated energy supply systems in precast concrete buildings in a most reasonable and cost-effective way.

АННОТАЦИЯ

В основу статьи положены результаты исследований, выполненных авторами в области проектирования, строительства и эксплуатации интеллектуальных зданий и сооружений.

Установлено, что рационально выстроенная структура интеллектуального здания обеспечивает получение объективной информации о состоянии инженерных систем (в том числе системы энергоснабжения) здания и их работы, оптимизацию управления инженерным оборудованием, что позволяет сократить общие расходы, обеспечить возможность принятия оперативных решений при возникновении чрезвычайных ситуаций и их своевременную локализацию.

Установлены основные компоненты интеллектуального здания: элементы, реагирующие на присутствие или отсутствие (действие или бездействие) пользователя интеллектуальным зданием и изменение параметров окружающей среды; средства автоматики, регулирующие параметры интеллектуального здания на основе анализа состояния окружающей среды и изменения ее параметров; алгоритм саморегуляции интеллектуального здания, направленный на повышение комфорта и безопасности его пользователя.

Определены инженерные системы, образующие единую информационную сеть: автоматизированная система управления зданием; структурированная кабельная система; кабельная канализация и исполнительные механизмы; система сбалансированного энергоснабжения; система кондиционирования и вентиляции воздуха; автоматизированная система водоснабжения; автоматизированная система теплоснабжения и энергосбережения; локальная вычислительная сеть; учрежденческие автоматические телефонные станции; система коллективного приема телевизионных сигналов; автоматизированная система лифтового оборудования; система электрочасофикации; местное вещание, оповещение, система управления эвакуацией людей при чрезвычайных обстоятельствах; система безопасности здания.

Проведенные исследования позволили установить рекомендуемый перечень инженерных систем зданий и сооружений, в отношении которых целесообразно применить единую автоматизированную систему управления зданием; основные функции этих систем, включая системы энергоснабжения; основные компоненты автоматизированной системы энергоснабжения здания, технические и технологические требования к ней; группы

энергопотребления в системе энергоснабжения зданий в зависимости от условий их использования; базовые функциональные характеристики компонентов автоматизированной системы энергоснабжения, определяемые в техническом задании (потребляемая мощность, рабочее сетевое напряжение, тепловыделение, электромагнитная совместимость технических средств и пр.); особенности автоматизации систем энергоснабжения в зданиях из сборного железобетона; базовые функциональные характеристики периферийных устройств отображения информации, обеспечивающие формирование тревожного сигнала о возникновении чрезвычайной ситуации; требования к организации электропитания устройств единой автоматизированной системы управления зданием, с учетом организации системы гарантированного электроснабжения и установки резервирующих источников питания.

Полученные результаты позволяют наиболее рациональным и экономичным образом проектировать автоматизированные системы энергоснабжения в зданиях из сборного железобетона.

Keywords: building intellectualisation, automated building control system, building utilities, balanced energy supply system, automatics tolls, environment parameters variation, smart building self-regulation, unified information network, building security system, basic performance characteristics.

Ключевые слова: интеллектуализация зданий, автоматизированная система управления зданием, инженерные системы зданий, система сбалансированного энергоснабжения, средства автоматики, изменение параметров окружающей среды, саморегуляция интеллектуального здания, единая информационная сеть, система безопасности здания, базовые функциональные характеристики.

INTRODUCTION

Ever more demanding requirements of customers, operators and resource suppliers for the constructed buildings in terms of their cost-effectiveness, comfort and safety of staying in them, satisfaction of the growing demands of people including individual views with regard to the appropriate level of the quality of life have resulted in the need for the design of the new types of buildings, optimisation and improvement of existing ones, implementation of effective technologies for construction and operation of these buildings throughout their full lifetime.

Due to the need to solve these problems, the engineering and scientific community faces several extremely interesting challenges. Here, the decisive role should be played by intellectualisation of facilities; in combination with optimisation of consumption of resources (such as energy, materials, labour, financial resources), it resolves the task of comprehensive provision of security as well as the task of interactive building utilities control and, therefore, improvement of people's quality of life. A modern building should be considered as a sophisticated engineering system that, in terms of functions performed and their interrelations, in terms of complexity and importance of implemented tasks is not inferior to any mechanisms or even surpasses them.

AUTOMATED BUILDING CONTROL SYSTEMS

Intellectualisation of buildings is not an aim but only a means to reach the true ultimate aim – provide services and create products and infrastructure that are cost-effective and have high quality.

Buildings resulting from application of intellectualisation technologies and processes are more cost-effective in operation resulting in significantly shorter investment return period due to more efficient work of personnel and reduction of building maintenance costs. By contrast, the cost of operation of the so-called "averaged" building in the ex-USSR countries is ten or more times higher than the cost of construction. It means that the main component in the building cost is the cost of its operation, while formation of an intellectual engineering infrastructure in it raises its liquidity significantly, as a result of implementation of various energy- and resource-saving control algorithms. Indeed, a smart building provides optimal distribution of resources and contributes to the reduction of the operating costs using the user-friendly monitoring and control interface. Also, utilities integrated by the unified automated control system are capable to provide complete adaptation to possible changes in the future.

The following major components can be distinguished in a smart building:

- elements responding on presence or absence (activity or inactivity) of smart building users and on variation of environment parameters;
- automatics tools regulating the parameters of a smart building in accordance with the results of analysis of environment condition and variations of environment parameters;
- smart building self-regulation algorithm focused on improvement of comfort and safety for its users.

Also, different utilities make up a complex capable to perceive, accumulate and exchange information between components and to produce adequate response from its components. The utilities making up the unified information network are:

- automated building control system (hereinafter referred to as the ABCS) or automated building operation control system;
- structured cabling system (hereinafter referred to as the SCS);
- cable conduit system and actuators;
- balanced energy supply system;
- air conditioning and ventilation system;
- automated water supply system;
- automated heat supply and energy saving system;
- local computer network;
- private automatic branch exchanges (PABX);
- community antenna television (CATV);
- automated lift equipment system;
- electric clock system;
- local broadcasting, warning and emergency evacuation system;
- building security system.

In terms of technology, the automated building control system is the major element arranging the activity of building utilities (energy supply, lighting, heating, air conditioning, sewerage etc.). The effectiveness of the ABCS operation is predetermined by the number of monitoring points (monitoring devices) installed in the building. A monitoring point (a monitoring device) is a device for automatic regulation or control over one or several physical values or technological plants. It should be noted that, taking into consideration the international norms regulating the ABCS design and construction, at least 15,000 monitoring points must be installed in a building, while only 2,000 is the sufficient number of such points in accordance with Russian norms.

The ABCS is a set of software and hardware that use data received from monitoring points and take into consideration the mathematical models of their interaction and desirable environment parameters predefined by the user to forecast possible results of joint operation of systems and also provides:

- real-time collection of information about the condition of all building utilities at the operator's workstation;
- 24-hour monitoring of condition of all building utilities and automatic recording of all events that take place (including the cases when the current values of parameters deviate from specified or user-defined values), with tools making available the formation of the database (report base) to contain statistical information about the systems' operation and automatic tabulation of reports recording the consumption of various types of energy by various consumers and by the building as a whole;
- prevention of duplication of functions carried out by the building utilities and their colliding operation (e.g. heating and air conditioning systems);
- possible reduction of the number of attending maintenance technicians;
- building utilities operation mode arrangement in accordance with diurnal variations of ambient temperature and the number of people in a building, with the tools for remote system switching to manual or automatic control mode;
- optimal energy consumption, with a view to keep and maintain the environment as comfortable as possible in building parts where people currently present, and to provide redistribution of energy resources between systems to ensure there effective usage and saving;
- variation and correction of parameters of the internal environment, taking into consideration the desirable user-defined parameters;

- centralised monitoring and control for building utilities in case of emergency onset including timely localisation of emergencies and making prompt decisions when they arise.

SMART BUILDING ENERGY SUPPLY SYSTEM AUTOMATION

The balanced electric power supply system of a smart building provides an organisational structure of the energy supply system capable to ensure stable uninterruptable activity of users and enterprises. It has be said that the quality of electrical energy delivered now to the users in our country does not meet the requirements of regulations being in force, including frequency deviations, voltage depressions, high-frequency noise etc. Therefore, connection of high-tech equipment, sensitive to the electric energy quality worsening, to the really existing electric mains can result not only in malfunctions but also in premature failures. Taking into consideration that the customers' requirements for the electric energy are different, it is reasonable to subdivide the customers into different groups, and their integration into a unified system shall be carried out at the level of the energy engineer's service, using the tools making it possible to automate the complete energy supply system of a building. The following energy consumption groups exist:

- general electric power supply system (hereinafter referred to as the GEPS);
- smart lighting system (hereinafter referred to as the SLS);
- secure electric power supply system (hereinafter referred to as the SEPS);
- high-tech equipment electric power supply system (hereinafter referred to as the HTEEPS);
- grounding system (hereinafter referred to as the GS);
- key energy indicators' monitoring and control system (hereinafter referred to as the EIMCS).

Such a subdivision makes it possible, on the one hand, to resolve the task of reliable balanced electric power supply for any building (or enterprise) and, on the other hand, to ensure high quality of electric energy delivered to a customer.

The general electric power supply system shall be used to provide electric energy to the customers not critical in terms of the electric energy quality, such as local lighting fixtures, general-purpose household appliances etc. This system consists of three major elements:

- power cable part itself, terminated by electric outlets providing appropriate power;
- lead-in distributors and automatic devices subdividing the users into sections and consumer groups;
- microcontrollers, voltage sensors and current sensors, suitable for determination of electric mains load and energy quality in active mode.

While the first and the second elements of this system are usual in electric power supply system configurations, the third element is directly designed for the GEPS automation; indeed, it is an intellectualisation element for this system. Microcontrollers, voltage sensors and current sensors shall be considered as an intermediate link in the energy engineer's service that implements not only monitoring of major parameters but also redistributes the electric energy when the enterprise structure is changed. The third element in the system is mandatory.

The smart lighting system shall be used to provide high-quality and cost-effective lighting conditions in all points throughout a building. For this system, the unified organisational centre establishment is expected for the lighting equipment control in accordance with the preset programme or in line with the current situation. Due to the SLS, the following parameters can be taken into consideration for the lighting control:

- people's presence or absence in a room;
- external lighting condition;
- positions of personnel at work etc.

The secure electric power supply system shall be used to ensure reliable high-quality uninterruptable electric power supply for high-tech equipment, both under normal conditions or in case of failure of standard energy supply as a result of emergencies or energy supply quality worsening under industrial or other noises.

The need for the secure electric power supply system results from really-existing worsening of electric energy standards (voltage: 220 V ± 10%; frequency: 50 Hz ± 1%; non-sinusoidality factor: 8%, for long time, and up to 12%, for short time) due to electromagnetic processes in the wiring that result in impulse noises. The SEPS is a set of uninterruptable power supplies (UPS) and secondary backup electric power supply sources – diesel generator units (DGU), interacting through appropriate circuits to ensure reliable implementation of tasks by the equipment. Self-contained local uninterruptable energy supply systems providing independence of electric energy consumers from noises in the industrial mains make it possible, depending on the equipment class and configuration, to neutralise all noises arising in the mains or their specific combination.

Various configurations may be used to build the SEPS for a set of consumers located, in terms of their territorial layout, on several floors or in several buildings. No, three SEPS structure alternatives are the most common ones:

– decentralised. In this system type, a consumer or a group of local consumers are provided with the electric energy from separate (local) UPS having appropriate power. The advantages of the decentralised SEPS include availability of the selective protection of separate elements in an electric circuit making it possible, in case of failure of an UPS, to disconnect only specific parts of the system; also, separate devices in the system can be reconfigured quickly (increase of power and extension of holdup time for separate UPSs etc.). The disadvantages of the decentralised SEPS include system's low reliability due to the need to use large number of devices, ineffective use of charge of accumulator batteries as a result of impossibility to ensure equal load for all UPSs, and low stability in case of overloads resulting from erroneous connection of an additional load or a short circuit. Application of this system type is preferable if the electric circuit topology is sophisticated, if separate groups of equipment are located at large distances or there are no premises for installation of high-power UPS. If the decentralised SEPS is implemented, UPS with power from 250 VA to 6 kVA shall be used;
– the centralised system where the single UPS (or several UPSs connected in parallel) shall be installed to provide power supply for all consumers in a building. The advantages of this system are as follows:
– load with high unit capacity can be connected;

- system power reserve can be accumulated due to high-capacity batteries used, making the centralised system less sensitive to local overloads and capable to survive even short circuits with transient resistance higher than some value determined by the UPS output power reserve;
- significant extension of system holdup time due to disconnection of less critical consumers;
- high reliability due to the reduction of the number of devices;
- prevention of overloads of the neutral conductor at the UPS input making the whole electric power supply circuit more reliable.

The disadvantages of the centralised system:

- cost growth when longer holdup time is necessary. Indeed, to make the holdup time longer for a separate group of equipment, the holdup time for the whole system must be extended;
- separate room must be allocated for the UPS installation;
- high probability of a local failure, i.e. de-energising of consumers as a result of failure of the branched output electric power supply circuit or failure of one of consumer (e.g. if a short circuit arise in a power circuit).

Application of a centralised system is preferable when the great number of equipment installed within one building must be protected. If the centralised SEPS is implemented, UPS with power from 7.5 kVA to 500 kVA shall be used. Among the options for configuration of the centralised system is the configuration with several installed UPSs connected in parallel. Here, the full system power may be used, or hardware redundancy may be available.

- the combined system where the central UPS is used to provide the electric power supply for all equipment components in the system; however, supplementary low-power UPSs shall be installed for especially critical sections within the network (such as critical servers, workplaces etc.). Such a system makes it possible to extend the electric power supply holdup time, with the SEPS general reliability becoming higher.

It is obvious that both centralised and decentralised SEPS are used quite rarely. The most preferable alternative is the combined system, optimal in terms of power and equipment cost, identification of critical consumers and minimisation of the number of consumer groups by appropriate configuration of a local computer network. For any chosen alternative of the secure energy supply system based on UPSs, if long-time operation in independent mode (i.e. with the input electric mains deactivated) is necessary, one or several diesel generator plants should be added in the complex to ensure long-time independent operation. Generators must be provided with an automatic start and shutdown system using the load switching and may be additionally provided with remote control and monitoring desks. To choose the power and number of generator plants, the connected load power must be taken into consideration, and whether the quite large equipment can be installed within a building or in the immediate vicinity of it. The reasonable design for the generator plant is a soundproof casing or a weatherproof container. If several generators are connected, the special control and synchronisation unit for parallel DGP complex shall be installed on a common load.

For the secure electric power supply system consumers, subdivision into two groups is reasonable:

- group A – the equipment that needs the electric power supply with stably high electric energy quality characteristics and for which no power interruptions are admissible (in accordance with the process cycle conditions). This group of consumers shall include all computer equipment, communication systems, active network equipment, video surveillance and alarm equipment;
- group B – the equipment connected directly to the diesel generator plant output, for which stably high electric energy quality characteristics are not required and short power interruptions (30…120 s) are admissible. This group of consumers shall include emergency lighting systems, air conditioning equipment for the UPS complex installation and the set of guarding and alarm facilities and other equipment protected by local UPSs.

Due to this classification, i.e. identification of two groups of consumers in the secure electric power supply system, where these consumers are connected to the different types of power supplies (UPS and DGP), the following results become achievable:

- reduce the load for UPS and extend the UPS holdup time in the emergency mode by exclusion of the air conditioning and emergency lighting system from the group A;

– reduce the level of noises in a protected electric power supply grid for switching on/off the equipment for which the non-linear current consumption with high starting currents is typical.

For the SEPS design, data must be taken into consideration that describe the current and expected condition of the equipment that needs connection to the secure electric power supply grid. Also, to calculate the necessary UPS power, it should be taken into consideration that, during long operation of high-power UPSs with a distributed consumer's network connected to their input, local overloads and unauthorised load connections are not impossible. Therefore, to ensure stable trouble-free equipment operation, its power shall be chosen with 15–20% margin from the designed load power. On the other hand, to provide backup for the parallel UPS complex in a building, the following condition must be met: the designed load power must not exceed the total UPS power not including the backup. To calculate the diesel generator plant power, not only the total power consumption for the load must be taken into consideration but also the minimal admissible load equal to 30%, because in case of long operation of a generator plant with smaller load, the motor service life is reduced significantly and special measures for maintenance are necessary.

The high-tech equipment electric power supply system is designed to arrange the power cable structure in the building (or enterprise), capable to provide distribution and reliable connection of the SEPS to the full set of equipment. The equipment shall be considered as high-tech when it needs high quality characteristics for the electric power supply in accordance with its purpose and must run uninterruptedly, or the interrupts must be short in accordance with the process cycle of the major activity carried out by the enterprise (depending on the purpose of the equipment in operation). This equipment shall include the computing equipment and special banking equipment, communication systems and active network equipment, equipment for video surveillance and alarm, emergency lighting and guarding facilities etc.

The high-tech equipment electric power supply system shall be implemented in a way making it possible to control, in a centralised manner, the active condition of high-tech equipment including remote disconnection from the energy consumption system in accordance with the preset programme; this will make it possible to use the system power reasonably. The high-tech equipment electric power supply system is built similarly to the general electric power supply system, using the parallel cabling method, with similar functions for the electric power supply quality monitoring and control; this, in turn, makes it possible to control and redistribute power consumption between the groups within the system.

The grounding system shall be used for protective grounding, i.e. to provide reliable protection of building equipment against insulation breakdowns and other emergencies and situations hazardous for human health. The protective grounding provides safety requirements in work with electrical installations, protection of computing machinery and computer networks against electrical noises, pickups and static electricity. The protective grounding shall be made in cable ducts, using the cables of the uninterruptable electric power supply subsystem.

The key energy indicators' monitoring and control system shall be used to monitor and control the quality indicators and consumption throughout the energy supply system as a whole. This system is a component of the ABCS. The key energy indicators' monitoring and control system shall be considered within the general system of a smart building not only as a system for adjustment of electric parameters but as a system providing interactions between an UPS and ABCS. Indeed, the key energy indicators' monitoring and control system is a software and hardware complex that makes it possible to implement interaction of high-power UPSs with servers and appropriate workstations, using the computer control systems. Adequate interaction between the system and the ABCS is necessary because in emergencies the operating groups need information about the condition of each UPS. They can use this information to make a decision on further only true choice of an algorithm for termination of operation of energy-dependent subsystems (or for maintaining operability of these subsystems). Here, software must be used to build an algorithm for operation termination (or continuation), and it must be sufficiently smart to create own database for information about critical situations.

The key energy indicators' monitoring and control system has a four-level structure consisting of elements as follows:

- information bus;
- smart controllers with service drivers;

- actuator sensors and alarm sensors;
- hardware and software complex for supervisory visual monitoring and control of the system condition.

The information bus connects the system sensors with controllers and shall be used for transmission of signals for activation/deactivation of lighting fixtures, activation/deactivation of workgroups in GEPS, SEPS and HTEEPS energy supply systems, information about the condition of system's energy-related characteristics (voltages, currents, electrical noises etc.). The following requirements are applied to the key energy indicators' monitoring and control system:

- availability of forced shutdown of non-critical devices in order to extend the UPS service life. The devices responsible for especially important operation processes must remain operable or must be switched to inactive condition without loss of data;
- availability of load distributed throughout the full GEPS complex;
- availability of submission of complete information to the ABCS including the following information:
- UPS condition (temperature, condition of batteries etc.);
- existing input voltage;
- existing current etc.;
- availability of equipment interaction in the key energy indicators' monitoring and control system for correct termination (continuation) of operation of servers in emergencies;
- availability for the ABCS to control the condition of the key energy indicators' monitoring and control system.

SPECIFIC FEATURES OF AUTOMATION OF ENERGY SUPPLY SYSTEMS IN PRECAST CONCRETE BUILDINGS

For the development of automated energy supply systems in precast concrete buildings, it should be taken into consideration that, due to high concentration of steel reinforcement in building structures, it is not only affected by electric and magnetic fields but, as a result of this effect, generates own fields that can distort both signals from monitoring devices and instructions sent to actuators. In this regard, these devices shall be installed in such a way as to minimise this effect. This factor should also be taken into consideration to choose the data transmission method for communication between these devices:

- twisted pair, the cheapest cabling connection. The advantages are low price and easy wiring;
- coaxial cable. Shielding contributes to resolving the problems with radiation from conductors because a wire can behave as an antenna. The price is within the middle range;
- multiconductor cable. Transmission rate per one wire is low, eliminating the signal reflection problems and making the interface circuits easier and cheaper. The disadvantages are: the need for shielding, high cost;
- fibre-optic cable is noise-protected. It is recommended for application when electromagnetic noises exist;
- radio channels are not recommended because the buildings are shielded;
- infrared channel is not sensitive to electromagnetic noises but it can work only within the line-of-sight distance;
- microwave channel. As compared with infrared channels, microwave channels provide higher transmission rate within the line-of-sight distance.

CONCLUSION

A smart building is a combination of engineering, technical and technological solutions focused on creation of a highly-efficient cost-effective system meeting, as far as possible, the needs of users and owners of a building (or an installation). This effect is achievable due to integration of building's major utilities into the unified information and control system and their interaction based on the unified data transmission medium.

The studies carried out made it possible to specify:

- the recommended list of utilities for buildings and installations for which the unified automated building control system application is reasonable;
- major functions of these systems including the energy supply systems;

– major components of the automated building energy supply system, technical and process-related requirements for it;
– energy consumption groups in the building energy supply system, corresponding to their usage conditions, such as a smart lighting system, a secure electric power supply system etc.;
– basic performance characteristics of components of the automated energy supply system described in the requirements specification (power consumption, operating mains voltage, heat release, electromagnetic compatibility of equipment etc.);
– specific features in automation of energy supply systems in precast concrete buildings;
– basic performance characteristics of peripheral data display devices providing generation of emergency onset alarm;
– requirements for arrangement of electric power supply for the devices within the unified automated building control system, taking into consideration the arrangement of the secure electric power supply system and installation of backup power supply units.

The gained results make it possible to design automated energy supply systems in precast concrete buildings in a most reasonable and cost-effective way.

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Статья поступила в редколлегию 20.11.2017.