
Substantiation of factors and criteria of efficiency evaluation of the military automated control system operation

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Abstract

The article deals with outcomes of the conducted research, which are valuable for the Armed Forces personnel of all levels involved in the ensuring the military automated control system (MACS) operation. The article is devoted to the urgent issue of efficiency evaluation of the MACS operation. The analysis of existing methods of efficiency evaluation of the MACS operation is conducted; the approaches to the definition of the MACS operation efficiency are analyzed. It was found inconsistencies in the existing methods of efficiency evaluation of the Military Automated Control System and principles of modern Automated Control System operation based on the analysis. The substantiation of the sustainability factor (criteria) as the main factor (criteria) of the efficiency of the aviation and air defense Automated Control System (ACS) operation is conducted in the article.

The usage the proposed factor to evaluate the efficiency of the MACS operation allows considering not only the network structural sustainability but also its own sustainability, taking into account the limited bandwidth of the communication system. This approach will help reduce the cost of the Armed Forces of Ukraine to lease digital streams.

Keywords: automated control system, efficiency, sustainability, bandwidth.

Introduction

The analysis of the military art development, the wars and armed conflicts experience of the last decades shows that the superiority achievement factor in the troop's management becomes more and more important in the present conditions of considering operations (combat operations). In turn, the automation introduction is the main focus of improving and developing the commanding troops (forces) process in the leading countries of the world (Osborn Kris, 2018).

The use of automated control systems (ACS) makes it possible to significantly increase the efficiency of forces and means using of all branch of Armed Forces. This is especially true for the Air Force, as the fleeting and volatile nature of warfare (operations) requires adequate decisions in the shortest possible time (Nisienko Borys, 2017).

The functioning of the ACS in modern armed conflicts is determined by the fact that the elements of the control system become the priority goals of the enemy. Their destruction makes it possible to gain an advantage over troops who have lost centralized control in the short term.

The troop's management in the modern operations (combat operations) conditions is a complex process. The main of its content is: continuous collection, study and synthesis of the situation; decision-making; bringing orders, orders and signals of combat management to the subordinate troops; modeling and planning of operations; organization and support of interaction; organization and considering measures to support the combat readiness of troops; organization of comprehensive security; constant monitoring of the tasks

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accomplishment and providing the necessary assistance to the subordinates.

The fulfillment of these tasks implies the stable and efficient the military automated control system (MACS) operation. The main factors for efficiency evaluation of the system are: combat readiness, sustainability, mobility and bandwidth.

According to the experience of considering anti-terrorist operation and training with military communications units, one of the main factors affecting efficiency of the MACS operation is the reduction of the capacity of leased digital channels during the revitalization of the work of governing bodies.

Material and Method

The purpose of the article is to explore the possibility of using sustainability factors to evaluate the efficiency of the aviation and air defense ACS operation.

To ensure achievement of the article's purpose, it is recommended to decompose the objective of the scientific research and to describe each stage of the research:

First, to consider the conditions and major operational and tactical factors that affect the

The traditional method of improving the communications quality in the Armed Forces of Ukraine is to increase the leasing capacity of telecommunications operators. But this method has proven ineffective in practice. It has little effect on communication quality and significantly increases the financial cost of renting. Therefore, the question arises of the substantiation of factors and criteria for evaluation the efficiency of the MACS operation, by which it is possible to calculate the minimum required bandwidth of leased channels to ensure the required level of efficiency of the MACS operation.

efficiency of the aviation and air defense ACS operation;

Secondly, to analyze the existing techniques for evaluation the efficiency of the aviation and air defense ACS operation;

Third, to justify the factor and the criterion for evaluation the efficiency of the aviation and air defense ACS operation.

During the study, the following were analyzed and used: analysis, synthesis, induction, deduction, generalization.

Results and discussion

3.1. The task of evaluation the efficiency of the MACS operation has to be solved at all stages of its life cycle, from the stage of development and adoption to service and ending with service in the troops. The purpose is to determine the suitability of the system to perform its tasks in different conditions of combat use.

The efficiency of control means the influence of a control system on the attainment of the ultimate objectives of combat operations or the degree of troops potential combat capabilities use in an operation (Medvedev V.K., 2018).

Quantitatively, the system efficiency can be assessed using the efficiency factors – a numerical factors that characterize the tasks completions degree, which set before the system from different points of view. Comparison of the quantitative factors of the systems shows how (or

how many times) one system is better (or worse) than the other in one factors or another, or how much one system is more efficient than the other.

The aviation and air defense ACS are a complex, hierarchical system with numerous functional connections and tasks. A number of publications are devoted to the research of the efficiency of complex control systems (Korenivska I.S., 2019; Kucherenko Yu.F., 2019). Their analysis shows the efficiency of the military command and control system operation depends on many operational tactical factors. They can conditionally be divided into two groups: directly and indirectly affecting the military command and control system. The influence degree of all operational tactical factors is almost impossible to take into account. Therefore, it is necessary to determine and analyze only operational and tactical factors

directly affecting the aviation and air defense ACS in the operations context to develop recommendations for improving the aviation and air defense ACS in the interest of increasing the operation efficiency. These factors include:

Air defense missions in defense operations and the procedure for their execution;

The aviation and air defense control system adopted;

Possible influence of the enemy.

The impact of these factors leads to incomplete realization of the potentials inherent in the aviation and air defense control system, and in some cases, their significant reduction. That is why the system has sufficiently high operational and tactical requirements for efficiency, which will allow solving qualitatively the set tasks.

Currently the aviation and air defense ACS have been adopted by the Armed Forces of Ukraine. The new the aviation and air defense ACS are gradually equipping the Air Force control points. The existing Air Force communication system is used to transmit the necessary flow of information between control points.

Analysis of the existing communication system [2016, May 4; 2016, December 18] showed the following shortcomings in its functioning:

The public telecommunications network used as the communication grid does not provide prompt and high quality solutions to management problems due to poor quality during peak times;

Considerable money is spent on renting a public telecommunications network;

Civil satellite systems are sensitive to changes in weather conditions. They do not work in motion. The cost of traffic requires an undue expense;

There is no fixed assets reservation at the control point and there are no communication channels at the destination;

Civilian radio-relay equipment discloses telecommunication nodes and reduces their mobility during deployment;

Absence of a false control points system.

Thus, the main task is to ensure the effective functioning of the the aviation and air defense ACS in modern conditions.

The main functional purpose of the aviation and air ACS is:

- Collecting, processing, storing, displaying and analyzing information;

- Transfer of information, commands, orders and signals of combat control between control points.

A MACS operation will operate under extremely difficult conditions during combat operations. The use of enemy fire and electronic means will adversely affect its functioning.

That is why the task of ensuring the sustainability of the aviation and air defense ACS elements is the most difficult and important. Requirements for the sustainability of the data subsystem, which is an element of the aviation and air defense ACS, are paramount importance.

3.2 One of the main tasks in assessing the complex systems efficiency is the formation and continuous improvement of the factors system. They should be adequate to the factors that reproduce the basic properties of the systems being evaluated.

Research and evaluation of the efficiency of the MACS operation, despite the sufficient number of publications (Rozhkov L.I., 1977; Bogovik A.V., 2006; Kucherenko Yu.F., 2019; Medvedev V.K., 2018) remains quite difficult a theoretical and practical challenge.

Changes in the state of the control system are in the process of functioning due to the influence of external and internal factors. Therefore, the procedure for evaluation the efficiency of the control system will be predicting the system functioning result (Zagorka O.M., 2020).

In practice, in solving problems related to the assessment of control systems combat capabilities, try to use single generic factors. It integrally assesses the impact of the control system on troop efficiency. However, the use of a generalized factor is associated with difficulties. They are due to the complexity of taking into account in the factor structure the totality of factors influencing it, and the possibility of obtaining it in the experimental research. This leads to the fact that in a comprehensive research of the aviation and air defense ACS efficiency, used

a set of factors, which are determined by the tasks to be solved.

An analysis of existing methods of assessing the control system efficiency shows that there are several approaches to research and evaluate the efficiency of the ACS.

The first approach is to evaluate the troops combat use efficiency. In the second case, the control efficiency evaluation is based on the analysis of the control system efficiency, in the course of solving tasks in aviation and air defense control under the given using conditions. Factors that evaluate the control system efficiency based on the aviation and air defense efficiency analysis in the reflection of air strikes are the control system combat efficiency factors. Accordingly, the factors that evaluate the ability of the control system to solve the information processing and control problems with the subordinate forces are called operation factors.

3.3. A MACS operation will operate under extremely difficult conditions during combat operations. The use of enemy fire and electronic means will adversely affect its functioning.

Therefore, the ensuring the aviation and air ACS elements sustainability is the most difficult and important. Requirements for the data subsystem sustainability as an aviation and air defense ACS element are paramount importance (Isakov E.E., 2009).

Therefore, the system ability to ensure the exchange of information between control points of a given volume in regulatory terms (Q), it is advisable to choose as the main factor of the aviation and air defense ACS efficiency.

This factor is a function of such a characteristic of the aviation and air defense ACS as sustainability ($K_{st_{ACS}}$):

$$Q = f(K_{st_{ACS}}) \quad (1)$$

It is characterized by the probability that the information retention time (t_z) will not exceed the admissible ($T_{z_{dop}}$), that is $Q = P(t_z \leq T_{z_{dop}})$.

The requirements for the allowable time ($T_{z_{dop}}$) delay of passing different information types are different. They depend on the information type being transmitted and the control level.

A generalized factor can be used in this approach to determine the probability of information passing through the aviation and air defense ACS in a specified time limits:

$$P(t_z \leq T_{z_{dop}}) = Q = f(K_{st_{ACS}}) \quad (2)$$

It determines the probability of information passing through the aviation and air defense ACS within the specified time limits.

The evaluation of the aviation and air defense ACS by the selected factor allows determining whether the system can provide the necessary information on time.

The modern operations main features are the determination, high dynamism, sharp and frequent changes of the situation. Therefore, as a criterion for evaluation the aviation and air defense ACS operation efficiency selected the requirements of the control system for the probability of passing messages within the specified time.

As a generalized factor of the sustainability of the aviation and air defense ACS is used the coefficient of sustainability $K_{st_{ACS}}$, which is determined by the by using the Eq.(3):

$$K_{st_{ACS}} = \frac{1}{N} \sum_{i=1}^N K_{st_i} \quad (3)$$

where N – is the number of information destinations;

K_{st_i} – the sustainability of the i^{th} information direction of communication;

$$i = \overline{1, N}$$

The sustainability of each i^{th} information direction is determined by using the Eq.(4):

$$K_{st_i} = K_{Gi} P_{zvi} \quad (4)$$

where K_{Gi} is a coefficient of readiness of the i^{th} information direction;

P_{zvi} – is a probability of connectivity of the i^{th} information direction.

In Eq. (4), the coefficient of readiness K_{Gi} determines the time parameters of the information direction failure-restoration process in case of fire and radio-electronic influence of the enemy and the probability of connectivity P_{zvi} are the structural-probabilistic parameters of this process.

A time factor of the sustainability of the i^{th} information direction is the readiness factor K_{Gi} , which is determined by the failure time T_{0i} and recovery time T_{Bi} (Isakov E.E., 2009):

$$K_{Gi} = \frac{T_{0i}}{T_{0i} + T_{Bi}} \quad (5)$$

However, this factor in this form does not take into account the level of technical staff. This also makes it impossible to accurately estimate the readiness factor.

To address this shortcoming, the study introduced a staff readiness factor K_p that shows the probability of timely completion of tasks to bring the equipment into working condition.

$$K_p = \frac{1 - e^{-\frac{T_n}{T_h}}}{1 - e^{-1}} \quad (6)$$

where T_h is the standard time for the troubleshooting task;

T_n is the time it takes to complete a troubleshooting task with existing technical staff.

Thus, the coefficient of readiness is calculated by using the Eq.(7):

$$K_{Gi} = \frac{T_{0i}}{T_{0i} + T_{Bi} K_p} \quad (7)$$

In Eq. (4), the probability of connectivity of the i^{th} information direction P_{zvi} means the probability that there is at least one path in a given direction by which the transmission of information with the required quality and volume is possible:

$$P_{zv} = P(k \geq 1 | \{Q_k\} \in \{Q_p\}) \quad (8)$$

where k is the number of workable paths in a given information direction, providing the specified quality of service;

Q_k is the bandwidth on a given information direction;

Q_p is the required bandwidth on the specified information direction.

The benefits of using this factor are:

- Reliability of switching equipment is taken into account;
- The type of physical channel of information transmission is taken into account;
- Availability of backup channels and routes is taken into account;

- The connectedness of the distributed structure is taken into account.

The probability of connectivity P_{zv} is calculated based on the following baseline data (Barabash O.V., 2005):

- The probability of transmitting the message in the relevant information direction;
- Structures of information and telecommunication system.

Considering that connectivity can be broken not only because of disability due to reasons of reliability, survivability, jamming resistance and cyber security, but also due to the lack of free channel resources (bandwidth of information directions allocated for the aviation and air defense ACS operation is less than necessary), then the probability of connectivity P_{zvi} can be represented by using the Eq. (9):

$$P_{zvi} = P_{str zvi} P_{in zvi} \quad (9)$$

where $P_{str zvi}$ is the probability of structural connectivity of the i^{th} information direction;

$P_{in zvi}$ is the probability of information connectivity and the i^{th} information direction.

The structural connectivity probability of the i^{th} information direction is calculated by using the Eq. (10):

$$P_{str zvi} = (1 - P_{vi})(1 - P_{fi})(1 - P_{ri})(1 - P_{ki}) \quad (10)$$

where P_{vi} is probability of failure of the aviation and air defense ACS elements due to the influence of internal destabilizing factors and natural processes of reliability;

P_{fi} is the probability of physical damage of the aviation and air defense ACS elements;

P_{ri} is the probability of suppression of the aviation and air defense ACS elements;

P_{ki} is the probability of failure of the aviation and air defense ACS elements due to information and technical influences;

The concept of information connectivity was introduced to take into account information bandwidth when determining the likelihood of communication between control points:

If the bandwidth on the i^{th} information direction Q_{ki} is more or equal to the required bandwidth on the i^{th} information direction Q_{pi} , that is $Q_{ki} \geq Q_{pi}$, then the probability of information connectivity is equal to:

$$P_{inz_i} = \frac{Q_{ki}}{Q_{pi}} = 1. \quad (11)$$

If the bandwidth on the information direction Q_{ki} is less necessary Q_{pi} , then the intensity of data packets entering the network will be higher than the processing speed of these packets and the queue will start to increase in the network. When maximum capacity is accumulated, if the packet intake speed exceeds the packet processing speed, the queue will reach its maximum value and continue to grow. If the drive overflows, the entry of all subsequent packages will be blocked. This will mean loss of connectivity in this information direction (Berkman L.N., 2001).

Conclusions

The analysis of the factors that influence efficiency of the MACS operation and the proposed scientific and methodological method for assessing the system efficiency have shown that the sustainability of the MACS operation can be broken not only for reasons related to reliability, survivability, jamming resistance and cyber security, as well as insufficient information capacity.

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In this case:

$$P_{inz_i} = \frac{Q_{ki}}{Q_{vi}} \quad (12)$$

Where Q_{vi} is the information flow received for service in the i^{th} information direction.

Bandwidth is closely linked to sustainability. There is a need to constantly increase bandwidth requirements by increasing the amount of information circulating in the control system.

Determining the minimum permissible bandwidth requirements for information directions will reduce redundancies in digital lease bookings ordered by telecommunications operators.

Further research will be directed to the development of techniques for calculating the minimum required bandwidth of information directions. It will increase the efficiency of the MACS operation to a level that will ensure the continuous troops management.

This approach will help reduce the cost of the Armed Forces of Ukraine to lease digital streams.

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