

INTEGRATED APPROACHES TO THE ASSESSMENT OF RISK SCENARIOS TO THE NATIONAL POWER SYSTEM

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Abstract: Ensuring the resilience and reliability of the National Power System (NPS) has become a strategic priority for modern states, given the critical role that electricity infrastructure plays in national security, economic stability, and societal well-being. The increasing complexity of the NPS, combined with emerging threats such as system malfunctions, cyber intrusions, and intentional harmful actions, requires comprehensive and integrated risk-assessment methodologies. This paper examines multi-layered approaches to evaluating risk scenarios that threaten the functioning of the NPS, with a specific focus on operational insecurity and the potential for terrorist-related disruptions. By synthesizing insights from systems engineering, critical infrastructure protection, and risk analysis, the study presents a framework that integrates technical, organizational, and environmental factors into a unified risk-assessment model. The findings highlight the need for cross-sector coordination, advanced monitoring tools, and adaptive response strategies to strengthen the resilience of national power infrastructures. Ultimately, this research contributes to developing more robust methods for anticipating, evaluating, and mitigating high-impact risks to the power system.

Keywords: assessment, risk scenarios, National Power System.

1. INTRODUCTION

The National Power System (NPS) represents one of the most essential components of a country's critical infrastructure. Its uninterrupted operation underpins nearly all sectors of modern life, from healthcare and industry to transport and communication [27], [29], [35]. As energy demand grows and power networks expand in technological complexity, the NPS faces increasing vulnerability to a wide array of risk factors. These include technical failures, natural hazards, cyber threats, and

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intentional disruptive actions. Consequently, the assessment and management of risks to the NPS have become central issues in national resilience planning [11], [14], [16].

Among the most significant concerns are insecurity in the functioning of the NPS – such as cascading failures, equipment malfunctions, and operational instability – and the heightened possibility of terrorist attacks targeting power generation, transmission, or control infrastructure. While attacks on energy systems are relatively rare, their potential consequences are severe, including widespread blackouts, economic disruption, and threats to public safety [28], [33], [34]. Therefore, understanding these risks requires more than traditional single-factor models; it necessitates an integrated approach that considers technical systems, human factors, interdependencies, and emerging threat landscapes [8], [12], [15], [19].

Integrated risk-assessment methodologies combine multiple analytical perspectives – engineering analysis, probabilistic risk assessment, scenario modelling, and organizational resilience frameworks – to capture the complexity of threats facing the NPS [24], [26]. Such holistic methods enable stakeholders to identify vulnerabilities, evaluate the likelihood and impact of different scenarios, and prioritize mitigation measures across physical, digital, and organizational domains.

This paper explores these integrated approaches in depth, focusing on how they can be applied to assess two critical categories of risk: (1) insecurity in the functioning of the NPS and (2) potential terrorist actions against the system. Through this analysis, the study aims to contribute to the ongoing efforts to ensure the security, stability, and resilience of national power systems in an increasingly uncertain environment. [1], [3], [18].

The NPS functions as an interconnected system to the European Power System – ENTSO-E, which represents the European Network of Transmission System Operators for Electricity [2], [10], [13].

Romania, through the national electricity transmission company, Transelectrica, which is a national transmission and system operator (TSO), has an active and essential role within ENTSO-E, being a full member [17], [20], [23]. It manages and operates the electricity transmission system, ensuring electricity exchanges between Romania and the countries of the European Union and the neighbouring countries that are not part of the European Union (Serbia, Ukraine and the Republic of Moldova) [30], [32].

The NPS, through the Electricity Power Transmission Grid, is composed of the following critical energy infrastructures, fig.1:

- 82 power substations, of which:
 - 1 power substation in a gauge of 750 kV, but functioning at 400 kV;
 - 38 power substations of 400 kV;
 - 43 power substations of 220 kV.
- 8834.4 km overhead power lines, of which:
 - 3.1 km – 750 kV;
 - 4915.2 km – 400 kV;
 - 3875.6 km – 220 kV;
 - 40.4 km – 110 kV (interconnection Serbia, Ukraine and the Republic of Moldova).

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- 216 transformation units totaling 38 058 MVA.
- 1 National Energy Dispatch – NED;
- 5 Territorial Dispatchers – TED [21], [25], [31].

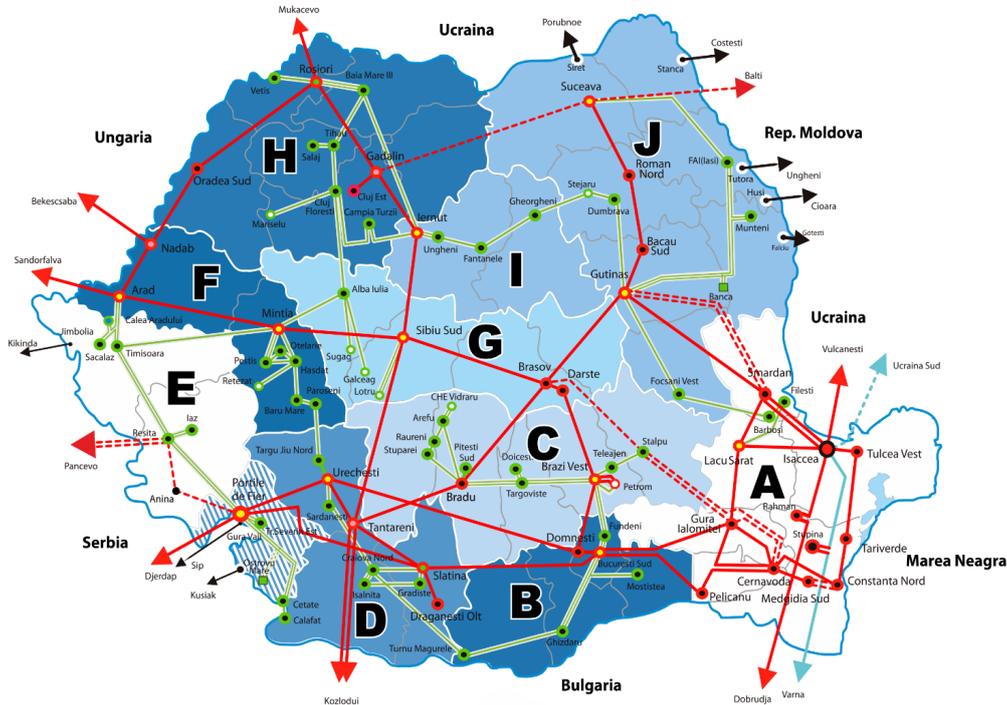


Fig.1. National Power System map (source: Transelectrica)

2. ASSESSMENT OF RISK SCENARIOS

2.1. Insecurity in functioning of the NPS

The identification, assessment and manifestation are shown in Table 1 [4], [5], [6]

Table 1. Insecurity in functioning of the NPS

Risk scenario: INSECURITY IN FUNCTIONING OF THE NPS											
1	Local technical incidents	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 5px;">Likelihood</td> <td style="text-align: center; background-color: #ffff00;">3 Medium</td> </tr> <tr> <td style="padding: 5px;">Gravity/ Impact</td> <td style="text-align: center; background-color: #ffff00;">3 Medium</td> </tr> <tr> <td style="padding: 5px;">Risk level</td> <td style="text-align: center;">9</td> </tr> <tr> <td style="padding: 5px;">Scenario type</td> <td style="text-align: center; background-color: #ffff00;">7 – 12 Moderate</td> </tr> </table>	Likelihood	3 Medium	Gravity/ Impact	3 Medium	Risk level	9	Scenario type	7 – 12 Moderate	<ul style="list-style-type: none"> Equipment triggers take place and some equipment becomes unavailable for a very long period of time; The risk of overloads on important lines and transformation units, including interconnection lines, increases and then cascading faults occur; A separation of the system
Likelihood	3 Medium										
Gravity/ Impact	3 Medium										
Risk level	9										
Scenario type	7 – 12 Moderate										

			<p>may occur and certain areas may function in island mode;</p> <ul style="list-style-type: none"> • Difficulties arise in ensuring the adequacy of the NPS due to a reduced level of production in power plants. This causes the limitation or total loss of reserves; • Major deviations of the NPS functioning parameters are recorded; • The N-1 safety criterion is no longer met; • Also, the low level of production and loading of certain lines may lead to the impairment of the static and dynamic stability of the NPS; • There is a major risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers. 								
2	Multiple technical incidents caused by extreme weather conditions	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>Likelihood</td> <td style="text-align: center;">3 Medium</td> </tr> <tr> <td>Gravity/ Impact</td> <td style="text-align: center;">3 Medium</td> </tr> <tr> <td>Risk level</td> <td style="text-align: center;">9</td> </tr> <tr> <td>Scenario type</td> <td style="text-align: center;">7 – 12 Moderate</td> </tr> </table>	Likelihood	3 Medium	Gravity/ Impact	3 Medium	Risk level	9	Scenario type	7 – 12 Moderate	<ul style="list-style-type: none"> • Extreme weather leads to accidental failure of several equipment (possibly of the same construction type) in a very short time; • Disturbances occur in the road transport network, which leads to delays in carrying out the faults remediation work/repair of equipment; • Difficulties may arise in carrying out faults remediation work in substations, caused by the large number of equipment of the same type affected and the lack of equipment in security stocks; • Problems arise in ensuring that the N-1 safety criterion is met; • Problems arise in supplying some grid areas for a very
Likelihood	3 Medium										
Gravity/ Impact	3 Medium										
Risk level	9										
Scenario type	7 – 12 Moderate										

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			<p>long period, correlated with the time required to repair/replace destroyed/damaged assets;</p> <ul style="list-style-type: none"> • There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers. 								
3	Simultaneous technical incidents	<table border="1"> <tr> <td>Likelihood</td> <td>3 Medium</td> </tr> <tr> <td>Gravity/ Impact</td> <td>4 High</td> </tr> <tr> <td>Risk level</td> <td>12</td> </tr> <tr> <td>Scenario type</td> <td>7 – 12 Moderate</td> </tr> </table>	Likelihood	3 Medium	Gravity/ Impact	4 High	Risk level	12	Scenario type	7 – 12 Moderate	<ul style="list-style-type: none"> • Separation of a grid area may occur where there are not enough production units to ensure consumption of the area; • Deviations of functioning parameters outside the permissible limits shall occur; • The N-1 safety criterion is no longer met; • Difficulties may arise in carrying out faults remediation work in substations, caused by the large number of equipment of the same type affected and the lack of equipment in security stocks; • Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace damaged assets; • Congestions can occur on interconnection lines and even the impossibility of securing electricity exports; • There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
Likelihood	3 Medium										
Gravity/ Impact	4 High										
Risk level	12										
Scenario type	7 – 12 Moderate										
4	Complexity of control mechanisms of power systems	<table border="1"> <tr> <td>Likelihood</td> <td>2 Low</td> </tr> <tr> <td>Gravity/ Impact</td> <td>4 High</td> </tr> <tr> <td>Risk level</td> <td>8</td> </tr> </table>	Likelihood	2 Low	Gravity/ Impact	4 High	Risk level	8	<ul style="list-style-type: none"> • As a result of the triggering of some equipment in the PTG, very large power movements appear that completely differ from the movements analyzed when 		
Likelihood	2 Low										
Gravity/ Impact	4 High										
Risk level	8										

		<table border="1"> <tr> <td>Scenario type</td> <td>7 – 12 Moderate</td> </tr> </table>	Scenario type	7 – 12 Moderate	<p>planning the functioning of the NPS;</p> <ul style="list-style-type: none"> • The risk of overloads on important lines and transformation units, including interconnection lines, and the risk of cascading faults occurring increases; • A separation of the system may occur and certain areas may function in island mode; • Difficulties arise in ensuring the adequacy of the NPS due to a reduced level of production in power plants. This causes the limitation or total loss of reserves; • Major deviations of the NPS functioning parameters are recorded; • The N-1 safety criterion is no longer met; • Also, the low level of production and loading of certain lines may lead to the impairment of the static and dynamic stability of the NPS; • There is a major risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers. 						
Scenario type	7 – 12 Moderate										
5	Unwanted power movements	<table border="1"> <tr> <td>Likelihood</td> <td>3 Medium</td> </tr> <tr> <td>Gravity/ Impact</td> <td>5 Very high</td> </tr> <tr> <td>Risk level</td> <td>15</td> </tr> <tr> <td>Scenario type</td> <td>13– 16 Bad</td> </tr> </table>	Likelihood	3 Medium	Gravity/ Impact	5 Very high	Risk level	15	Scenario type	13– 16 Bad	<ul style="list-style-type: none"> • Very large power movements appear that completely differ from the movements analyzed when planning the functioning of the NPS; • The risk of overloads on important lines and transformation units, including interconnection lines, increases; • System operation is hampered by large forecasting errors and
Likelihood	3 Medium										
Gravity/ Impact	5 Very high										
Risk level	15										
Scenario type	13– 16 Bad										

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			<p>cascading equipment triggers and even loss of control over a grid area may occur;</p> <ul style="list-style-type: none"> • Disturbances can affect all energy markets in the region or across Europe, namely the functioning of the interconnected systems of ENTSO-E members; • Forecast errors/imbalances in different control blocks can lead to incidents/frequency deviations in the synchronous grid area; • Limitations of energy imports/exports may occur; • Extensive damage may occur leading to the failure of supplying electricity to a large number of consumers. 								
6	Serial faults of equipment	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>Likelihood</td> <td style="text-align: center;">2 Low</td> </tr> <tr> <td>Gravity/ Impact</td> <td style="text-align: center;">3 Medium</td> </tr> <tr> <td>Risk level</td> <td style="text-align: center;">6</td> </tr> <tr> <td>Scenario type</td> <td style="text-align: center;">4 – 6 Low</td> </tr> </table>	Likelihood	2 Low	Gravity/ Impact	3 Medium	Risk level	6	Scenario type	4 – 6 Low	<ul style="list-style-type: none"> • Improper operation behavior of multiple equipment leads to equipment triggers or equipment damage. Some equipment is also accidentally withdrawn from operation for remediation or verification; • The N-1 safety criterion is no longer met; • Separation of a grid area may occur where there are not enough production units to ensure consumption of the area; • Deviations of functioning parameters of the NPS outside the permissible limits shall occur; • Difficulties may arise in carrying out faults remediation work in substations, caused by the large number of equipment of the same type affected and the lack of equipment in security stocks;
Likelihood	2 Low										
Gravity/ Impact	3 Medium										
Risk level	6										
Scenario type	4 – 6 Low										

			<ul style="list-style-type: none"> Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace damaged assets; There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers. 								
7	Human errors	<table border="1"> <tr> <td>Likelihood</td> <td>3 Medium</td> </tr> <tr> <td>Gravity/ Impact</td> <td>5 Very high</td> </tr> <tr> <td>Risk level</td> <td>15</td> </tr> <tr> <td>Scenario type</td> <td>13– 16 Bad</td> </tr> </table>	Likelihood	3 Medium	Gravity/ Impact	5 Very high	Risk level	15	Scenario type	13– 16 Bad	<ul style="list-style-type: none"> The risk of overloads on important lines and transformation units, including interconnection lines, and the risk of cascading faults occurring increases; A separation of the system may occur and certain areas may function in island mode; Difficulties arise in ensuring the adequacy of the NPS due to a reduced level of production in power plants. This causes the limitation or total loss of reserves; Major deviations of the NPS functioning parameters are recorded; The N-1 safety criterion is no longer met; Also, the low level of production and loading of certain lines may lead to the impairment of the static and dynamic stability of the NPS; There is a major risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
Likelihood	3 Medium										
Gravity/ Impact	5 Very high										
Risk level	15										
Scenario type	13– 16 Bad										
8	Strikes, riots, protest actions of employees	<table border="1"> <tr> <td>Likelihood</td> <td>2 Low</td> </tr> <tr> <td>Gravity/ Impact</td> <td>4 Very high</td> </tr> </table>	Likelihood	2 Low	Gravity/ Impact	4 Very high	<ul style="list-style-type: none"> The lack of staff leads to a decrease in fuel reserves for power plants, the quality of operating services decreases, the intervention 				
Likelihood	2 Low										
Gravity/ Impact	4 Very high										

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		<table border="1" style="width: 100%;"> <tr> <td style="width: 50%;">Risk level</td> <td style="width: 50%;">10</td> </tr> <tr> <td>Scenario type</td> <td style="background-color: yellow;">7 – 12 Moderate</td> </tr> </table>	Risk level	10	Scenario type	7 – 12 Moderate	<p>time for repairing faults increases, and some maintenance works are stopped;</p> <ul style="list-style-type: none"> • Due to the low number of staff there is a risk of mistakes due to insufficient training of the available staff or fatigue; • Problems arise in forecasting consumption on the energy market due to the unpredictable nature of the protest events; • The occurrence of accidental events in the NPS may lead to extensive damage in the context of lack of qualified staff. 				
Risk level	10										
Scenario type	7 – 12 Moderate										
9	Unusually large errors in the forecast of power produced in renewable energy plants	<table border="1" style="width: 100%;"> <tr> <td style="width: 50%;">Likelihood</td> <td style="width: 50%;">2 Low</td> </tr> <tr> <td>Gravity/ Impact</td> <td style="background-color: orange;">4 High</td> </tr> <tr> <td>Risk level</td> <td>8</td> </tr> <tr> <td>Scenario type</td> <td style="background-color: yellow;">7 – 12 Moderate</td> </tr> </table>	Likelihood	2 Low	Gravity/ Impact	4 High	Risk level	8	Scenario type	7 – 12 Moderate	<ul style="list-style-type: none"> • There is a positive or negative imbalance between the forecasted power and that which can be produced in renewable energy plants; • Disturbances occur in the electricity market through large variations in the electricity trading price or an insufficient level of offers; • Reduced production in certain plants leads to large power movements to deficient areas and results in voltage deviations and difficulties in compensating reactive power; • For certain time intervals problems arise in ensuring that the N-1 safety criterion is met; • Low production level and loading of certain lines as well as low inertia level can lead to the impairment of the static and dynamic stability of the NPS; • In conditions of low production in power plants
Likelihood	2 Low										
Gravity/ Impact	4 High										
Risk level	8										
Scenario type	7 – 12 Moderate										

			and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.								
10	Pandemic	<table border="1"> <tr> <td>Likelihood</td> <td>1 Very low</td> </tr> <tr> <td>Gravity/ Impact</td> <td>1 Very low</td> </tr> <tr> <td>Risk level</td> <td>1</td> </tr> <tr> <td>Scenario type</td> <td>1–3 Very low</td> </tr> </table>	Likelihood	1 Very low	Gravity/ Impact	1 Very low	Risk level	1	Scenario type	1–3 Very low	<ul style="list-style-type: none"> Operational staff at dispatch centers, power substations and power plants is affected and lead to an acute shortage of qualified staff necessary to ensure the safe functioning of the NPS; Also, the lack of staff at all entities in the NPS leads to a decrease in fuel reserves for power plants, the increase of the intervention time for repairing faults, the cessation of maintenance works; Due to the low number of staff there is a risk of mistakes due to insufficient training of the available staff or fatigue; Problems arise in forecasting consumption on the energy market due to the unpredictable nature of the pandemic events; The occurrence of accidental events in the NPS may lead to extensive damage in the context of lack of qualified staff and high intervention time.
Likelihood	1 Very low										
Gravity/ Impact	1 Very low										
Risk level	1										
Scenario type	1–3 Very low										

2.2. Terrorist attack of the NPS

The identification, assessment and manifestation are shown in Table 2. [7], [8], [9], [22].

Table 2. Source: Terrorist attack on the NPS

Risk scenario: TERRORIST ATTACK ON THE NPS							
1	Internal cyberattack on critical infrastructure	<table border="1"> <tr> <td>Likelihood</td> <td>3 Medium</td> </tr> <tr> <td>Gravity/</td> <td>5</td> </tr> </table>	Likelihood	3 Medium	Gravity/	5	<ul style="list-style-type: none"> The attacker (hacker/cracker) acts as an employee of the National Power System (NPS) and
Likelihood	3 Medium						
Gravity/	5						

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<p>within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.</p>	Impact	Very high	<p>disconnects lines, transformers or changes the functioning instructions of some generation units, modifies power reserves, changes the functioning schedule of dispatcher units;</p> <ul style="list-style-type: none"> • During a cyberattack, it is possible that computer systems may be blocked for use by people other than the hacker or cracker. This affects the possibilities of taking control and restoration measures for the NPS; • Disturbances occur in the electricity market; • The disconnection of some production units and equipment within the Power Transmission Grid (PTG) and the Power Distribution Grid (PDG), leads to large power movements to deficient areas and results in the overload of some equipment and voltage deviations and difficulties in compensating the reactive power including during a blackout; • For certain time intervals problems arise in ensuring that the N-1 safety criterion is met. Also, the low level of production and loading of certain lines may lead to the impairment of the static and dynamic stability of the NPS; • In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
	Risk level	15	
	Scenario type	13– 16 Bad	

			<ul style="list-style-type: none"> The cyberattack may extend to other computer systems belonging to other Transport Operators (TOs) in the region and may lead to the impossibility of receiving or providing support to other countries in the region. 								
2	<p>External cyberattack on critical infrastructures that are not part of the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.</p>	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>Likelihood</td> <td style="text-align: center;">3 Medium</td> </tr> <tr> <td>Gravity/ Impact</td> <td style="text-align: center;">5 Very high</td> </tr> <tr> <td>Risk level</td> <td style="text-align: center;">15</td> </tr> <tr> <td>Scenario type</td> <td style="text-align: center;">13–16 Bad</td> </tr> </table>	Likelihood	3 Medium	Gravity/ Impact	5 Very high	Risk level	15	Scenario type	13–16 Bad	<ul style="list-style-type: none"> The attacker (hacker/cracker) penetrates the communication and data transmission computer systems of the energy market participants and acts as an employee working with these systems and manipulating the functioning conditions of the energy market (demands and offers on trading platforms, functioning schedules of production units); During the attack, it is possible that computer systems may be blocked for use by people other than the hacker or cracker. Disturbances occur in the electricity market; Changing the functioning schedule may lead to shutdown of some production units and to the production of imbalances which further may lead to frequency deviations or large power movements towards the deficient areas, voltage deviations and difficulties in compensating the reactive power; For certain time intervals problems arise in ensuring that the N-1 safety criterion is met. Also, the low level of production and loading of certain lines may lead to the
Likelihood	3 Medium										
Gravity/ Impact	5 Very high										
Risk level	15										
Scenario type	13–16 Bad										

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			<p>impairment of the static and dynamic stability of the NPS;</p> <ul style="list-style-type: none"> • In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers. • The attack may have very serious consequences in the context in which it occurs against the background of high consumption values in the NPS, periods with extremely high temperatures or amid abundant rainfall. 								
3	<p>External terrorist attack on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">Likelihood</td> <td style="width: 50%; text-align: center;">3 Medium</td> </tr> <tr> <td>Gravity/ Impact</td> <td style="text-align: center;">5 Very high</td> </tr> <tr> <td>Risk level</td> <td style="text-align: center;">15</td> </tr> <tr> <td>Scenario type</td> <td style="text-align: center;">13– 16 Bad</td> </tr> </table>	Likelihood	3 Medium	Gravity/ Impact	5 Very high	Risk level	15	Scenario type	13– 16 Bad	<ul style="list-style-type: none"> • The attacker (terrorist) destroys technical equipment (lines, transformers, generators, electrical equipment in substations or plants, servers of central command systems, central telecommunications installations); • In the event of a terrorist attack on power lines, substations or power plants, equipment triggers take place and some equipment becomes unavailable for a very long period of time; • In the event of a terrorist attack on the servers of central command systems, central telecommunications installations, the operation and control capacity of the NPS is being affected in the long run; • Difficulties arise in ensuring that the N-1 safety criterion is met; • Triggering some production
Likelihood	3 Medium										
Gravity/ Impact	5 Very high										
Risk level	15										
Scenario type	13– 16 Bad										

			<p>units and equipment within the PTG and the PDG, leads to large power movements to deficient areas and leads to large power movements to deficient areas and results in voltage deviations and difficulties in compensating the reactive power;</p> <ul style="list-style-type: none"> • Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace destroyed/damaged infrastructures; • In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers. 								
4	Internal terrorist attack on the management centers within the National Power System or Power Transmission Grid	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td style="padding: 2px;">Likelihood</td> <td style="text-align: center; padding: 2px;">3 Medium</td> </tr> <tr> <td style="padding: 2px;">Gravity/ Impact</td> <td style="text-align: center; padding: 2px;">5 Very high</td> </tr> <tr> <td style="padding: 2px;">Risk level</td> <td style="text-align: center; padding: 2px;">15</td> </tr> <tr> <td style="padding: 2px;">Scenario type</td> <td style="text-align: center; padding: 2px;">13– 16 Bad</td> </tr> </table>	Likelihood	3 Medium	Gravity/ Impact	5 Very high	Risk level	15	Scenario type	13– 16 Bad	<ul style="list-style-type: none"> • The attacker (terrorist) acts as an employee and disconnects lines, transformers or changes the functioning instructions of some generation units, modifies power reserves, changes the functioning schedule of dispatcher units. These lead to large power movements to deficient areas and result in voltage deviations and difficulties in compensating the reactive power; • Also, the goals of the attacker are the destruction of SCADA - EMS, SCADA - DMS systems, regulator f – P, central control systems, planning and operating systems, IT centers, data storage systems, control command systems from major power substations
Likelihood	3 Medium										
Gravity/ Impact	5 Very high										
Risk level	15										
Scenario type	13– 16 Bad										

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			<p>and plants or telemanagement centers.</p> <ul style="list-style-type: none"> • Affected management centers can no longer ensure the management, operation or monitoring of installations. This affects the possibilities of taking some control and restoration measures for the NPS; • Disturbances occur in the electricity market; • Large power movements to deficient areas can lead to congestion on interconnecting lines and even the impossibility of ensuring electricity exports; • There is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers. 								
5	<p>Sabotage actions by an internal employee on critical infrastructure within the National Power System or Power Transmission Grid: power plants, power substations, overhead power lines, dispatchers, etc.</p>	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td style="padding: 2px;">Likelihood</td> <td style="text-align: center; padding: 2px;">3 Medium</td> </tr> <tr> <td style="padding: 2px;">Gravity/ Impact</td> <td style="text-align: center; padding: 2px;">5 Very high</td> </tr> <tr> <td style="padding: 2px;">Risk level</td> <td style="text-align: center; padding: 2px;">15</td> </tr> <tr> <td style="padding: 2px;">Scenario type</td> <td style="text-align: center; padding: 2px;">13– 16 Bad</td> </tr> </table>	Likelihood	3 Medium	Gravity/ Impact	5 Very high	Risk level	15	Scenario type	13– 16 Bad	<ul style="list-style-type: none"> • The attacker (saboteur) destroys technical equipment (lines, transformers, generators, electrical equipment in substations or plants) or performs other actions that lead to disconnection or triggers of lines or transformation units, accidental shutdown of the production of groups in power plants; • Some equipment become unavailable for a very long period; • Difficulties arise in ensuring that the N-1 safety criterion is met; • The disconnection of some production units and equipment within the PTG leads to large power movements to deficient areas and results in voltage deviations and difficulties in
Likelihood	3 Medium										
Gravity/ Impact	5 Very high										
Risk level	15										
Scenario type	13– 16 Bad										

			<p>compensating the reactive power;</p> <ul style="list-style-type: none"> • Problems arise in supplying some grid areas for a very long period, correlated with the time required to repair/replace destroyed/damaged assets; • In conditions of low production in power plants and large power movements to deficient areas, there is a risk of extensive damage to the NPS leading to the failure of supplying electricity to a large number of consumers.
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2.3. Risk scenarios estimation and assessment algorithm

2.3.1. Likelihood Estimation

LEVEL	LIKELIHOOD	Time
1. Very low	It has a very low likelihood of occurring. Normal measures are required to monitor the evolution of the event.	over 20 years
2. Low	The event has a low likelihood of occurring. Efforts are needed to reduce the likelihood and/or mitigate the impact produced.	16 – 20 years
3. Medium	The event has a significant likelihood of occurring. Significant efforts are needed to reduce the likelihood and/or mitigate the impact produced.	11 – 15 years
4. High	The event has a likelihood of occurring. Priority efforts are needed to reduce the likelihood and mitigate the impact produced.	6 – 10 years
5. Very high	The event is considered imminent. Immediate and extreme measures are required to protect the objective, evacuation to a safe location if the impact so requires.	1 – 5 years

2.3.2. Gravity Estimation

LEVEL	GRAVITY / IMPACT
1. Very low	The event produces a minor disturbance in the activity, without material damage
2. Low	The event causes minor material damage and limited disruption to activity
3. Medium	Injuries to staff, and/or certain losses of equipment, utilities and delays in providing the service.

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4. High	Serious staff injuries, significant loss of equipment of installations and facilities, delays and/or interruption of service provision.
5. Very high	The consequences are catastrophic resulting in deaths and serious injuries to staff, major losses in equipment, installations and facilities and termination of service provision.

2.3.3. Risk Level Calculation

LIKELIHOOD	Very high 5					
	High 4					
	Medium 3					
	Low 2					
	Very low 1					
	0	Very low 1	Low 2	Medium 3	High 4	Very high 5
GRAVITY / IMPACT						
Note: The risk is given by the product between Likelihood and Gravity / Impact						

2.3.4. Risk Scenario Type

Risk level: 1 – 3	Risk level: 4 – 6	Risk level: 7 – 12	Risk level: 13 – 16	Risk level: 17 – 25
Very low	Low	Moderate	Bad	Very bad

3. CONCLUSIONS

Integrated risk-assessment methodologies significantly enhance the resilience of the NPS – By combining technical, organizational, and security-intelligence approaches, a more comprehensive picture of system vulnerabilities can be achieved than with any single method alone. This holistic perspective ensures that risks arising from both operational instability and intentional malicious actions are properly identified and prioritized. **Insecurity in the functioning of the NPS is multifaceted, stemming from both internal system weaknesses and external environmental stressors** – Ageing infrastructure, insufficient redundancy, inadequate maintenance, cyber-physical interdependencies, and human-factor errors all contribute to systemic fragility. Integrated assessment enables early detection of these weaknesses and supports preventive interventions that reduce the likelihood of cascading failures. **Terrorist attacks pose high-impact, low-frequency threats that require specialized assessment techniques** – Unlike routine technical failures, terrorist scenarios demand the integration of intelligence analysis, threat modeling, and scenario-based stress testing. The study confirms that combining physical-security evaluations with cyber-security risk modeling provides a more realistic understanding of attack feasibility and potential consequences;

Interconnectedness increases both system efficiency and systemic vulnerability – Modern NPS networks exhibit tight coupling between power generation, transmission, communication systems, and automated control technologies. Integrated risk analysis shows that failures in one domain – whether due to internal insecurity or external attacks—can propagate rapidly across the system, underscoring the need for unified monitoring and response frameworks. **Building resilience requires coordinated technical, organizational, and policy measures** – Effective mitigation involves not only engineering solutions (such as redundancy, modernization, and hardened infrastructure) but also robust governance mechanisms, emergency response planning, cross-sector communication protocols, and continuous cybersecurity improvements. The integrated approach reinforces the importance of systemic coordination among national agencies, operators, and security services;

Proactive preparedness is more effective and less costly than reactive response – The assessment confirms that early identification of vulnerabilities, regular simulation exercises, and timely investment in security and reliability enhancements significantly reduce the long-term risk exposure of the NPS. Integrated methodologies support decision-makers in allocating resources efficiently to areas with the highest risk-reduction potential. **Integrated risk assessment strengthens national security and public trust** – Because the power system is a critical infrastructure on which all other sectors rely, ensuring its stability and protection from intentional attacks is fundamental to national resilience. A systematic, integrated approach enhances the nation’s capacity to prevent, withstand, and rapidly recover from disruptive scenarios, ultimately safeguarding societal continuity and economic stability.

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