

ELECTRICITY CRISIS MANAGEMENT: NATIONAL, REGIONAL AND BILATERAL MEASURES

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Abstract: Electricity crises – triggered by supply shortages, infrastructure failures, extreme weather events, geopolitical tensions, or market disruptions – pose significant challenges to economic stability, public welfare, and national security. Effective management therefore requires a coordinated framework operating at national, regional, and bilateral levels. National strategies typically focus on strengthening grid resilience, diversifying generation sources, improving regulatory oversight, and deploying demand-side management tools. Regional measures emphasize integrated power markets, interconnection upgrades, shared reserve capacity, and coordinated emergency protocols to ensure system stability across borders. Bilateral cooperation further enhances crisis response by enabling targeted power exchanges, cross-border infrastructure development, technical assistance, and joint investment in renewable or flexible generation resources. Together, these multi-layered mechanisms provide a comprehensive approach to preventing, mitigating, and responding to electricity crises. This paper examines the interplay among national, regional, and bilateral measures and highlights best practices that can support a more secure, sustainable, and resilient electricity landscape.

Keywords: electricity crisis, national, regional, bilateral measures, blackout.

1. INTRODUCTION

Power systems worldwide are experiencing increasing vulnerability due to rapid fluctuations in demand, evolving generation portfolios, geopolitical uncertainties, and the growing frequency of climate-related disruptions [22], [25], [28]. For many states, ensuring a stable and affordable electricity supply has become a central policy

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priority, as shortages can undermine economic productivity, public welfare, and national security.

The complexity of modern power systems – characterized by cross-border interconnections, diversified energy mixes, and liberalized market structures – demands a multifaceted approach to crisis management [1], [2], [10].

This study examines the strategic frameworks and operational mechanisms employed at the national, regional, and bilateral levels to prevent, mitigate, and respond to electricity crises [12], [14], [16].

National measures often focus on capacity planning, grid resilience, demand-side management, and emergency response protocols. Regional cooperation, particularly within integrated power pools or supranational organizations, enhances collective security of supply through shared resources, harmonized regulations, and coordinated market interventions [17], [23], [27].

Bilateral agreements, meanwhile, serve as flexible instruments for targeted support, enabling electricity imports, mutual assistance, and joint infrastructure development between neighboring states [13], [20], [26].

By analyzing these levels of intervention, this research seeks to illuminate how multi-layered governance structures contribute to electricity security. It explores the effectiveness of different mechanisms, the institutional challenges that hinder coordinated actions, and the evolving role of cross-border collaboration in an increasingly interconnected energy landscape [4], [18], [24].

Through this lens, the study aims to provide a comprehensive understanding of electricity crisis management as both a national responsibility and a collective regional endeavor [3], [5], [11].

2. NATIONAL, REGIONAL AND BILATERAL PROCEDURES AND MEASURES IN THE EVENT OF AN ELECTRICITY CRISIS

The Romanian Power System functions as an interconnected system to the European Power System – ENTSO-E, which represents the European Network of Transmission System Operators for Electricity, according with *figure 1*.

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 [15], [19].

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).

The National Power System, through the Electricity Power Transmission Grid, is composed of the following critical energy infrastructures [21]:

- 82 power substations (400 kV and 220 kV);
- 8834.4 km overhead power lines (400 kV and 220 kV);
- 216 transformation units totaling 38 058 MVA.
- 1 National Energy Dispatch – NED;
- 5 Territorial Dispatchers – TED.

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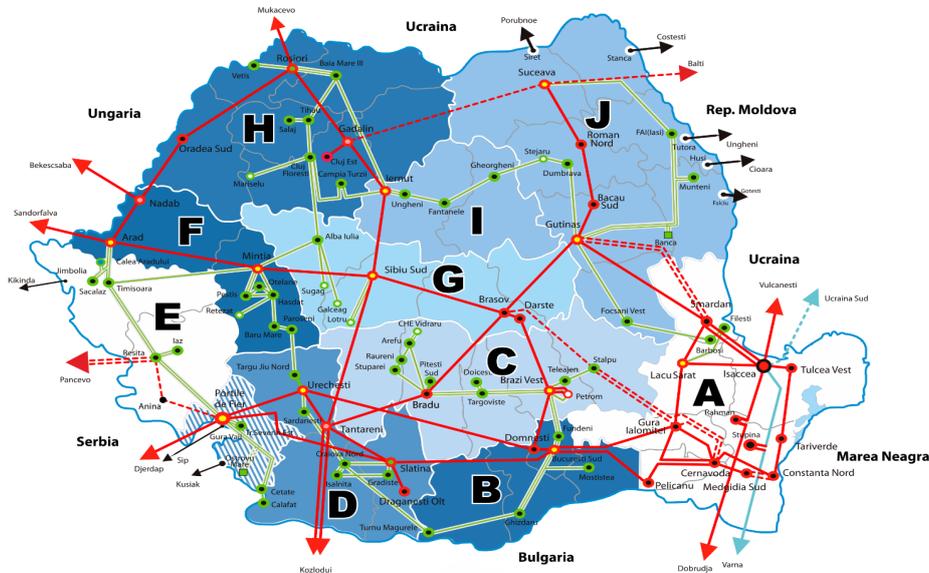


Fig.1. National Power System map (source: Transelectrica)

2.1. National procedures and measures

In accordance with the requirements of the „Law no. 123/2012 on electricity and natural gas” and the „Regulation on technical safeguard measures in exceptional situations arising in the functioning of the National Power System”, approved by NAER Order no. 142/2014 a set of safety measures („of safeguard”) is established to prevent or limit the effects of exceptional situations that may occur in the functioning of the NPS [6], [7].

2.1.1. Measures regarding the functioning of the energy market

The basic principle of action in the event of a crisis situation is to allow the electricity market to function even in situations when demand and supply are limited and the price of electricity experiences steep variations.

NAER Order no. 142/2014 provides for two categories of measures that apply both by the Transmission System Operator and the Distribution Operators to final electricity consumers supplied directly from the NPS power substations. The first category consists of technical measures without impact on the electricity market, and the second category is technical and commercial measures, of which the last measure in order of application is the limitation of electricity consumption to certain categories of industrial consumers, without resorting to the interruption of their electricity supply.

The consumption limitation/reduction measure is applied in installments, as a measure of last resort, only to those industrial consumers who have the technical possibility of reducing consumption by appropriately adapting the technological process, being conditioned by the issuance of a Decision of the Government of

Romania, at least 5 days before the moment of application and with a prior notification of consumers of at least 24 hours.

The final customers to whom the consumption limitation measures are applied have provided for this obligation in the transmission or distribution contract, as the case may be.

The measure to suspend the electricity market will be taken only in special situations, as a last resort when all the measures listed below have been exhausted, namely:

Measures without impact on the electricity market:

Measures that are applied to prevent a crisis situation in the functioning of the NPS and do not affect the functioning of the electricity market:

- loading the groups to the maximum available power (including starting the groups in reserve);
- increasing the available power of the NPS, by making available the production units under repair (returning to operation ahead of schedule the groups under repair);
- reducing the dispatchable consumption declared as load offer on the balancing market;
- requesting emergency assistance from neighboring TSOs;
- transition to minimum voltage band functioning in the Distribution Power Grid (DPG).

Technical and commercial measures with an impact on the electricity market:

Safeguard measures that apply in crisis situations in the functioning of the NPS – technical and commercial measures that may affect the electricity market:

- increasing the technological system reserves in production units that can function on alternative fuel, in order to use them as appropriate;
- reduction/cancellation of available interconnection capacity in the export direction;
- reduction/cancellation of notified exchanges in the export direction;
- limitation of electricity consumption in installments, under the conditions established by Government Decision and in accordance with the provisions of the Limitations Norm.

Once the crisis has been triggered, the TSO may apply technical and commercial safeguard measures to prevent crisis situations affecting the functioning of the electricity market, namely:

- increasing the technological system reserves in production units that can function on alternative fuel (e.g. fuel oil), in order to use them as appropriate;
- reduction/cancellation of available interconnection capacity in the export direction;
- reduction/cancellation of notified exchanges in the export direction.

2.1.2. Measures regarding manual interruption of consumption

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In unforeseen situations that endanger the functioning of the NPS, at the TSO level there is also the possibility of manually disconnecting certain categories of industrial consumers, for a limited period of time, after which these consumers are re-powered at a minimum technological power, so as not to endanger the security of the installations and staff.

The manual interruption of consumption shall be carried out in exceptional circumstances arising in the functioning of the NPS, in accordance with the Operational Procedure (OP) No TEL-07.III AV-DN/24_ The method of elaboration and application of the manual disconnection regulations of certain categories of final customers, by instalments, in exceptional situations arising in the functioning of the NPS – hereinafter referred to as “The manual disconnection regulation”.

The manual disconnection regulation is applied as a last resort, in situations that could not be anticipated in the functioning of the NPS, situations that endanger the functioning of the NPS or an area of the NPS, in order to prevent the propagation or aggravation of this situation.

The manual disconnection regulation applies to the following exceptional NPS functioning situations:

- transition to isolated functioning of the NPS, after the activation of the automatic device at decreasing frequency, if the frequency cannot be restored and maintained at values > 49 Hz, due to lack of available active power;
- isolation of an area of the NPS, where the frequency and/or voltage cannot be restored to values allowing synchronization of some generating groups or synchronization of the area to the NPS, due to the lack of available active power in the area;
- through the grid supplying an area of the NPS (lines, transformers, autotransformers), loads that exceed the permissible limit values from the point of view of the equipment (thermal limit) occur and these cannot be removed by other measures during the permitted overload functioning;
- in an area of the NPS or in most of it, after all adjustment measures have been taken, the voltages are maintained at values not more than equal to the value of the sacrifice voltage (360 kV for the 400 kV grid, 180 kV for the 220 kV grid and 85 kV for the 110 kV grid) and this situation may endanger the stability of functioning;
- the decrease below the normal limits of the reserve against the static circulation stability limit by a characteristic section through which a deficient area is supplied, until the slow tertiary reserve in that area is started or, when it is missing, until the application of the Regulation limiting the electricity consumption, by instalments, in crisis situations arising in the functioning of the NPS;
- the occurrence of a short-term active power deficit (4 ÷ 48 hours) leading to an hourly deviation from the programmed balance, inadmissible according to the ENTSO-E rules, until the mobilization of the slow tertiary reserve or, when it is missing, until the application of the Regulation limiting the electricity consumption, by instalments, in crisis situations arising in the functioning of the NPS.

All consumers to whom the Manual disconnection regulation and the Regulation for limiting/reducing electricity consumption may apply are industrial consumers, household consumers being excluded.

Also, the number of industrial consumers connected to the PTG is low and do not have special protection against disconnection.

2.1.3. Special protection against disconnection

The manual disconnection regulation applies only to final customers included in the current regulation. These final customers are industrial consumers who, through the technological process used, have the capacity to be disconnected for a pre-established period and then need to be re-powered to the minimum technical power.

The manual disconnection regulation applies until the previously provided conditions disappear, as a result of a change in the situation in the NPS or the successful implementation of recovery measures (mobilization of adjustment energy, commissioning of grid elements) or, when this is not possible, until the application of the Regulation for limiting electricity consumption.

The manual limitation of consumption shall be carried out in foreseeable situations in the functioning of the NPS, in accordance with OP No TEL-07.III AV-DN/13_The method of elaboration and application of the regulation for limiting electricity consumption, by instalments, in crisis situations arising in the functioning of the NPS .

The limitation regulation applies in the following crisis situations of functioning of the NPS:

- national fuel shortages;
- energy deficits, determined by the evolution of the international economy;
- energy deficits, determined by the country's defense needs;
- energy deficits, determined by environmental protection needs;
- energy deficits in a deficient NPS area, determined by the unavailability of production sources in the area and limited grid capacity to ensure the safely transmission of necessary power from other areas.

The determination of the likelihood of a crisis situation occurring in the functioning of the NPS is made by the TSO on the basis of the short and medium term adequacy analyses of the NPS, taking into account:

- the fuel stocks and the conditions for carrying out the economic activities that provide them (extractive industry, transport);
- the state of the National Natural Gas Transmission System;
- the volume of water reserves in reservoirs;
- the availability of electricity production units;
- the electricity consumption at the level of the NPS or at the level of an area of the NPS;
- the PTG and PDG availability.

Also, at regional and European level, the STA (Short Term Adequacy forecasts) process is carried out daily for the next seven days by RSCs (Regional Security Coordinator), based on daily analyses for the next seven days.

The regulation for limiting the electricity consumption applies, following the adoption of a Government Decision, as a last safeguard measure taken in crisis

situations arising in the functioning of NPS that may be foreseen in the medium and long term, which endangers the functioning of the NPS or of an area of the NPS.

In critical situations in the NPS, the economic operators included in the regulation limiting the electricity consumption are notified in writing by the TSO on the provision for the application of the Regulation limiting the electricity consumption. The regulation applies only to final customers included in the current regulation. These final customers are industrial consumers who, through the technological process used, have the capacity to reduce their electricity consumption.

2.1.4. Prevention and preparedness measures

Prevention and preparedness measures at the design and planning stage:

- Analysis of the operational behavior of electrical equipment (determination of equipment with high failure rate and elimination of non-conformities).
- Analysis of the operational behavior of the lines (detection of areas where triggers occur frequently due to extreme weather events).
- Imposition of specifications for the purchase of electrical equipment to ensure their proper functioning in the event of low temperatures.
- Imposing, through design regulations increased earthquake safety conditions for lines of maximum importance for the NPS, for substations and control centers buildings, for the foundations of electrical equipment and transformation units.
- Imposing, through design regulations increased safety conditions for lines of maximum importance for the NPS (use of active conductors with low coefficient of expansion, use of pipe with high degree of mechanical strength).
- Use of electrical equipment with composite tires instead of porcelain in areas with high seismic activity.
- Expertise of old generation equipment.

Prevention and preparedness measures in development and investment work:

- Initiation of investment works/major maintenance to diminish galloping effects, improve the insulation level of lines, etc.).
- Replacement of concrete pillars with metal pillars.
- Implementation of the development plan of the Power Transmission Grid.
- Implementation of the development plan of the Power Distribution Grid.
- Installation of monitoring systems on lines.
- Periodic audit and updating/upgrading the safety of computer systems.
- Use of modern and high-performance forecasting techniques based on multicriterial analysis, leading to a robust dimensioning of NPS power reserves.

Preventive and preparedness measures during maintenance work:

- Implementation of the maintenance plan of the Power Transmission Grid.
- Implementation of the maintenance plan of the Power Distribution Grid.
- Implementation of the maintenance plan for electricity production companies.
- Maintenance of control systems.

- Maintenance of system automation.
- Maintenance of automation in power plants
- Maintenance of the automatic device at decreasing frequency, automatic device at decreasing voltage.
- Maintenance of heating systems.
- Eliminating weaknesses and deficiencies in transmission and distribution grids;
- Filling with oil, SF6 gas.
- Eliminating hot spots.
- Equipment operation checks.
- Diesel Groups checks.
- Batteries checks.
- Periodic checks on the condition of the foundations of the pillars in the areas adjacent to river streams.
- Checks on the track of lines where there is a risk of landslides.
- Checking the functioning of the tap-changer switches at the transformer units.
- Maintenance of line safety lanes and removal of dry vegetation from the interior of safety lanes.
- Mowing vegetation inside the substations.
- Maintaining switching equipment (separators) in proper condition to allow handling in conditions of ice formation on contacts.
- Maintenance of substation constructions (concrete channels and pillars, equipment foundations) and of the foundations and anchoring systems of the lines pillars.
- Maintaining the proper functioning condition of AC installations in relay cabins, batteries and telecommunication cameras.
- Maintaining the proper functioning condition of the cooling systems of the transformer units.
- Snow removal of roads and access routes in substations.
- Prevention and preparedness measures as features:
- Fuel insurance for Diesel Groups.
- Backup supply insurance with Diesel Generators, UPSs and batteries.
- Proper equipment with fire extinguishers in substations.
- Providing disinfectant materials, masks and gloves for employees.
- Prevention and preparedness measures as trainings and courses:
- Staff training on fire prevention and extinguishing in electrical installations.
- Staff training on the risks of cybersecurity breaches.
- Professional training of operational staff.
- Other prevention and preparedness measures:
- Staff information and education programmes on national programmes to combat the pandemic.
- Vaccination programmes for staff.
- Measuring the temperature of employees.

- Individualization of the employee work schedule (work in shifts or with delayed schedule, teleworking programmes).
- Periodic ventilation, sanitation and disinfection of work spaces.
- Limitations on access to the command rooms of dispatcher control centers and remote control centers and, respectively, to the command rooms of PTG substations.

2.1.5. Mitigation and restoration measures

Response and restoration measures regarding the staff:

- Instructions charts.
- Insurance of technical intervention staff.
- Insurance of auxiliary intervention staff (financial, commercial, logistics).
- Insurance of operative staff and intervention and technical staff (use of management staff or semi-qualified staff or with similar qualifications to ensure continuity, reduction of the number of shifts, extension of the work schedule, etc.).

Response and restoration measures regarding the need for materials and machinery:

- Insurance of intervention/reserve pillars and accessories for lines (insulators, clamps, conductors).
- Provisional insurance of underground power lines.
- Insurance of mobile cells.
- Insurance of equipment (electric equipment) from safety/intervention stock.
- Elaboration of standard quotations for intervention works (replacements of equipment, pillars, transformation units) and assessment of a medium time of replacement/remediation.
- Insurance for Diesel groups.
- Insurance for batteries and UPS.
- Fuel reserves insurance (for diesel groups)
- Oil and SF6 gas reserves insurance.
- Winter material insurance (clothing, food, etc.)
- Fleet insurance.

Other response and restoration measures:

- Insurance of redundant/independent lines of communication (fail-safe).
- Providing spaces with special facilities (accommodation, food, sanitation, medical and psychological services) that allow the protection of staff with essential attributions for the functioning of the NPS.
- Conventions with companies specialized in construction works in the electrical field.
- Conventions with companies that own machinery for intervention.

2.1.6. The entity responsible for declaring the crisis

According to the National Disaster Risk Management Plan in Romania, the National Emergency Management System contains the following components:

- emergency committees;
- The Department for Emergency Situations;
- The General Inspectorate for Emergency Situations;
- professional emergency services and voluntary emergency services;
- operative centers and intervention coordination and management centers;
- emergency operative centers;
- commander of action/intervention.

In the event of a crisis situation, the following entities within the Ministry of Energy shall act:

- The Ministerial Committee for Emergency Situations, respectively
- The Ministerial Operative Center, and – as a part of The Ministerial Operative Center – The National Operative Center in the Energy Sector.

The entity responsible for declaring the crisis situation is *The National Operative Center in the Energy Sector*.

The following are part of The National Operative Center in the Energy Sector structure:

- Representative of the Ministry of Energy – President;
- President of the Transelectrica S.A. (TSO) Directorate;
- President of the Hidroelectrica S.A. Directorate;
- President of the Nuclearelectrica S.A. Directorate;
- Director of the Transgaz S.A.;
- Director of Power plants Bucharest S.A.;
- Director of OMV Petrom S.A.;
- President of the Oltenia Energy Complex S.A. Directorate;
- President of the Hunedoara Energy Complex S.A. Directorate;
- President of the Romania Electricity Distribution S.A. Directorate;
- President of the Oltenia Electricity Distribution S.A. Directorate;
- President of the E – Distribution S.A. Directorate;
- Director of DelgazaGrid S.A. - Director of UNO DEN;
- Director of the Energy Sector Risk Management and Prevention Department of the Ministry of Energy;
- Director of the Competent Authority for Ensuring Electricity Supply, within the Ministry of Energy.

The roles and responsibilities of The National Operative Center in the Energy Sector structure:

- it assesses the crisis situation;
- it is the entity responsible for declaring /ending a crisis;
- it ensures the implementation and coordination of the measures contained in the Risk Preparedness Plan (RPP);
- it interacts with other entities of crisis management organized at national level; - provides support to other national agencies/national departments/ministries;

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- it ensures coordination for the provision of assistance and necessary resources (materials, machinery and work staff) at national level;
- it allocates the necessary resources for restoration actions;
- it allocates the necessary financial resources for restoration actions;
- provides the information office with information on the development of events and measures taken in energy crisis situations.

Other Operative Centers at the level of Entities within the NPS (the Operative Work Center in the Energy Sector):

- Representative from the administrative management; Manager/director of the operation and maintenance department;
- The manager of the Department for Emergency Situations;
- The manager of the Department of labor protection;

The roles and responsibilities of the Operative Work Center in the Energy Sector:

- it ensures the implementation of the measures decided by the National Operative Center in the Energy Sector in the affected areas with priority on the safety and health of staff, minimizing the damage caused to the assets in the NPS, as well as on the environment and other goods;
- provides support for intervention staff in case of fires or security incidents;
- it ensures the evacuation of non-essential (technical or non-technical) staff from the affected areas; - ensures communication points;
- it reports to the National Operative Center in the Energy Sector all relevant information related to the measures taken and requests assistance/support if necessary;
- it ensures the recording/preservation of necessary information to be used in the post-factum analysis of the causes that led to the occurrence of the crisis situation and the measures taken;
- provides coordination with local authorities to ensure medical needs, public order.

2.1.7. The main stages of action in case of a crisis situation

- declaration of crisis situation;
- information/announcement of crisis situation;
- assessment of the situation and risks;
- identification of necessary resources (human, material and machinery);
- adopting a response strategy according to the Risk Prevention Plan;
- implementation of the response strategy;
- field analysis of the effects of the crisis;
- post incident analysis and establishment of measures for prevention in the future;
- ending the crisis.

1. Appropriate mechanisms for information flows

The management of the crisis situation depends to a very large extent on the quality of the information received (their fairness and promptness) by the deciding

factors. In this respect, the information received must have as its source direct on-the-spot observations reported by qualified staff.

The information shall be immediately reported to the National Operative Center in the Energy Sector (directly, or through the Operative Work Center in the Energy Sector).

Depending on the crisis situation, the National Operative Center in the Energy Sector will take the following measures:

- it will issue a *Pre-Alert* briefing: providing information on the possible occurrence of a crisis situation;
- it will issue an *Alert* notification: informing that although the crisis situation is not imminent, elements have appeared that have worsened/aggravated the previous state;
- it will issue a *Danger* notification: informing that the crisis is imminent and the responsible factors must take the necessary measures to minimize the damage/losses that will be caused by the crisis situation.

- declaration of the *Crisis* situation.

For information and coordination of actions, the following command centers will be used:

- National operative center at the level of the Central Energy Dispatch;
- Local operative centers at the level of Territorial Energy Dispatchers;
- Local operative centers at the level of Territorial Units within Transelectrica S.A.;
- Local operative centers at the level of Energy Distribution Dispatchers;
- Local operative centers at the Regional Unit level within the Distribution Operators;
- Local operative centers at the level of Energy Dispatchers of Production Units.
- Local operative centers at the level of Energy Dispatchers of Large Consumption Units.

Through these command centers, all relevant information will be transmitted, regarding:

- the state and operating mode of the NPS;
- measures ordered by the National Operative Center in the Energy Sector;
- implementation mode of the actions/measures ordered by National Operative Center in the Energy Sector;
- aspects of the crisis situation.

All information available in the territory shall be centralized at the central command center (at the level of the Central Energy Dispatch) which shall carry out the National Operative Center in the Energy Sector information.

Informing the public opinion, the mass media will be centralized through a press officer designated by the National Operative Center in the Energy Sector.

At the time of the onset of the crisis, the Operative Work Center in the Energy Sector organizes intervention teams including key staff, teams that will act in the following directions:

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- *Operational:*
 - identifies potential hazards that may arise and acts to eliminate them;
 - takes the measures of safe disconnection/withdrawal from operation of damaged equipment;
 - takes measures to stop production units safely (if necessary);
 - takes measures arranged according to the events and the peculiarities of the crisis situation.
- *Maintenance:*
 - intervenes to repair equipment failures;
 - identifies potential hazards that may arise and act to eliminate them;
 - takes measures arranged according to the events and the peculiarities of the crisis situation.
- *Security*
 - restricts access to non-essential staff;
 - ensures access for essential staff;
 - ensures access to vehicles for evacuation or for ambulances.
- *Administrative:*
 - provides assistance for rescue and transport operations to first aid centers or medical centers;
 - ensures records of staff actively participating in the crisis;
 - takes measures arranged according to the events and the peculiarities of the crisis situation.
- *Labor protection:*
 - ensures the necessary measures in terms of labor protection;
 - provides assistance for measuring gas emissions/concentrations;
 - identifies and collects evidence, information related to labor protection aspects necessary for post incident analysis/investigation;
 - takes measures arranged according to the events and the peculiarities of the crisis situation.
- *Occupational medicine:*
 - ensures rapid access and intervention of medical staff for providing first aid;
 - ensures the delivery of medical assistance;
 - requests specialized medical assistance;
 - takes measures arranged according to the events and the peculiarities of the crisis situation.
- *Firefighting:*
 - intervenes rapidly to identify and extinguish fires;
 - requests the intervention of the fire teams within the Emergency Situations Inspectorate;
 - evacuates staff from fire areas;
 - takes measures arranged according to the events and the peculiarities of the crisis situation.
- *Transport:*
 - ensures the availability of the entire fleet for intervention and evacuation actions;

- ensures the presence of specialized staff at the site of the incident to ensure intervention in case of minor malfunctions to the intervention vehicles, ambulances, etc.;
- provides fuel supply to vehicles, machinery, Diesel Groups;
- provides assistance in organizing transport conditions;
- takes measures arranged according to the events and the peculiarities of the crisis situation.
- o communications;
 - ensures the functionality of the communication network;
 - intervenes in order to repair the failures occurring in the communication equipment;
 - takes measures arranged according to the events and the peculiarities of the crisis situation.
- *Communications:*
 - ensures the functionality of the communication network;
 - intervenes in order to repair the failures occurring in the communication equipment;
 - takes measures arranged according to the events and the peculiarities of the crisis situation.

Essential staff, criteria for determining it:

The heads of each organizational unit within the NPS entities shall establish the key staff in crisis management. The following categories of essential staff will be identified:

- technical and non-technical management staff;
- operational staff (operative management, operative service, maintenance);
- communications staff;
- maintenance staff;
- staff for supply;
- staff to ensure the transport and handling of materials;
- staff responsible for emergency situations;
- staff responsible for labor protection;
- staff responsible for occupational medicine and occupational health;
- external communication staff.

2.2. Regional and bilateral procedures and measures

2.2.1. Agreed mechanisms to cooperate within the region

Ensuring coordination before and during the electricity crisis Regional Coordination Centers (RCCs) currently provide a set of mandatory services for all TSOs to which they are affiliated, in accordance with EU legislation such as: [6,7]

- establishing common grid models;
- coordinated security analysis;
- coordinated capacity calculation;
- coordination of the decommissioning programme;

- short-term adequacy forecast;
- support for the coordination of defense and restoration plans;

In addition to the above, the RCC “TSCNET” works with TSOs and other RCCs on an early warning system to identify and mitigate potentially critical grid situations (CGS).

Starting with 2010, the EAS (ENTSO-E Awareness System) software platform was developed at the ENTSO-E level, which offers all partner TSOs a real-time global picture of the European transmission grid, a better understanding of the problem, in case of an emergency situation, of some disturbances.

The EAS platform provides the opportunity for TSOs to:

- develop the ability to assess the type and size of a disturbance;
- make the decision to act or not, without aggravating the state of the system;
- coordinate measures to solve problems related to consumption/production/power grid and system restoration;
- option to cooperate with other TSOs.

Throughout the crisis situation, the European information platform EAS (ENTSO-E Awareness Systems) will be used, the ENTSO-E and the Regional Coordination Centers will be informed and the coordinated measures established by them according to the procedures, regulations and international agreements in force will be taken.

Thus, the crisis situation is managed in collaboration and coordination with all TSOs in the region, through entities within the ENTSO-E and the Regional Security Coordination Centers, applying the dedicated procedures in force (Critical Grid Situation Procedure, coordination on Short Term Adequacy, and monitoring of frequency and cross-border exchanges by Regional Coordination and Monitoring Centers organized within AMPRION – Germany and SwissGrid – Switzerland).

2.2.2. Regional and bilateral action measures in the event of a crisis

- announcement of the crisis situation at ENTSO-E level;
- urgent communication and consultation with counterpart entities at regional and/or bilateral level to analyze the effects caused by the crisis situation;
- synchronization at bilateral /regional level with the purpose of implementing the response strategy;
- acting in the sense given by the strategy to manage and eliminate the crisis.
Other measures:
- improving the adequacy indicators of the power systems in the region with the help of the shared power reserve and the additional reserve available at the interface with neighboring regions, as well as establishing the maximum quantities of electricity to be delivered at regional or bilateral level;
- improving security of supply (SoS) by eliminating congestion;
- substantial increase in net interconnection capacity;
- post incident analysis and establishment of measures for prevention in the future.

The trigger for assistance:

- major disturbances in the NPS in a certain part of the country, and the Transmission System does not have the capacity to support the deficit from one area to another;
- difficulties arise in ensuring the adequacy of the NPS as a result of unscheduled outages of production capacities;
- trigger elements specific to risk scenarios with regional effects appear;
- the restoration activity of the neighboring power system requires this.

2.2.3. Mutual aid agreements to cooperate and coordinate actions before and during the energy crisis

Within the region of which Romania is part, the following bilateral operational agreements are in force:

- Mutual Aid Convention (Agreement on Provision of Mutual Emergency Energy Assistance for Ensuring the Reliable Operation of Power Systems of Bulgaria and Romania) that provides for the granting of a quantity of electricity between the two countries for the purpose of helping one of the countries in crisis.
- Mutual Aid Convention (Agreement on Provision of Mutual Emergency Energy Assistance for Ensuring the Reliable Operation of Power Systems of Serbia and Romania) that provides for the granting of a quantity of electricity for the purpose of helping one of the countries in crisis.
- Mutual Aid Convention (Agreement on Provision of Mutual Emergency Energy Assistance for Ensuring the Reliable Operation of Power Systems of Ukraine and Romania) that provides for the granting of a quantity of electricity for the purpose of helping one of the countries in crisis.
- Exploitation Convention (Operational Agreement) concluded between the TSOs of Romania and Serbia provides for the granting, as appropriate, of aid in the framework of the NPS restoration actions, through the 400 kV OHL Iron Gates - Djerdap interconnection line.
- Exploitation Convention (Operational Agreement) concluded between the TSOs of Romania and Bulgaria provides for the granting, as appropriate, of aid in the framework of the NPS restoration actions, through the interconnecting lines between the two countries.
- Exploitation Convention (Operational Agreement) concluded between the TSOs of Romania and Hungary provides that, as far as possible, support shall be given to restoring the neighbouring system by maintaining the voltage on the interconnecting lines and providing a quantity of electricity through the lines between the two countries [8], [9].

3. CONCLUSIONS

1. Crises are multi-dimensional: technical, economic and political

Electricity crises (shortages, blackouts, price spikes) rarely arise from a single cause. They result from interacting technical failures, market design weaknesses, fuel or supply shocks, and governance failures. Effective management therefore requires

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cross-sector diagnosis and integrated responses rather than siloed technical fixes. Implication: Crisis teams must include grid engineers, market operators, fuel/logistics experts, legal advisers and political decision-makers.

2. Preparedness matters more than ad-hoc response

Systems with established contingency plans, clear operational triggers, and pre-agreed emergency procurement/shortage allocation rules recover faster and incur lower economic and social costs than those that improvise. Implication: National and regional plans should codify threshold metrics, roles, and quick-action procurement channels before crises occur.

3. Robust real-time data and situational awareness are indispensable

High-granularity, near-real-time data on demand, generation, interconnector flows and reserve margins enables precise, proportionate interventions. Lack of transparent data increases risk of overreaction and public distrust. Implication: Invest in telemetry, interoperable data platforms and transparent dashboards shared across jurisdictions.

4. Market design must allow for crisis instruments without undermining long-term signals

Markets that rigidly prioritize short-term price signals can struggle to secure capacity and fuel resilience. Conversely, heavy-handed price caps or bans can deter investment. Well-designed capacity mechanisms, reliability options, and demand-response contracts can bridge short-term reliability and long-term investment. Implication: Deploy temporary crisis instruments (e.g., scarcity pricing, bilateral reliability contracts) while protecting investor confidence through clear sunset clauses and compensation frameworks.

5. Demand-side resources are cost-effective and underutilized

Demand response, targeted conservation, and demand-flexibility (industrial interruptibility, smart appliances) reduce peak stress more quickly and cheaply than building generation. Implication: Prioritize incentives and legal frameworks for rapid demand reductions, including pre-agreed compensation for curtailed consumers.

6. Regional integration increases resilience but requires coordinated governance

Cross-border interconnectors and regional markets smooth local shocks and share reserves, lowering overall costs. However, benefits materialize only if operational rules, cost allocation and emergency coordination are harmonized. Implication: Strengthen regional institutions (TSO coordination, contingency sharing agreements) and create binding rules for emergency cross-border flows and compensations.

7. Bilateral agreements fill gaps where multilateral coordination is slow

Between neighboring states with strong trade links, bilateral emergency supply and assistance agreements (fuel swaps, emergency reserve sharing, back-up generation dispatch) can be faster and politically simpler than larger multilateral arrangements. Implication: Negotiate bilateral memoranda of understanding that specify triggers, modalities, payment terms and liability for emergency transfers.

8. Social equity and communication shape legitimacy

Crisis measures that ignore vulnerable populations (low-income households, critical health facilities) or that lack clear, consistent communication provoke non-compliance and political backlash. Implication: Embed social protection (priority supply for critical services, targeted subsidies) and a transparent public communication strategy into crisis plans.

9. Institutional clarity reduces delay and blame-shifting

Where responsibilities for procurement, rationing, and emergency declaration are fragmented, decision-making stalls. Clear authority lines (who declares emergency, who can order load shedding, who controls emergency procurement) are essential. Implication: Legislate decision authorities and fast-track procurement powers, with parliamentary/oversight review after the fact.

10. Flexible financing and contingency funding are necessary

Crisis responses require rapid spending (fuel imports, emergency generation hires, compensation). Budgetary rigidity can delay action or transfer costs in destructive ways. Implication: Maintain contingency finance lines, pre-approved credit arrangements with clear accountability rules.

11. Legal and contractual clarity prevents costly disputes

Ambiguous contracts (PPAs, interconnector usage rights) generate litigation during stress, delaying relief. Pre-agreed force-majeure, scarcity pricing rules and dispute-resolution fast-tracks reduce uncertainty. Implication: Standardize emergency clauses and dispute escalation timelines in key contracts.

12. Energy security and climate policy must be reconciled, not treated as trade-offs

Short-term energy security responses (e.g., temporary fossil fuel use) can coexist with long-term decarbonization if governed by transparent, time-limited measures and accompanied by accelerated clean investments. Implication: Approve temporary emergency fuel measures with explicit sunset clauses and parallel commitments to accelerate renewables, storage and grid upgrades.

13. Technology matters – but institutions decide outcomes

Grid hardware (storage, smart inverters, microgrids) expands options, yet without institutional frameworks (market rules, operator training, regulatory support) technology adoption will not translate into crisis resilience. Implication: Pair technical investments with regulatory reforms and operator capacity building.

14. Simulation, drills and after-action reviews are cost-effective

Tabletop exercises and full-scale drills reveal procedural gaps and boundary issues between national and regional actors. Systematic after-action reviews convert lessons into concrete reforms. Implication: Mandate periodic simulations across agencies and neighboring jurisdictions; publish transparent post-crisis reviews with accountability and reform timelines.

15. Monitoring and metrics: adopt outcome-focused KPIs

Measure preparedness and response using standard metrics: unserved energy (MWh), outage duration per customer, time-to-restore, economic cost per MWh unserved, proportion of critical services maintained, and equity indicators. Implication: Use these KPIs for benchmarking across regions and to justify investments.

16. Research gaps and future agenda

Key empirical and modelling gaps remain: optimal mix of regional vs bilateral reserves; cost-effective allocation of demand-response across socioeconomic groups; legal templates for rapid cross-border aid; behavioral responses to conservation appeals; and quantifying climate-extreme impacts on combined generation-fuel-transmission failures. Implication: Prioritize interdisciplinary research funding and data-sharing protocols to fill these gaps.

REFERENCES

- [1]. **Andraş A., Brînaş I., Radu S.M., Popescu F.D., Popescu V., Budilică D.I.**, *Investigation of the Thermal Behaviour for the Disc-Pad Assembly of a Mine Hoist Brake Using COMSOL Multiphysics*. Acta Tech. Napoc.-Ser. Appl. Math. Mech. Eng. 64, 227234, 2021.
- [2]. **Arad S., Marcu M., Pasculescu D., Petrilean D.C.**, *Aspects of the electric arc furnace control*, Proceeding. of international symposium advanced engineering & applied management, Faculty of Engineering Hunedoara, 2010.
- [3]. **Cruceru A.E., Popescu F.G., Fita D.N., Marcu M.D., Olteanu R.C., Schiopu A.M., Popescu G.**, *Chapter 4: Exploring the Dimensions of Energy Security in Relation to the National Power Grid Current Approaches in Engineering Research and Technology*, Vol. 10, Book Publisher International, India, pp.54–69, 2024.
- [4]. **Cruceru A.E., Popescu F.G., Fita D.N., Marcu M.D., Olteanu R.C., Schiopu A.M., Popescu G.**, *Chapter 10: Electricity Storage: The Main Pillar of Energy Security Scientific Research, New Technologies and Applications*, Vol. 10, Book Publisher International, India, pp.145–172, 2024.
- [5]. **Fita D., Cruceru A., Popescu G., Draghila M., Lisu A., Radu Al.**, *Smart Power – Analiza Soft și Hard în Relațiile Internaționale*, Editura Risoprint Cluj Napoca, pp.162., 2025.
- [6]. **Fîță N. D., Lazăr T., Popescu F. G., Pasculescu D., Pupăză C., Grigorie E.**, *400 kV power substation fire and explosion hazard assessment to prevent a power black-out*, In International Conference on Electrical, Computer Communications and Mechatronics Engineering-ICECCME (pp. 16-18), 2022.
- [7]. **Fîță N.D., Marcu M.D., Păsculescu D., Popescu F.G., Lazăr T.**, *Security risks assessment on the 400/275/25 kV Elvanfoot power substation from Scotland in order to ensure resilience and energy security*, IEEE, Proceedings of International Conference on Electrical, Computer and Energy Technologies, Cape Town-South Africa, 2023.
- [8]. **Fîță N.D., Obretenova M.I., Popescu F.G.**, *Romanian Power System – European energy security generator*, Lambert Academic Publishing, ISBN: 978-620-7-46269-8, 2024.
- [9]. **Fîță N.D., Obretenova M.I., Schiopu A.M.**, *Național Security – Elements regarding the optimisation of energy sector*, Lambert Academic Publishing, ISBN: 978-620-7-45693-2, 2024.
- [10]. **Fîță N.D., Tătar A., Obretenova M.I.**, *Security risk assessment of critical energy infrastructures*, Lambert Academic Publishing, ISBN: 978-620-7-45824-0, 2024.
- [11]. **Handra A.D., Păsculescu D., Uțu I., Marcu M.D., Popescu F.G., Rada A.C.**, *Tehnici de optimizare in energetica*, Editura Universitas, Petrosani, 2022.
- [12]. **Lazar T., Marcu M.D., Utu I., Popescu F.G., Pasculescu D.**, *Mașini electrice - culegere de probleme*, Editura Universitas, Petroșani, pp. 197, 2023.
- [13]. **Manea F., Ilia G., Ghicioi E., Pupazan D.G., Prodan M., Nicola A.H.**, *The Experimental Study of Flame Behavior of Flexible Polyurethane Foam (Sponge), as a Sound-*

Absorbing Element, FIRE-SWITZERLAND, Volume8/Issue4, Article Number 127, Published MAR 26 2025.

[14]. **Marcu M., Niculescu T., Slusariuc R. I., Popescu, F.G.,** *Modeling and simulation of temperature effect in polycrystalline silicon PV cells*, IOP Conference Series: Materials Science and Engineering, Vol. 133, No. 1, pp. 012005, 2016.

[15]. **Pasculescu D., Slusariuc R., Popescu F.G., Fita N.D., Tatar A., Lazar T., Buica G.,** *Modeling and simulation of lighting of a road with 2 strips per direction to en 13201: 2015 Standard*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.65-74, 2022.

[16]. **Păsculescu D., Romanescu A., Păsculescu V., Tătar A., Fotău I., Vajai Gh.,** *Presentation and simulation of a modern distance protection from the national energy system*, 10th International Conference on Environment and Electrical Engineering, pp. 1-4. IEEE, 2011.

[17]. **Petrilean D.C., Fiță N.D., Vasilescu G.D., Obretenova M.I., Tataru D., Cruceru E.A., Mateiu C.I., Nicola A., Darabont D.-C., Cazac A.M., Bejinariu C.,** *Sustainability Management Through the Assessment of Instability and Insecurity Risk Scenarios in Romania's Energy Critical Infrastructures*, SUSTAINABILITY, Volume17/Issue7, Article Number 2932, Published MAR 26 2025.

[18]. **Popescu F.D., Radu S.M., Andras A., Brinas I., Marita M.-O., Radu M.A., Brinas C.L.,** *Stability Assessment of the Dam of a Tailings Pond Using Computer Modeling—Case Study: Coroiești, Romania*. Applied Sciences, 14: 268, 2024.

[19]. **Popescu F.G., Arad S., Marcu M.D., Pana L.,** *Reducing energy consumption by modernizing drives of high capacity equipment used to extract lignite*, Papers SGEM2013/Conference Proceedings, Vol. Energy and clean technologies, pp. 183 - 190, Albena., Bulgaria, 2013.

[20]. **Popescu F.G., Marcu M.D.,** *Metode moderne de analiză și reducere a armonicilor de curent și tensiune*, Editura Universitat, Petroșani, 2016.

[21]. **Popescu F.G., Pasculescu D., Marcu M., Pasculescu V.M., Fita N.D., Tatar A., Lazar T.,** *Principles of effective energy management and power control system*, Annals of the University of Petrosani, Electrical Engineering, Vol.24, pp.111-118, 2022.

[22]. **Riurean S., Fiță N. D., Păsculescu D., Slușariuc R.,** *Securing photovoltaic systems as critical infrastructure: A multi-layered assessment of risk, safety, and cybersecurity*, Sustainability, 17(10):4397, 2025.

[23]. **Rosca S.D., Riurean S., Popescu G., Lazar T., Popescu F.G.,** *Development of a BCI video game for mental state recognition*, Annals of the University of Petrosani, Electrical Engineering, VOL. 26, pp. 383-390, 2024.

[24]. **Safta G.E., Fita D.N., Popescu F.G., Cruceru A.E., Olteanu R.C., Schiopu A.M., Popescu G.,** *Chapter 6: Improving the Quality of Electricity in Eastern Europe: Challenges and Solutions Scientific Research, Scientific Research, New Technologies and Applications*, Vol. 9, Book Publisher International, India, pp.132–149, 2024.

[25]. **Samoila B.L., Arad L.S., Marcu M.D., Popescu F.G., Utu I.,** *Contributions in Modern Electrical Engineering Higher Education Using Dedicated Applications*, International Symposium on Fundamentals of Electrical Engineering, Bucharest, 2018.

[26]. **Stepanescu S., Rehtanz C., Arad S., Fotau I., Marcu M., Popescu F.** *Implementation of small water power plants regarding future virtual power plants* 10th International Conference on Environment and Electrical Engineering, pp. 1-4, IEEE, 2011.

[27]. www.entsoe.eu

[28]. www.transelectrica.ro