European Network of
Transmission System Operators
for Electricity

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Explanatory Note for Methodology to Identify Regional Electricity Crisis Scenarios in accordance with Article 5 of the REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC

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Purpose and Structure of the Explanatory Note

This document is an explanatory note to accompany the methodology to be used for identifying electricity crisis scenarios at a regional level (hereafter the methodology) in accordance with Article 5 of Regulation of the European Parliament and of the Council on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC, (hereafter RP Regulation or RPR) developed by the European Network For Transmission System Operators for Electricity (hereafter referred to as 'ENTSO-E'), establishing appropriate tools to prevent, prepare for and manage electricity crisis situations.

This explanatory note provides a more detailed explanation of the methodology and is designed to be read alongside the methodology by stakeholders involved in the implementation, including TSOs', RCCs',Member States' competent authorities, regulatory authorities and the ECG.

This document:

- introduces key concepts of the methodology,
- describes the purpose of the methodology,
- suggests the link between the methodology and how and why risk preparedness plans relate to other existing and future regulations and procedures related to managing electricity crises,
- provides an overview of the methodology and timeline,
- explains the step by step process defined by the methodology,
- discusses probabilistic vs. deterministic assessment of likelihood and impact, and
- discusses the process for development of scenario-specific likelihood and impact evaluation methods.

Key concepts

1. What is an electricity crisis?

As stated in the RP Regulation, 'electricity crisis' means a present or imminent situation in which there is a **significant** electricity shortage, as **determined by the Member States** and described in their risk-preparedness plans, or in which it is impossible to supply electricity to customers. In plain words, an electricity crisis is expected to have the following characteristics:

- it will be caused by a rare event, or combination of events (e.g. extreme weather combined with some specific outages),
- it will seriously disrupt electric power supply (i.e. will affect either a large proportion of the energy users, or last for a significant time, or both),
- as electricity supply is required for so many other networks and activities, it can result in further disruption of economy, markets, essential services and even endanger lives or the environment,
- it will have a lasting negative consequence for the Member State.

2. What is a regional electricity crisis scenario?

RPR distinguishes two types of electricity crises: national and regional. A national crisis affects at most one Member State, while a regional one may affect two or more Member States at the same time.

Note, that a particular regional electricity crisis may simultaneously affect Member States, that do not have a common border (with a direct cross-border power system connection) and do not belong to the same region, as defined in RP Regulation («'region' means a group of Member States whose transmission system operators share the same regional coordination centre as referred to in Article 36 of Regulation (EU) 2019/943»). To illustrate this, think of hypothetical scenarios such, as:

- a cyberattack affects power systems of some Member States using a common vulnerability of some critical software that those Member States' TSOs use, but regardless of their regional coordination centres or common borders,

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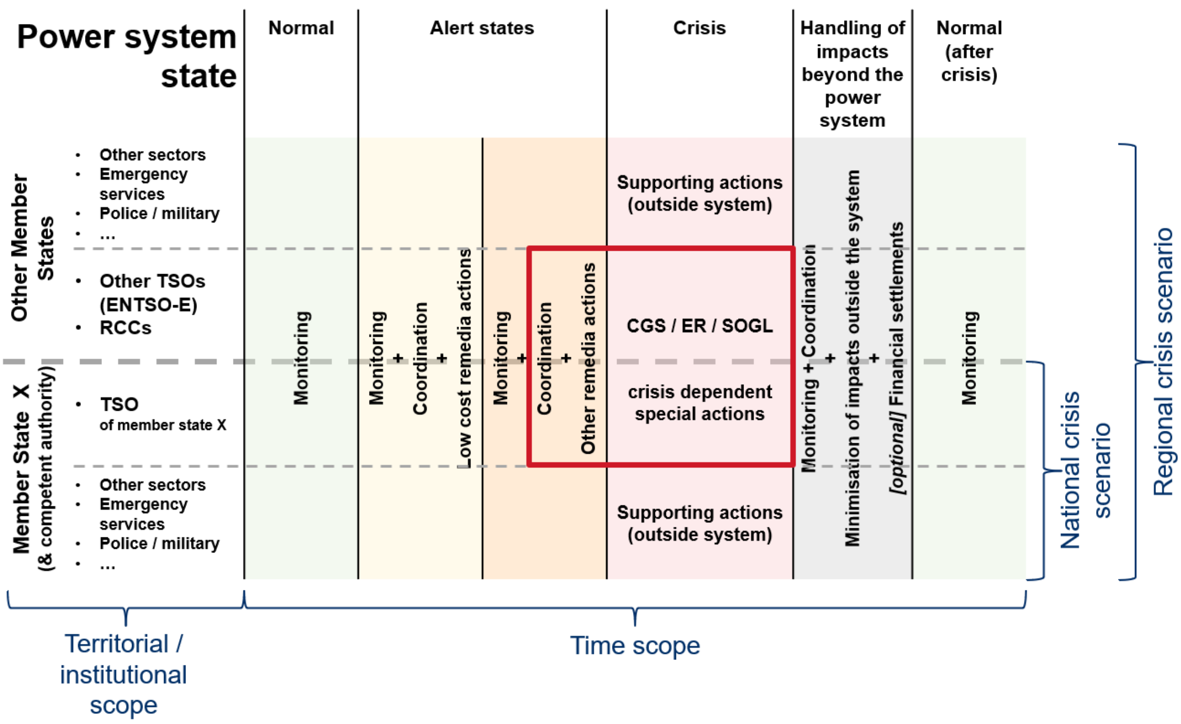
- a prolonged disruption in natural gas supply affects all Member States, in which power generation is significantly dependent on this fuel.

Purpose of the methodology

The Risk Preparedness Regulation sets a new framework to enhance the resilience of the European electricity system against unexpected events and to improve cross-border cooperation. Existing practices on security of electricity supply across Europe tend to be national in focus. The aim of Risk Preparedness Regulation is to ensure that all Member States put in place appropriate tools to identify, prevent, prepare for and manage electricity crises in cooperation with each other in a regional context through establishing a common approach amongst Member States to identify and assess risk, share information and provide transparency.
As a result of the RP Regulation, each Member State will have national risk preparedness plans for crisis scenarios identified by itself (under article 7 or RPR) and by ENTSO-E (under article 6 of RPR), with regional, bilateral and national measures. The purpose of the methodology is therefore to identify the most relevant regional electricity crisis scenarios and thereby enable the affected Member States to establish their risk preparedness plans and agree upon regional and bilateral measures "that are planned or taken to prevent, prepare for and mitigate electricity crises".

Link with the methodology and risk preparedness plans

A precise explanation of the risk preparedness plan is laid out in Chapter III of the RP Regulation. The diagram below illustrates (in a simplified way) what might be considered as the scope of the risk preparedness plans. The diagram also helps to demonstrate what the relationship might be between the risk preparedness plans and both existing and future regulations relevant to the electricity markets.



CGS is a Critical Grid Situation which is a potential emergency state, c.f. SO GL article 18(3), identified in the operational planning phase.

The establishment of Risk Preparedness Plans is the responsibility of the Member States' competent authority (RP Regulation Article 10.1). These Plans might include:

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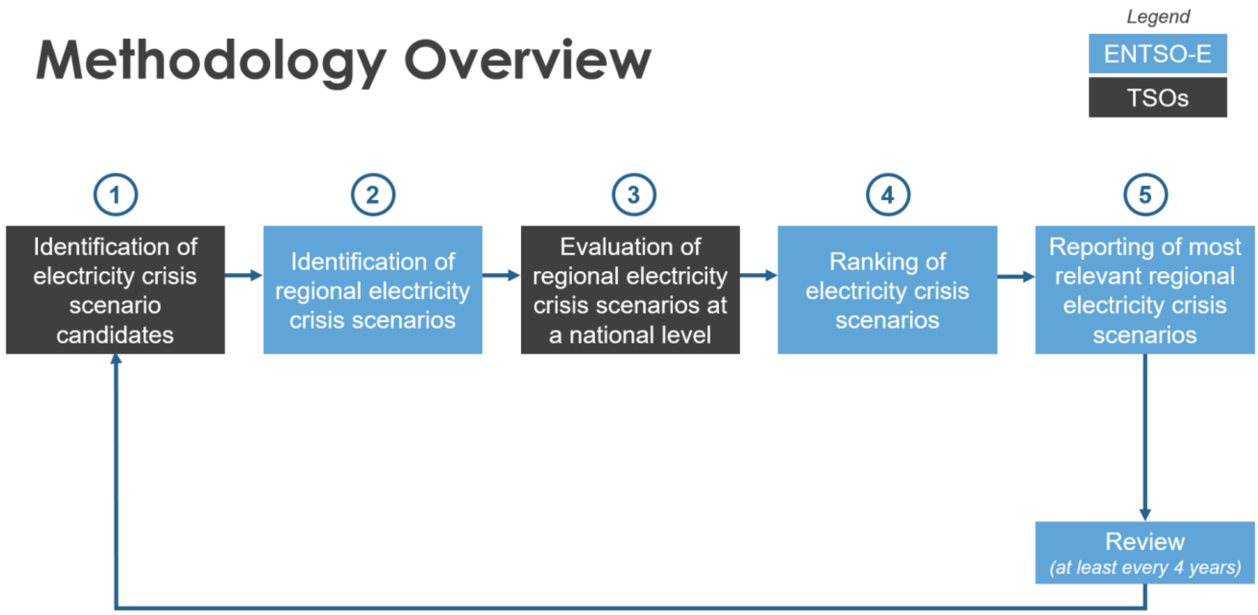
- A role for national organisations from outside the energy sector in handling aspects of the crisis. These may be e.g. emergency services, cybersecurity authorities, police, operators of other critical infrastructure, which provides essential services, the military.
- Prescribed stakeholder actions. Some of the actions may be just an application of other existing regulations and procedures (e.g. NC ER or SO GL), while some others may be specific to just a particular scenario.
- A key role for enabling efficient coordination across all stakeholders.
- Not every plan will cover the full scope but will be tailored separately for each crisis scenario.
- A communications plan/procedure

Methodology overview

The methodology is a step by step process which starts with a bottom up approach, in which TSOs initiate the process by proposing candidate regional electricity crisis scenarios, based on their expertise. The candidates are filtered by ENTSO-E, supplemented with possible missing scenarios, then passed back to TSOs for impact & likelihood evaluation. Those evaluations are then used to establish which electricity crisis scenarios are most relevant.

The diagram below presents a step by step overview of the methodology.



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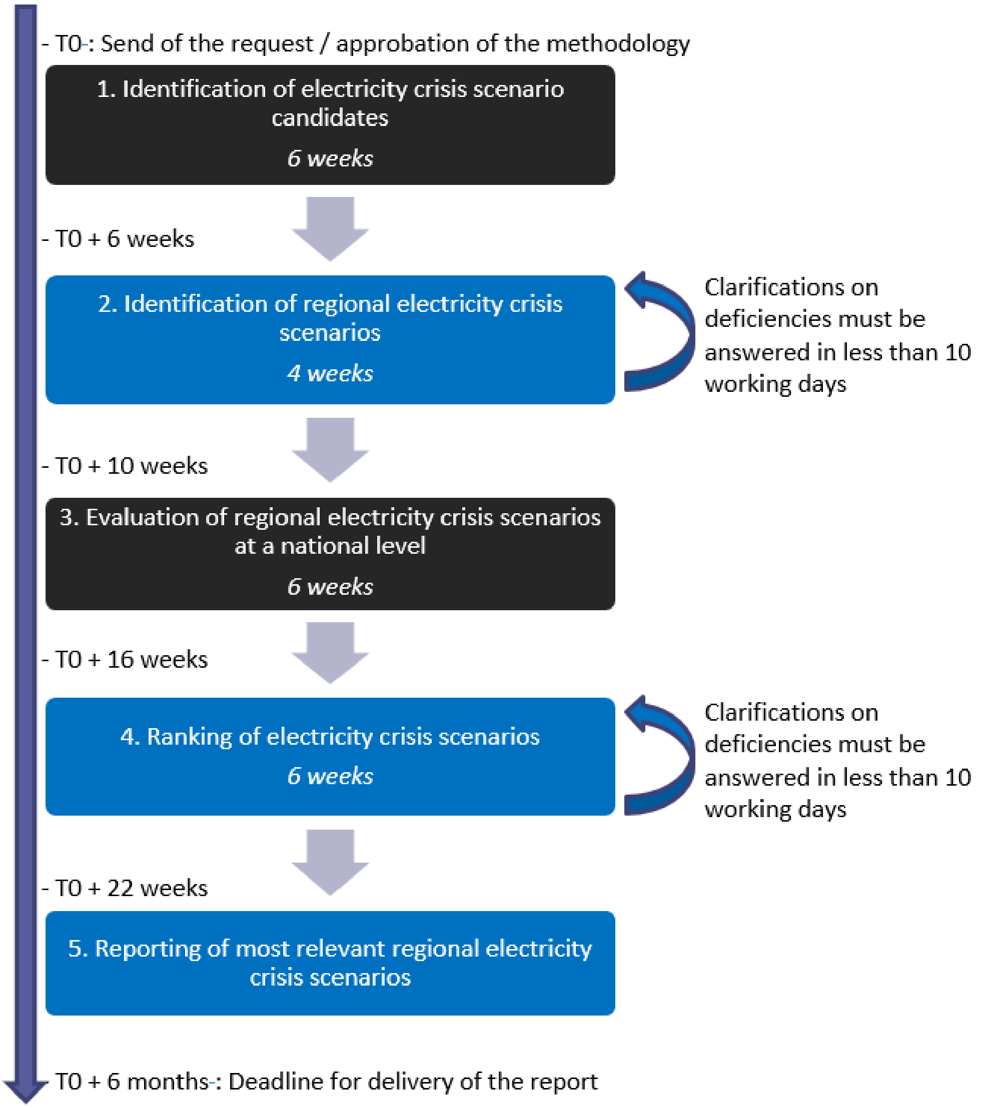
Methodology timeline



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Step 1 (Reference to Article 10 of the Methodology)
Identification of electricity crisis scenario candidates for a regional scenario

The bottom-up approach adopted in the first step of the methodology is motivated by the need to allow each TSO to express their concerns about any electricity crisis scenarios, which may affect them, and which have some form of cross-border dependencies. Each TSO has the most comprehensive understanding of its power system (and hazards which may affect it) but is not necessarily fully aware of the operation of the neighbouring power systems, and even less of an understanding of the systems which are further away. Thus, the most accurate local knowledge and understanding is gathered at the start of the process.

Scenarios should be sufficiently specific, so that every TSO for which the scenario is considered relevant, is capable of evaluating impact of materialization of that scenario.

The TSOs are required to:

- Identify crisis scenarios that are candidates to form a part of a regional crisis scenario, in close cooperation with the national competent authority.
- For each of these electricity crisis scenario candidates:
  - Provide a description;
  - Identify the cross-border dependencies;
  - Provide a contact information if more information is required on the scenario in the following weeks.
- Submit the scenarios to ENTSO-E. TSOs that share a Member State shall coordinate and submit a common list of electricity crisis scenario candidates.

When considering the events that could initiate an electricity crisis scenario the TSO should review the list of initiating events contained in Appendix II of the methodology. The list of hazards is adapted from *Commission Staff Working Document: Overview of Natural and Man-made Disaster Risks the European Union may face*, Brussels, 23.5.2017, SWD(2017) 176 final.

For the purposes of identifying these electricity crisis scenario candidates the TSO shall take into account:

- historical electricity crises that may occur again (both experienced nationally and by other TSOs);
- available operational expertise and experience on credible future crisis scenarios, including available documents such as Member State National Risk Analysis Reports or TSOs Risk Analysis Reports, and the competent authority expertise.

TSOs are expected to favour quality over quantity by pre-selecting the scenarios that they expect to be the most relevant. In particular, the most relevant electricity crisis scenario candidates are those where:

(a) The event has a regional impact, either because:

i. It is cross-border in nature (e.g. a large-scale weather event, unavailability of cross-border energy markets);

ii. It is national by nature, but the resulting electricity crisis has cross-border impacts;

iii. Two or more simultaneous initiating events, mutually aggravating, lead to a cross-border crisis in two or more Member States;

(b) It is possible to formulate a Risk Preparedness Plan for the scenario (the impacts can be prevented, prepared for or mitigated);

(c) An effective risk preparedness plan for a given crisis scenario is likely to require multi-party cross-border coordination.

ENTSO-E expects to receive up to 10 scenarios per Member State, from different initiating events.

As an example, for one Member State, the electricity crisis scenario candidates could be:

- 3 different scenarios involving rare and extreme natural hazards likely to occur in this Member State (ex.: heat wave, cold spell and extreme storm)
- 1 scenario involving an accidental hazard (ex.: simultaneous failing of a number of grid elements)
- 1 scenario involving malicious attacks (ex.: cyberattack)
- 1 scenario involving fuel shortage most relevant to this TSO (ex.: disruption of gas supply).

On the contrary, examples of unsuitable electricity crisis scenario candidates would be:

- Identical scenarios for one Member State (ex. 3 or more scenarios involving heat waves for one Member State, varying parameters such as duration or intensity of the natural hazard);
- Scenarios of national significance but no regional impact and/or no impact on energy supply (ex. media crisis targeting the shareholder of one TSO);
- Scenarios so extreme that it is impossible to formulate Risk Preparedness Plans (ex.: death of the sun, giant meteorite impact in Europe).

The crisis scenario description template contained in Appendix III.1 of the methodology will be completed by the TSO for each electricity crisis scenario candidate, in close cooperation with the national competent authority, such that it fulfils the requirements outlined in Article 5 of the methodology. In case there’s more than one TSO in a Member State, the TSOs in question should coordinate their scenario candidates, to avoid duplication and overlap, while keeping all candidates that do have potential for a regional impact.

As these electricity crisis scenario candidates will form a basis for the identification of regional crisis scenarios, relevant cross-border dependencies or impacts on other Member States have to be described (see Articles 3, 9 and 10 of the methodology).

The description has to be as precise and consistent as possible, as any given scenario must clearly and in sufficient detail describe the initial condition(s) of the system, a sequence (chain) of events following the initiating event, and the most likely consequences.

The scenario description shall – whenever available – contain quantitative data. A range of values is preferred to an exact number (when appropriate), and general characteristics of a geographic area is preferable to a city/district name as it will be easier to build regional scenarios. If available, technical (from TSO knowledge or past experiences), scientific or statistical findings should be included. When needed the scenario description shall be based on well-founded assumptions and expert assessments.

For example, a hypothetical “heat wave” scenario should list all important events and conditions that should coincide to possibly cause a crisis (i.e. not just temperature, but rise of demand, lower import capacity of overhead lines, lower output of thermal power plants, etc.), as well as quantitative ranges of severity of those events (e.g. daily peak temperature exceeding 30 degrees Celsius for at least 10 days, import capacity reduced by a certain amount of megawatts). With this level of detail, it will be possible to assess in the later steps of the process the similarity of scenario candidates from different Member States.

Step 2 (Article 11 of the methodology)
Identification of regional electricity crisis scenarios

Upon submission of the national crisis scenario candidates by the TSOs, ENTSO-E will have to process the received data (namely in terms of completeness and overall quality). In particular, ENTSO-E identifies missing scenarios which are considered to have a potential to become regional.

The best local knowledge of possible electricity crisis scenarios gathered from TSOs must now be analysed. The process of identification of regional electricity scenarios carried out by ENTSO-E shall involve:

1. Quality check on regional crisis scenario candidates (e.g. completeness etc.);
2. Aggregation of sufficiently similar electricity crisis scenario candidates;
3. Preparation of respective regional electricity crisis scenarios (based on previous steps 1 and 2);
4. Inclusion of possible missing regional scenarios, incl. as a result of consultation with RSC’s/RCC’s;

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5. Inclusion of scenarios related to fuel supply or connected infrastructure (not limited to natural gas transmission system).

As a result, the electricity crisis scenario candidates are collated and combined by ENTSO-E into regional scenarios. If any of the electricity crisis scenario candidate submissions received are considered deficient (see step 2 above), ENTSO-E shall ask the relevant TSOs to address the deficiency.

ENTSO-E shall consider infrastructure and fuel supply disruption scenarios, such as those related to the natural gas supply as developed by ENTSO-G, the threat of nuclear supply chain disruption identified in the ESA report on nuclear fuel supply, or other disruption scenarios identified by other agencies of the European Union such as ENISA that are considered relevant by DG Energy at the European Commission.

Those scenarios, and others that are judged relevant by ENTSO-E to be regionally relevant, will be added to the list of regional scenarios. ENTSO-E will complete the template in the Appendix III.2 of the methodology for each aggregated regional scenario. The electricity crisis scenario candidates that are deemed not to be regional will be retained for future reference but will not be developed by ENTSO-E and submitted to TSOs.

Step 3 (Article 12 of the Methodology)
Evaluation of regional electricity crisis scenarios at a national level

With a list of regional electricity crisis scenarios compiled by ENTSO-E in Step 2, it is time to refer to the TSOs for evaluation of each of the scenarios' likelihood and impact. According to the RP Regulation (Article 5), the end result of applying the methodology, is "identifying the most relevant regional electricity crisis scenarios". To objectively determine whether a cyberattack scenario is more or less relevant than a heat-wave scenario, or natural gas shortage scenario, a uniform method of measuring "relevance" must be used.

The evaluation method proposed is at the core of the methodology. It relies on:

- using likelihood, impact and cross-border dependency measures,
- defining fixed scales for all three measures, including purely quantitative scales for both likelihood and impact,
- requiring that all scenarios are evaluated for each Member State concerned, using those scales without any modification.

A severity rating of an electricity crisis scenario is established using the abovementioned scales.

At the time the methodology was created, there was no common regulatory framework that would allow to determine whether any given scenario would constitute an electricity crisis in any Member State (or ENTSO-E member TSO). The scale proposed was inspired by existing comparable efforts such, as "Incident Classification Scale"[1] of ENTSO-E and report "Overview of natural and man-made disaster risks the European Union may face"[2].

It is understood, that in any Member State, this rating may not conform to what the given Member State would rate as a crisis. Nevertheless, a common scale is necessary to ensure that electricity crisis scenarios may be compared in an objective manner.

1. Assessment of scenario rating per Member State

It is to be noted, that the regional crisis scenarios resulting from collating electricity crisis scenario candidates (Step 2) provided by the TSOs, are expected to differ from the original descriptions provided by the TSOs due to the regional collation and gap analysis process. Therefore, a complete assessment of each regional scenario must take place, even if the TSO already assessed the likelihood and impact of the scenarios it originally proposed.

[1] INCIDENT CLASSIFICATION SCALE – Final version for SOC approval, Incident Classification Scale Subgroup, 27 March 2018.

[2] Overview of natural and man-made disaster risks the European Union may face, Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO) (European Commission), 2017-12-18.

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Each TSO indicate, for their Member State, the likelihood and the impacts on the electricity system of each scenario identified consistent with the rating scales provided (Appendix I of the methodology), in terms of number of events per year, 'expected energy not-served percentage' (EENS%) and 'loss of load expectation' (or LOLE). The cross-border dependencies are also to be estimated with the rating scales in Appendix I.4 of the methodology.

It is also to be noted, that some of the regional electricity scenarios will not be relevant to at least some TSOs. Nevertheless, those TSOs are expected to explicitly rate them as "insignificant" to demonstrate that they have been considered.

2. Evaluation of likelihood

Historical frequency of occurrence of an initiating event may not be an acceptable estimator for the future likelihood of the same type of initiating event. In such situation's expert judgement, simulations or other forward-looking techniques should be used instead. If available, scientific or statistical findings should be taken into consideration. When needed the scenario description shall be based on well-founded assumptions and expert assessments.

A scenario may depend on a number of events and conditions that are not independent. The types of combinations can only be known after the regional crisis scenarios are identified according to provisions of Articles 7 to 13 of the methodology. The likelihood estimation will thus have to take into account both probabilities of each of the events and conditions, and their interrelationships (such as correlation or causality).

3. Evaluation of impact

Only direct impacts shall be assessed. Indirect impacts should not be considered, such as those that are delayed, or depend on additional factors outside of the scope of the scenario.

Derivation of the classification of impact has to be documented, so that retracing is possible when the analysis is updated or verified.

The impact is measured using two measures of failure to supply electricity:

- 'expected energy not-served' (EENS) in a given zone (Member State) and in a given time period (duration of load curtailment due to the electricity crisis scenario), energy which is expected not to be supplied due to insufficient resources to supply demand;
- 'expected energy not-served percentage' (or EENS%) is calculated by dividing expected energy not served by the estimated total annual energy consumption of a Member State;
- 'loss of load expectation' (or LOLE) represents expected number of hours in which in a given zone (Member State) resources are insufficient to supply the demand due to the electricity crisis scenario.

It is worth noting, that those definitions are similar, but not identical to definitions used in scope of the Short Term Adequacy (STA) methodology, which is defined according to RP Regulation Article 8. The differences in the definitions follow the differences in purpose of use:

- In scope of the STA methodology, EENS is expressed in units of power (megawatts), and not relative to Member State energy consumption. For assessing relevance of a regional electricity crisis scenario, it is desirable to factor out the level of power consumption of the Member States affected, to avoid a situation, in which crises would only be deemed regionally relevant, if they impact the Member States with highest energy use.
- In scope of the STA methodology, LOLE is calculated relative to a fixed time period. But when assessing the electricity crisis scenarios, it is meant to measure the duration of the electricity crisis itself.

Note that:

- LOLE expresses crisis duration – but could amplify a prolonged problem of a very low magnitude,
- EENS% will „catch" even a short-lived crisis impacting sufficiently large energy consumption volume.

4. Assessment of cross-border dependencies

The TSOs shall provide a cross-border dependency rating in accordance with the table shown in Appendix I.4 of the methodology and according to Article 9 of the methodology. At this point only a qualitative method of assessment of strength of cross-border dependencies is proposed.

Step 4 (Article 14 of the Methodology)
Ranking of electricity crisis scenarios

ENTSO-E shall first collect the evaluations of national impact to the regional electricity crisis scenarios completed by the TSOs. ENTSO-E shall check the evaluations for completeness and consistency with the impacted power systems and may delegate this task to the RCC(s). If needed, ENTSO-E (RCC) may ask TSOs for further clarification.

The scales for transforming the national impact rating and national rating of the strength of the cross-border dependencies into numeric values are given in Appendix I of the methodology, "I.5 Example of regional scenario rating" and "I.4 Cross-border dependency rating", respectively.

For an example of such calculation see Appendix I, "I.5 Example of regional scenario rating" of the methodology. The table shown in Appendix I.5 of the methodology demonstrates how the regional impact of each scenario is assessed using the following method:

- for each scenario, the national crisis scenario rating and cross-border dependency rating is collected.
- a rating of a scenario is calculated as a sum over all Member States of "overall impact ratings" weighted by the "overall ratings of the strength of the cross-border dependencies".

$$National\ Rating = Crisis\ Scenario\ Rating \times Cross\ Border\ Dependency\ Rating$$

The number (and thus crisis scenario rank) produced as a result, has no physical or e.g. monetary meaning. Its only meaning and role is to enable to select the scenarios of highest relevance to ENTSO-E members and their respective Member States for development of risk preparedness plans.

The regional rating for each crisis scenarios is then used to demonstrate the relevance of the crisis for the Member States impacted, the highest rating being the most relevant.

The scenario ranking will allow identification of electricity crisis scenarios that are most relevant at a European scale or for any group of Member States.

Step 5 (Article 15 of the Methodology)
Reporting of most relevant regional electricity crisis scenarios

The report produced by ENTSO-E will contain the output of the scenario rating from Step 4 which indicates the relevance of each regional electricity crisis scenario. The report will also contain information collated during the methodology process according to the list in Article 15 of the methodology.

Probabilistic vs. deterministic assessment of likelihood and impact

The two broad categories of methods for calculating measures of likelihood and impact, may be referred to as deterministic and probabilistic. Deterministic methods are based on the analysis of one or just a few system configurations selected as most representative of situations that can stress the system. Consider for instance, load flow analyses, where it is assumed that certain major lines or generators may become unexpectedly unavailable in addition to planned outages within a region. These methods allow the estimation of the impact of a specific situation on reliability, but they cannot estimate the overall system reliability. The specific situation has to be described in accordance with Appendix III.1 and III.2 of the methodology.

Probabilistic methods aim to estimate the likelihood and/or impact considering that the input variables are stochastic. Such methods perform a relevant calculation of a high number of configurations, with an associated probability of occurrence derived from the underlying variables of a complex model.

A probabilistic method is usually more suitable for representing all of the aspects of an electricity system. In fact, a probabilistic simulation can represent the overall power system by applying random number techniques to generate a wide range of possible states of that system. In that case the impact measure will be a probabilistic (EENS = Expected Energy Not Supplied), that is mathematically described by:

$$EENS = \frac{1}{N}\sum_{j \in S} ENS_j \quad \text{[MWh/year] or [GWh/year]}$$

where ENS_j is the energy not supplied of the system state j ($j \epsilon S$) associated with e.g. a loss of load event of the jth-simulation and where N is the number of simulations considered (assuming that the probabilities of all system states equal).

Process for development of scenario-specific likelihood and impact evaluation methods

The most appropriate way to ensure that the results of the evaluation of likelihood and impact, performed by the different TSOs, are comparable and consistent, is to use a common approach. The approach to evaluate the electricity crisis scenarios depends on the relevant type of hazards investigated (the evaluation methods are not the same for natural hazards, intentional attacks etc).

Consider the case of two hypothetical crisis scenarios, one resulting from a cyberattack, and the other from a prolonged cold spell. In the first scenario, producing a meaningful method for evaluating likelihood of this crisis' occurrence may be difficult. Also, past statistical data of cyberattacks leading to electricity crises is not sufficient. If a method were to be developed, it would require extremely sensitive TSO information such as the vulnerabilities of TSO's key IT systems, as well as cybersecurity risk controls used by that TSO. It would also be completely unrelated to the methodology required for assessing the likelihood and impacts of the cold spell scenario, where both weather and climate data is widely available, with tens of years of very detailed past records.

This illustrates, that:

- a common method suitable for every possible electricity crisis scenario may not exist, however scenario-specific methods may be defined more easily,
- scenario-specific methods could require substantial time and effort to define, and then build necessary computational tools and processes, for all TSOs to use,
- scenario-specific methods are likely to be more precise, and reflect closely the uncertainty of the scenario,
- the tools and the processes of using them would have to be tailored to match sensitivity of input information.

A solution to this challenge is provided in the methodology. During the first round of assessing which electricity crisis scenarios are the most relevant, there is no requirement to use a common methodology. In fact, it is expected TSOs make use of the best available techniques at their disposal. Once the most relevant crisis scenarios are known, ENTSO-E may propose the use of a scenario-specific (and possibly probabilistic) method for evaluating the likelihood and impact measures, relevant to the particular scenario and the nature of its uncertainty. Such methods shall be consulted with TSOs potentially affected by a particular electricity crisis, designed and implemented, then approved by ACER to be used in future updates of the assessment of the most relevant electricity crises. The process for creation of such common methods is provided in Article 8 of the methodology.

For the development of such a method to be useful, the scenario must be expected to remain among the most relevant regional scenarios in the next iteration of the methodology.

Until scenario specific detailed methods are established, the common methods for obtaining comparable results from TSO's evaluations are the common scales for likelihood and impact. The TSO shall assess likelihood and impact using the common scales provided in the tables shown in Appendices I.1 and I.2 of the methodology. As long as the values defined in the classification tables are not modified by TSOs, the assessment results should be comparable between Member States. Scenario-specific methods – when established – would then be able to increase accuracy of the evaluation.

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