# ENERGY SECURITY - RISKS AND RESILIENCE OF THE ENERGY SYSTEM IN ROMANIA

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**Abstract:** The paper reports the results of research conducted through studies on critical situations, mismatches, strategy deficits and tactics with reference to Romania's energy security, the geo-technological and strategic safety of the exploitation of hydrocarbon resources in the Romanian coastal area of the Black Sea, and renewable resources. In the energy field, the systematization of critical situations and mismatches is essential for ensuring the stability and efficiency of the system.

In a concrete contextual sense, the energy strategy is considered an "integrating matrix".

The article deals with the risk in the power supply system and the resilience of the energy system, as well as the modeling of energy events with high impact and low probability.

The transition to new modern practices for the formalization of energy security in the Romanian National Power System is operationalized, also targeting the related resilience, and is materialized through digitalization and automation, flexibility through energy storage, modernization of networks and infrastructure to reduce losses, improvement of regulations and market mechanisms, emergency plans and cybersecurity for critical infrastructure.

**Key words:** energy security, geo-technological security, strategic security, resilience, fossil fuels, renewable energy, onshore/offshore resources.

## 1. INTRODUCTION

Energy security, including geo-technological for Romania, is a complex concept that combines energy security, geopolitics and technology to ensure stable and

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sustainable access to energy resources when the existence and influence of risks to operation are established [26], [27], [30].

This implies in a global context alignments such as:

- *Energy security*. Aims at diversifying sources, infrastructure resilience and increasing the share of green energy (renewable energy) to reduce dependence on fossil fuels.

- *Energy geopolitics*, which involves control over oil, gas and critical minerals and which, in fact, influences international relations. The competitiveness between the USA, EU, China and Russia on the energy market and green technologies is a prerequisite for the new energy cold war.

- *Emerging energy technologies* envisage promotions for green hydrogen (alternative to fossil fuels), energy storage.

- *Digitalization* involves optimizing consumption and securing networks through Artificial Intelligence.

Regarding energy security, it is conclusive to identify the threats and challenges that mainly refer to cybersecurity, [5], [18], [22] (cyber-attacks on electrical networks or oil infrastructures), as well as climate change, [16] (climate impact on energy production).

These are joined by the raw materials crisis, [20], [23] (energy, mining) which refers, in particular, to the dependence on rare materials for green energy (lithium, cobalt, cadmium). General strategic development in Romania, by amplifying the activities of valorizing mineral/energy resources from the soil and subsoil, from the marine environment, can take place when tactical practices (underground mining technologies and quarries, onshore and offshore geological deposits) have the potential for effectiveness, operationalization under conditions of resilience in the face of risks and various challenges [28], [33], [36].

Relying on endogenous, own forces in inducing a strategic evolutionary vector with a relevant level of certainty, reliability and feasibility for Romania does not mean autarky, or isolation or investment self-separation.

As such, endogenous strategic resources alone, including geo-technological ones, do not offer the agreed set of properties of strategic energy sufficiency and therefore, in an overall view, interconnection and energy links are promoted, especially for investments at the national, European and global levels.

## 2. SYSTEMATIZATION OF CRITICAL SITUATIONS, INCONSISTENCIES

In the energy field, the systematization of critical situations and non-correlations is essential to ensure the stability and efficiency of the system.

Structuring the main critical situations and non-correlations refers to:

- *Critical situations in the energy system:* imbalances between production and consumption, production deficit, major technical failures such as damage to the transport and distribution infrastructure (high-voltage lines, transformers, interconnection stations), failures in power plants (thermal, hydroelectric, nuclear, renewable), failures of SCADA and automation systems, variability of production from wind and solar sources, lack of storage capacity to balance renewable energy, natural gas or oil crisis - impact on thermal power plants, logistical problems in the supply of coal or other resources. Also among the critical situations are cyber attacks on industrial control systems (ICS/SCADA), critical infrastructure security, etc.

- *Misalignments in the energy system*, which refer to inconsistencies between demand and supply, lack of flexibility in adapting production, lack of rapid responses to frequency and voltage fluctuations, insufficient storage capacity or regulation of energy flows, insufficient infrastructure for the transport of renewable energy, inefficient renewable production forecasting system, energy policies not aligned with EU states, tariffs and market mechanisms that do not reflect the reality of demand and supply, delays in the development of new infrastructure, insufficient financing for the modernization of the energy system [29], [35].

For the domestic energy situation, based on the analyses carried out to exemplify the levels and challenges of risks and resilience in the energy system in Romania, the critical alignments on which short and medium-term action is proposed for remediation are presented below.

– Priorities for Ensuring Romania's Energy Security, [19] include themes, topics, objectives, activities and actions that present an aggregate deficit of: 1) assumed vision, 2) real strategy, 3) legislation, 4) plans and programs, 5) sources of financing.

– Closing the coal mines in the Jiu Valley and Oltenia [10]. In particular, on average the cost of a ton of coal from the Jiu Valley underground reaches 70-75 Euro/ton and is sold for 53 Euro/ton (the difference being subsidized by the public budget), while the average international price for imported coal is approx. 60-70 Euro per ton of coal equivalent. The Romanian state pays subsidies of hundreds of millions (billions, over time) of Euros in an area with questionable mining efficiency. Currently, the last mines (Lupeni, Livezeni, Lonea) are in liquidation. The deficit of strategy and vision after 1989 until now is also linked to the fact that in the Oltenia Carboniferous Basin, the Rovinari, Turceni and Ișalnița thermal power plants were retrofitted with external credits to use fuel with a calorific value of approx. 1600 kcal/kg from lignite mines and quarries. The underground lignite mines are closed. The lignite quarries are closing, and the CETs in the area no longer have sufficient fossil fuels, they do not have methane gas combustion systems. Mining and energy employees are being laid off, with compensatory salaries and the anthropogenic environmental effects are serious, with land and groundwater disturbed by the overburdening [3], [24], [34].

– The nuclear power units at the Cernavoda NPP, [15], in the CANDU system, in number of 3, are unfinished, and Unit no. 1 the oldest in operation, requires either refurbishment or permanent shutdown.

– The uranium mines in the Băița Bihor area, in the Oravița-Ciudanovița area are closed or in the process of closing (Crucea mine) [8]. The Uranium Preparation Plant in Feldioara will reduce its activity until it is shut down. The deposits in Grințieș, Bicazul Ardelean have expressed interest in exploitation.

– The Hydroelectric Units, [12], are late for completion/commissioning.

– The deposits and production of crude oil and natural gas in Romania, owned/managed by OMV Petrom, [6], have an irreversible decrease in the resource base through exploitation/depletion.

– Refineries, storage and transportation systems for hydrocarbons still do not offer options and alternatives for reducing/eliminating imports, dependence on energy resources from other countries.

– A firm Strategy/Program for the exploitation of geothermal energy must be formulated.

– The application of thermosolar technology for buildings of all categories is not sufficiently promoted.

– The application of photovoltaic technology for buildings of all categories is not sufficiently promoted and applied throughout the country. The "solar tower" technology is not promoted in any case.

– Wind technology is insufficiently developed in areas of Romanian maritime waters (Black Sea).

– Not enough attention is paid to the Circular Economy for Energy from Waste, [3], although Romania is critically facing the waste problem, [13], and there are prospects of interest for methane hydrates on the bottom of the Black Sea [7], [25].

– The geo-technological and strategic security of the exploitation of energy and mineral resources in Romania is affected by critical technological and tactical situations in offshore exploitation in the Romanian coastal area of the Black Sea [2]. The Offshore Law was drafted, [17] and then GEO No. 114/2018 was issued, which raises different views regarding the feasibility and economic viability of investments.

– The provisions found in the current Offshore Law mainly cause specific attitudes among investors with reference to the trading of natural gas through the stock exchange.

– The requirement to perfect and improve offshore legislation is recognized so that companies have investment security and predictability.

– In the context, there is: stagnation and lack of offensive for collaborations, cooperation, attracting investments, insufficient managerial capacity in the field, physical and moral wear and tear of the National Energy System of production, transport, distribution, reduced research for the identification of new energy deposits and resources [11], [31], [32].

## 3. POWER SYSTEM RISK AND ENERGETIC POWER SYSTEM RESILIENCY

In our opinion, in order to understand the risk in the power system and the resilience of the domestic energy system, in order to formalize results that can be used for countermeasures, it is necessary to present some characteristics in relation to some considerations such as:

– About the risk of the Energy System (in the System) / Production / Distribution of Electricity [4];

– About the resistance / resilience to damage / shock of the Energy System / Production / Distribution of Electricity;

– Correlations, dependencies, conditionality, articulations, compositions between "risk" and "resistance / resilience to damage / shock" in / of the Energy System / Production / Distribution of Electricity.

In this context, a model-based, inclusive-neutral and iterative/reiterative treatment of risk and resilience issues in the national energy system is envisaged, mainly through the following aspects:

- Introduction to Power System Stability (stability categories);
- Clustering of power system stability classification;
- Correlations, dependencies, conditionality, articulations, compositions between power system stability, security and reliability;
- System security assessment with solutions to the transient stability problem;
- Simulations of dynamic responses of the power system (PS);
- Formalization of tangible behavioral characteristics of the Power System to shock/event demands, with reference to the ratio between the influence of various uncontrollable variables manifested for the failure, by shock/event of the Power System and the initial value of the safety/resistance footprint in which the respective failure occurred;
- Protective relocations in the PS;
- Improving transient stability to oscillations of local and inter-zonal modules in the Production/Distribution of Electricity;
- Event description (causes of outages, lessons learned, application of controls, defense plans, restoration plans, online security assessment, reliability management, real-time monitoring and control, dynamic risk-based security assessment);
- Energy system risk management in a multi-objective framework (hybrid fuzzy method and simulation);
- Use of genetic algorithms and Artificial Intelligence;
- Conflict risks in ES;
- ES resilience metrics;
- Metric development by identifying objectives, measurement characteristics, comprehension, understanding, practice, non-redundancy;
- Defensive, transparent and repeatable metrics;
- Development of a resilience indicator through major components such as preparedness, mitigation measures, response capabilities and recovery mechanisms:
- Incident management and ES command, recovery, restoration mechanisms;
- Managerial risk in SE.

In SE management, risk assessment is distinguished between two alignments that refer to the decision-makers' aversion to uncertainties.

Displaying aversion refers to: a) a strong action assumption, a situation in which the alignment is risk neutral and b) an unrealistic/unrealistic action assumption, when the alignment is characterized by an "infinite" risk. Typically, a visible assumption of risk among SE managers occurs when uncertainty is uniformly distributed over the entire problematic area subject to organization and management.

In such a vision, the index of unrealistic risk assumption in SE in absolute value is constant or negative. Thus, new elements of behavioral potential are gained, under conditions of real uncertainty, manifested in the complex, dynamic environment of the Energy System.

The Energy System (ES) as a system objectively evolves due to the time factor, which on its axis displays the entity from one state to another.
The results of classical event management in SE change to the extent that attitudes towards risks are evolutionarily dependent on the trajectory of SE as a system.

Pratt, J.W., (1978/ reed. 2020), [9], and Arrow, K.J., (2012), [14], emphasize that in the context of high risk potential, it is necessary to take into account only attitudes towards small, reduced risks that could be defeated. It is appreciated that this theory, for the contemporaneity positively affected by the generalization of information technologies (including through Artificial Intelligence) that support knowledge in SE, can no longer be accepted absolutely and generally.

On the other hand, boundary-pushing methodologies that allow the perceptible examination of managerial reality in SE create premises for "attacking" medium and large (high) risks.

The method of strategies for close (close) perception of facts subject to evolutions (transformations) in the SE is marked by quasi-continuous feedback information (feedbacks), a situation in which one benefits from the rationalization of behavioral acts towards risks. Usually, in the SE, endogenous aversions (retentions) towards risks are recorded and it is even more possible to manifest excessive aversions, which temper acts of resilience.

The efficient path on which a resistant SE must be found is that of "optimized visible/perceptible trajectories", relying on adaptive behavior.

"Optimal singularity" is the phrase that fits operational SE in the usual epistemological context.

Currently, there are more and more situations in which SE in Romania is confronted with the relative uncertainties of the stochastic dynamic behavior of the energy environment.

The variations of the energy environment are, however, conventionally dependent on the actions exerted on it with the help of the control function.

Therefore, it is found that numerous requirements/decision problems in SE activities are reduced to the essential problem of stochastic control.

Solving optimization problems is a quasi-generalized requirement for all areas in which SE subsystems operate.

A resilient decision in SE adopted is never completely independent and therefore, in connection/connection/articulation with other decisions, it determines SE to find itself implicitly in quasi-permanent risk situations. In such a framework, resilient behavior is a priority and fundamentally important in the face of risks.

As such, managerial risk in SE can be redefined with the degree of confidence in decisions regarding the future as uncertainty erodes. The most efficient method of advancing on this alignment is to increase the predictive power to reduce uncertainties regarding the future behavior of SE as a system.

The quasi-infinite set of contexts generates multiple risk situations.

Even if a new risk or a set of risks is faced, it must be realized that around the risks annihilated in the SE there are other risks, which through a "vacuum" are installed in the area of the managerial issue.

When the objective probability of the risks is measured (has quantified results) it is appreciated that the risks in the SE are formalized and can fall under the incidence of facing.

When objectively appreciated probabilities are not obtained, the risks in the SE have high contents of intrinsic, undeterminable uncertainties. Usually, the aversion to risks in the SE is expressed by the concavity of the utility function.

In the context of the above clarifications, the solution to facing risks in the SE can be done with the help of stochastic evolution scenarios of the SE environment, constantly taking into account the pre-established objectives to be achieved [6].

In the risk management of SE in Romania, classical and neoclassical knowledge become substance for the efficient operationalization of tools against various non-conforming reminiscences of energy activity.

Reminiscences (anamnesis) mark the access to managerial truths, bring back to attention the past (“once”) and space (“somewhere”). In the risk management of SE, the theory of reminiscence is associated with the theory of concepts.

The theory of resilient managerial concepts in SE can be considered the last stage of the energy managerial epistemology.

Risk, defined as the variation of potential differentiated outcomes in SE in Romania (variation to which a probability can be associated) is expressed using the formula:

*Risk = [the probability of an event occurring] x [the consequences if it occurs]* (1)

Mechanisms for neutralizing risks in the economy are created depending on the risk situation.

The general set of measures to combat the possible consequences of a potential risk in the SE is divided into two groups:

– Preventive measures. (precautionary tasks taken in advance to prevent possible losses in the SE infrastructures, especially in the operational context).

– Compensation measures. (tasks taken to compensate for adverse effects in the event of negative damage to the SE infrastructures).

The perspectives of action complementarity towards the risks of energy damage can be treated modelistically. (fig. 1)

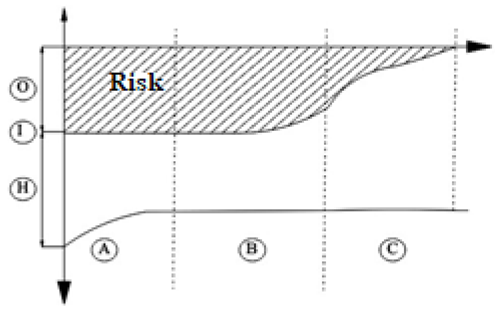


**Fig.1.** Delimitation of operational areas in the event of risk in SE in Romania
I = uncertainty; O = opportunity; H = hazard;
A; B; C = operational areas in SE.

At the same time, in our opinion, a pre-computerized mathematical/symbolic model associated with a Model of Reconsideration of Management Methods and Techniques in the Field of Unpredictable Events in SE in Romania must be created, through the Bayesian, descriptive, and deterministic approaches, as well as dynamic, experimental, functional, normative, and operational approaches.

These are joined by the systemic, static, and statistical approaches.

## 4. MODELING OF HIGH IMPACT AND LOW PROBABILITY (HILP) ENERGETIC EVENTS

From global practice, it usually results that energy events, especially those with high negative impact, generally have a low probability of occurring.

If they occur in the general energy picture, they are characterized by catastrophic states, of high amplitude and with rarely encountered effects.

However, in any strategy in the field it is useful to formalize an at least theoretical, conceptual framework for modeling high-impact events with low frequency, in order to support informed decisions in Energy Systems (ES).

In this paper, we address the research alignments for such situations and indicate that we start from the systematization of a matrix of dangerous events (natural and/or man-made) that lead to the loss of network infrastructure or cause damage to the security and resilience of electrical networks.

In this context, the planning and allocation of "emergency" resources, appropriate for such events, will be mathematically formalized in order to quantify the understanding of their probability and the extent of their potential impact.

When events are of low probability, an informal and/or informed perspective on risk is required for planning, as there is no statistical basis for directly estimating the probabilities and consequences of their occurrence in the ES. Specifically, a symbolic, pre-computerized mathematical model will be developed to support the modeling of risk associated with high-impact, but low-frequency events.

A range of hazards/threats to the integrity of the ES infrastructure can be considered, an understanding of their probability of occurrence, and a methodology for addressing vulnerabilities in the ES's critical assets in the face of such events is developed.

The model resulting from the integration of these elements allows for sensitivity assessments based on optional risk management strategies in the ES.

For the case of the Romanian Power System, mathematically expressed investigations and results on the role of systemic resilience, preparation for high-impact and low-probability events and the consequences of prolonged disruptions in the SE are taken into account. At the same time, it is useful to systematize the conceptual and general technical paradigms for the development of risk models in the SE. In fact, the clustering of model classes is performed for the modeling framework approached. Basically, the main components of the SE risk modeling framework are iteratively approached, namely the characterization of hazards and events in the SE, the relevant SE attack factors and the level of vulnerability to such factors, the consequences of the loss of different combinations of network assets in the SE.

Risk modeling, in this context, in the National Energy System involves:

– hazard identification and their probabilistic characterization in the SE (associated event frequencies);
– initialization of the development of events in the SE (selection of representative events for analysis);
– quantification of the infrastructure response (probabilities of asset failure in the SE);
– assessment of the consequences (power outages);
– integration of the model for the development of risk profiles in the SE.

Basically, a matrix of hazard classes is developed in association with a matrix of asset classes. This combination will be found in the model highlighting the SE assets that are potentially vulnerable. In fact, the probabilistic characterization of the degree of hazard in relation to the resilience of the SE is quantified.

Then, an algorithm is developed to estimate the frequencies of triggering events in the SE based on the comparison of hazard curves (source hazard) and quasi-discrete events characterized probabilistically from which resilience scenarios will be generated. Through this article, we propose the establishment of a Platform for the implementation and integration of the model that allows the flexibility of the personalized approach in the Romanian Energy System.

The evaluation of safety alternatives in the SE involves taking into account future events, which could have more than one outcome.Measuring resilient knowledge also means making assessments regarding the probability that certain events will occur in the future in the SE.The probability of events in the SE can be affected by external or internal changes in the energy environment.

In this way, efforts are measured and known to minimize possible factors that may be associated with risks in the SE, or to develop mechanisms to reduce risks when they occur in the SE. Possible risks and uncertainties in the SE, in general, can be grouped, for example, according to their type. Before starting the analysis of future results, for new support infrastructures for the safety of the SE, it is considered important for Romania to clarify the relevant terms of the current energy resilience flow, grouped as follows:

– *Risk,* defined as the variation of possible outcomes in the SE, to which a probability can be associated;
– *Uncertainty*, which manifests itself in the lack of knowledge regarding the probability distribution of events in the SE or future outcomes;
– *Probability,* as a statistical value, relying on the characterization of the possibility of an event occurring in the SE.

Finally, a Risk Neutralization Management Model in the SE can be developed.

## 5. THE TRANSITION TO NEW MODERN PRACTICES FOR FORMALIZING ENERGY SECURITY IN SEN ROMANIA

For any present situation $S_p$ of the energy security state, an operator $\partial$ is applicable to redefine the elaboration process towards a different situation $S_p^1$:

$$S_p \xrightarrow{\partial} \mathrm{S}_\mathrm{p}^1 \quad (1)$$

The above relationship is motivated by programmed developments for energy security supported by the Developmental Theory–in–Action [1].

Current practices in relation to new energy technologies / including the involvement of renewable resources (solar, solar thermal, wind) highlight dynamic evolutionary situations in the Romanian National Power System.

The combination of pre-established energy development scenarios with new energy security technologies at the national level always signifies the dominance of the latter, which determines superior situations of the type depicted by the relationship above.

## 6. CONCLUSIONS

The solutions for managing critical situations and mismatches in SEN Romania, also aiming at the related resilience, are realized through:

- digitalization and automation (SCADA, IA for forecasting);
- flexibility through energy storage (batteries, hydrogen, P2X);
- modernization of networks and infrastructure to reduce losses;
- improvement of regulations and market mechanisms;
- contingency plans and cybersecurity for critical infrastructure.

This systematization for SEN Romania can be expanded depending on the specific context of the targeted energy system.

Future trends for geo-technological energy security for Romania focus on alignments such as:

- increasing investments in energy through the exploitation of onshore and offshore natural gas;
- increasing investments in new generation nuclear energy;
- developing smart and decentralized grids;

expanding renewable energy (solar and wind) on a national scale.

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