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QUALITY CRITERIA FOR CRITICAL INFRASTRUCTURE PROTECTION SYSTEMS

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Abstract
Using a variety of protection systems makes current problem of selecting appropriate criteria for their quality. The paper proposes an approach for their determination and based on generalizes indicators of their quality. The approach is related to the adjustment of certain quality criteria, taking into account the characteristics of the systems to protect critical infrastructure sites. Seven of these criteria are presented in the paper and the conditions for their use have been analyzed.

Keywords: Criteria, quality, system, protection

INTRODUCTION

It is well known that in accordance with ISO 9000/2000, the American Quality Society and many other organizations (http:/asq.org/glossary/q.html 2017, Tsonev S., Vitlyemov V., Koezh P 2004), quality is defined as a set of properties and characteristics of an article, defining its ability to satisfy certain needs of the consumer under specific operating conditions. From this definition it follows, that not all the properties and characteristics of the article come into the composition of its quality, but only those which determine the properties of the product to satisfy a certain need.

The quality indicator is a quantitative expression of one or several product properties, and the quality criteria are the requirements for a given indicator or set of indicators to have certain values. Depending on the nature of the properties, that quantitivly characterize the criteria and indicators for quality are being - physical, chemical, mechanical, biological, etc., and depending on their character - indicators for reliability, ergonomics, functionality, flawlessness, for patent purity, transportability, completeness. In addition, all quality criteria and indicators are divided into single, complex, and integral.

The single quality indicator characterizes only one of the products properties - tensile strength, hardness, relative elongation, etc.. The complex quality indicator characterizes a certain set of properties, that are part of the quality structure. It can be grouped and summarized. The grouped quality indicator is characterized by several simple properties or complex property, such as the reliability, which is determined by the repairability, durability, and storage properties. The integral quality indicator characterizes in a quantifying way the whole set of properties with which it is accepted to evaluate a product.

Most often, the integrated indicator reflects the relationship between the total useful effect of a product and the sum of the costs of its creation and operation. For example, an integrated quality indicator for a given protection system may be the volume of the "protected" area with certain performance for a certain period of time (eg until it is out of use), to the costs for creating, maintaining, operating, repairing and utilizing this module.

Due to the fact that in most cases the costs of setting up and operating the protection systems are relatively well defined theoretically they are not of interest. On the other hand, the quality criteria based on single and group indicators are incomplete and could be used either to solve private tasks or to combine them into a set of criteria.

Therefore, the study proposes adapting certain quality criteria based on summarized quality indicators, adapted to the specifics of the systems for protection of the critical infrastructure.

Criteria for the Quality of Object Protection Systems

The primary purpose of the systems for object protection is to prevent attacks on them or to reduce the effect of those attacks. This could be achieved by preventing attacks and destroying or damaging the attackers, and by hindering their access to areas from which they can attack. In general, the description of those characteristics includes the probabilities for and magnitude of the impacts both of the attacking devices on the protected objects and on the modular systems for their protection, as well as those caused by the systems and means for protection against the attackers (Tsonev S., Vitlyemov V., Koezh P., 2004).

Let us assume that there are "I" possible types of means for attack against "J" protected objects. Let's also assume that there are "M" types of modular security systems, each of which is designed to cover one or more objects.

Let's introduce the following labels:

- P_{ij} - the probability for "i"-type of attacking, to inflict a real impact on the "j"-type of protected object (i=1÷I, j=1÷J);
- $Q_{i/j}$ - the probability for the security system to actually impact the "i" type of attack by covering the "j" object;
- $R_{im/j}$ - the probability for this type of attack to actually effect the "m"-type of protection module, when attempting to impact the "j" protected object;
- α_{ij} - loss caused by "i" type of attack in real impact on a "j" protected object, without the covering of "m" type protection module;
- $\gamma_{im/j}$ - loss caused by "i" type of attack in real impact on the "m" type protection module, when attempting to impact on "j" covered object;
- β_i - loss caused to the "i" type of attacking mean by the protection system;

With certain values of these parameters it is possible to formulate the following main groups of quality criteria for protection systems:

Criteria for Minimum Average Total Loss (of the protected objects and the protection modules)

This criterion takes into account the average losses inflicted by the attackers against all objects - both the protected objects and the components of the security system. Its overall look is:

$S1 = \sum\sum\sum P_{ij}R_{im/j}\alpha_{ij}\,\gamma_{im/j} = \min$ (1)

where summing is for i=1÷I, j=1÷J и m=1÷M.

It is known (Georgiev N., 2014) that $Q_{i/j}$ can be considered as depending on the likelihood that the intelligence subsystem will, in a timely manner, detect the "i" means of attack ($Q_{i/j1}$), the likelihood of this information being transmitted in the required quality, and on its basis, to be made a decision for impact against the "i" type of attack($Q_{i/j2}$) and the likelihood that the impact of the protection system to be effective, i.e. the impact on the "i" type of attack ($Q_{i/j2}$) to realize loss β_i ($Q_{i/j3}$). Furthermore, it can be assumed that during the operation the value of P_{ij} and $R_{im/j}$ are of relatively constant values - P_{ij0} и $R_{im/j0}$. These values can be substantially changed with coefficient K_{ij}, which depends mainly on the actions of the protection system ($K_{ij} = 1 - Q_{i/j}\beta_i = 1 - Q_{i/j1}Q_{i/j2}Q_{i/j3}\beta_i$).

By introducing the parameters described above, the criterion for minimal average total losses becomes:

$S1 = \sum\sum\sum P_{ij0} R_{im/j0} K_{ij} \alpha_{ij} \gamma_{im/j} =$

$= \sum\sum\sum P_{ij0} R_{im/j0} \alpha_{ij} \gamma_{im/j} (1 - Q_{i/j1} Q_{i/j2} Q_{i/j3} \beta_i) =$

$= \sum\sum\sum V_{ijm} P_{aij}$ (2)

where:

$V_{ijm} = P_{ij0} R_{im/j0} \alpha_{ij} \gamma_{im/j}$ - coefficient for importance of the "i" attacking mean against the "j" protected object and the "m" module of the security system;

$P_{aij} = (1 - Q_{i/j1} Q_{i/j2} Q_{i/j3} \beta_i)$ - coefficient for response of the protection system against the "i" attacking mean against the "j" protected object and the "m" module of the security system.

Formula 2 characterizes the average risk not only through the actions of attacking means, but also by the counteracting of the protection systems ($Q_{i/j}$ and β_i). It should be noted that the relationship between α_{ij} and $\gamma_{im/j}$ on the one hand and $Q_{i/j}$ and β_i on the other hand, is more complex and its determination is appropriate to be done for fixed situations, or by using the game theory. However, the approximation used does not change the overall quality dependency between the quality of the system and the parameters involved in Formula 2.

Obviously, the minimum of the average risk is achieved by taking into account both the importance of individual attacking means V_{ijm} and the capabilities of the defense system to counteract it P_{aij}.

This criteria is applicable if the protected objects and modular systems are of comparable value. In addition, the criterion is appropriate in cases where it is necessary to maintain the capacity of the protection systems with a view to their further use. This is applicable, for example, in the case of expected long-term aggressive actions against a large number of critical infrastructure sites, where both their potential and the potential of the defense system needs to be stored.

In the case of protection of important critical infrastructure objects as well as episodic aggressive actions, this criterion is not appropriate because it provides for the use of a "self-defense" resource of the security system modules.

Minimum average loss criteria

The minimum average loss criterion only considers the losses of the protected objects and is of the type:

$S2 = \sum\sum\sum P_{ij} \alpha_{ij} = \min$ (3)

where summing is for $i=1 \div I$, $j=1 \div J$.

Taking into account the parameters used for Formula 2 we can record the minimum average loss criterion as:

$S2 = \sum\sum\sum Pij0Kij\alpha ij =$

$= \sum\sum\sum Pij0\alpha ij(1 - Qi/j1Qi/j2Qi/j3\ \beta i) =$

$= \sum\sum\sum Vijmo\ Paij$ (4)

where Vijmo = Pij0αij is the coefficient of importance of the "i" attacking mean in its action against "j" protected object.

Obviously, in this case, the criterion envisages minimizing the losses of the protected sites, regardless of the losses of the protection modules. It should be taken into account that the application of this criterion should be done taking into account all possible scenarios for the development of the situation. In multivariate or multi-stage attack scenarios, losing the capability of protection devices in order to minimize the losses of the protected sites could lead to many times greater losses in subsequent periods of time. The criterion is also not applicable if there is a group of objects of critical importance and a group of other protected objects - of lesser importance. In this case, in a given situation, the criterion would provide for a cost of an unjustified resource to protect minor objects, risking a loss of ability to protect others due to destruction of components of the security system. Such are numerous cases of destruction of anti-aircraft defense at the outset of the attacks, with the subsequent almost trouble-free execution of the main tasks of the attacking group.

This criteria is applicable if the protected objects are of equal importance, single or small groups are expected to attack them, and the protection systems can be recovered relatively quickly or are with a high degree of self-defense.

Criteria for maximum permissible average losses

In order to overcome the weaknesses of the minimum average risk criteria, and to ensure a certain level of protection, a method of fixing the allowable losses is used. The method provides for the average loss (total or only of the protected objects) in any scenario of aggression not to exceed predetermined values, ie.:

$S1 < S1гр$ or $S2 < S2гр$ (5)

where S1гр and S2гр are the limit values for the respective average losses.

This approach is applicable if it is inadmissible to reduce the residual value of the protected objects and the modular systems or only the protected objects, respectively, below certain values. In principle, it can not be used if there are particularly important objects to be preserved independently of the other losses (eg nuclear power plant). In this case can be used a combination of the minimal average risk criterion (for the priority site - the nuclear power plant) and the criterion of the maximum allowable average losses of the other protected sites.

Criteria for the maximum average losses of the opponent

This criterion is based on the hypothesis that site protection should be achieved by minimizing the capabilities of the attacking means, ie. the criterion is:

$S4 = \sum\sum\sum Qmi/j\ \beta mi = max$ (6)

where summing is for $i=1 \div I$, $j=1 \div J$ and $m=1 \div M$.

In practice, the criterion means a denial of protection for specific objects and is most often applicable if it is example for such case is the loss of airplanes that led to the end of US involvement in the Vietnam war, the denial of action in some areas with politically unacceptable losses of their own forces and resources and other. In some cases, the criterion can be used in the presence of extremely many and relatively equally important protected objects, which transforms the task of protecting them into a task to protect the territory in which they are located (reducing the capacity of the means attacking that territory) (Stoichev K., Popov A., Lichkov N., 2012).

Criteria for providing the minimum needed average enemy losses

This criterion is a modification of the opponent's maximum average loss criterion and is related to the introduction of a requirement to guarantee a certain minimum value for these losses, which means:

$S4 \geq S4гр$ (7)

where S4гр is a limit, admissible value for the average loss of the opponent.

This criteria is applicable if the objectives of the defense are, in the event of attack, to attain at least certain losses of the opponent which would lead to certain consequences (eg denial or inability to continue aggressive actions). The realization of the criterion for ensuring the minimum necessary average losses of the attackers also makes sense of a constraining factor, leading to the refusal to carry out the aggression.

Maximum loss ratio criteria

$S4/ S1 = max$ or $S4/ S2 = max$ (8)

This approach is applicable if the protected objects and systems are in relative parity with the capabilities of the attacking means and the aim of the counteracting is to achieve a faster loss of enemy capacity while maximally preserving its own. This type of criteria can also be called criteria for action, aiming at preserving the maximum ratio of the forces.

CONCLUSION

These criteria are based on aggregated indicators for the quality of the protection systems. Their use depends on the specific scenarios of aggression - for example, with the expected aggression by terrorist groups, the minimum average loss or maximum permissible such (Dochev D., Petkov Y., 2008.). In the event of a short aggression from another country, it is appropriate to match the criterion of maximum average losses of the opponent or the maximum loss ratio criterion. In case of expected long-term aggressive actions could be used the minimum average general losses criterion. It is also possible to use other criteria, obtained by different combinations of the already available such, as well as by grouping certain sets of defense objects, modular systems and attacking means, and setting different private criteria for each individual group.

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