"SAFETY" AS A CHARACTERISTIC OF ONE OF THE SINGLE RELIABILITY PROPERTIES

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Abstract

The paper deals with the problems of interrelation between two most important properties of technical (production) systems: safety and reliability that were considered historically separately. However, recently both properties have proven to be increasingly more interrelated, which makes their joint study topical. And the safety may be treated as the most important reliability property, determining to a great extent all the remaining single reliability properties. The relation between the notions of "technical safety" and "energy safety" is also studied.

Keywords. Object, single properties, safety, reliability, technical perfection, interrelation, costs, failures, effects.

In 1980 the terminology in [1], possibly for the first time in the world practice, included such properties as stabilability, survivability, controllability and also **safety** as the object's principal properties forming a complex reliability property of energy systems in addition to those indicated in the then State Standard 13337-75 [2] (or in the current State Standard 27.002-89).

We will consider expediency of applying the notion of safety in reliability on the example of power plants, though in our opinion all the information given below is true for other technical (production) objects.

As concerns safety that is defined as an object's property to prevent people and environment from dangerous situations, the terminology in [1] explains: "the necessity to consider "safety" property in the context of "reliability" can be shown on the following example. Reliability …of a system can be low … because of high probability for people and environment to be injured at any failure of operation … This is a low safety and hence a low reliability".

However, so far some doubts are cast upon the need for the notion "safety" within the framework of "reliability". In our opinion it is caused by the following factors.

Over the course of the whole history of electric power industry development the safety problem has been given great attention thanks to physicotechnical features of electromagnetism. Electromagnetic fields, high currents, discharges and charges, high voltages as well as high temperatures, pressures, etc. in the electric power industry are known to be hazardous for people and environment. For safety reasons concentration in relatively small volumes of considerable amounts of substances dangerous for man and also substances with considerable own energy reserve is also important.

A great number of problems in safe control of power plants stipulated, from the outset, independent consideration of safety as an energy object's property without its relations with other properties and particularly with the reliability property. And the safety problems were solved so successfully that the safety level of an object seemingly had no effect on its reliability.

Hence, it was believed that safety and reliability are two different object's properties that are not connected to one another. Therefore, even nowadays some specialists suppose that safety and reliability are properties to be studied in parallel, independently of each other.

On the other hand, however, danger is always realized as an industrial accident, as a result of a certain type of random events (failure flows):

- failures of production equipment elements;
- natural phenomena;

- erroneous actions of personnel;
- random external effects of man-induced or social nature, i.e. failures that can be simultaneously failures in a sense of safety and other single reliability properties.

The events of the recent two-three decades have confirmed validity of the statement about existing interrelation and urgency of considering this interrelation between safety and reliability. Accidents at nuclear power plants, for example, involve not only dangerous consequences, but long-term failures of their operation and serviceability, long restoration works. Attempts to decrease safe distances between conductors at different potentials; utilization of toxic SF_6 gas insulation and as a result complete change of geometrical forms, sizes, designs and methods of safe maintenance of power units and also their reliability indices; increased environmental pollution; introduction of advanced technologies ("warm" and cryogenic superconductivities) and many other achievements of the technological progress – these combined factors revealed in practice the safety impact on the complex property of object reliability. In [1], therefore, it was proposed that safety should be considered as a single reliability property along with its other properties.

Safety is surely a specific single property of reliability, since it reflects the level of performing only the functions induced solely by the fact of object creation rather than its purpose, as distinct from other properties specified by both the purpose and the fact of object creation. The safety, however, should be considered in terms of reliability as the rest of single properties because the hazard for people and environment arises, as was mentioned, as a result of failures in the process of object operation.

Besides, the link of safety with other reliability properties is presented in [1] because of the fact that some notions applied to determine such properties as longevity, survivability also take into account safety problems. So, in reliability "the limiting state" is defined as an object state, at which it must not operate further due to *unavoidable violation of safety requirements* or unavoidable decrease in operability level or inadmissible decrease in operation efficiency". "The contingency armor is a minimum power supply level, at which industrial or some other consumers stop operating without damage of facilities, product, half-finished material, raw material and at preservation of minimum required sanitation, fireproof conditions and *safety* support".

Nonetheless some specialists continue expressing doubt about validity to refer safety to a single reliability property. Their main arguments are the following:

- a small number of studies treating safety as a reliability property and numerous studies continuing to consider safety separately. In other words, there is no need for the safety property in the reliability aspect;
- the emerging notion "energy safety (security)" makes it expedient to concentrate on it.

As was already mentioned, the first argument seems to be explained by the specific feature of safety as an object's property.

The second argument concerns to a great extent the fact that no matter how "mighty" this or that language is, there are always situations, when we have not enough words for defining different objective factors. The way out, as usual, is to apply adjectives to the basic notion. The same we have in this case: different types of safety are denoted as purely technical (including firefighting, chemical, radiation, nuclear, etc.) safety, industrial (production) safety, technological safety, environmental safety, (electric) energy safety and so on. Reliability is related to technical and environmental safety, however in no way to energy safety (more "energy security" named) that is a component of the economic security and correspondingly the national safety (national security). The technical safety differs from the energy security in the depth of damaging factors. The area of study on the energy security applies to global (and possibly catastrophic) consequences for a country on vast territories and for a long time. Besides, the energy security is based on the reasonable reliability of energy systems.

As a single reliability property the paper discusses exactly the technical safety including environmental safety. In this case all the arguments concerning safety apply primarily to energy objects (equipment, installations, devices) and to a lesser extent to electric power systems.

As distinct from other single reliability properties the technical safety is considerably regulated and characterized in such documents (in Russia) as "The rules of power plant installation", "The rules of safe operation", "The safety regulations", Constructions norms and regulations, etc.

A latest document regulating safety is the Federal Law "On technical regulation" [3]. The Law is entirely devoted to all types of safety only, without reliability. Item 2 of clause 6 of the Law contains the statement: "Approval of technical regulations for other purposes is inadmissible". In our opinion, as a result the role of the Law considerably decreases, and the sphere of applicability is unreasonably reduced. It is obvious that not only safety, but reliability as a complex property of objects, and quality of all types of products, etc. should be certified at all levels. In this aspect the Law "On technical regulation" needs adjustments.

Both safety and other single reliability properties, primarily failure-free operation, maintainability, depend on the accepted sizes of switchgears, height of wire suspension, width of service corridors, height of fencing, applied protection devices, etc. Surely, the accepted sizes of installations can be substantially decreased, making thus the corresponding objects cheaper. However, in this case the safety margins and correspondingly the object safety and reliability will decrease, since the number of overlaps between phases and to the ground increases because of different reasons.

Reliable operation of power units is ensured only, provided the strength of insulation used exceeds possible maximum voltage levels of insulation during continuous operating conditions and at short-term overvoltages. The insulation strength increase, however, leads to the pronounced increase of power unit cost and proves to be economically inexpedient. An excessive decrease of electric strength of insulation can cause heavy emergencies (equipment failures).

Grounding devices to protect from overvoltages, provide normal operating conditions and also create safe conditions for operation of power units are also an important element of power units along with insulation strength.

Recently the number of different aspects of safety to be considered has increased. One of the problem aspects concerns a direct impact of power system objects on the safety of people and environment. This aspect in turn is divided into safety at normal operation of power system objects and the safety of objects during their emergencies (faults). This statement can be illustrated by an example of the known views that a coal-fired power plant at its normal operation is more dangerous for people and environment due to large-scale emissions of harmful substances than a nuclear power plant. However, in the case of a failure of nuclear reactors at NPP its danger becomes much higher than the danger of failure at TPP.

The second aspect applies to the safety hazard because of interruption in power supply to consumers. Violation in power supply of consumers can lead to runaway of their dangerous production processes which can become uncontrollable and entail negative consequences for people and environment not only within the corresponding production, but in neighboring and remote areas.

Finally, another aspect of safety problem to be considered and which is related to reliability is the problem of protecting both a human being from technical (industrial) facilities and facilities from dangerous actions of the human being that are performed either unconsciously or unskillfully, by mistake, because of poor discipline, as a result of subversive act or terrorist act, etc. A typical example in this respect is the Chernobyl disaster. Nobody disputes that the personnel of the plant was to blame (they treated carelessly the nuclear reactor).

The above said confirms once again the role of safety within the complex property of reliability. Such events have started to occur increasingly often lately and lead not only to the

dangerous consequences but to long-term failures of operation and operability of the facilities. Obviously there are common reasons for decrease in safety and reliability.

Speaking of the single reliability properties an emphasis should be placed on the fact that they have different degrees of importance. Therefore while studying and ensuring them it is important to follow a certain sequence.

The sequence in consideration of the single properties is not so important for the facilities to be studied in terms of reliability in the course of operation. Each property can be estimated when necessary separately from one another depending on the situation. However, for designing the sequence of ensuring the single properties is very important. For example it is senseless to ensure high survivability prior to ensuring a necessary level of safety, longevity, failure-free operation, maintainability and stabilability (that has to be ensured previously by the appropriate means).

It is known that:

- single properties are interdependent and interrelated;
- the same means are applicable to ensure different single properties;
- a relative cost of ensuring the required level of different single properties varies;
- in a correctly ranged sequence it is cheaper to ensure each subsequent single property if all the previous properties are ensured.

Taking into account the above facts the rational sequence of single properties of reliability should be as follows:

1. Safety
2. Longevity
3. Failure-free operation
4. Maintainability
5. Stabilability
6. Survivability
7. Controllability
8. Resource supply
9. Storability

In this list "safety" takes the first place though it should be noted that in [1] "safety", without any ground, closed the list of single properties. The priority of safety as a single property of reliability can be substantiated by the following reasons.

Ensuring safety of an object is a very costly measure. In fact it is a considerable share of the whole object cost, which is particularly well seen in the electric power plant whose cost is determined, as was already mentioned, by the distances between the plant's elements, which are approved in terms of safety. This also affects the other properties of the object. It has been noted in the technical literature lately that the cost of ensuring safety grows because of the need to take into account all aspects of safety that were considered above.

The next factor characterizing safety as a single property of reliability is a high degree of its standardization level. In fact ensuring the appropriate level of safety implies meeting the required safety standards. The requirements for meeting the safety standards are "strict", up to the point: if safety standards of a constructed object are not met the construction of the object is considered to be inadmissible and it is naturally not necessary to consider the other reliability properties of the object.

It should be noted that the safety level to be ensured depends on the level of "wealth" of the country where the objects are constructed. More developed countries can afford a higher level of safety for their technical and industrial objects. These countries have higher living standards, longer life interval and higher cost of life. At the same time the reliability standards are also high. As an example we can mention such a normative index of reliability as a probability of shortage-free power supply. Whereas in the USSR it was taken equal to 0.996 in the Western countries this index was 0.9996.

The second property in the list is longevity. Longevity is also so important because of considerable costs and a large impact it has on the subsequent single properties. Considerable costs are related to the fact that to increase longevity (technological life span, service life) it is necessary to apply expensive advanced materials and technologies that possess the properties of thermal stability, chemical stability, higher durability etc.

The analysis of other properties from the above list can be continued, however we do not do it because the paper is devoted to the property of safety. It is important to pay attention to another point: the properties indicated in the list relative to the resulting effect of the object operation (element, system) can be subdivided into internal and external in terms of their manifestation. The external properties include only one property of failure-free operation which characterizes the resulting effect of the object operation, i.e. power supply to consumers. All the remaining properties characterize behavior of the object itself in terms of reliability and manifest themselves externally by influencing failure-free operation (continuity and duration of interruptions in power supply). Schematically these interrelations between the properties are presented in Fig.1. The figure shows role and place of safety in the complex property of reliability.

In conclusion it is sensible to emphasize the following.

Technical (production, industrial) safety is a very important component of the complex property of the object reliability. The absence of the need to consider it as a property of reliability in the past for energy systems is explained by the great attention paid exclusively to the safety problem itself which, in turn, predetermined a high level of safety within reliability. Currently the situation is changing essentially due to complication of the safety problem and a great impact on the remaining single properties of reliability.

As to the need and absence of the need to study one property or another in terms of reliability we can show two characteristic examples. Nowadays there is a single property which is very much in demand. This is supply of different resources – financial, labor, material and particularly primary energy resources (different fuels). In the USSR with centralized vertically-integrated management of the economy this property (supply of resources) was less urgent since there was the guideline of first-priority fuel supply to power plants. Therefore there were practically no power supply limitations due to interrupted fuel supply to power plants in those times, which can hardly be said about the current situation.

The second example is related to the energy security as it is currently considered in Russia. During soviet times we did not pay so much attention to the energy security problem for the reason of no need for it because the country was considered to have surplus energy resources and the Unified Energy System was the most efficient in the world. Replacement of vertical integration by horizontal, privatization of energy sectors and quasi market relations in the economy made the problem of energy security in Russia extremely urgent and not only at the national level but at the regional level as well despite the fact that the country still has surplus energy resources. It may sound ironic but it is a fact that the national energy security was first completely ruined and now the heroic efforts are made to restore it under new conditions.

For the same reasons and for the reasons considered in this paper it becomes urgent to consider safety within the complex property of reliability. Generalizing we can say that the demand for safety is determined by the urgency and extent to which the property is ensured.

The question of what method to choose for studying safety remains open. In our opinion there can be two options. Safety can be studied within reliability as one of its single properties and it can be studied separately since the danger for people and the environment, as was mentioned above, may arise under normal operation of object, i.e. in the absence of failures. This can be related to the low technical perfection of an object. Technical perfection is the property of higher rank. It includes the properties of safety, reliability and some others. On the other hand it is obvious that people in danger do not care about the reasons for low safety: unreliability or technical

imperfection. In any case safety should be ensured. Besides it is also obvious that safety in terms of perfection and safety in terms of reliability are interrelated.

A suggestion, though disputable, has been put forward lately to consider technical safety within the framework of energy security. However, in any case, it is indisputable that solutions to the problems of safety and practices of ensuring safety affect reliability of an object and safety should be taken into account in the study of reliability.

Conclusion

In our opinion it is more justified and correct to consider technical safety in terms of all aspects of its manifestation as one of the most important single properties of reliability of a technical object.

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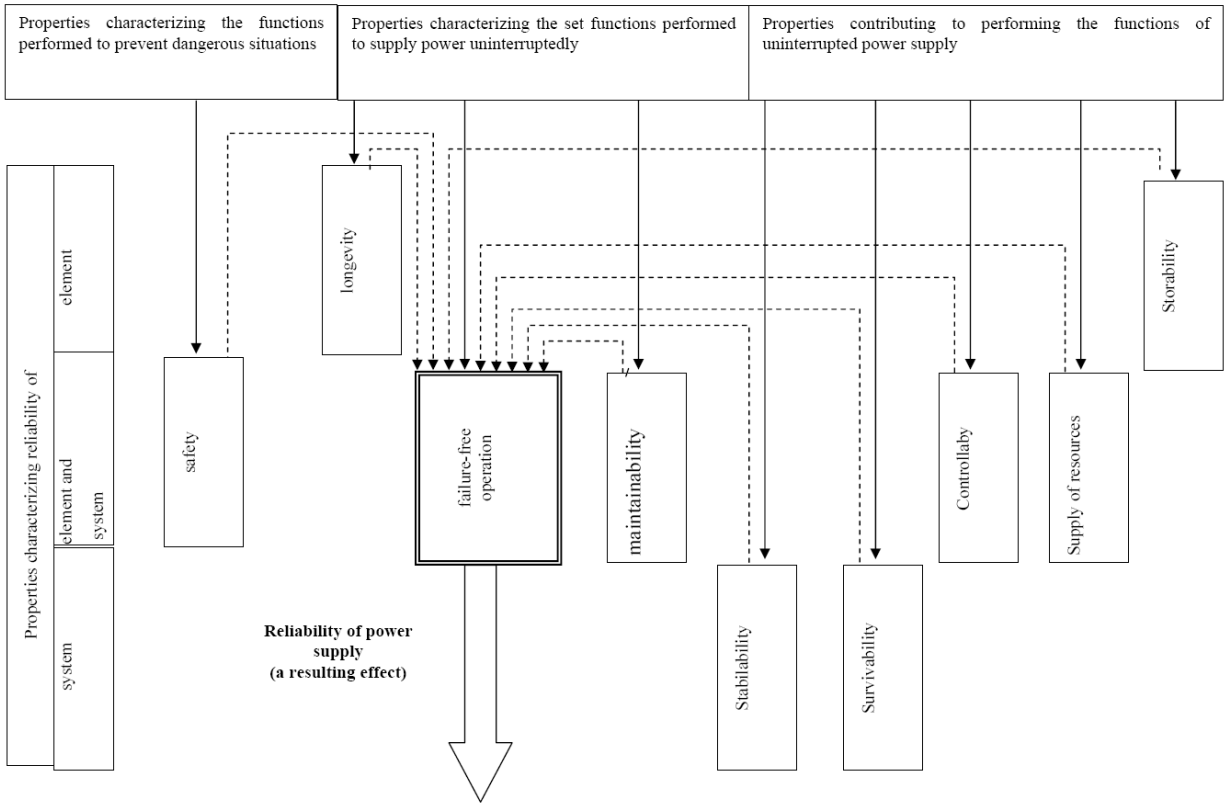

Fig. 1. Interrelations of single reliability propertie