All TSOs Biennial Progress Report on

Operational Probabilistic Coordinated Security Assessment and Risk Management

December 2021

entsoe

ENTSO-E Mission Statement

Who we are

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the **association for the cooperation of the European transmission system operators (TSOs)**. The 42 member TSOs, representing 35 countries, are responsible for the **secure and coordinated operation** of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

ENTSO-E **brings together the unique expertise of TSOs for the benefit of European citizens** by keeping the lights on, enabling the energy transition, and promoting the completion and optimal functioning of the internal electricity market, including via the fulfilment of the mandates given to ENTSO-E based on EU legislation.

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the **security of the interconnected power system in all time frames at pan-European level** and the **optimal functioning and development of the European interconnected electricity markets**, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

ENTSO-E plays a central role in enabling Europe to become the first **climate-neutral continent by 2050** by creating a system that is secure, sustainable and affordable, and that integrates the expected amount of renewable energy, thereby offering an essential contribution to the European Green Deal. This endeavour requires **sector integration** and close cooperation among all actors.

Europe is moving towards a sustainable, digitalised, integrated and electrified energy system with a combination of centralised and distributed resources.

ENTSO-E acts to ensure that this energy system **keeps consumers at its centre** and is operated and developed with **climate objectives** and **social welfare** in mind.

ENTSO-E is committed to use its unique expertise and system-wide view – supported by a responsibility to maintain the system's security – to deliver a comprehensive roadmap of how a climate-neutral Europe looks.

Our values

ENTSO-E acts in **solidarity** as a community of TSOs united by a shared **responsibility.**

As the professional association of independent and neutral regulated entities acting under a clear legal mandate, ENTSO-E serves the interests of society by **optimising social welfare** in its dimensions of safety, economy, environment, and performance.

ENTSO-E is committed to working with the highest technical rigour as well as developing sustainable and **innovative responses to prepare for the future** and overcoming the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with **transparency** and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders.

Our contributions

ENTSO-E supports the cooperation among its members at European and regional levels. Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.

To carry out its **legally mandated tasks**, ENTSO-E's key responsibilities include the following:

- Development and implementation of standards, network codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy;
- Assessment of the adequacy of the system in different timeframes;
- Coordination of the planning and development of infrastructures at the European level (Ten-Year Network Development Plans, TYNDPs);
- Coordination of research, development and innovation activities of TSOs;
- Development of platforms to enable the transparent sharing of data with market participants.

ENTSO-E supports its members in the **implementation and monitoring** of the agreed common rules.

ENTSO-E is the common voice of European TSOs and provides expert contributions and a constructive view to energy debates to support policymakers in making informed decisions.

Table of Contents

Executive Summary 4

Progress 4

Challenges 5

Next Steps 5

1 Introduction 6

1.1 PRA benefits 6

1.2 Relevant research 7

1.3 2021 Biennial PRA Report outline 7

2 Obligation and legal mandate 8

CSAM Article 44 8

3 Historical and current governance 9

3.1 1st Project team – Data Collection for Probabilistic Risk Assessment (DCfPRA) 9

3.2 2nd Project team – Implementation of data collection for Probabilistic Risk Assessment (IDCfPRA) 9

3.3 Working Group Probabilistic Risk Assessment (WG PRA) 10

4 Progress on Operational Probabilistic Coordinated Security Assessment and Risk Management 11

4.1 Progress achieved compared to 2019 levels 11

4.2 Progress achieved via existing ENTSO-E supported projects 12

4.3 Challenges: what are the consequences for TSOs and RSCs? 15

5 Future roadmap 16

5.1 Planning complexity 16

Conclusion 17

Abbreviations 18

References 18

Executive Summary

Consistent with the legal mandate[1], the 2021 Biennial operational probabilistic coordinated security assessment and risk management Progress Report (hereafter the *2021 Biennial PRA Report*) provides a view on all TSOs' progress towards an operational probabilistic coordinated security assessment and risk management (hereafter PRA). The 2021 PRA Report is the first public report in response to this requirement.[2] It details all TSOs' out-look of the expected challenges and the next steps towards the development of a PRA methodology (PRAM) by the end of 2027. This is pursuant to the methodology for coordinating operational security analysis (hereafter CSAM), specifically Article 44 (1) and 44 (2).

Following ACER's decision to establish the CSAM in June 2019, TSOs have set-up sequential governance structures, within ENTSO-E's steering group operational framework and under the guidance of the System Operations Committee, to prepare and plan for the move towards PRA.

A robust probabilistic approach to security assessment requires a large set of high-quality data to accurately predict risks and contingencies, and subsequently consequences, in the power system. Therefore, the key objective to-date has been ensuring efficient and secure data collection processes accompanied by continuous quality management. ENTSO-E project teams have focused on surveying existing data collection practices within the TSO community, identifying the required data and setting out a prioritisation timeline for the different data sets. It has also become clear that establishing consistency across the TSO community is a prerequisite for sustainable progress.

Progress

Over the period from June 2019 to June 2021, TSOs supported by ENTSO-E have made the following key progress:

1. **A 1st version of the PRAM has been developed. This sets out the highest priority data requirement for all TSOs, namely the faults, disturbance and outages statistics, which require a long representative history.**

2. **Common grounds for registering and collecting the required data was identified as a must for implementing PRA, so the grid disturbance definitions document for the power system above 100 kV has been updated.[3] In addition, a consistent data template for registering information has been developed. Based on all TSO surveys, 75% of the twenty-nine TSOs who participated have indicated they are partially ready or fully ready to produce the data consistent with the template.**

3. **A preliminary set of real-time and historical data that affect the power system's operating conditions has been identified (hereafter referred to as exogenous data). Exogenous data details factors that are outside the system operator's control (e.g. weather). It is foreseen that a long representative history of exogenous data, in addition to incidents, outages and faults, will contribute to the implementation of PRAM.**

1 Methodology for coordinating operational security analysis, Article 44(1) and 44(2).

2 Similar reports are expected on a biennial basis until the PRAM is developed. This is consistent with the obligation set out in the CSAM.

3 The document is based on the 2017 version of the Guidelines for the Classification of Grid Disturbances above 100 kV. More information here.

Challenges

Changes in TSOs' operational processes, particularly at a pan-European level, are accompanied by challenges and hurdles, particularly given TSOs' individual data collection processes and individual IT infrastructure, which result in different starting points. The key challenges identified in this report, via an all-TSO survey, include the challenges associated with:

- **changes to current TSOs' internal, regional and pan-European processes requiring a move from a well-proven and comprehensible deterministic approach to a more complex probabilistic one;**
- **the need for additional investment (labour and IT) that is required to address a move towards PRA;**
- **managing an increased volume of data while simultaneously ensuring the data is secure and is of high quality; and**
- **ensuring the development of a methodology, consistent with the legal mandate; one that strikes a balance between complexity, practicality, network security and socio-economic benefits.**

Next Steps

Having identified the above challenges, the next steps include continuous TSOs' engagement, via ENTSO-E governance, to prepare and develop the methodology for PRA, while mapping out the processes that may be impacted and the degree of impact. In addition, to ensure data collection and quality management, an ENTSO-E IT infrastructure is expected to be developed to monitor and address data collection inconsistencies across TSOs.

This will occur simultaneously while considering the additional data and/or frameworks that will be required for PRA (such as additional operational data).

The Working Group PRA (WG PRA) is setting up the groundwork and investigating options and strategies for the PRAM development, which will be subject to regulatory authorities' approval.[4] The focus will be on identifying and engaging with historical and current research on the topic. As such, the WG PRA would like to extend an invitation to relevant parties (i.e. research institutes or other bodies) to get in touch if they wish to discuss their PRA-related research.

- **To reach the WG PRA, please email us at PRA@entsoe.eu**

4 CSAM Article 44(4) and System Operation Guideline Article 7

1 Introduction

Historically and currently in Europe, power system operational security management has relied on the 'N-1' criterion[5] as the criteria governing security assessment. This means that the power system is always able to withstand an unexpected failure or outage of a system component while accommodating the new operational situation and without violating existing security limits.

PRA is a complementary operational security management approach which allows individual TSOs to consider the probability, and subsequently the consequence, of the failure of the power system to establish its security limits. This is an expansion to existing methods ('N-1' criterion), which assume that all disturbances and failures are of equal probability. The establishment of the PRA approach entails quantifying the expected performance of the system while considering the uncertainties in its operational conditions (for example, weather conditions and generation) over a specified period.

1.1 PRA benefits

To assess all TSOs' perspectives on a move towards a probabilistic coordinated security assessment, consistent with the legal obligation discussed below, WG PRA conducted a 2021 survey covering the expected benefits, challenges and hurdles associated with PRA at a pan-European level. Twenty-nine TSOs provided input to the survey. The 2021 survey identified TSOs' perspectives on the expected benefits of PRA, which can be summarised as follows:

- **A pan-European methodology to assist in decision making** – this may provide the ability to better anticipate the behaviour of the grid, whereby uncertainties (threats of weather, variations in generation, etc.) can be proactively managed. It may also allow TSOs to identify optimal maintenance and outage timing as well as choose the optimal remedial action. This may result in an optimisation of socio-economic benefits and a reduction in operation expenditures.
- **Data-driven framework** – PRA is expected to be a data-driven and innovative way of working, which would facilitate better operational decisions. It may allow for greater flexibility in operating the system rather than the traditional 'N-1' criterion.
- **Mitigating detrimental consequences** – PRA may facilitate the optimisation of socio-economic outcomes, an increase in safety, a higher but considered utilisation of the grid and a more precise awareness of operational security.
- **Improved network asset management and planning** – This assists TSOs in determining the most suitable and efficient asset configurations in advance by evaluating the risk of potential contingencies for the configurations. It may allow TSOs to cautiously optimise the utilisation and extend the lifetime of their assets.

5 Throughout this report, the 'N-1' criterion is considered pursuant to System Operation Guideline definition; that is, 'N-1' refers to the N-state minus 1 contingency. Each contingency can consist of one element (ordinary contingency) or several elements (exceptional contingency).

1.2 Relevant research

PRA has been a trending topic at the R&D stage for decades. The 1st International Conference on Probabilistic Methods Applied to Power Systems was hosted in 1986.[6] However, despite years of research on the topic, PRA mostly remains at the R&D stage.

The Generally Accepted Reliability Principle with uncertainty modelling and through probabilistic risk assessment (GARPUR)[7] project is an inter-TSO project which has been able to identify and focus entirely on developing a PRAM to be applied to the processes of system development, asset management and system operation. [1] It was a collaborative project of 7 TSOs and 12 R&D providers, funded by the European Commission, which ran from autumn 2013 to October 2017. Not only did the project result in a new methodology for risk assessment and economic impact, but it also suggested a roadmap towards a progressive implementation of probabilistic reliability management approaches. As stated in the final report and brochure from the GARPUR project, the accuracy of the probabilistic reliability management approach is dependent upon the availability and quality of data. As a first step, TSOs have to collect relevant reliability data, i.e. failure data, outage and restoration durations and interruption cost data. Based on the data, improved models will be developed and gradually these actions will provide TSOs with more precise results from the use of the probabilistic reliability management approach and support an iterative improvement of models.

As there may be other relevant research relating to PRA implementation, ENTSO-E's WG PRA would like to invite relevant parties to get in touch if they wish to discuss their research. If you would like to get in touch, please email us at PRA@entsoe.eu.

1.3 2021 Biennial PRA Report outline

The 2021 Biennial PRA Report is divided into five chapters:

- **Chapter 1** introduces the report, briefly explains what PRA is and its expected benefits, and explores the relevant research in the field.
- **Chapter 2** outlines the legal ground for the implementation of PRA and the creation and publication of this Report.
- **Chapter 3** sets out the ENTSO-E governance structures and project teams that were established to achieve the legal obligations and the current roadmap of the instated workgroup responsible for managing the efforts towards the development of a PRAM by 2027.
- **Chapter 4** gives a comprehensive view of the PRA progress so far by highlighting outstanding developments, reviewing future potential hurdles and obstacles and assessing necessary steps and precautions for developing the methodology on common PRA by 2027.
- **Chapter 5** presents a roadmap for moving towards a PRAM by 2027.

6 More information on https://www.pmaps.world/

7 More information available here

2 Obligation and legal mandate

The overarching framework that governs the move towards PRA for security assessment is set out in the System Operation Guideline (SO Regulation also known as SOGL) [2]. SO Regulation Article 33 (2) requires TSOs to include in their contingency list an exceptional contingency when operational or weather conditions significantly increase its probability of occurrence. SO Regulation Article 75(1) mandates the creation of CSAM [3].

SO Regulation Article 75(1)(b) requires that the CSAM shall at least cover the principles for common risk assessment. The approved CSAM Article 44 is titled 'Towards probabilistic risk assessment', and the specifics of Article 44 are set out below.

CSAM Article 44

1. *All TSOs shall publish, with the support of ENTSO-E, a report on the progress achieved in Europe on the operational probabilistic coordinate security assessment and risk management. The first report shall be published in 2021 and afterwards on a biennial basis, by 31 December. ENTSO-E shall publish this report on its website.*

2. *When reporting on the progress achieved, all TSOs shall at least:*

   (a) *Provide information on the functioning of the operational processes and infrastructure required to collect and process the data referred to in paragraph 3; and*

   (b) *Elaborate on the achievements, potential hurdles and forward planning concerning the development of the methodology on common probabilistic risk assessment referred to in paragraph 4.*

3. *By nine months after the adoption of the CSAM, without prejudice to the applicable of Article 40(5) of the SO Regulation, all TSOs shall identify the data that needs to be collected in order to develop the operational probabilistic coordinated security assessment and risk management. They shall review it as necessary based on the findings of the reports established in accordance with paragraphs 1 and 2 and of the approval of the methodology on common probabilistic risk assessment in accordance with paragraph 4.*

4. *By 31 December 2027, all TSOs shall jointly develop the methodology on common probabilistic risk assessment taking full account of the requirements of Article 75(1)(b) and Article 75(5) of the SO Regulation, and shall propose it as an amendment of this methodology in accordance with Article 7(4) of the SO Regulation. After its approval in accordance with Article 7 of the SO Regulation, the methodology on common probabilistic risk assessment shall form an annex to this methodology.*

5. *All TSOs and RSCs with the support of ENTSO-E shall setup the operational processes and infrastructure required to collect and process the data referred in paragraph 2(b) by 21 months after the adoption of CSAM.*

3 Historical and current governance

This section sets out ENTSO-E's governance structures and the project teams that were established to achieve the legal obligations.

3.1 1st Project team – Data Collection for Probabilistic Risk Assessment (DCfPRA)

Following the approval of the System Operation Committee's (SOC) of the project initiation document for Data Collection for Probabilistic Risk Assessment on 16 July 2019, a project team was established under the supervision of the Steering Group Operational Framework (StG OF). The project team encompassed 6 TSOs[8] and set out to achieve the following objectives:

- Survey the current practices of European TSOs;
- Review the past and current R&D projects, focused on PRA, and organise a public workshop to gather inputs from TSOs experts and research institutes;.
- Identify the scope of data that should be collected first and propose a data structure for this collection to fulfil the CSAM obligation;
- Review the existing data collection initiatives and propose recommendations to update the guidelines currently applied for the ENTSO-E Disturbance and Fault Statistics (EDFS) reporting, to ensure consistent data collection practices for all TSOs; and
- Propose an implementation strategy highlighting the next steps.

The project team achieved its objectives and formally ended in June 2020. The project team highlighted that the observed status quo, whereby each TSO had individual definitions and unique data collection practices, is not acceptable as it may prevent TSOs from being able to apply and develop the PRAM by 2027. Therefore, the project team recommended that data collection must occur after the development of a set of guidelines that harmonise data collection across TSOs.

3.2 2nd Project team – Implementation of data collection for Probabilistic Risk Assessment (IDCfPRA)

Following the formal closure of the 1st project team and SOC's approval of a project initiation document for the 2nd project in June 2020, IDCfPRA was established under the supervision of StG OF. The project team encompassed 10 TSOs[9] and set out to achieve the following objectives:

- Establish a comprehensive classification scheme of threats, which represents all causes of outages that may be encountered by a European TSO, for the purpose of collecting data on disturbances and their causes in the European power grids;
- Identify and develop a document structure to amend the "Guidelines for Classification of Grid Disturbances above 100 kV". The amendments implied the creation of an updated document structure including methodologies and classification documents for the purpose of PRA, as well as other related groups such as Incident Classification Scale (ICS) and EDFS, in order to increase synergies and avoid double reporting; and
- Identify a list of potential exogenous data the collection of which would be of relevance for PRA.

The project team achieved all its objectives and formally ended in September 2021. The project team highlighted some recommendations for the next steps, which primarily centred around ensuring the integrity, security and quality of the data collected.

8 The 1st project team included members from the following TSOs: ČEPS, Landsnet, National Grid, REE, RTE and Terna.

9 The 2nd project team included members from the following TSOs: ČEPS, Energinet, Fingrid, Landsnet, NGESO, REE, RTE, Stattnet, TenneT and Terna.

3.3 Working Group Probabilistic Risk Assessment (WG PRA)

Although the two projects were successful at achieving their objectives, it became clearer that there was a need for a long-standing and consistent governance structure within ENTSO-E to fulfil the long-term mandate to ensure continuity and knowledge retention for such a complex topic. Therefore, SOC approved the establishment of a (semi) permanent structure until 2027, with the main objective of supporting TSOs to fulfil their PRA-related mandates. Following the approval of the Terms of Reference for WG PRA in April 2021, the working group was established. The working group includes members from 11 TSOs[10] as well as 2 Regional Security Coordinators (RSCs).

The objectives of the working group are to:

- Develop the PRAM and proactively provide expertise and support the TSOs on the implementation and interpretation of the methodology;
- Develop and set up, together with RSCs, the infrastructure required to collect and process the data for PRA;
- Manage the changes and necessary amendments on CSAM entailed by the PRAM and assess whether there is a need to amend the operational network codes and guidelines (i.e. SO Regulation);
- Deal with all other network code regulatory issues of relevance related to PRA, including the implications and impact on system operation from/to the connection codes and market codes;
- Proactively follow the development of new regulations and monitor developments in the field of PRA;
- Develop and publish (on ENTSO-E's website) a report on the progress achieved in Europe on PRA; and
- Manage and facilitate a constructive dialog between ENTSO-E, stakeholders and regulatory authorities.

As of December 2021, the WG PRA is divided into three workstreams, as shown in figure 3.1. The workstreams are expected to be revised and updated on an annual basis to accommodate for the continuous evolution of the work.

As indicated in Figure 3.1, Workstream 1 will be responsible for the biennial report, stakeholder engagement and proactive engagement with industry evolutions. Workstream 2 will be responsible for continuous ENTSO-E infrastructure development and improvement, to monitor data collection. Workstream 3 will be responsible for the methodology and definition development, which will include the development of the PRAM.

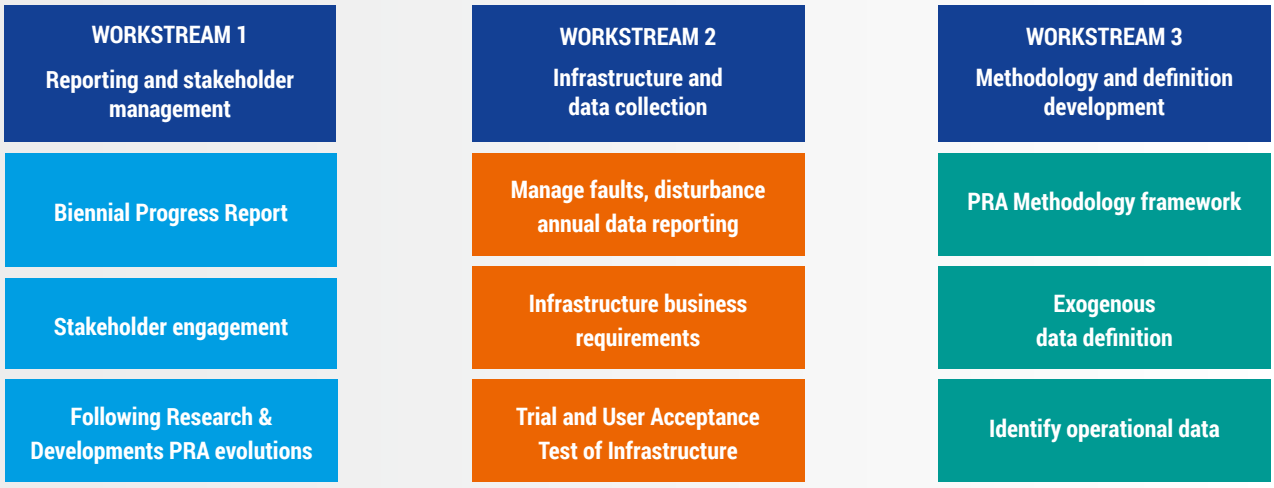

Figure 3.1: Overall roadmap into the future. WG PRA is divided into three workstreams with their own main focus areas.

10 As of September 2021, the WG PRA includes members from the following TSOs and RSCs: ČEPS, Elia, Energinet, HOPS, Landsnet, Nordic RSC, REE, REN, RTE, SEPS, Stattnet, TenneT, TSCNET.

4 Progress on Operational Probabilistic Coordinated Security Assessment and Risk Management

This chapter provides a more detailed view of the progress on PRA so far by highlighting the developments, reviewing future potential hurdles and obstacles, and assessing the necessary steps and precautions for developing the common PRAM by 2027. Furthermore, it provides a description of what the developments may mean for TSOs and RSCs in Section 4.3.

4.1 Progress achieved compared to 2019 levels

As previously mentioned, to assess all TSOs' preparedness towards PRA, WG PRA conducted a survey covering the expected benefits and challenges/hurdles in implementing PRA at a pan-European level (with a particular focus on data collection practices) as well as questions about the PRA's advancement so far and future prospects (2021 survey). The survey's questions were extended from a similar survey made in 2019 by the 1st Project team on the same topics (2019 survey).

A comparison between the 2019 and the 2021 surveys identified that several TSOs have progressed in different areas related to PRA, which can be summarised as follows:[11]

- Improvements can be found in TSOs' capacity to collect information about flows and voltage following the occurrence of a contingency. For example, there is a 44% increase in the number of TSOs that collected this information in 2021 compared to 2019 levels.
- Improvements can be seen in how many TSOs classify their contingencies (ordinary/exceptional/out of range); 12% of TSOs have progressed from "No but could do if needed" to "Yes".
- Two TSOs have progressed from not using the data to calculate particularised probabilities to some use of them. Although most TSOs are not yet able to use the data to calculate particularised probabilities, this evolution could mean a change of trend.

Given the importance of data integrity and quality and given that data collection practices require continuous and consistent improvement, WG PRA intends to run a similar survey for the next biennial report to measure the 2023 progress against the observed 2021 levels.

11 24 TSOs provided answers to the 2019 survey whereas 27 TSOs provided answers to the 2021 survey, of which 18 TSOs had provided answers to the 2019 survey.

4.2 Progress achieved via existing ENTSO-E supported projects

Since 2019, progress includes the development of the first version of the PRAM, the publication of a new document with definitions for grid disturbances in the power system above 100 kV, a set of exogenous data to be utilised to improve PRA outcomes, and the beginning of the collection of the data required for PRA and management of its quality.

4.2.1 PRA methodology – first version

The first version of the PRAM describes the minimum data required to assist in its development. The minimum data required relates to faults, outages and interruptions, in addition to a minimum set of characteristics (for example, start and end time, location, component type and energy not supplied when relevant for each fault, disturbance and outage). Future versions are likely to include additional data and/or methodology specification and development.

4.2.2 Common definitions for grid disturbances in the transmission grids

The updated ENTSO-E Grid Disturbance Definitions for the Power System above 100 kV [4] establishes common terminology and concepts for existing disturbance definitions to support the development of a PRAM. The document is based on existing standards and processes that most TSOs already use. The aim is that the content should be used by all TSOs in Europe.

It was identified that several of ENTSO-E's existing reports rely on their own concepts and definitions. Therefore, instead of creating another set of definitions and data to support the PRAM, the Project Team Implementation of Data Collection for Probabilistic Risk Assessment built on an existing grid disturbance definition document. This sets out a common set of principles for identifying incidents, disturbances and faults in the power grid and the common practices for registering and reporting this information. By doing so, ENTSO-E can reduce double registering and reporting of data, increase and level the quality of the data and make it easier to exchange and derive data for new use in the future.

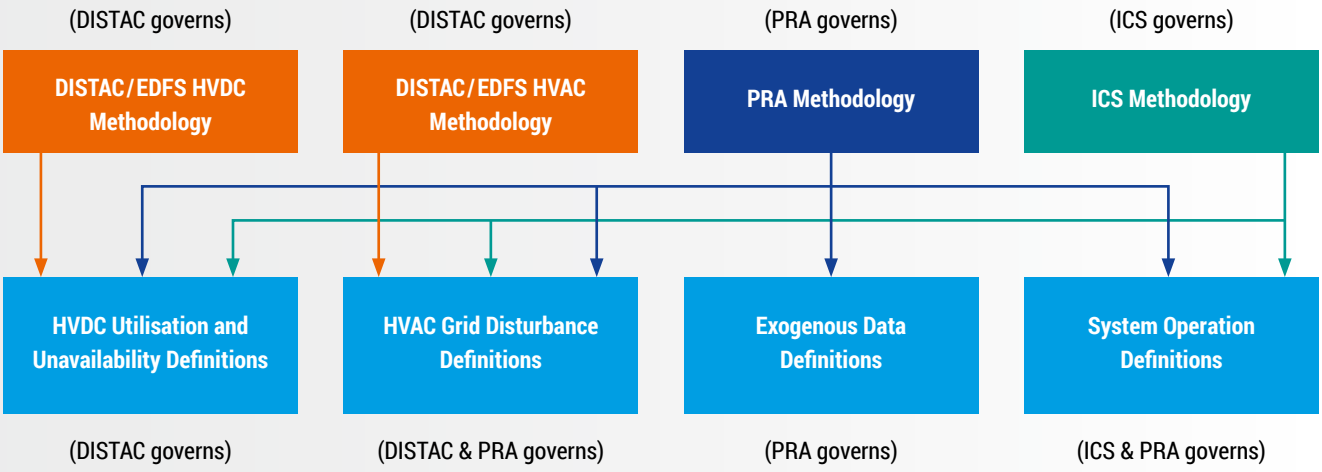

Figure 4.1: The proposed structure of methodologies and definitions in ENTSO-E. Definitions provide vocabulary and concepts related to the topic. Methodologies use these common definitions to describe workflows, processes and a subset of data used to produce the desired output, for example, documents and/or software solutions. Each document is governed by one or more groups.

4.2.3 Exogenous data used with Probabilistic Risk Assessment

To complement the grid disturbances data, a set of exogenous data (based on the threat scheme analysis) was determined. The main use of the exogenous data is to identify the effect of and/or the correlation between external influences (such as weather or external market conditions) on faults, outages and disturbances. A representative history of exogenous data, in addition to incidents, outages and faults, will contribute to producing a probabilistic risk methodology that is robust and consistent with historical experience to the largest degree.

The exogenous data set out a preliminary list of data requirements, which are expected to be refined/updated as the PRAM evolves and develops. As such, this document may be updated from time to time to reflect changes to the PRAM.

The survey conducted by WG PRA asked all TSOs what exogenous data they already collect, with the results presented in Figure 4.1. As is evident, many TSOs already collect a considerable amount of external data to support their activities. However, implementing a centralised platform for collecting exogenous data would greatly increase the data at each TSOs' disposal while also decreasing the amount each TSO invests to maintain their data connections.

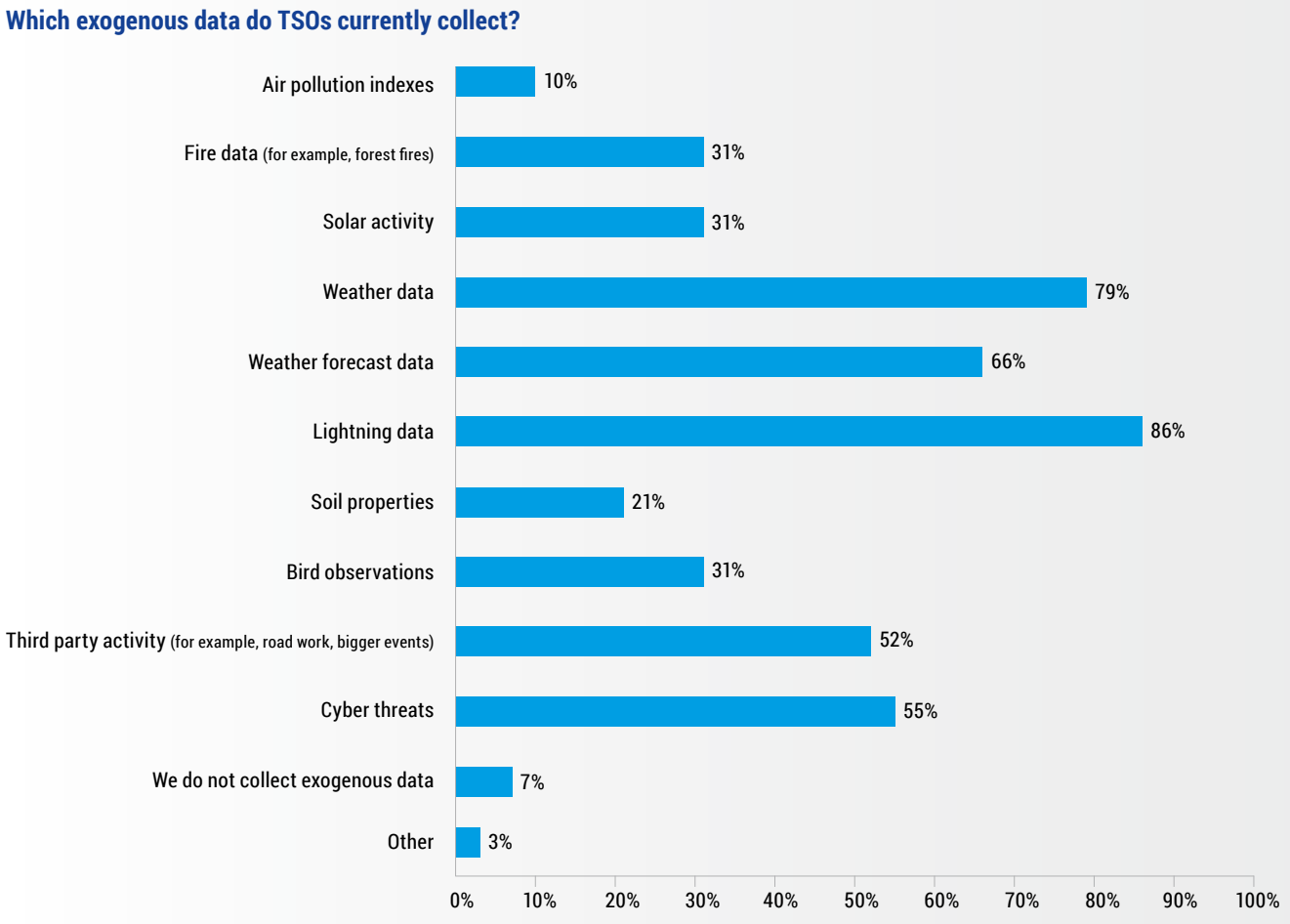

Figure 4.2: A list of exogenous data and the percentage the percentage of TSOs who collect them. 29 TSOs responded to the survey. Results shown are an analysis of the conducted survey for all TSOs.

4.2.4 Data collection and quality management

A robust probabilistic approach to security assessment requires a large set of high-quality data to accurately predict risks and contingencies in the power system as such efficient and secure data collection, in addition to continuous quality management, is a prerequisite for PRA to function correctly.

The software and infrastructure requirements for a fully functioning PRA are high as there are 42 TSOs operating the pan-European transmission grids, all possessing different IT systems and infrastructure tailored to their specific needs and which may require individually addressed solutions to fit the PRA scope as well as be compatible with national regulations. Furthermore, PRA requires centralised as well as local setups that communicate and function together efficiently and securely. The result must be an extendable solution that can adapt to a wide set of needs so that future improvements can be implemented.

As previously mentioned, to harmonise the datasets from all TSOs in Europe and to enforce the reporting of high-quality data, ENTSO-E has published common disturbance definitions [4]. The 2021 survey identified that approximately a third of the TSOs are fully ready to collect information about grid disturbances, faults and outages according to the definitions by the end of 2021, and that half of the respondents are partially ready to collect that information.[12] The remainder were not ready to collect this information by the end of 2021, with some requiring external assistance to reach the data collection requirements.

The WG PRA has setup a data quality roadmap, whereby TSOs are expected to initially report PRA-related data in an aggregated form which conforms to the newly published grid disturbance definitions by 2022. The aggregated reporting sheets are designed to ensure TSO compatibility and to assess and improve quality over time. Further detailed reporting may only occur once a secure infrastructure is in place, which will consider TSOs' security obligations and national obligations.

The 2021 survey has highlighted data security as a concern. WG PRA is aware of the importance of secure data exchange in a world with increasing cyberthreats and is conscious of developing solutions that prioritise data security in compliance with ENTSO-E processes and Codes.

12 Note that 27 TSOs responded to the survey.

4.3 Challenges: what are the consequences for TSOs and RSCs?

Most changes in TSOs' operational process, particularly at a pan-European level, are accompanied by challenges and hurdles. The 2021 survey on TSOs' perspectives has identified several challenges of moving towards PRA, which can be summarised as follows:

- **Changes to current processes** – the PRAM is likely to result in changes to existing TSOs' processes, including the system operators' way of working. There is an operational challenge to ensure that operators can trust in the results of a PRA-based security assessment. The 'N-1' criterion is well-established, easy to understand and thus easier to trust. In addition, the methodology will translate a range of probabilities to a binary decision for system operators. Inherently, this would require the establishment of an 'acceptable' risk level at the TSO, regional or pan-European level.

- **Additional investment for all TSOs** – the methodology is expected to require significant investment, both in the level of resources and IT systems, to facilitate changes to processes and internal procedures to ensure appropriate readiness. This may be a difficult exercise for TSOs with competing priorities and limited budget.

- **Data volume and quality** – to appropriately establish a robust methodology, it must be based on accurate and high-quality data, which is consistent across all TSOs. The quality and quantity of input data will be a challenge. For example, TSO must be able to have reliable and effective probabilistic data for their grid-elements' faults/outages such that reliable security assessment may be performed to expand the 'N-1' criterion.

- **Balancing network security against socio-economic benefits** – high complexity and the large amount of required PRA data may lead to calculation errors without adequate controls. In addition, the methodology will need to strike a balance between the tendency to neglect contingencies due to their low probability (which could increase the risk level compared to today) and the need to consider forecast uncertainties (which contributes to lowering the risk level). The PRAM must balance the conflict of interest between higher capacity utilisation and safety, while not leading to their deterioration, compared to deterministic approaches, to optimise the socio-economic operation of the grid. Another concern is how future data volumes will integrate with historical data as the electric power system is ever evolving; what has previously increased the operational risks may not be critical at all in the future and vice versa. Adapting to new risks as they appear increases the complexity even further.

5 Future roadmap

The previous chapters have reflected on the completed work, consequences, deliverables and the regulatory mandate underpinning the move towards PRA. This chapter looks ahead by providing a high-level timeline of PRA-related activities.

5.1 Planning complexity

Incorporating PRA in security assessment is a complex matter. As it largely remains in the R&D stage, there is no common understanding of the topic in the TSO community and TSOs are investigating methods/approaches which are practical and achievable for all TSOs. Some TSOs are reluctant to incorporate PRA in their operations due to the deterministic character of (local) rules and regulation; therefore, one of the key focus areas over the next stages is internal and external stakeholder management to ensure a common understanding of TSO starting points, their individual issues, and to plan for a PRAM that can be applied on a pan-European level.

The high-level timeline in Figure 5.1 illustrates the WG PRA activities planned as of September 2021. The timeline is focused on future work and does not show already completed tasks as these are discussed extensively in previous chapters of this report. In terms of data collection, there is a standard assumed planning approach. Prior to the implementation of a particular data collection, definitions documents will be developed to ensure consistency in the data collection as far as reasonably practical. The infrastructure development referred to in the figure relates to ENTSO-E IT infrastructure which will monitor the quality and consistency of data collection across TSOs.

Of note, the greatest planning complexity relates to the PRAM being developed in parallel to the data collection. The two are co-dependent and can influence one another to some degree, which is why data collection and PRAM development are assumed to be undergoing continuous development to ensure feedback loops are considered.

Due to the complexity associated with the planning and the long timeframe for the PRAM development, the timeline is subject to change depending on the evolution of the work. The timeline evolution is expected to be discussed in the upcoming biennial report in 2023, 2025 and so on.

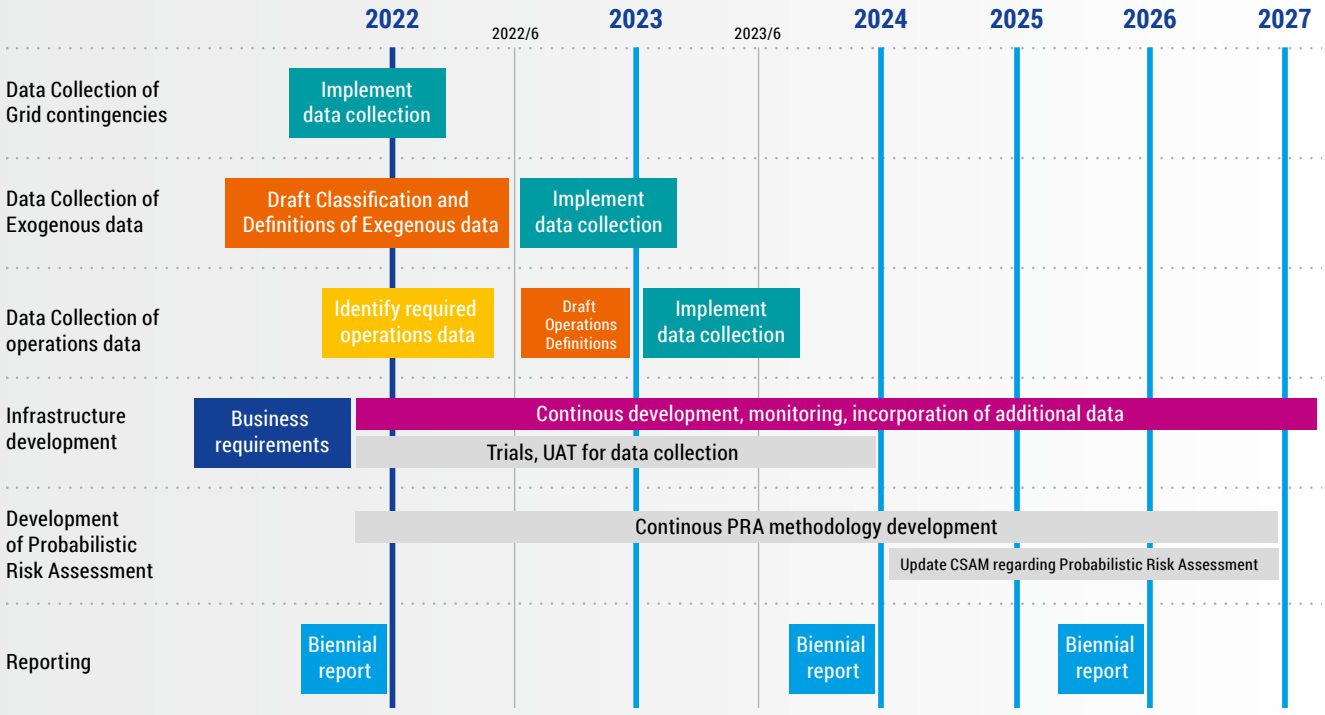

Figure 5.1: High level swimming lane timeline of the development process of the data collection, PRAM and administrative tasks. The timeline is subject to change depending on the evolution of the work.

Conclusion

Since 2019 and consistent with the legal mandate in CSAM Article 44, all TSOs, supported by ENTSO-E, have been investigating and preparing for a move towards a probabilistic approach for risk assessment in the power grids as a potential complement to the currently used 'N-1' criterion. Current advancements include the publication of common definitions for grid disturbances in the power system above 100 kV [4], the first draft of the PRAM and a set of exogenous data to be used in connection with the TSO collected data.

Data collection for faults, disturbance and outages is on-going and the results will be monitored via ENTSO-E processes, on an annual basis commencing 2022, to confirm that the collected data are of high quality. Any gaps will be addressed throughout the annual data collection process. The secure exchange and storage of this data is of outmost importance, and efforts are being made to ensure that the data is handled accordingly.

The PRA project's governance has changed from project teams with short-term mandates to a working group with long-term objectives and a (semi) permanent structure until 2027. This is because, although the two previous PRA projects were both successful at achieving their objectives, it became clear that there was a need for a long-standing and consistent governance structure within ENTSO-E to ensure continuity and knowledge retention for such a complex topic.

There are many expected challenges and hurdles, the main ones being updates and changes to current processes, the implementation of the framework at each TSO, and the harmonisation of all the collected data so that the resulting calculations will be accurate. The working group will facilitate cooperation between TSOs to enable them to directly benefit from each other's experience. PRA may improve operational planning and optimise the utilisation of TSOs' assets. However, TSOs expect to take a considered approach to ensure that overall system risk is proportionate to the benefit.

The next steps for WG PRA will be to maintain stakeholder engagement and uphold common understandings of the requirements and potential benefits, especially as the PRA approach is mainly at the R&D stage. Moreover, common definitions and methodologies are to be improved to provide the necessary framework for the development of the PRAM, consistent with the legal mandate, by 2027.

It is expected that the PRAM will be drafted by 2027, having regard to TSOs' progress in the biennial reports until then. Considerations regarding the implementation timeframe will be included in the PRAM, noting that implementation will occur post-2027.

Abbreviations

Acronym	Meaning
CSAM	Methodology for coordinating operational security analysis
DCfPRA	Data Collection for Probabilistic Risk Assessment
DISTAC	Disturbance Statistics Classification (subgroup under ENTSO-E Regional Group Nordic)
EDFS	ENTSO-E Disturbance and Fault Statistics
ENTSO-E	European Network of Transmission System Operators for Electricity
GARPUR	Generally Accepted Reliability Principle with Uncertainty modelling and through Probabilistic Risk Assessment
ICS	Incident Classification Scale
IDCfPRA	Implementation of Data Collection for Probabilistic Risk Assessment
NC ER	Network Code Emergency Restoration
PRA	Probabilistic Risk Assessment
PRAM	Probabilistic Risk Assessment methodology
RSC	Regional Security Coordinator
SOC	System Operation Committee
SOGL	System Operation Guideline
StG OF	Steering Group Operational Framework
TSO	Transmission System Operator
WG PRA	Working Group Probabilistic Risk Assessment

References

[1] "The GARPUR project results – Using Probability and Risk to Allow Power Systems to operate closer to their optimum," October 2017.

[2] Commission Regulation (EU), 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation, 2017.

[3] ACER, Methodology for coordinating operational security analysis, 2019.

[4] ENTSO-E Grid Disturbance Definitions for the Power System above 100 kV, ENTSO-E, 2021.

This report was prepared by the ENTSO-E Working Group Probabilistic Risk Assessment

Publisher

ENTSO-E AISBL
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Design

DreiDreizehn GmbH, Berlin | www.313.de

Images

Cover: iStockphoto, Sitthiphong
page 6: iStockphoto, metamorworks
page 14/15: iStockphoto, BuckleyPics

Publishing date

December 2021

European Network of
Transmission System Operators
for Electricity